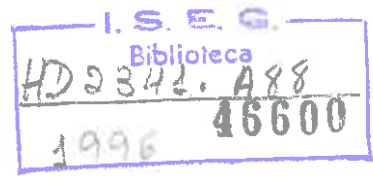


SUBMITTED TO THE UNIVERSITY OF SUSSEX



EXTERNAL LINKAGES, INNOVATION AND  
THE SMALL AND MEDIUM-SIZED ENTERPRISE:  
THE ROLE AND EFFECTIVENESS OF PUBLIC TECHNOLOGY POLICY  
IN PORTUGAL

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for the Degree of Doctor of Philosophy in  
Science and Technology Policy Studies

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April 1996

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I hereby declare that this thesis has not been submitted,  
either in the same or different form, to this or any other  
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To Ana, with whom life  
is a continuous challenge

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EXTERNAL LINKAGES, INNOVATION AND THE SMALL AND MEDIUM SIZED  
ENTERPRISE: THE ROLE AND EFFECTIVENESS OF PUBLIC TECHNOLOGY  
POLICY IN PORTUGAL

## SUMMARY

The thesis explores the relationships between innovation, external linkages, and the role played by small and medium sized enterprises in the process of innovation in Portugal. To test such relationships, an analysis of the external linkages of a representative sample of Portuguese firms in the electronics and the mouldmaking industries was carried out. Since it was found that industrial biotechnology scarcely exists in Portugal, no analysis of this industry was conducted.

28 interviews, evenly distributed between electronics and mouldmaking enterprises, were arranged. They involved personnel having senior executive responsibility, lasted around 2 hours, and were followed by a visit to the premises.

The research tried to validate the following set of hypotheses:

- 1) Although the extent and quality of linkages with other enterprises is significantly important across (Portuguese) industries, there is a distinctive weakness in the pattern regarding the extent and quality of their linkages with academic research, and with public sector institutions;
- 2) Portuguese high technology enterprises (in the electronics industry) preferentially link with academic research rather than with public sector institutions; the opposite trend characterises a low-medium technology industry (mouldmaking); and
- 3) In general terms, small and medium sized firms tend to establish more linkages than large enterprises.

Regarding the main findings of the thesis, we may highlight these points:

A close liaison with a source of science and technology could have positive effects in the Portuguese electronics industry, since the generation of knowledge and technology is still limited in Portugal. This was evident in the case of those firms establishing close links with private non-profit organisations.

The Portuguese mouldmaking industry is mainly located in two industrial districts. Technical change occurs through horizontal linkages amongst a large number of SMEs. This process has been put into practice by a particular cluster of companies. Their effective networking gave them a competitive advantage *vis-à-vis* other mouldmaking enterprises outside the network, both in Portugal and abroad.

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## 1. INTRODUCTION

This thesis explores the relationships between innovation, external linkages, and the role played by small and medium sized enterprises (SMEs) in the process of innovation in Portugal.

The main theme of this study is the relative weakness of the Portuguese national system of innovation (NSI). Although most of the institutions generally considered to be important for a national system are in place (universities, research institutes, government agencies, firms, etc), the thesis will argue that the network of relationships between these institutions is very weak. The earlier literature (eg Corado-Simoes 1991; Fontes and Coombs 1994; Simões 1993) supports this view, but the empirical evidence of our own research reported in Chapter 8 is the decisive evidence in support of this conclusion.

Empirical research in other countries as reported in Chapter 3 points to the great importance of external linkages and in view of this the thesis concludes in Chapter 10 by indicating some appropriate policies which might help to overcome these weaknesses.

We believe that the technological networking between the above mentioned institutions would facilitate the creation and/or improvement of the Portuguese innovation system.

Bearing in mind what we have just said, we have decided to thoroughly analyse the current situation of the external linkages in the country, as a means of improving our knowledge on this issue in order to, on the one hand, consolidate the linkages which already exist and, on the other hand, to generate new linkages which are essential for the establishment of the Portuguese system of innovation.

The sources of innovation (von Hippel 1988) have changed over time. In his early work, Schumpeter (1912-1961, seventh printing) stressed that any innovation was the result of the radical and heroic action of a single entrepreneur. Later (1928, 1939-1982, 1942-1987, sixth edition) he pointed to the advantages of large

oligopolistic companies in financing R&D (Research and Development) and in promoting innovations. As Freeman (1974) also suggests, the establishment of R&D laboratories in the big private companies was one of the most important institutional innovations in the last century. Since then, scientific activities and technical change became increasingly interdependent.

Similarly, the previous linear models of innovation have been supplanted by interactive models (see Rothwell 1992 for a review of the five generation innovation processes). In the present period of intense, rapid technological change, and taking into account the fundamentally uncertain and disruptive character of the process of innovation, no single firm can "go it alone" any longer. Therefore, innovation is increasingly being understood as an interactive process (Lundvall 1988) among enterprises, between enterprises and universities, and between enterprises and governments.

Such an interactive process does facilitate greater technological cooperation and networking. Indeed, Freeman (1992) argues that the capacity to adapt to major changes in technology has historically depended on the development of a network of scientific and technical institutions, both in the private and public sectors. The truth is that networking, be it external or internal, is now becoming of critical importance for effective innovation (see, for example, Gelsing 1992; Gjerding 1992). It applies not only to collaboration within and between the scientific and technical institutions, but also to cooperation between enterprises, between producers and users (see, in particular, Lundvall 1988, 1991, 1992c, 1993), and even between competitors (eg von Hippel 1989).

No doubt, government and university laboratories, and non-profit institutions also contribute significantly, and sometimes decisively, towards scientific and technological innovations. In fact, the public sector plays a relevant role in the process of innovation. It is involved in direct support of science and development, its regulations and standards influence the rate and direction of innovation, and is usually the single most

important, though more or less competent, user of innovations developed in the private sector (Gregersen 1988, 1992). As far as individual enterprises are concerned, they respond to constraints and opportunities created by scientific and technological policies implemented by national governments and, to a larger extent, by a more dynamic, integrated, and technologically convergent economic environment.

To capture this new infrastructural dimension of economic innovation, the concept of "national system of innovation" has been recently proposed.

Indeed, since the mid-1980s an increasing number of researchers and scientists (Freeman 1987, 1988b; Lundvall 1988, 1992b; Nelson 1988, 1993; Porter 1990a, 1990b;...) have been involved in a search for the origins of national competitiveness. Their main goal has been to tackle the problem of how technology policies, economies, competitiveness, human capital, industrial relations and the economic and political institutions influence each other. Besides, research on innovation systems also offers an opportunity for increased understanding of the relations between institutional and technological change.

Interestingly enough, much of this research has been concentrated both on the so-called large and smaller high-income countries and in the lower income countries (to adopt the taxonomy of countries presented in Nelson 1993). With very few exceptions (eg Mjøset 1992 focussing on the Irish Republic), the small less advanced countries, like Portugal, have been kept out of the picture.

Furthermore, only a handful of studies (eg Caraça, Gonçalves, Brito, Mateus, Ribeiro, Faísca and Moreno 1993; Corkill 1993; OECD 1993b; Ruivo 1991a, 1991b; Spinnato 1993) has up to now surveyed the Portuguese environment. For example, Corkill (1993), in an overview of the structure of the economy, identified a range of weaknesses, some of which have long retarded the country's development, namely a backward agriculture, poor infrastructure, inadequate systems of education and training, and a fragmented and under-capitalised industrial base.

The other above-mentioned studies have all stressed the point that links between R&D institutes and industrial production are

also particularly weak. There is thus a strong need for policies to strengthen such linkages.

Small and large firms play different, yet complementary, roles in the process of innovation (Acs and Audretsch 1990; Rothwell 1983, 1989). It is a symbiotic relationship, which may be seen as an attempt to combine the behavioural advantages of small firms in innovation with the resource-related advantages enjoyed by large companies (Rothwell and Zegveld 1982).

Additionally, the extent of each contribution differs from industry to industry, and is in a continuous process of evolution and change. In some areas, the relative contribution of small enterprises is growing, whereas in other areas it is declining. Furthermore, it also varies with the diffusion, throughout the system, of generic technologies, namely information and communications technology, as well as with the different stages of the industry's life cycle (Abernathy and Utterback 1978; Utterback and Abernathy 1975; Vernon 1966).

On the other hand, the small firm sector is a major component of Western industrial structures (CEC 1990). Amongst that large population, a significant proportion depends on technology as the basis of their present and future competitive position. For such firms, innovation is the key to survival and growth.

Also in Portugal, small enterprises constitute a major part of the country's productive system (CEC 1990). Hence, Portuguese public sector institutions may also play an important role in establishing and strengthening linkages with Portuguese firms.

Consequently, as already referred to above, in order to empirically test the relationships between innovation, external linkages, and the role played by small and medium sized enterprises in the process of innovation in Portugal, an extensive, detailed analysis of the external linkages of a representative sample of Portuguese firms was carried out.

We have tried to cover a wide spectrum of the country's industry in our study. Therefore, adapting the taxonomy of sectoral patterns of innovation proposed by Pavitt (1984), we have initially selected three Portuguese industries, biotechnology (a *science-based* industry), electronics (a *technology-based*

industry), and mouldmaking (a *traditional* industry). These particular industries were chosen because of the interest in finding out the extent and quality of their linkages with other enterprises, with academic research, and with public sector institutions.

Furthermore, they are all quite characteristic, peculiar industries. On the one hand, the mouldmaking industry is a sector which is traditionally part of toolmaking, a skilled branch of engineering. In Portugal, the moulds produced are mostly destined for the plastics industry. Household appliances (32%), automobile (20%), electrical equipment (10%), electronics and telecommunications (9%), packaging (9%), and toys (8%), are the industries which absorb most of the output of this sector (ICEP 1995). Hence, the mouldmaking industry is one of the most important traditional industries in Portugal.

Electronics, on the other hand, had such pervasive effects throughout the economy that it not only led to the emergence of a new range of products, services, systems and industries in its own right, but it also affected directly or indirectly almost every other branch of the economy (Freeman and Perez 1988).

Finally, biotechnology has in itself the potential to substitute electronics as the new techno-economic paradigm.

However, when conducting our field-work, we were immediately confronted with a methodological impediment. Industrial biotechnology, like other science-based industries (for example, engineering ceramics, optoelectronics, or parallel computing), scarcely exists in Portugal. Research in these industries is predominantly concentrated in the laboratories of universities and polytechnics, in private non-profit institutions, and in some specialised government laboratories.

As already mentioned, such evidence was only empirically substantiated after conducting a set of interviews in a small number of enterprises with marginal interests in the biotechnology field. These findings will be discussed in Chapter 6, when we will analyse in greater detail the current situation of the Portuguese biotechnology industry.

Therefore, the research had to exclusively focus on both the

electronics and mouldmaking industries.

Finally, let us point out one area which will not be discussed in our thesis, despite its potential relevance. We refer to the role played by the European cooperative programmes, such as BRITE-EURAM, ESPRIT, and others.

The reader should bear in mind that we are studying the external linkages of Portuguese enterprises at the national level, with the intention of improving our knowledge on this issue in order to, on the one hand, consolidate the linkages which already exist and, on the other hand, to generate new linkages which are essential for the establishment of the Portuguese system of innovation.

Nevertheless, we may add that the country's participation in the European Union's R&D programmes is globally quite weak, with the exception of BRITE-EURAM and ESPRIT. Moreover, it is not the Portuguese business sector, but rather the higher education sector and the private non-profit sector which monopolise the country's involvement in those programmes (Caraça, Gonçalves, Brito, Mateus, Ribeiro, Faísca and Moreno 1993). However, in Chapter 8 (section 8.3.5.) we discuss briefly the general positive stimulus from participation in the European Union, even though industrial participation in the R&D programmes has been very restricted. This is not a surprising feature, bearing in mind that industrial technological cooperation at the national level (which barely exists in Portugal) does act as a learning process for cooperating with foreign partners in subsequent phases (Barañano-Martínez 1994).

The thesis is therefore structured in the following three parts: (1) The first one includes Chapters 2, 3, and 4. **Chapter 2** reviews previous research on general theories of innovation, discussing both the neo-classical and the evolutionary schools of economic thought and focussing afterwards upon the relative contribution of enterprises to innovation, referring in particular to the advantages and disadvantages of small and large firms in the process of innovation, as well as on their dynamic complementarities. **Chapter 3** then comprises a detailed survey of the existing literature on technological collaboration, centring

on its growing importance, the main reasons leading to cooperation, its advantages and disadvantages, and the focus, and forms of industrial collaboration; the role of trustful partnerships is also analysed, since they may turn out to be a crucial element of competitiveness. Finally, Chapter 4 covers three interconnected topics, namely i) the special problems of small countries confronted with increased internationalisation and globalisation of technological activities; ii) government policies to promote innovation, which is particularly pertinent in the case of small countries; and iii) the "hot" issue of research on national systems supporting technical change.

(2) The second part encompasses Chapters 5 and 6. Chapter 5 briefly outlines Portugal's recent history, as an explanatory introduction to a detailed analysis of the evolution of the Portuguese scientific and technological (S&T) system. We will discuss the country's S&T system rather than its innovation system simply because, as outlined before, Portugal is a country with an incomplete, non-integrated innovation system. For instance, its financial system for supporting innovation is rather incipient, virtually non-existent. Financial markets and venture capital are still under-developed. Small and medium sized enterprises find it difficult to access sources of finance other than traditional loans, at high cost, despite some efforts to promote the development of compensatory mechanisms (OECD 1995b). Therefore, although we all acknowledge that there is more to innovation than just R&D, important though that might be, our analysis will focus basically upon the S&T system's four main sectors, the public, the higher education, the private non-profit, and the business ones. Chapter 6 then centres the analysis upon the Portuguese business sector, and pays particular attention to the two Portuguese industries selected for the research, electronics and mouldmaking (as well as a brief reference to biotechnology, as mentioned above).

(3) The third part comprises Chapters 7, 8 and 9. Chapter 7 shows how the enterprises in the sample were selected, and then introduces the questionnaire used in the field-work, describing its main topics and some of the recodification processes. Chapter

8 is exclusively devoted to the results of the research, attempting to validate a set of hypotheses, which have emerged both from the literature survey and the experience of the Portuguese S&T system. Finally, in view of the density of data presented in Chapter 8, **Chapter 9** intends to give a general overview of the empirical findings.

Finally, **Chapter 10** presents the main findings of the thesis, and then suggests a number of policy measures and areas for further research.

## 2. THE THEORETICAL FRAMEWORK

### 2.1. Introduction

Since Portugal is a small country in which small and medium-sized enterprises (SMEs) play a very important role, we concentrate in this introductory review of the literature mainly on the findings of economics research relating to small firms.

We propose a two-fold approach to a better understanding of the role small enterprises play in the process of innovation.

We start by reviewing the relevant literature on the theory of innovation (*point 2*). Far from being exhaustive, this survey nevertheless enables us to identify two major schools of economic thought, known as the neo-classical and the Schumpeterian (or evolutionary) ones. Both these schools show some limitations and drawbacks in explaining the innovation process. It is undeniable, however, that the Schumpeterian school provides a superior interpretation of the process of innovation itself. A particular emphasis is also placed upon the contribution of Freeman and Perez to the clarification of the evolutionary economic theory. Following in the footsteps of Schumpeter, we try to comprehend the relative contribution of large and small enterprises to innovation (*point 3*). In his early work, Schumpeter (1912-1961, seventh printing) had stressed the role of innovative small firms, but later (1928, 1939-1982, 1942-1987, sixth edition) had pointed to the advantages of large oligopolistic companies in financing R&D (Research and Development) and promoting innovations. We suggest that between these two kinds of firms often occur cases of dynamic complementarities, and that they both possess intrinsic advantages and disadvantages in the innovation process. Furthermore, research carried out both in Europe and the USA indicates that there are also differences and similarities in the ability to innovate and adopt new technologies in different types of industries (see, for example, Freeman 1994; Nelson and Winter 1977). Finally, in an attempt to

better characterise the small firm sector and to understand the differing needs of its enterprises with respect to innovation, a taxonomy of small and medium sized companies is proposed, supported by three studies into technology strategies in this type of enterprise.

## 2.2. General Theories of Innovation

### 2.2.1. The neo-classical economic theory

Let us start our analysis of the relationship between enterprises, markets, and technical change by focussing upon the (still) prevailing neo-classical orthodoxy.

The neo-classical economic theory infers that enterprises are confronted with a complete set of existing techniques allowing an immense range of combinations of factors of production, though in general restricted to two, Capital (K), and Labour (L), in order to produce an Output (Q), which may be analysed using a Cobb-Douglas production function. Mathematically, this production function is represented by  $Q = f(K, L)$ . The production function specifies all the alternative "efficient" techniques in a certain stage of knowledge required to produce a specific level of output. At any given period of time, the enterprise is capable of selecting, from among a limitless number of techniques (combinations of K and L), the ones which minimise the cost of production or, inversely, maximise its profits. A movement along the production function merely indicates the immediate replacement of an already existing technique for another. Furthermore, a change in the production function as a whole signals a progress in the state of the technology and denotes technological advance in the model. As Freeman and Perez (1988) argue:

"Most formulations of neo-classical theory put the main emphasis on varying combinations of labour and capital and on substitution between them, and implicitly or explicitly assume responsiveness even to small changes in these relative factor prices in either direction, i.e.

"reversibility" (Freeman and Perez 1988: 49, 58)

Solow was probably one of the most influential neo-classical growth theorists, with his two seminal papers, one theoretical (Solow 1956), the other empirical (Solow 1957). In an article published in 1981, Nelson reviewed the basic ideas formulated in Solow's latter paper, and summarised the role of the production function in neo-classical growth theory as follows:

"Firms are the key productive actors, transforming inputs into outputs according to a production function. The production function, which defines the maximum output achievable with any given quantity of inputs, is determined by the state of technological knowledge. Technological knowledge is assumed to be public or at least this is implicit in models based on an industry or an economy-wide production function. Firms choose a point on their production function to maximize profits, given product demand and factor supply conditions. Generally these markets are assumed to be perfectly competitive so that a firm treats prices as parameters. Assuming factor prices adjust, and no Keynesian difficulties exist, the model is consistent with full employment and usually this condition is assumed. Over time, output grows as inputs increase and firms move along their production functions, and as technology advances" (Nelson 1981: 1031)

Most economists agree upon the pivotal role played by the business sector within a national system of innovation (although this is not quite the case regarding Portugal, as discussed below). However, some of Solow's basic ideas are far from being accepted now by some of the most prominent researchers and scholars. Even within the neo-classical tradition, the so-called "new-growth theory" (see, for example, Romer 1986) has revised some of the key assumptions and now places far greater emphasis on the role of R&D, education, human capital, and technical change.

Schumpeterian economists have made a more radical critique. For example, Dosi (1988a) argues that, in his view:

"... the "core" of the *strongest* version of the theory embodies [nine hypotheses, the most resilient ones being] (i) the behaviour of the agents can in general be characterized by substantive rationality (literal maximization of something or approximations to it), or, alternatively, market processes are such as to select the

"maximizers", whether they know it or not; [and] (v) uncertainty, when it occurs, can be reduced to incomplete information whereby the agents can still behave "rationally" by generating probabilities with which they make maximizing calculations" (Dosi 1988a: 121)

It is not our intention, in this chapter, to thoroughly examine Dosi's nine hypotheses. Instead, we believe that a better approach is to select a couple of assumptions formulated by Solow (1957) and try to criticise them, focussing upon their shortcomings and drawbacks. These assumptions have been selected as those which have the greatest relevance to the main purpose of this thesis.

#### 2.2.2. A critique of the neo-classical economic theory

One major postulate derived from Solow's ideas is that "technological knowledge is assumed to be public". Consequently, companies are able to freely select the most suitable technique, from a wide range of techniques obtainable in the form of blueprints "off the shelf". As the knowledge embedded in the technology is regarded as a costless good, an enterprise wishing to manufacture a particular product will be free to obtain, at no cost, all the required knowledge to produce it efficiently. However, when dealing with "the real world", this assumption presents some problems. In fact, there are significant costs for a company, when it selects the most appropriate technology, and even more when learning about that technology. In other words, much knowledge is exclusive to specific processes, and is also often tacit, meaning that it is not freely incorporated in an operating manual or a blueprint. As Dosi (1988b) suggests:

"... *tacitness* refers to those elements of knowledge, insight, and so on that individuals have which are ill defined, uncodified, unpublished, which they themselves cannot fully express and which differ from person to person, but which may to some significant degree be shared by collaborators and colleagues who have a common experience" (Dosi 1988b: 1126)

Dodgson (1993), writing about the nature of technological

knowledge, also suggests that much technological knowledge is tacit, cumulative, firm specific, and difficult to price. A similar argument is supported by Pavitt (1991), who argues that innovative activities are firm specific, cumulative, differentiated and highly uncertain. Moreover, he stresses the central importance of tacit knowledge obtained through experience and how this, amongst other things, ensures that what firms did in the past will condition what they do in the future. Again, Dosi (1988b) emphasises exactly this last point, saying that:

"What the firm can hope to do technologically in the future is narrowly constrained by what it has been capable of doing in the past" (Dosi 1988b: 1130)

As early as 1974, Collins, in a case study of the network set up for the high pressure gas laser, noted that:

"Nearly every laboratory expressed a preference for giving information only to those who had something to return" (Collins 1974: 181)

which again highlights the fact that the possession of (tacit) knowledge, far from being openly accessible to other firms, represents a form of competitive advantage for an enterprise. Pavitt (1984) has also empirically questioned the neo-classical argument that knowledge is freely and publicly available. In a paper describing and explaining sectoral patterns of technical change on about 2,000 significant innovations in Britain since 1945, he showed that:

"... 59 percent (of the knowledge inputs) came from within the innovating firms themselves, and about a third from other industrial firms" (Pavitt 1984: 346)

Consequently, he stresses that:

"Given that innovating firms evaluate their own knowledge contributions at nearly 60 percent of the total, we cannot realistically assume that there exists a generally available and applicable stock or pool of knowledge, where each firm - being very small in relation to the total stock or pool - can gain much more from drawing on the pool, rather than by adding to it" (Pavitt 1984: 347-348)

The idea of the general "pool" or "stock" of knowledge skips a central characteristic of industrial technology, ie the specificity in terms of functional applications, and of the aptitude of the innovating enterprise to grab the pertinent knowledge for a period of time. This is noticed by the differentiated nature of most of the expenditures related to innovations and innovative activity. As Pavitt (1984) pointed out:

"In Britain and elsewhere, about three-quarters of all expenditures on industrial R&D is on "D", and an equivalent sum is spent on testing and manufacturing start up. The purpose of these expenditures is to mobilise skills, knowledge and procedures in the firm in order to commercialise specific products and production processes, with the characteristics of operation, reliability and cost that satisfy user needs" (Pavitt 1984: 348)

He then adds that:

"... the costs of transmission (of an innovation) from one firm to another can be high, even in the absence of legal protection or secrecy in the innovating firm" (Pavitt 1984: 348)

Consequently, it is difficult to sustain the hypothesis that technology is publicly available and is easily and costlessly transmitted among firms.

Another disputable neo-classical assumption is that of "profit maximisation". In a world characterised by the existence of firms with very differing sizes, some of them huge multinational corporations, we are now confronted with the fact that the manager is (usually) no longer the owner. This is particularly true in the big corporations, where their complex organisational structure has led to a division between control and ownership. Furthermore, the managers, owners, shareholders, and workers of a company do not definitely share the same interests, either in the short or in the long run. In other words, it is no longer possible to maintain that the whole internal body of a firm has consistent goals and motivations.

In conclusion, the pivotal predicament with neo-classical economic theory is related to the exogenous way technical and

institutional change is dealt with. As Lundvall (1992c) puts it:

"In a world where agents are perfectly rational (maximisers of utility and profit, with unlimited access to information, and an unlimited capacity to gather and process information) and where all transactions take place in pure markets, with anonymous relationships between buyers and sellers,..." (Lundvall 1992c: 45)

In such an "ideal" (and static) world, the immense variety of sources and types of technology is not taken into account by the neo-classical economic theory. This implies that there are some weaknesses when applying it to explain the general process of innovation and the role of enterprises in it. In reality, the model does not differentiate between the innovativeness of firms of differing sizes.

### 2.2.3. The Schumpeterian theory

In contrast to the neo-classical economic theory, the Schumpeterian (also known as evolutionary) theory has always stressed the dynamic and systemic nature of the innovation and diffusion processes, as well as the close links and feedbacks between them. In fact, as pointed out by Clark and Juma (1988):

"Schumpeter is one of the few economists who both questioned the static underpinnings of neo-classical economics and at the same time suggested an alternative approach. By locating economic transition within the broad context of social change, Schumpeter adopted, like Marx, an *evolutionary model* in which technological change and the efficacy of the *entrepreneur as an innovative agent* played the most significant role" (Clark and Juma 1988: 211) (emphasis added)

In order to develop his framework, Schumpeter (1961, 1982) starts with a multi-firm/multi-sector model of an economy characterised by circular and static flows. In this economic system, equilibrium quantities and prices are firmly instituted, so the system is kept going through straightforward standard decisions taken by managers and workers. In such a background of routines, any innovation, he argues, is the radical and heroic action of

an entrepreneur. The established set of prices and quantities is thus in disarray following the action of the entrepreneur who, in turn, is being (highly) rewarded by the exceptional profits he is accumulating generated by the introduction of the innovation. This monopolistic and lucrative position attracts other entrepreneurs, which in turn sets up a competitive process thus diminishing profits from supernormal levels to new normal ones. During this phase of instability the initial innovation may father a whole cluster of associated innovations. Therefore, economic development will be accomplished through a process of trial-and-error. In the end, a new position of equilibrium is reached, though anticipating a fresh wave of innovations which will trigger the whole process again, giving rise to the cyclical phenomenon of economic growth.

In his late work, Schumpeter (1987) began to revise his analytical framework, particularly considering the changing nature of entrepreneurship. He incorporated innovation in the regular activities of the big concerns, thus contributing to the comprehension of the colossal upswing in R&D during the post-war period. He wrote:

"Technological progress is increasingly becoming the business of teams of trained specialists who turn out what is required and make it work in predictable ways. The romance of earlier commercial adventure is rapidly wearing away, because so many more things can be strictly calculated that had of old to be visualized in a flash of genius" (Schumpeter 1987: 132)

It is then possible to identify two basically distinctive Schumpeterian models of innovation. As Rothwell and Zegveld (1985) put it:

"In the first case Schumpeter stressed the importance of *exogenous science and invention* which, via the medium of entrepreneurial activity, led to the growth of new industrial branches and new areas of demand (the Schumpeter I model); in the second case he emphasized the role of *endogenous science and technology* in the R&D laboratories of major companies - strongly coupled to exogenous science and technology - which again led to new patterns of production and new market structures (the Schumpeter II model)" (Rothwell and Zegveld 1985: 61) (emphasis added)

It was Freeman, Clark and Soete (1982) who first labelled these two Schumpeterian models of innovation as Mark I (or "entrepreneurial" innovation) and Mark II (or "managed" innovation), respectively. Referring to the latter, they contend that:

"In Schumpeter II... therefore there is a strong positive feedback loop from successful innovation to increased R and D activities setting up a "virtuous" self-reinforcing circle leading to renewed impulses to increased market concentration. Schumpeter now sees inventive activities as increasingly under the control of large firms and reinforcing their competitive position. The "coupling" between science, technology, innovative investment and the market, once loose and subject to long time delays, is now much more intimate and continuous" (Freeman, Clark and Soete 1982: 41)

At this stage, it is worth underlining some of the most prominent postulates of Schumpeter's theoretical approach, namely the fact that in the Mark I model, major scientific and technological developments are largely exogenous to existing firms and market structures, and generate the growth of new industries and the emergence of new product groups, as well as of dynamic, small, though fast growing new enterprises, headed by individual entrepreneurs, who play the key role as innovators. On the other hand, in the Mark II model, science and technology have become an endogenous activity conducted by the R&D laboratories of large, oligopolistic companies, which are pushing economic progress. Therefore, it is important to stress the relative contribution of enterprises of differing sizes to innovation.

#### 2.2.4. A critique of the Schumpeterian theory

We thoroughly agree with Freeman (1988a) when he argues that:

"Among the positive merits of Schumpeter's work were his consistent emphasis on innovation as the main source of dynamism in capitalist development, his sense of historical perspective, his recognition of the importance of the conceptual distinctions between invention, innovation and diffusion of innovations, and his recognition of the vital importance of the links between organisational, managerial,

social and technical innovations" (Freeman 1988a: 5)

However, as he also stresses, albeit Schumpeter's approach acknowledges technical change as an endogenous component to the economy, wherefore proposing a more pragmatic interpretation of the role played by technology, and its influence on a firm's behaviour in a capitalist economy, as compared with the neo-classical framework, it is still limited. Some of these drawbacks encompass his interpretations regarding (i) the nature of the innovative activity and (ii) the determinants of the process of diffusion of innovations.

Considering first the nature of the innovative activity, we wrote above that, according to Schumpeter (1961, 1982), any innovation is the radical and heroic action of an entrepreneur. Hence, it is obvious he was not considering the extremely significant role played by incremental and continuous technical changes, which represent a gradual variation in the parameters of the economic system. Freeman (1974) fills this theoretical void with his definition of industrial innovation:

"Industrial innovation includes the technical, design, manufacturing, management and commercial activities involved in the marketing of a new (or *improved*) product or the first commercial use of a new (or *improved*) process or equipment" (Freeman 1974) (emphasis added)

Many authors (eg Gardiner and Rothwell 1985; Hollander 1965; Rothwell 1976; Rothwell and Zegveld 1985) have positively substantiated that these "minor" technical changes are a significant source of productivity improvement. Speaking about the development of the hugely successful Sulzer weaving machine, Rothwell and Zegveld (1985) wrote:

"This was a radical design innovation - the world's first shuttleless loom - that passed through *ten prototype stages* over many years before the commercial launch of the Mark 11 version. Throughout its development *the Sulzer loom was tested regularly in the weaving mills of potential customers* and it was feedback from these that provided much of the impetus for further redesign. Finally, ... the Sulzer loom underwent many design improvements during subsequent years that enabled it to maintain its competitive lead. Indeed, while the Mark 11 was a machine for producing plain



cotton-staple goods only, it was explicitly designed with its later transformation into a *more universally applicable machine in mind*" (Rothwell and Zegveld 1985: 48-49) (emphasis added)

Therefore, we have to assume that, rather than a one-off event, technological innovation is indeed a dynamic, iterative process, requiring continuous adjustments in order to remain successful, closely involving in this process the users of the innovation. Another interesting feature is the aptitude of some innovations to generate a family of derivatives, in order to broaden the product's appeal. This is known as "robust" design, and is the case of the Ford Cortina model and the Boeing 747 (Gardiner and Rothwell 1985).

Turning now to the determinants of the process of diffusion of innovations, we must contest Schumpeter's belief that it only involved the movement of the original innovation from firm to firm. In fact, he seldom acknowledged the likelihood of the imitating enterprise to become involved in an attempt to make technological refinements on the initial innovation. He did not contemplate innovation as an interactive process (Lundvall 1988, 1992a, 1992c), in which technologically active customers as well as suppliers may further the evolutionary improvements of the technology, consequently influencing the entire diffusion process. This technological role of the user may influence the profitability of the demand side and therefore, along with elements affecting supply side profitability, contribute to the determinants of the rate of diffusion. Accordingly, the customer's technological input to the producer's innovation (as the Sulzer weaving machine case illustrates), as well as the incremental innovations launched autonomously either by the supplier or by the user, are integral parts of the diffusion process. Furthermore, the users of the new technology being diffused should not be viewed as passive recipients or victims regarding that technology, but as subjects assuming a dynamic part in the process of innovation and, consequently, diffusion. Indeed, Rothwell (1986) argues that, in general, leading-edge customers can play an important role in "pulling" innovations from their suppliers, both large and small.

### 2.2.5. An alternative approach: Freeman and Perez's taxonomy of innovations

Several authors (Dosi 1982; Freeman and Perez 1988; Nelson and Winter 1977; Perez 1983; Sahal 1985;...) have suggested alternative approaches to Schumpeter's theoretical framework, in order to overcome its limitations and drawbacks. An indispensable initial approach is the identification of the attributes of those critical changes in technology that have such extensive aftermaths that they deserve to be labelled as "technological revolution", or "changes of techno-economic paradigms", or "change in technological regime". Indeed, as Lundvall (1992a) puts it:

"Sometimes, an innovation might be almost inevitable - the new combination might be easy to find and to realise. In other cases, it might take an enormous intellectual effort or an extremely creative mind, to identify a potential new combination. And, sometimes, the process of innovation results in radical breaks with the past, making a substantial part of accumulated knowledge obsolete" (Lundvall 1992a: 8)

Decisive in the new interpretation of Schumpeter's theory is thus the taxonomy of innovations advanced by Freeman and Perez (1988), which is strongly supported by empirical research on technical change and innovation. Their argument is that particular types of technical change - which they term as "changes of techno-economic paradigms" - have such far-reaching repercussions for all sectors of the economy that their diffusion is accompanied by a deep structural crisis of adjustment, in which social and institutional transformations in the national system of innovation are required to bring about an improved "match" between the new technology and the system of social management of the economy. However, as soon as such a better match is accomplished a relatively steady pattern of long-term investment behaviour can arise for the next two or three decades. Accordingly, they propose a distinction between (1) incremental innovations; (2) radical innovations; (3) new technology systems; and (4) changes of techno-economic paradigms.

(1) incremental innovations: occur more or less continuously in

any industry or service activity although at differing rates in different industries and different countries. Incremental innovations are concerned only with improvements in existing products and processes. These innovations in products are intrinsically associated with the concept of learning-by-using (Rosenberg 1982), increasing the efficiency of the use of complex systems. On the other hand, incremental innovations in processes are reflected in a learning curve which is correlated with the production of the same commodity, time and time again, thus leading to the notion of learning-by-doing (Arrow 1962), increasing the efficiency of production operations. Incremental innovations are also intimately dependent upon a close learning-by-interacting (Andersen and Lundvall 1988; Lundvall 1988) relationship between the producer and the user, resulting in product innovations.

(2) radical innovations: they have been the main concern of most diffusion studies, regularly displaying the standard sigmoid pattern identified in the "fundamental" diffusion models (Mansfield 1961; Metcalfe 1988; Rogers 1983) and in product cycle theory (Abernathy and Utterback 1978; Vernon 1966). Radical innovations are discontinuous events and usually they are not the result of buildups, modifications or improvements in existing products or processes. Freeman and Perez (1988) argue that:

"... in recent times [radical innovations] are usually the result of a deliberate research and development activity in enterprises and/or in university and government laboratories.... Radical innovations are unevenly distributed over sectors and over time,.... They may often involve a combined product, process and organisational innovation. Over a period of decades radical innovations, such as nylon or "the pill", may have fairly dramatic effects, i.e., they do bring about structural change but in terms of their aggregate economic impact they are relatively small and localised, unless a whole cluster of radical innovations are linked together in the rise of new industries and services, such as the synthetic materials industry or the semiconductor industry" (Freeman and Perez 1988: 46)

(3) new technology systems: they are based on a combination of radical and incremental innovations, which are technically and economically interrelated, affecting several branches of the

economy, as well as giving rise to entirely new sectors. Obvious examples are the cluster of synthetic materials innovations, petro-chemical innovations, and machinery innovations in injection moulding and extrusion. Other examples are the cluster of electrically driven household consumer durable innovations, and the plastics machinery innovations. The concept of "natural trajectories" introduced by Nelson and Winter (1977) helps to explain the technical interrelatedness of these clusters of radical and incremental innovations. They argue that:

"While natural trajectories almost invariably have special elements associated with the particular technology in question, in any era there appear to be certain natural trajectories that are common to a wide range of technologies. Two of these have been relatively well identified in the literature: progressive exploitation of latent scale economies, and increasing mechanization of operations that have been done by hand" (Nelson and Winter 1977: 58) (emphasis added)

(4) changes of techno-economic paradigms: they may be defined as those new technology systems which are so far-reaching in their effects that they have a major influence on the behaviour of the whole economy. These new techno-economic paradigms carry with them genuine technological revolutions, embodying complex structural changes and, consequently, structural crises of adjustment, though at the same time leading to major periods of economic development. It is worth mentioning that the expression "changes of techno-economic paradigms" rather than "changes of technological paradigms" (Dosi 1982) emphasises that the changes involved go beyond specific product or process technologies and affect the input cost structure and conditions of production and distribution throughout the system. The introduction of electric power or steam power are examples of such fundamental transformations. Freeman and Perez (1988) argue that:

"A vital characteristic of this fourth type of technical change is that it has pervasive effects throughout the economy, i.e. it not only leads to the emergence of a new range of products, services, systems and industries in its own right; it also affects directly or indirectly almost every other branch of the economy, i.e. it is a "meta-paradigm".... This fourth category corresponds to Nelson

and Winter's concept of "general natural trajectories" and, once established as the dominant influence on engineers, designers and managers, becomes a "technological regime" for several decades." (Freeman and Perez 1988: 47)

As a conclusion, we may claim that in this analysis of changing techno-economic paradigm, institutions and organisation forms in firms and society respond to and influence technological change. Each successive techno-economic paradigm is associated with different inputs of large and small firms, management style and practices, and relationships between firms and other organisations.

However, as Perez (1983) contends, it is often difficult for companies to adapt to a change of paradigm. Indeed, as mentioned above, the diffusion of a new techno-economic paradigm is boosted by the abundant availability and declining cost of a new basic factor of production (according to Kondratiev's waves, these would be respectively cotton, coal, steel, oil, and microelectronics), which is initially just realised in a few leading sectors. Although this diffusion process will eventually spread to all sectors of the economy, thus affecting enterprises of differing sizes across-the-board, the critical question we may ask is whether the size of a firm (be it small or large) will be a decisive factor in a company's successful response to technological change. In other words, are small firms intrinsically more innovative than their larger counterparts, or vice-versa? This is the focus of the next section.

### 2.3. The Relative Contribution of Enterprises to Innovation

It was argued above that neo-classical economic theory did not discriminate between the innovativeness of firms of different sizes. On the other hand, it was probably Schumpeter who mostly emphasised the contribution of firms of differing sizes to innovation, at first stressing the key innovative role played by the individual entrepreneur (Mark I model) and later highlighting the important part performed by the R&D laboratories of large, oligopolistic companies, which were pushing economic progress

(Mark II model).

### 2.3.1. Large enterprises or small firms?

In order to better understand the relative contribution of large and small companies to innovation, it is worthwhile to briefly present the theoretical models of technology-based product cycles, proposed by Abernathy and Utterback (1978), Utterback and Abernathy (1975), and Vernon (1966).

Vernon (1966) argued, referring to his Product Cycle theory, that in the early phases of the product cycle a great amount of product innovation takes place, thus requiring risk capital, entrepreneurship, and the presence of high-level scientific, engineering and marketing skills. Product performance is then the dominant factor determining competitiveness. As individual industries mature, the scope for smaller producers is reduced due to the increased cost of research and development, the standardisation of products, and the general change in emphasis from product technology to process improvements.

Utterback and Abernathy (1975) described the nature of innovation in small firms. They proposed a three-stage division of firms, in terms of their pattern of development. They contended that "Stage I" firms are at the beginning of their evolutionary process, basically responding to market needs with high performance products. Their production process tends to be fluid and unstructured. Innovations which occur in "Stage I" firms tend to be product rather than process innovations; indeed, this type of enterprise places high priority on product innovation as a competitive strategy. The change incorporated often involves original technology as opposed to transferred or licensed technology. Most companies in "Stage I" are new, relatively small, rapidly growing technology-based enterprises. By contrast, "Stage II" enterprises have begun to move towards a more structured production process. Their innovations tend to be stimulated by technological opportunities and their primary strategy is sales maximisation. Finally, "Stage III" firms have

a very structured and systemic production process. Innovations are stimulated by production-related factors in an effort to minimise cost. Most enterprises in "Stage II" and "Stage III" are relatively large, and innovations occurring in these stages tend to be process innovations.

Three years later, Abernathy and Utterback (1978) pointed out that, in the early stages of the development of a major new class of product, technological development is particularly centred in major product innovation, associated with high rates of natality (and of mortality) of new, dynamic, flexible, small firms, which exploit temporary monopolistic positions. As the technology matures, technological development shifts from major product innovation to process innovation and minor product improvement. A relatively more stable oligopolistic structure is likely to emerge, mainly concentrated on larger enterprises.

Summing up, we may contend that, according to these models, technological opportunity and firm size evolve together over time. In the early stages of high technological opportunity, innovations are generated by small firms, and are mainly directed to opening up new product markets. With greater technological maturity, innovative activities become concentrated in bigger firms, and are directed to improving process technology.

Two case studies (Kaplinsky 1983; Rothwell and Zegveld 1982) illustrate and reinforce these arguments.

Kaplinsky (1983), referring to the US computer-aided-design (CAD) industry, contends that its development comprised four major stages.

During the first phase, development was centred in *established large corporations* in the defence, aerospace, and aeronautical industries, in cooperation with mainframe computer producers.

The second phase was typified by the advent of the *new, small spin-off enterprises*, from both CAD manufacturers and electronics firms, which played the central part in the swift diffusion of CAD devices into the electronics industry.

The third phase was characterised by remarkably rapid market growth, as the use of CAD spread across manufacturing, a process induced by the *spin-off firms*. *Large companies* initiated a series

of take-overs of some of these fast-growing, new, small firms, thus increasingly concentrating the industry.

At the advent of the fourth phase in development, the market was controlled by turnkey producers supplying either mainframe systems or mini-computer systems. Since the beginning of the 80s, with the increase in the number of users, a *market-niche* has appeared for dedicated systems. These are based on limited software packages for precise applications. A number of micro-computer-based firms, established by *spin-offs from existing CAD producers*, and using "mature" application programmes engendered by the latter, have also begun to arise.

Another example of this process can be found in the evolution of the US semiconductor industry (Rothwell and Zegveld 1982). It was in the *R&D laboratories of a big company*, Bell Telephone Laboratories, that transistors were discovered, and many of the ensuing basic breakthroughs were also made there. Initially, these new devices were manufactured largely for in-house use only. However, its initial quick market diffusion was led by *new, small, fast-growing enterprises* created by technological entrepreneurs, most of them spinning-off from established large companies.

From the late 1960s onwards, a process of *industrial concentration* began to take place, leading to the agglomeration of the output of the US semiconductor industry in the top ten or so companies.

Nowadays, the major prospects for newcomers seem to be not in semiconductor production itself, but instead in *specialist market niches*, such as the application of semiconductor devices to the manufacturing of novel products, in particular in the general area of "information technology".

On the grounds of the preceding two brief accounts, we may hold that, while established major companies contributed with much of the crucial, state-of-the-art technology, venture capital and technically skilled personnel, which were critical to new technology-based enterprise start-up, the latter provided the risk-taking entrepreneurial push and rapid market exploitation. We do believe, then, that accent should be put on the

*relationships between small enterprises and big companies, instead of only looking at them separately. In fact, between small and large firms often occur cases of dynamic complementarities* (Rothwell 1983, 1989).

### 2.3.2. Dynamic complementarities and complementary assets

A significant characteristic of the emergence of a new industrial structure is the pattern of dynamic complementarity found between new, small enterprises and established, large companies. Furthermore, it is imperative to ponder their interactions in order to thoroughly comprehend the evolutionary dynamic of technologies and industrial sectors. Indeed, as clearly emphasised by Rothwell (1989):

"(i) Innovatory advantage is unequivocally associated with neither large nor small size.

...

(v) Small and large firms do not exist in isolation from one another. In the case of the US semiconductor and CAD industries, both small and large firms played important, but different, roles in the dynamic of industrial growth.

(vi) Any study of the roles of small and large firms in industrial innovation and growth should be dynamic; their relative roles might vary considerably over the industry cycle" (Rothwell 1989: 62)

This last point is particularly meaningful, as it relates to the notion of dynamic complementarities, a concept introduced by Rothwell (1983, 1989). Indeed, as Rothwell (1991) stresses:

"... many kinds of interaction can and do occur between large and small firms. These range from rather straightforward supplier-customer relationships to more complex *dynamic complementarities* during the evolution of new technology-based industrial sectors" (Rothwell 1991: 110) (emphasis added)

Therefore, as the description of the evolution of the American CAD and semiconductor industries thoroughly demonstrates, not only did small and large enterprises separately play a significant role in technological innovation, but they repeatedly performed interactive and complementary roles. On the one hand,

new, small, fast growing companies were of paramount consequence in the dynamic development, swift market diffusion, and commercial exploitation of the new technologies. Moreover, it seems that these kinds of firms are originally better accommodated to capitalise on innovative techno-market regimes, breaking out from older ones within which established corporations might be firmly tied. In spite of this more conservative position, large companies contributed to the beginning of a new technological paradigm, playing the crucial initiating role in basic invention and innovation. Furthermore, they also were remarkably constructive, both in creating novel devices largely for in-house use only, and in developing new technological avenues. In fact, their highly inventive character is stressed by Freeman (1982) who, speaking about the American semiconductor industry, says that:

"... it is important to keep in mind the following points: first that the larger corporations (Bell, GE, RCA, IBM, etc.) did continue to contribute a large share of the key innovations - perhaps as much as half - throughout the post-war period...; secondly, that they accounted for more than half the key process innovations...; thirdly, that in Europe and Japan, both the imitation process and the innovation process were dominated to a much greater extent by the large corporations" (Freeman 1982: 138)

Summing up the above discussion, we may cite Rothwell and Zegveld (1982) who, referring to the changing role small firms play in an industry, as it develops from newness to maturity, argue:

"Thus we see a pattern in which small firms play a highly significant role at the beginning, but whose role as a major force in the industry diminishes, partly through take-overs and mergers, partly through the entry of established large firms from other areas, and most importantly through successful growth. We also see that the possibilities for new small entrants, on a significant scale, diminish as the costs of entry (capital, marketing, distribution, R&D) rapidly increase and, perhaps, as the technological possibilities for the development of novel products decrease. However, even in the latter stages of evolution, SMEs can play an important role as suppliers of specialist devices and as sub-contractors to the large firms; they can even still enter the industry by catering for narrow market niches" (Rothwell and Zegveld 1982: 246)

Similarly, Hagedoorn and Schakenraad (1991), in their study of new materials, point in the same direction, arguing that:

"In many sub-markets of new materials large, diversified and integrated materials companies appear to be able to play a major role, in particular in high volume markets due to the effects of economies of scale. On the other side of the spectrum, small and medium sized companies can play a role in some low volume niche markets, such as in specialty materials, and in those design-oriented areas where small research-intensive firms can play a leading role as innovators" (Hagedoorn and Schakenraad 1991: 431)

Teece (1986, 1991) introduced the notion of complementary assets, as a means of explaining why enterprises or organisations which discover new products, new methods of production or new financial mechanisms, do not necessarily profit the most. Time and time again, competitors/imitators appear to gather massive gains. In fact, if new technologies are not effectively secured (for instance, through patenting), the result is that the innovation will be successfully marketed by the firm possessing the correct set of complementary assets. As this is, in principle, independent of the frequently unexpected innovation, it may be just by coincidence that the company which initially introduced the innovation also enjoys the best combination of assets. This is probably the reason why many innovative enterprises vanish from the market, after having experienced an initial success. Therefore, Teece (1986, 1991) argued that full commercial rewards from innovation can only be achieved if enterprises can access complementary assets such as competitive manufacturing and distribution and marketing. In his own words:

"Innovative new products and processes will not yield value unless they are commercialised.... The profitable commercialisation of technology requires timely access to complementary assets on competitive terms. Thus, an innovating firm or consortium that has developed a new product or process with good commercialisation prospects has taken only the first step. It must then secure access to complementary technologies and complementary assets on favourable terms in order to successfully commercialise the product or process.

Assets such as marketing, competitive manufacturing, reputation, and after-sales support are almost always needed" (Teece 1991: 411)

In a previous article (Teece 1986), he had already explained the nature of complementary assets, differentiating among generic, specialised, and cospecialised assets:

"Generic assets are general purpose assets which do not need to be tailored to the innovation in question. Specialized assets are those where there is unilateral dependence between the innovation and the complementary asset. Cospecialized assets are those for which there is a bilateral dependence" (Teece 1986: 289)

Teece's theory also brings a new perspective on the continuing debate on whether small and large enterprises contribute most to innovation and technical change. According to it, we may conclude that the size of a firm is not decisive *per se*, but it is of critical importance whether the enterprise possesses a set of complementary commercial, financial and organisational assets compatible with the product or process innovation. We will resume this discussion further below.

The question we now have to ask is whether the trend we have witnessed in the American CAD and semiconductor industries will also apply to a larger set of industries and firms. In other words, how far is it possible to prove precisely the relative contribution of small and large enterprises to innovation in differing industries.

### 2.3.3. The Science Policy Research Unit's database

A project initiated in 1971 at the Science Policy Research Unit (SPRU), and aimed at directly measuring innovation activity, had tried to answer this question. The SPRU data consist of a survey of 4,378 innovations which were assembled over a period of fifteen years. They were compiled from the judgements of what constitutes a significant innovation from many different independent experts representing several industries.

Over the years, a number of articles and papers were published, covering research focussing on different aspects of the database (Pavitt 1984; Pavitt, Robson and Townsend 1987a, 1987b, 1989; Robson, Townsend and Pavitt 1988;...).

The SPRU innovation data reveal several patterns with respect to the distribution across manufacturing industries and across firm sizes. Pavitt, Robson and Townsend (1987a: 306-307) have shown that, in descending order, the most innovative industries were machinery (573 innovations), mechanical engineering (558), electronics (428), chemicals (421), electrical engineering (346), and instruments (332). Conversely, the least innovative industries were printing (29 innovations), paper (54), shipbuilding and offshore engineering (67), aerospace (85), and rubber and plastics (91). Enterprises with fewer than 200 employees accounted for 31.6 percent of the innovations in instruments, 26.2 percent in machinery, 20.1 percent in textiles, leather and clothing, and 17.5 percent in electronics.

The ratio of the share of manufacturing firms' innovations to their shares of employment for the period 1981 to 1983 (Pavitt, Robson and Townsend 1987a: 304) was greatest (2.07) for enterprises with between 100 and 199 employees. The second highest ratio (1.90) was for companies with at least 50,000 employees, while the third highest ratio (1.58) was for firms employing between 200 and 499. They have also demonstrated that the relatively high innovative activity of small firms is a comparatively new phenomenon that did not emerge until around 1970. In fact, in the period 1956-1960, the ratio for the largest companies was about four times greater than it was for enterprises with between 100 and 199 employees.

These findings are particularly relevant, as they show above average innovation intensity among both small enterprises and large companies, thus suggesting that the relationship between innovative intensity and firm size may well be U-shaped. This contradicts the standard Galbraithian view (based upon Schumpeter 1987) that research intensity increases more than proportionately with firm size. Furthermore, they are also inconsistent with the conclusions presented earlier by a number of studies on innovation, market structure, and size of firm (Comanor 1967; Mansfield 1969; Mowery and Rosenberg 1979; Scherer 1965a, 1965b, 1982;...), and reviewed in two influential books (Kamien and Schwartz 1982; Scherer 1980).

Indeed, with the exception of the chemical industry, where research intensity increased steadily with the size of the enterprises, in the majority of those studies it was possible to reach the conclusion that there is a tendency for R&D intensity to increase more than proportionately with firm size up to some point which varies from industry to industry, and then to level off (and even fall), hence suggesting a r-shaped relationship between firm size and innovative intensity. In contrast, Soete (1979), in his analysis of 130 US corporations with more than 25,000 employees, disputes this understanding, arguing that there is some tendency for R&D intensity to increase with size of firm with the largest size-groups.

One possible explanation for the divergence between the findings of the SPRU team and, say, those of Scherer (1982) is advanced by Robson, Townsend and Pavitt (1988), who suggest that:

"Measured differences between the two countries (*the UK and the USA*) are likely to result from a number of causes: (a) ...; (b) different biases in the samples (*innovative activity in large firms in the USA, but in all firms in the UK; ...*); (c) ...; (d) measurement of different types of technological activity (*mainly incremental inventions in the USA, and significant innovations in the UK*); (e) measurement of different stages in the diffusion process (*all anticipated uses of patented inventions in the USA, but the first commercial user of significant innovations in the UK*)" (Robson, Townsend and Pavitt 1988: 7-8) (emphasis added)

Turning now to the question of the nature of the institutions within which innovations are created, the principal assumption emerging from the above mentioned studies is that a market structure intermediate between a perfectly competitive market and a monopolistic one would promote the highest rate of inventive activity. This conclusion derives mainly from Comanor (1967), who hints that where entry barriers are relatively low, there is little motivation to innovate, since the entry subsequent to an innovation would swiftly wear away any economic gains. At the same time, in industries with high entry barriers, the lack of potential entry may lessen the incentive to innovate.

This overall conclusion runs counter to the standard Schumpeterian hypothesis which pontificates that research

intensity increases more than proportionally to market concentration.

One possible reason for the discrepancies between the two standard hypotheses outlined above and the conclusions of the empirical studies referred to earlier lies in the likelihood that the statistical evidence is not identifying the true effect of size and concentration on innovative activities. Furthermore, beyond size of firm and market structure, there are other characteristics of industrial structure which may influence the rate of inventive activity. Dosi and Orsenigo (1988), for example, argue that industrial structure should be described "in terms of level and distribution of firm size, technological capabilities, technological variety, behavioural and organizational diversity" (Dosi and Orsenigo 1988: 20). Or, as Coombs, Saviotti and Walsh (1987) argue, referring to the empirical studies on innovation, size of firm, and market structure:

"Indeed, we are convinced that the existing confusion is the result of inadequacies in the theoretical framework used in these analyses (and that the solution does not lie in more empirical work). In particular, we question the implicit assumption that economic variables such as firm size and market concentration are the *independent* variables of the problem, that is, the *causes* of different patterns of innovation" (Coombs, Saviotti and Walsh 1987: 113)

In any case, what is important to retain as a result of the research on the SPRU's database is, on the one hand, the recent increase of the small enterprises' share in innovation intensity and, on the other hand, the continuing importance of large companies in the process of innovation.

#### 2.3.4. A taxonomy of sectoral patterns of innovation

In an influential article published in 1984, Pavitt followed a new line of research. Based on a preliminary (and incomplete) sample of data on about 2,000 significant innovations gathered in the SPRU's database, he investigated and attempted to explain

the similarities and differences in the ability to innovate and adopt new technologies in different types of industries.

In the SPRU database, each innovation "is attributed three numbers in the Standard Industrial Classification, or Minimum List Heading, as it is called in the UK: (1) the sector of production of the innovation; (2) the sector of use of the innovation; (3) the sector of the innovating firm's principal activity" (Pavitt 1984: 345). Therefore, the two first classifications allow Pavitt to trace each innovation from the producer to the user, which is the relevant characteristic in this connection.

In addition, following Scherer (1982), he defines "as product innovations those innovations that are used *outside* their sector of production, and *process* innovations as those that are used *inside* their sector" (Pavitt 1984: 348). He thus uses the sector as the point of reference in his definition of innovation, rather than the firm.

These two main premises along with information on the means of appropriating benefits from the innovation and on user needs allow Pavitt to make a sectoral division of innovating enterprises.

Initially, he identifies three main sectors in the manufacturing industry, one being subdivided into two smaller sectors, thus ending up with four sectors. He terms them as (1) supplier-dominated firms; production-intensive firms, split into (2) scale-intensive firms and (3) specialised suppliers firms; and (4) science-based firms.

(1) supplier-dominated firms: innovations are mainly process innovations and, as most new technology comes from suppliers of equipment, materials, software and other inputs, the opportunities for firm-specific technological advantage are few. Furthermore, these companies usually have a relatively weak R&D department. Typically, supplier-dominated enterprises are of small size and may be found in industries such as textiles, leather and footwear, agriculture, housing, private services, and traditional manufacture. In these sectors, the process of innovation is primarily a process of diffusion of best-practice

capital goods and of innovative intermediate inputs, such as synthetic fibres, produced by other firms. Supplier-dominated firms tend to appropriate the benefits from innovation by trademarks, special design and marketing/advertising.

(2) scale-intensive firms: innovation concerns both processes and products. The main sources of new technology are in-house production engineering departments, design offices, and suppliers of specialised inputs, with whom they have complementary relationships. Production activities generally involve mastering complex systems and, often, manufacturing complex products. Economies of scale of various sorts are significant. Firms tend to be large, they produce a relatively high proportion of their own process technology, devote a relatively high proportion of their own resources to innovation, and tend to vertically integrate into the manufacturing of their own equipment. These firms are present in industries such as food and drink, metal manufacturing, shipbuilding, motor vehicles, bricks, pottery, glass and cement, steel, and consumer durables. Their principal techniques of appropriating the benefits from innovation are secrecy in the production processes and know-how in the production.

(3) specialised suppliers firms: innovative activities relate primarily to product innovations which enter other sectors as capital inputs. Hence, these enterprises compete on the performance and reliability of their equipment, rather than on price. Firms tend to be relatively small, they operate in close contact with their users and embody a highly specialised knowledge in design and equipment-building. In fact, the main sources of technology are the firm's design office, and the production engineering and systems activities of customers. Typically, these firms belong to the mechanical engineering and the instrument engineering industries. Their means to appropriate the benefits from innovation are firm-specific skills, which result in both continuous developments of their products and the ability to adjust to user needs and user demands.

(4) science-based firms: innovation is directly linked to technical paradigms made possible by scientific advances.

Technological opportunities for innovating are therefore very high. Consequently, the premium for innovative success is also generally high, as successful enterprises often become large rather quickly. Furthermore, the cumulativeness of technical advances frequently allows them to remain large and successful thereafter. Innovative activities are based in a massive in-house R&D effort. A high proportion of their product innovation enters a wide number of industries as capital or intermediate inputs, thus enabling horizontal diversification into new product markets. These firms are represented in the chemicals industry (and increasingly in biotechnology) and in the electrical and electronic engineering industry. These enterprises are able to protect their innovations partly by entry barriers, and partly by patents, trademarks, and secrecy.

In subsequent articles (Pavitt, Robson and Townsend 1987b, 1989), Pavitt improved his taxonomy of sectoral patterns of innovation. Among other important refinements we may highlight the fact that i) he excluded from the taxonomy the "supplier-dominated" category of firm since, as Porter (1985) stressed, it leaves accumulated technological skills and the strategic initiative with suppliers; ii) in its place, Pavitt introduced a new basic technological trajectory of enterprises, which he labelled as "information-intensive", its main source of technology being the software/systems departments of the firms as well as specialised suppliers, and having a particularly active role in the financial services, and retailing; and iii) he suggests that individual enterprises can fit in more than one basic technological trajectory, as in the case of a large computer firm which can, at the same time, be information-intensive, scale-intensive, and science-based.

A number of researchers and scholars had also tried to better Pavitt's taxonomy. It may be worthwhile briefly focussing here on the work by Imai and Baba (1991).

In an interesting paper, they suggest the possible relationships between i) three distinct international network modes (traditional multi-domestic, global, and cross-border) and ii) six sectoral groups of industries (*traditional supplier-dominated*

*industry*, including agriculture, housing, traditional manufacturing, and personal services; *specialised-supplier industry*, containing specialised machinery, and instruments; *scale-intensive industry*, comprising steel, glass, consumer durables, and autos; *science-based industry*, incorporating chemicals, and pharmaceuticals; *new information-intensive service industry*, embracing banking, insurance, and tourism; and *emergent generic-complex industry*, encompassing electronics, mechatronics, and computers telecommunications).

Referring back to Pavitt's taxonomy, we may conclude that the basic technological trajectories of enterprises are clearly determined by their core activities. Furthermore, the likelihood for technology-based diversification is strongly influenced by their distinct capabilities and directions for technical change. Additionally, we must keep in mind that strong functional differences exist between industries that seem alike on the grounds of high R&D inputs, specially at the small firm level. This evidence on differences between small enterprises from distinct industrial sectors is particularly pertinent, because small firms have made important contributions to innovation and growth in specific high technology industries. In fact, besides the previously referred cases of the American CAD and semiconductor industries, Rothwell (1989) argues that it was the appearance of the integrated circuit and of the microprocessor which allowed the access of new small enterprises to the UK electronic computers sector, manufacturing primarily mini and micro-computers and peripherals, thus supplying the many new niche opportunities that arose.

As Rothwell and Zegveld (1985) state:

"Two important points emerge from the above discussion. The first is that the debate concerning firm size and innovation should proceed on a sector-by-sector basis. The second is that a dynamic approach clearly is necessary: the relative contribution of firms of different sizes to innovation in a particular industry might depend on the age of that industry; the type of innovation typically produced by large and small sized firms at different stages in the industry cycle might vary also, ie product or process innovations" (Rothwell and Zegveld 1985: 200)

Hence, we can highlight the fact that both large firms and small enterprises make important contributions to technological innovation, albeit their relative contribution change over the industry life cycle. This leads us to the discussion of the advantages and disadvantages of small and large firms in the innovation process.

#### 2.3.5. Advantages and disadvantages of small and large firms in the process of innovation

During the 1960s, a distinct focus of industrial policy in a number of major European countries was that of industrial concentration. Mergers between enterprises were advocated and promoted, the idea being to create major national companies with the technical, production and financial strengths to entitle them to compete successfully in world markets. In comparison, since the mid-1970s, many European governments have increasingly put emphasis on measures headed towards small and medium sized enterprises.

Three fundamental reasons were behind this shift of policy. Firstly, Birch (1979) published a paper in which he stressed the employment-creating potential of small firms. Secondly, such companies were believed to have greater than average ability for the industrial and economic regeneration of the so-called "depressed" or "development" regions, which exist in all European countries. Finally, emphasis was being laid on the innovatory potential of small enterprises, which were said to possess certain intrinsic advantages in innovation.

In fact, the debate regarding the relative advantages and disadvantages of small firms in innovation rotates largely around the issue of the advantages and disadvantages of scale. Indeed, according to Rothwell (1983), the innovatory advantages and capabilities of small enterprises are mainly *behavioural*, and include management dynamism, organisational flexibility, rapid internal communication, high degree of adaptability, etc. On the other hand, those of large firms are mainly *material*, such as large financial and qualified manpower resources, extended

external scientific and technological networks, large marketing resources, comprehensive range of management skills, etc.

It is interesting to note that many large companies, including major US corporations such as 3M, tried to blend their material advantages with the behavioural advantages of the small enterprises, relocating their innovatory activity in comparatively small units.

In return, big companies are disadvantaged because of their highly structured, hierarchical organisation, which may conduce to the suppression of the free flow of potentially innovative ideas. Their R&D process may also be affected, becoming much less sensitive to market demands. Small firms can also suffer from a multitude of problems, namely those related to their financial, legal, managerial, marketing, and technological activities, which may influence negatively their process of innovation.

It is important to keep in mind that the small enterprise sector plays a very significant role in the economies of the Western developed countries. Dodgson and Rothwell (1989a) argue that it comprises well over 90 per cent of all industrial firms in the five leading European economies. Not surprisingly, a high degree of heterogeneity also exists among small and medium sized firms. In an attempt to better characterise the small firm sector and to understand the differing needs of its enterprises with respect to innovation, Dodgson and Rothwell (1989a) and Rothwell (1991) propose a simplified taxonomy of small and medium sized firms in manufacturing industry. This will be the focus of the next section.

#### 2.3.6. A taxonomy of small and medium sized enterprises

Small and medium sized enterprises (SMEs) can be divided into four broad categories, namely (1) subcontractors firms; (2) SMEs in traditional industries; (3) modern, niche-strategy SMEs; and (4) new technology-based firms (NTBFs).

(1) subcontractors firms: many thousands of SMEs work as manufacturing subcontractors for other companies, supplying sub-

assemblies and components according to the strict specification of their customers, both small and medium sized enterprises and large corporations, as in the case of Japan (Shapira 1992). Normally, they do not perform R&D in any formal sense.

(2) SMEs in traditional industries: in general, this category includes old companies operating in established areas such as footwear, garments, leatherware, metalworking, textiles, and woodworking. Currently, they are facing strong competition from the developing countries, particularly in terms of low labour costs. As these enterprises are not expected to generate significant product technological innovations, they are forced to upgrade the quality of their products through an optimal access to existing technology, which normally is exogenously produced by materials and equipment suppliers. Access to management expertise and the possibility of benefiting from the many opportunities modern microelectronics devices can offer is also of paramount importance for these small firms.

(3) modern, niche strategy SMEs: these are enterprises active in the fields of CAD, electronics subsystems, scientific instruments, and specialist machinery and equipment areas. They operate mainly for specialist market niches, supplying often small batch or custom-built products, using in the process up-to-date technology. These firms have to perform some in-house R&D, as they need to be innovative in order to survive. Notwithstanding, to complement their commonly limited in-house R&D resources, the companies also need a frequent access to external sources of scientific and technological expertise, establishing formal and informal linkages with other enterprises, with academic research, and with public sector institutions.

(4) new technology-based firms (NTBFs): these typically small, young enterprises operate at the forefront of newly emerging technologies, exploring embryonic market areas with a very strong potential for growth, such as biotechnology. Rothwell (1984) contends that NTBFs are indeed playing an extremely important role in the emergence of such new, technology-based industrial sectors. In a review of literature and hypotheses on NTBFs, Bollinger, Hope and Utterback (1983) argue that:

"Although no clear-cut definition of a new technology-based firm exists, analysts generally use characteristics to distinguish between those companies which qualify as such enterprises and those businesses which do not. First, one can usually clearly identify a small nucleus of people, ranging from one to four or five, as the founders of the organization. Second, the company is totally independent in that it is not a part or subsidiary of a large firm.... Lastly, the primary motivation for founding such enterprises should be to exploit a technically innovative idea" (Bollinger, Hope and Utterback 1983: 2)

Albeit the total independence of a NTBF seems to be an open question (eg, a large pharmaceutical corporation may be interested in financially supporting a small biotechnology enterprise), it is a fact that most of the new technology-based firms started as spin-offs both from large, established companies, and from university departments, aiming at exploring radical product innovations. The general characteristics of the founders of NTBFs are also very important for their success, in particular if they come from a wide range of disciplines, such as management, engineering, marketing, etc. These points are stressed by de Vet and Scott (1992). Referring to the Southern Californian medical device industry, they contend that:

"There is evidence... that when radical product innovations occur they often tend to induce much spin off and the formation of new small firms.... Key personnel (i.e. experienced and knowledgeable workers in charge of crucial firm operations) are central to the spin-off process. Certainly these are among the individuals most strategically placed both to perceive new commercial opportunities and to take advantage of them" (de Vet and Scott 1992: 152)

Taking into account the fact that NTBFs operate in high risk sectors, no wonder that their major source of technical know-how and the primary basis of these enterprises' technological accumulation is their in-house R&D activities, to which a considerable percentage of resources are allocated. NTBFs' external linkages are also of particular relevance, specially regarding academic research, but also with other enterprises and with public sector institutions.

### 2.3.7. Case studies

Two researchers from SPRU, Dodgson and Rothwell, were responsible for three studies into technology strategies in innovative small and medium sized enterprises, known as i) the Celltech study (Dodgson 1990); ii) the IRDAC study (Dodgson and Rothwell 1989b; Rothwell and Dodgson 1989); and iii) the Small Firm Linkages study (Beesley and Rothwell 1987; Rothwell and Dodgson 1991). We will now briefly refer to them, as they illustrate in practice what we have just written.

i) the Celltech study: this medium sized enterprise, one of Europe's foremost independent biotechnology firms, experienced rapid growth and high profits since its foundation. Initially, its technological expertise came mainly from external sources, such as from academia and from the skills developed in other companies by its employees. It swiftly generated its own expertise, heavily investing in R&D and recruiting a high number of graduate scientists. As a consequence, it has registered a vast number of patents. The extent of its external linkages is impressive, and includes long-term collaboration with universities, with research institutes, and with some of the world's biggest pharmaceutical corporations. Its internal organisational structures are flexible and creative, contributing to very good internal communications and information flow patterns. It also follows an adaptive business strategy in order to be able both to react promptly to changes in the technological, competitive, and regulatory environment and, as often as possible, to influence it. Finally, we must point to the superior quality of leadership and vision provided by its management.

ii) the IRDAC study: this research looked at the commitment to R&D and the patterns of growth of 12 leading-edge, niche strategy European SMEs. Most of them had initially obtained their technological expertise on the grounds of externally acquired know-how. They rapidly started their movement up the technological learning curve, banking increasingly on internally-generated knowledge, spending high levels of financial resources

on R&D and recruiting a large number of qualified and committed R&D personnel, namely graduate scientists and engineers. They paid special attention to feedback from customers and suppliers, as well as to external financial, marketing, or technological advice, as these factors may influence their long-term development. It was found that the competitiveness of these enterprises depended to a great extent on their comparative technological advantage. Their market strategy comprised an active search for future strategic market niches where they might be able to compete on technological leadership. One important factor supporting the success and growth of the companies was the quality of their management.

iii) the Small Firm Linkages study: this research aimed at exploring the degree of external technological linkages of a sample of 103 innovative small firms in the UK. It detected a number of forms of external linkages, comprising collaborative R&D, subcontracted R&D, manufacturing relationships, marketing relationships, and linkages with educational establishments, other public sector bodies and research associations. The chief part of these innovative small enterprises was found to have some sort of external linkages involving know-how transfer, which was of relevance to the growth of their business. Moreover, few innovative SMEs formed linkages with large companies, and they also preferred to establish strong "near-to-market" interactions involving product development along the vertical supplier-manufacturer-customer chain. The extent of internal technological competences, particularly the quality and quantity of in-house employment of technical specialists, was one of the most significant reasons influencing the willingness and capability to establish external technological links. As Dodgson (1993) points out:

"SMEs can be further disadvantaged in their external search processes (for new information or ideas) and other learning activities, since they often lack suitably qualified technical specialists. Such personnel are often scarce, and therefore too expensive for SMEs, but this problem is often compounded by a lack of awareness on the part of smaller firms of the value of employing highly skilled personnel.... Of equal importance is the fact that lack of

qualified scientists and engineers (QSE) can inhibit the SME's ability to disseminate and further develop technological know-how, even when it does succeed in acquiring it from external sources" (Dodgson 1993: 146)

Below, he adds that:

"... lack of QSE in a SME generally doubly inhibits technological accumulation, through limits on the more obvious mechanism of in-house R&D and through the inability satisfactorily to access external know-how.... The importance of having employees capable of being receptive to external sources of information applies not only to *product* innovation but also to *process* innovation" (Dodgson 1993: 147)

Therefore, one common, important characteristic derived from the three studies outlined above is that innovative, outward-looking small and medium sized enterprises need to sustain a continuing high level of effective business, marketing and technical linkages with external agencies, if they are to maintain, and improve, their technological dynamism and market competitiveness. In other words, if they want to be (highly) successful.

#### 2.4. Conclusions

In this chapter, we have tried to analyse and understand the role played by small and large firms in the process of innovation. Based upon a review of the relevant literature on the theory of innovation, it was possible to distinguish two leading schools of economic thought.

The neo-classical economic theory regards technology as being freely and effortlessly available to all firms, irrespective of their size. Furthermore, it usually restricts to only Capital and Labour the range of combinations of factors of production, hence allowing neo-classical economists to make generalisations on the behaviour of enterprises. Obviously, this assumption is far from being realistic when comparing with what happens in the "real world", as it postulates an over-simplified economic model. This does not take into account an immense variety of sources and types of technology. Moreover, the model does not differentiate

between the innovativeness of small and large enterprises. Finally, while stressing that enterprises have indistinguishable access to credible information, thus being able to act with absolute knowledge and foresight, neo-classical economists have paved the way to the formulation of anti-monopolistic, anti-trust policies in a number of Western countries.

The evolutionary theory provides a much more realistic interpretation of the process of innovation in enterprises. To start with, neo-Schumpeterians stress that technical knowledge is usually not easily obtainable "off the shelf" and that a learning process is needed to use it efficiently. They have also improved the economic models proposed by the neo-classical school, introducing more pragmatic variables. As a consequence, they maintain that it is not pertinent to make universal generalisations on the behaviour of enterprises, since these are intrinsically heterogeneous. This point is illustrated by the different, but crucial, roles played by small enterprises and large companies, during the Schumpeter Mark I and Mark II models of innovation, respectively.

In fact, a symbiotic relationship exists between small and large firms. The empirical evidence reviewed shows that during the evolution of a new technology, or a new industry, they both perform different and yet complementary roles. The extent of each contribution differs from industry to industry, and is also in a continuous process of evolution and change. In some areas, the relative contribution of small enterprises is growing, whereas in other areas it is declining. Furthermore, it also varies with the diffusion of generic technologies, namely information and communications technology, throughout the system, as well as with the different stages of the industry's life cycle.

Referring specifically to the small firm sector, it has been demonstrated that one of the most important requirements of its enterprises with respect to innovation is a frequent access to external sources of scientific and technological expertise, namely the establishment of formal and informal linkages with other enterprises, with academic research, and with public sector institutions. The importance of external linkages in successful

technological innovation will thus be the focus of the next chapter.

### 3. EXTERNAL LINKAGES AND TECHNOLOGICAL INNOVATION

#### 3.1. Introduction

In Chapter 2 we have pointed to some of the advantages of an evolutionary approach to the understanding of innovative activities. This is especially true in the case of the rise of collaborative agreements and arrangements, which are the subject of this chapter. The empirical research discussed in Chapters 8 and 9 demonstrates very clearly the way in which external linkages have been, and are, evolving in two Portuguese industries. But to understand this phenomenon, it is essential to locate it in a wider international context, to see how far the Portuguese case confirms the findings of the previous research literature or otherwise. Consequently, this chapter reviews the findings of this earlier literature.

Collaboration between enterprises is currently a widespread phenomenon, engulfing not only large companies, but also small and medium sized firms. Moreover, cooperative agreements are no longer restricted to high-technology industrial sectors. Consequently, we are confronted with an enormous complexity surrounding industrial partnerships. Despite this intricacy, industrial collaboration has an increased significance. Bearing in mind this situation, we start by addressing the vast range of motives behind the growing importance of industrial cooperation (*point 2*).

After a thorough review of the relevant literature, we focus our attention upon the main reasons, the advantages and disadvantages, the focus, and the forms of technological collaboration.

Then, with an illustrative purpose, we select for analysis a particular mode of inter-firm agreements, informal networking. This has attracted our interest because of its potential relevance to the Portuguese case.

The reasons which led to increased industrial collaboration are

also forcing companies to learn new rules of behaviour. In this context, we argue that trusting relationships between partners may turn out to be a crucial element of competitiveness (*point 3*). Trustful partnerships could also contribute to the creation of a new high trust-based economic system, which may have in itself the potential to revitalise declining or threatened economic areas, as is the case of some regions of Portugal. The specialised literature shows that there is a multitude of interpretations regarding the intricate and interrelated topics concerning industrial cooperation. Thus, in this chapter, we will try to be as clear and informative as possible.

### 3.2. Industrial Collaboration

One of the most interesting, and widely studied, features of the industrial dynamics during the 1980s was centred around the growing importance of industrial cooperation. On technological collaboration see, for example, the book edited by Coombs, Richards, Saviotti and Walsh (1996), and the earlier survey on "Networks of Innovators" (*Research Policy*, vol 20, no 5, October 1991).

Yet, the trend towards collaboration in industry has a long history. Alic (1990) indicates that, as early as 1775, Josiah Wedgwood and a group of Staffordshire potters tried to bring together the first known R&D association. Similarly, Freeman (1991) reminds us that there has been a history of formal R&D collaboration from the 1920s.

What indeed makes the recent spate of cooperative associations original is their extent. In a study of the successful management of collaboration commissioned by the Centre for Exploitation of Science and Technology (CEST), it is argued that:

"Firms co-operate with suppliers, customers and competitors, and with firms with which they have no commercial relationships. They work jointly with universities, polytechnics, independent research and technology organisations and government laboratories. The focus and scope of these collaborations vary widely, with broad differences between and within industrial sectors.



They can vary from simple and brief contracts to large-scale, long-term joint ventures" (CEST 1991: 1)

Chesnais (1988b) further stresses this reasoning when he contends that:

"Co-operation and/or technology exchange between firms (or between firms and other categories of research organisations) can either take place at a single given point of the R&D-to-commercialisation process or cover the whole process. It can concern either the creation of new technology or the acquisition and use of an already existing one or, again, both. Co-operation can concern exclusively R&D or it can also involve arrangements for market access and joint commercialisations. It can take place between firms of equal or near equal strength or, on the contrary, of very different size and financial power" (Chesnais 1988b: 52)

The current wave of increased use of agreements by enterprises seems to be related to the particular set of phenomena which have prevailed in the world economy since the end of the 1970s, and which have also strongly affected the evolution of the industrial innovation process itself.

Indeed, Rothwell (1992) suggests that we are now entering the fifth generation innovation process. The first and the second models regarded innovation as a linear sequential process, respectively driven by technology (technology-push) and pulled by market demand (need-pull). The third generation began to realise that science, technology, and the marketplace were coupled in a much more interactive way. As Rothwell and Zegveld (1985) state:

"According to this model innovation is regarded as a logically sequential, though not necessarily continuous process, that can be subdivided into a series of functionally separate but interacting and interdependent stages. The overall pattern of the innovation process can be thought of as a complex net of communication paths, both intra-organizational and extra-organizational, linking together the various inhouse functions and *linking the firm to the broader scientific and technological community and to the marketplace*. In other words the process of innovation represents the confluence of technological capabilities and market needs within the framework of the innovating firm" (Rothwell and Zegveld 1985: 50) (emphasis added)

The fourth generation innovation process marked a shift from perceiving innovation as a strictly sequential process to understanding it as a largely parallel process. Based to a significant extent on the Japanese experience, it integrates and overlaps research with all phases of product development, manufacturing, and distribution. Increased emphasis was also placed on the closer integration of enterprises. These linkages were both horizontal, with competitors and with firms performing similar activities in other industrial branches, and vertical, with suppliers and customers in complementary activities. According to the major features of the fifth generation model, industrial innovation is becoming faster. In order to produce new products flexibly, quickly, and to a higher quality, new forms of agreements between companies are needed, involving inter-company networking. As Chesnais (1988b) underlines:

"In the face of financial and economic uncertainty and turbulence in the world economy and of parallel rapid and radical technological change, the new forms of agreements offer firms a way of ensuring, in a wide variety of situations, a high degree of flexibility in their operations. When technology is moving rapidly, the flexible and *risk sharing* (or indeed risk displacing) features of interfirm agreements, offer firms in particular a wide range of possibilities for acquiring key scientific and technical assets from outside" (Chesnais 1988b: 53)

Technological collaboration is thus in major part a result of the uncertainties engendered by contemporary technological change. Furthermore, there is also considerable uncertainty as to the most appropriate configurations of the technology, and the markets in which it is to be used. Consequently, the network mode of collaboration can offer enterprises a new way of handling these "imperfections", in particular those related to innovation. A number of researchers and scholars (eg Freeman 1991, Saxenian 1991, Scott 1991,...) even suggest that innovation networks may be described as the organisational form for the new techno-economic paradigm of information technology. As DeBresson and Amesse (1991) put it:

"Perhaps networks are a form of organization better adapted to the technological revolution in which we are living....

Large vertically integrated firms have dominated the fourth Kondratieff. Are networks the next generation of organizations best adapted to the fifth Kondratieff?" (DeBresson and Amesse 1991: 370)

The present period of intense technological collaboration in industry can to a degree be also explained by the profound impact of the new techno-economic paradigm of information technology on existing enterprises and sectors. This novel paradigm generates the need for new organisational structures, in order to adapt to and reflect the opportunities and threats provided by radical technological change. Those new structures include greater technological cooperation and networking. Indeed, as Freeman (1991) points out:

"Characteristic of periods of change of techno-economic paradigm is the rise of new firms associated with competence in the new technologies and the strategic re-positioning of many established firms as they try to cope with the rapid structural and technical change affecting their markets and their very existence. If we take into account also the international aspects of production, marketing and technology development, then clearly a period of great turmoil could have been expected in the 1980s, *with many new strategic alliances and networks*" (Freeman 1991: 509) (emphasis added)

A similar line of thought is sustained by Teece (1988), who contends that even research-intensive enterprises will have to embark in some sort of inter-firm agreement, when a shift in the technological paradigm renders the existing skill base of the firms obsolete or irrelevant.

### 3.2.1. The growing importance of industrial collaboration

Referring now specifically to inter-firm collaboration, it was found that it involved predominantly large companies belonging to the so-called "economic Triad" (Europe, Japan, and the USA) (Gugler 1992, Hergert and Morris 1988, Hladik and Linden 1989), and in particular those working in the newer technologies of information and communications, in biotechnology, and in new materials (Hagedoorn and Schakenraad 1990, 1991, 1992). However,

small and medium sized enterprises were also increasingly involved in the corporate networking process. For example, Furukawa, Teramoto and Kanda (1990) point out that Japanese small businesses are organising dynamic networks for technological activities, in order to develop and commercialise their own technology. They contend that "According to a survey of R&D in 1987 there were 981 INTACs [Inter-Industrial Network for Technological Activities] in 1986. This was about three times as many as in a previous survey (357) held in 1984" (Furukawa, Teramoto and Kanda 1990: 39).

A general picture thus emerges of increased numbers of new collaborations being formed in the early and mid-1980s. Two further examples will suffice to illustrate this trend. In the United Kingdom, a detailed pilot study of the external inputs used by 103 innovatory small firms indicates "very significant levels of inter-company linkages relating to firms innovatory activities" (Beesley and Rothwell 1987: 189). In Japan, "A 1986 survey by the Japan Key Technology Centre revealed that nearly two-thirds of the 261 firms surveyed have engaged in inter-firm research projects" (Levy and Samuels 1991: 120).

What might be even more interesting to ponder are the reasons why different scholars and researchers reach different conclusions while trying to forecast the future trend of technological collaboration in industry. With respect to two fields of technology which are usually perceived as core technologies, ie biotechnology and information technology, while Mytelka (1991a) believes that a continued increase in the number of technological cooperation agreements is likely to persist during the 1990s, Hagedoorn and Schakenraad (1990) contend that a certain degree of stabilisation is expected in the short run.

Probably the major reason for the above mentioned discrepancy relates to the strong individual ways in which authors define industrial collaboration and distinguish between different organisational modes of inter-firm cooperation. For example, Hagedoorn and Schakenraad (1990) point out that:

"First of all, we defined co-operative agreements as common interests between independent partners which are not

connected through (majority) ownership. In the CATI [Co-Operative Agreements and Technology Indicators] information system only those inter-firm agreements are being collected that contain some arrangements for transferring technology or research. *Joint research pacts, second-sourcing and licensing agreements and research corporations are clear-cut examples.... Mere production or marketing joint ventures are excluded*" (Hagedoorn and Schakenraad 1990: 29) (emphasis added)

Conversely, Mytelka (1991b) argues that:

"... the one-way transfer of existing technology (as in *licensing or second-sourcing agreements, cross-licensing with a strictly marketing or market organizing objective and research contracts between a firm and a university or research institute*), frequently included in other taxonomies of partnering activity..., is not included here.... The range of strategic partnering activity... thus extends from pre-competitive R&D consortia... to a variety of technological cooperation agreements... that involve shared equity arrangements or go beyond the core - knowledge-production and sharing component to include *production and marketing cooperation*" (Mytelka 1991b: 2) (emphasis added)

The whole subject of technological collaboration is thus very complex. For a start, as mentioned above, we have found that almost every researcher has her/his own, unique, "pet" term to define it. To name but a few examples, collaboration is also known as alliances, cooperative agreements, dynamic networks, external linkages, industrial networks, innovation networks, inter-firm agreements, intermediate organisation, joint ventures, linkages, network forms of organisation, networks, partnerships, regional and industrial clusters, strategic networks, strategic partnerships, etc!!! It seems therefore useless to try to explain the differences between all of these terms, specially because of the wide range of existing cooperative agreements. Indeed, alliances, collaboration, cooperative agreements, networks, etc, have been defined by several authors in a very flexible way. For example, Mariti and Smiley (1983) have centred their definition upon inter-firm agreements, arguing that cooperative agreements are explicit, long-term agreements established between two or more companies.

On the other hand, Katz and Martin (1993) focussed their

interpretation of collaboration on scientific tasks. They suggest that it is "... the working together of individuals to achieve a common goal - in this case, the task of producing new scientific knowledge" (Katz and Martin 1993: 7).

Probably one of the most comprehensive and complete definitions of collaboration is advanced by Dodgson (1993). In his definition he maintains that it

"... includes any activity where two or more partners contribute differential resources and know-how to agreed complementary aims. In this definition may be included the following, both privately created and promoted by public policy:

(a) Collaborative research programmes or consortia.

(b) Joint ventures and strategic alliances.

(c) Shared R&D and production contracts.

Both vertical and horizontal linkages are included.... direct investment, licensing, marketing agreements and computerized networks and data-banks... are not included as they are essentially one-way transfers of know-how" (Dodgson 1993: 13)

Interestingly enough, in a paper presented at a workshop on "Networks of Innovators", DeBresson and Amesse (1991) wrote:

"As with any powerful concept, that of network is necessarily all-encompassing and therefore vague; it is given different meanings and subjected to various usages" (DeBresson and Amesse 1991: 364)

The plethora of previous definitions of technological collaboration, which illustrates the disagreements amongst authors regarding what should and should not be included in each definition, highlights the vagueness of the field we are entering. So far, in our opinion, only three general questions are widely assumed.

Firstly, it is accepted that partners working together can obtain mutual benefits which otherwise they could not achieve independently. Secondly, collaboration is believed to assist with uncertainty. Increasingly sophisticated and demanding consumers, the growing competition in, and internationalisation of, markets, as well as the rapidly changing, disruptive technologies, place a growing pressure on companies (and nations) to co-exist with, and to attempt to control, the uncertainties which are

challenging them. It is certainly easier to cope with such problems in a cooperative mode rather than in isolation. Finally, collaboration is believed to offer more flexibility than its alternatives (acquisitions, direct foreign investment, and mergers). It also facilitates the transfer of know-how between organisations more effectively and efficiently than market transactions.

A different way of analysing technological collaboration and network relations is the so-called "actor-network" theory (see, for example, Larédo and Mustar 1996; Mangematin 1996). This sociological approach is also concerned with institutions, in particular with the effect of organisational culture on behaviour, with hierarchical structures, and with power relationships. However, its main focus has been the interactions amongst actors, both within and between organisations. For example, it is interested in mapping, as well as in the processes of creation and evolution of, the networks of relationships between economic and technology policy-makers, innovators, potentially competing enterprises with complementary skills, public research laboratories, regulatory authorities, suppliers of finance, materials and components, and users. In other words, the "actor-network" concept pays attention to the fact that actors do not exist without the network of relationships they create in the course of their social existence and which define how they function and who they are.

This sociological approach also tries to describe how each participant in the network was drawn in by one or more of the others, and how the commitment of one is built on that of each of the others. In other words, how the involvement of actors with different goals, methods, orientations, and views, translate in the fact that they are all able to realise their separate aims by the achievement of a common goal, with which all their interests are bound up.

Therefore, in order to overcome the complexity surrounding industrial partnership, which we have briefly sketched above, we will try in the next sections to bring to light some of the key questions on technological cooperation.

### 3.2.2. Reasons for technological collaboration

An important issue with respect to inter-firm linkages is the reasons which induce enterprises to embark in a networking process. In fact, because innovation is a central element in the way firms compete, they are generally inclined to undertake technological development in-house. The growth in technology collaborations means therefore that more companies are choosing second-rate ways of operating. In short, they collaborate because they need to.

Enterprises tend to have their particular motives for cooperating, and these typically differ both for the firms involved and for each individual agreement and mode of collaboration.

A number of motives which relate to inter-firm cooperation are listed by Hagedoorn and Schakenraad (1990). These are:

- "- the extremely high costs and risks of R&D in high-tech industries;
- quick pre-emption strategies on a world scale which are preferable despite a "loss" of potential monopoly profit;
- technology transfer and technology complementarity;
- exploration of new markets and market niches;
- shortening of period between discovery and market introduction; and
- monitoring the evolution of technologies and opportunities" (Hagedoorn and Schakenraad 1990: 10)

Later, however, Hagedoorn (1993) contends that:

"From our material it becomes obvious that, if one looks at the general outcomes, only three motives play a role of true significance. Technology complementarity, reduction of the innovation time-span, and market access and influencing the market structure are the most mentioned motives. The first two motives are probably the most important motives for companies to engage in technology cooperation.... Other motives appear to play only a very limited role" (Hagedoorn 1993: 378)

From the textbooks, one learns that a large number of motives could lead companies to forge partnerships. Indeed, after a thorough review of the literature on cooperation, Barañano (1995b) proposes an exhaustive taxonomy of the motives for

technological collaboration, distinguishing between a technological, a corporate, a national, and an international perspective (see TABLE 1).

<b>TABLE 3.1: REASONS FOR TECHNOLOGICAL COLLABORATION</b>	
<b>TECHNOLOGICAL MATTERS</b>	<ul style="list-style-type: none"> <li>• High cost of technological development</li> <li>• Technological complexity and novelty</li> <li>• Nature of technological knowledge</li> <li>• Uncertainty</li> <li>• Definition and implementation of standards</li> </ul>
<b>FIRM'S STRATEGY</b>	<ul style="list-style-type: none"> <li>• Valuable supplement to in-house R&amp;D</li> <li>• Firm's growth and technological diversification</li> <li>• Firm's strategy of concentration</li> <li>• Exclude competitors</li> <li>• Observe novel technological developments</li> <li>• Cope with the shortening of the product life cycle</li> <li>• Cope with the reduction of the span between invention and market introduction</li> <li>• Expand product's scope</li> <li>• Failure of past mergers</li> <li>• Exploration previous to merger</li> <li>• Learning of firm's organisational and managerial issues</li> <li>• Acquisition of experience in collaboration</li> </ul>
<b>COUNTRY LEVEL</b>	<ul style="list-style-type: none"> <li>• Increase the domestic firms' competitiveness</li> <li>• Alleviate the burdens of public expenditure</li> </ul>
<b>GLOBAL LEVEL</b>	<ul style="list-style-type: none"> <li>• Cope with techno-globalism</li> </ul>

SOURCE: Barañano (1995b)

It is not our intention, in this chapter, to scrutinise Barañano's taxonomy. Instead, we will centre our attention in some of the most fundamental motives she advances, focussing our interest particularly on the technological and the corporate perspectives, reserving the examination of the remaining reasons for latter chapters.

Before starting our analysis, it is important to stress that we do believe that most of the motives advanced by Barañano are in fact deeply interrelated. It is only for methodological reasons that we will consider them independently of each other.

Although Hagedoorn (1993) does not grade the **high cost of technological development** among his three major reasons for technological collaboration, the fact remains that it normally ranks high in the literature. For instance, the high costs of initial product development and testing are a significant barrier to innovation, especially for smaller firms. In the study commissioned by CEST (1991), it is argued that:

"Developing new technology-based products is hugely expensive. System X, the digital telephone exchange system was estimated to cost over £1 billion. Developing a new drug costs at least £100 million. Sharing the costs of the development of such products shares the risk of such high levels of investment. It does, however, mean potential income streams are also shared" (CEST 1991: 2)

Collaborative agreements are thus particularly important in the areas of natural resource exploration and exploitation, and of large scale engineering and construction projects. Referring to the aircraft industry, Alic (1990) states that:

"Perhaps most important among the factors leading to cooperation in R&D are the *costs of continued participation in some technologies*. The expense and risk of independent efforts motivate downstream cooperation not only in microelectronics, but in the aircraft industry, where even very large companies have sought to spread costs through strategic alliances such as Airbus Industrie and International Aero Engines (IAE). Linking three European and three Japanese companies with the American firm Pratt & Whitney, IAE undertook a billion dollar development effort that would have been very risky if not impossible for the participants individually" (Alic 1990: 327-328)

It is also argued that enterprises are compelled to collaborate due to **technological complexity and novelty**. In reality, technological innovation has become a multi-specialist and intricate activity with many new processes and products emerging from complex, interdisciplinary research. Since very few, if any, firms do cover all specialisms, the need to link up with other companies possessing complementary expertise increasingly arises. As Saxenian (1991) contends:

"The cost of developing new products has... increased along with growing technological complexity. A computer system today consists of the central processing unit (CPU) which includes a microprocessor and logic chips, the operating system and applications software, information storage products (disk drives and memory chips), ways of putting in and getting out information (input-output devices), power supplies, and communications devices or networks to link computers together. Although customers seek to increase performance along each of these dimensions, it is virtually impossible for one firm to produce all of these components, let alone stay at the forefront of each of these diverse and fast changing technologies" (Saxenian 1991: 425)

Likewise, Dodgson (1989) points in the same direction, stressing that:

"It becomes essential to relate to the behaviour of firms in complementary horizontal and vertical activities, as the new technologies provide wider opportunities for those firms to affect competitiveness. To overcome the problems of complexity, high cost and high risk, activities previously proprietary to individual firms such as R&D and manufacturing may become shared between a number of firms. The necessary sacrifice of autonomy in the generation and diffusion of technology involves a strategy of sharing control in order to retain it. Without participation in multilateral technological arrangements, even the most advanced companies may lose their leadership positions" (Dodgson 1989: 6-7)

Enterprises also sign agreements to cope with the complex economic environment characterised by market, production, and technological **uncertainty**. Indeed, the sustained complexity of science and technology, as well as the multiplicity of potential sources of technology, ensures continuing uncertainty. A key feature stimulating collaboration is thus uncertainty about technological development and diffusion. As Dodgson (1993) puts

it:

"... collaboration is believed to assist with *environmental uncertainty*. Increasingly sophisticated and demanding consumers, the growing competition in and internationalization of markets, and rapidly changing and disruptive technologies place pressures on nations and firms to exist with, and attempt to control, the uncertainties confronting them. This is more easily achieved in collaboration than in isolation" (Dodgson 1993: 14)

The definition and implementation of standards is very important for the development and diffusion of a new technology. Horizontal and vertical agreements for product pattern and product-process standards are necessary to assure compatibility and integration with complementary products, particularly during the so-called introduction stage of the technological life cycle (Cainarca, Colombo and Mariotti 1992). Hence, standard setting allows firms to agree upon a novel, dominant design, starting from the large numbers of product designs that coexist during the initial period - the so-called "preparadigmatic stage of an industry" (Teece 1986: 288) - in the evolution of new technologies. As Mytelka (1991c) argues, referring to industrial collaboration within the framework of the ESPRIT programme:

"... firms in dynamic knowledge-intensive industries, see the need to develop standards at a far earlier stage in the production process - at the research phase itself. Collaboration in precompetitive R & D of the sort promoted through ESPRIT has a particular advantage in this respect because it ensures an early approach to the harmonization of technical solutions - environments, architectures, interfaces. At a latter stage in the investment process, common standards enable firms to develop compatible products and this, it is argued, is a prerequisite to the creation of new markets in these dynamic sectors" (Mytelka 1991c: 197)

Moreover, companies which are not participating in the process of standards formation face a severe disadvantage, as they have first to comply with the standards, and this takes time and allow participating enterprises an advantage. The exclusion of non-participants may thus explain why firms feel compelled to collaborate. As DeBresson and Amesse (1991) point out:

"... belonging to a network not only reduces the cost of information, but avoids being subject to subsequent exclusion and entry barriers.... A network provides access to the very process of standard setting, establishes agreed upon technological trajectories, and reduces duplicative research races, without reducing competition for alternative designs" (DeBresson and Amesse 1991: 368)

Inter-firm agreements also constitute a valuable supplement to in-house R&D. Rapidly changing technologies and shortening product life cycles, combined with economic and financial uncertainty, are forcing enterprises to innovate through a complementary mix of in-house R&D coupled to the results of R&D performed elsewhere. As Link and Tassej (1987) acknowledge:

"... the growth of world competition in technology-related areas makes this single-minded strategy of sole reliance on internally financed and internally conducted R&D insufficient and perhaps suicidal" (Link and Tassej 1987: 10)

Regardless, "... collaboration,... cannot in any sustainable way be anything but a *supplement* rather than an *alternative* to a firm's core method of technology development; internal R&D" (Dodgson 1993: 164).

Furthermore, collaboration may lead to a firm's growth and technological diversification. A company may desire, or be compelled, to enlarge its competences into a broader range of technological areas. Lewis (1990) provides the following elucidatory example of how a strategic alliance can create new markets and expand the product range of the partner(s):

"For its first 98 years Kubota, Japan's largest producer of farm equipment, never made anything more complex than a tractor. Then in 1988, from a gleaming new plant near Tokyo, Kubota shipped its first mini-supercomputer, one of the most advanced in the world. The design, chips and software were all American, resulting from strategic alliances with some of the sharpest startups in Silicon Valley. Kubota used its superb assembly know-how to combine the parts in a high-quality product. This is not another tale of the Japanese exploiting American technology, because everyone gained. Kubota entered a new growth business, while its U.S. partners acquired capital and manufacturing know-how to move ahead in their markets" (Lewis 1990: 12)

In addition, alliances may be used by companies, either in a defensive or in an offensive way, as a strategic tool to exclude competitors. We referred above to the strategic advantage that "Being a member of the "club" or semi-official cartel which controls standards and market access, for example in telecommunications equipment in Europe" (IEE 1992: 15) constitutes for a participating firm. Contractor and Lorange (1988) give us an illustrative example:

"Caterpillar Tractor is said to have linked up with Mitsubishi in Japan in order to put pressure on the profits and market share that their common competitor Komatsu enjoyed in its important home market, Japan.... Thus, even though the joint venture may not have great importance in itself for Caterpillar, it may act as a thorn in Komatsu's side and, thus, reduce its competitiveness outside Japan" (Contractor and Lorange 1988: 14)

Cooperation, too, may be the way that enterprises choose to observe novel technological developments. In fact, technological developments in certain industries (biotechnology, food processing, pharmaceuticals, computer technologies, and telecommunications), have extended the importance of accessing new or unfamiliar technologies, due to technological convergence. As Dodgson (1992) states:

"Collaboration allows firms to maintain a "watching brief" on developing technology without heavy investment; seen in the way large drugs companies collaborated with small biotechnology companies before investing in biotechnology themselves" (Dodgson 1992: 84)

In short, there are many reasons to collaborate. Indeed, any single case seems to be a particular, special story, with its own idiosyncrasies. Partners within a collaborative agreement are looking forward to attaining advantages of their partnership, which is not always possible. Therefore, we will now refer to the positive and negative outcomes which may be associated with inter-firm agreements.



### 3.2.3. Advantages and disadvantages of technological collaboration

From our review, it seems obvious that all the enterprises which embark upon a collaborative process are expecting to obtain some kind of positive results from their participation. Indeed, as Dickson, Smith and Smith (1991) stress:

"The fundamental motive, underlining all other reasons for combining firms' resources and skills, will always be some form of "gain" to the firm.... A broader definition would suggest that the notion of gain within collaboration refers to having the opportunity to derive more efficient use of internal resources through having access to external resources" (Dickson, Smith and Smith 1991: 148-149)

Positive outcomes are usually associated with success. However, it is notoriously problematic to define success in industrial cooperation. For a start, what is seen by one company as a success may be regarded by its partner as a failure, because the range of enterprises' circumstances as well as their expectations and experiences of cooperation are quite variable. Furthermore, these may also change during the lifetime of the alliance. As Contractor and Lorange (1988) refer:

"... the strategic rationales prevailing when a cooperative venture was formed may shift over time.... This erosion [of the fundamental strategic rationales] may come from external or environmental sources, such as when the technology contributed by one partner is obsolescent because of changes in the industry. Or the erosion may be internal, such as when one partner learns from the other, and the other partner then has nothing new to contribute" (Contractor and Lorange 1988: 25)

Hence, after reviewing the vast literature on cooperative agreements, we were able to identify and select a number of benefits which inter-firm collaboration may provide, and which are strongly related to the reasons to cooperate. With no particular ranking order, we present below a list of such advantages:

allowing firms to diversify into attractive but unfamiliar business areas, and diversifying from unfavourable businesses into more promising ones;

- avoiding duplication in research;
- avoiding missing out on important technology or information;
- combining skills and knowledge on an interdisciplinary basis;
- creating efficiencies through economies of scale, rationalisation, or specialisation;
- creating synergies between firms;
- enhancing research competition;
- expanding business internationally;
- facilitating information exchange;
- gaining efficiencies through the solution of common problems;
- improving user-producer relationships;
- learning how to cooperate, even when collaborative projects are not very successful, since lessons learnt can be applied in the future;
- pooling sub-critical R&D resources;
- reducing both the cost and time of a new innovation;
- reducing opportunism;
- reducing uncertainty;
- setting technical standards;
- sharing both the costs and risks of projects beyond the reach of a single enterprise;
- sharing expensive, non-divisible, equipment...

These (potential) positive outcomes are, nonetheless, quite hard to reach, because industrial collaboration is, in practical terms, very difficult to manage successfully. In fact, technological cooperation is relatively new for most of the individuals and institutions involved. In recent years, a great number of industrial linkages have faced problems due to inexperience on collaboration amongst their managers. Some of these predicaments reveal, on the other hand, weaknesses in the way companies manage the process of innovation. In addition, high initial expectations regarding the advantages of networking lead sometimes to future problems among partners, when mutual benefits are not delivered as anticipated. This situation may particularly occur in technological partnerships involving enterprises of differing sizes. For instance, in a series of case studies, Dickson, Smith and Smith (1991) point out the frustrated expectations of small firms collaborating with large companies. As Doz (1988) also argues:

"... many [partnerships] are a disappointment to partners. They do not actually yield the results expected by either or both partners, and even when a measure of success is

achieved the tensions in making partnerships work sometimes dwarf their success in the eyes of the participants" (Doz 1988: 318)

Failure in technological collaboration is thus somehow more easily identifiable than success. According to the criteria suggested by IEE (1992), a cooperative project fails:

- "\* When project achievements fall substantially below expectations;
- \* When a collaboration halts prior to completion;
- \* When a collaboration labours along unproductively because all or most participants have lost interest, but no one has the courage to call the whole thing off;
- \* When the opportunity costs outweigh the benefits; that is, when the project could have been better performed alone, or where the resources involved could have been put to more productive use" (IEE 1992: 42)

From the literature, we were able to identify and select a number of obstacles which may impede the enterprises from attaining the expected positive outcomes of collaboration. Without any pre-established order, we present below a list of such barriers:

- changes affecting collaborators;
- creation of potential competitors for the company;
- cultural differences;
- difficulty in maintaining secrecy;
- difficulty with sharing and allocating contributions and results;
- emergence of dependence on cooperating partners;
- harmonisation of different management styles;
- high negotiation and transaction costs;
- hindering of own developments;
- inadequacy of technical outputs;
- lack of extra internal funding;
- lack of interest among collaborators;
- lack of interest internally;
- lack of skilled users;
- loss of own knowledge lead;
- nature of intellectual property rights (IPR) agreements;
- opportunism;
- poor communication among the partners;
- problems with the technology adoption;
- process of agreeing intellectual property rights (IPRs);
- strategic moves of own organisation;
- structural changes to own organisation...

To sum up, companies involved in strategic partnering should try to capitalise as much as possible on the positive outcomes

associated with the networking process, while minimising at the same time the potential shortcomings related to cooperation.

#### 3.2.4. The focus of technological collaboration

Turning now to the focus of collaboration, we are confronted once again with a vast myriad of theoretical approaches, proposed by a multitude of researchers and scholars.

For instance, Gugler (1992) contends that not only are cooperative agreements mainly concentrated in high-technology industrial sectors and in industries which are increasingly using sophisticated technologies, but they are also being established in low technological sectors, and occurring even more so in the tertiary sector.

To a certain extent, Kleinknecht and Reijnen (1992) corroborate Gugler's assertions. Based upon a database covering the entire Dutch economy, they analyse R&D collaboration in a large sample of enterprises which is illustrative of all manufacturing and services industries in that country. They point out that:

"It turns out that R&D cooperation is a much more widespread phenomenon than is generally thought. In contrast to large parts of the literature, we find that firm size, market structure, R&D intensity, and high shares of product-related R&D have little impact on R&D cooperation between firms. *R&D cooperation does not typically occur between big, high tech firms which operate in global markets but occurs at least equally frequently between smaller firms in medium and low tech sectors*" (Kleinknecht and Reijnen 1992: 347) (emphasis added)

As we will demonstrate further below, their findings bear great relevance for our own research insofar as, among other topics, we will be studying the external linkages of the Portuguese mouldmaking industry, which is regarded as being a traditional industry.

Mowery (1989) also argues that technology is increasingly the focus of cooperation, and that strategic alliances between US and foreign firms are emerging in a wider range of industrial sectors. Nevertheless, there are substantive differences in the

focus of collaboration amongst industries. He stresses that collaborative ventures are now covering not only product development and production, but also marketing and distribution areas. As he points out:

"In more mature high-technology industries, such as telecommunications equipment, microelectronics, and commercial aircraft, the high costs of new product development, demanding requirements for systems integration, and the nature of political barriers to market access all mean that recent collaborative ventures have focused on *product development*. A similar focus characterizes collaborative ventures in robotics between user and supplier firms that exchange proprietary data.... In commercial aircraft, telecommunications equipment, and in segments of the microelectronics industry, the desire of U.S. firms for access to foreign capital or technology provides an additional motive to focus collaboration on research and product development.

In other high-technology industries with a large number of new firms, such as biotechnology, much domestic and international collaboration focuses on the *marketing and distribution* by established firms of the technologies developed by new entrants. This type of collaboration aids entry into new domestic or foreign markets and need not always incorporate joint product development. The major international collaborations in the automotive and steel industries center on the exchange of foreign process technology, managerial expertise and production systems for access to U.S. markets. These joint ventures accordingly deal with *production*" (Mowery 1989: 26) (emphasis added)

On the other hand, Cainarca, Colombo and Mariotti (1992) suggest that the focus of collaboration changes over the technological life cycle. In a similar way, Levy and Samuels (1991), referring to the debate over the kind of research (applied versus basic) which is most liable to industrial partnering, state that collaborative agreements also vary along the continuum from basic research to product development. Considering the specific case of Japan, they point out that:

"A government survey found 14 per cent of inter-firm collaboration was directed at basic research, whereas one-third involved applied research and more than half was devoted to product development" (Levy and Samuels 1991: 121)

An analogous trend was revealed in a study on inter-firm R&D

cooperation in Germany. According to this study, "Only in 3% of cases were the agreements purely for basic research,.... The majority of cases (64%) involved applied research and/or developmental work" (Brockhoff, Gupta and Rotering 1991: 223). Finally, regarding the strategic behaviour of companies with respect to collaboration, Hagedoorn and Schakenraad (1990) argue that, in all three core technologies they are studying (biotechnology, information technology, and new materials), networking is used by most of the firms to assist long-term strategic positioning, rather than focussing on short-term issues.

In short, the focuses of collaboration are manifold, depending, among other points, upon the firm's industrial sector, the nature of its R&D activities, the stage of the technology life cycle, and the strategic purpose of its linkages.

### 3.2.5. The forms of technological collaboration

Once again, we are entering a very "swampy" terrain. In fact, a disparate literature exists on the various modes of inter-firm cooperation. Inevitably, different authors propose different taxonomies regarding this issue, some of them really basic, others very complex. We will present below a number of such classifications.

Gugler (1992) simply distributes technological collaboration according to different criteria, eg its degree of formalisation, the role and geographic location of partners, etc. Indeed, as he argues:

"There are in fact several kinds of alliances: formal and informal alliances; vertical, horizontal and conglomerate links; equity and non equity agreements; local, national, continental or trans-oceanic alliances, etc" (Gugler 1992: 91)

In the study conducted for IEE (1992), the principal modes of collaboration are analysed. Regarding the alliances which form part of the enterprises' business strategies, it is argued that

marketing-based agreements, and licensing represent the lowest degree of control over technology, while mergers and acquisitions, joint ventures, and strategic alliances, stand for the highest. Conversely, focussing on the collaborations which form part of the firms' technology, contract research organisations, and other third-party R&D share the lowest degree of control over the course of technical developments, while collaborative R&D, collaborative technology diffusion, and co-development, are the highest.

Farr and Fischer (1992), based upon the general chain of events which describe the development of most weapons systems, also propose a taxonomy of inter-firm cooperation. They argue that, along the continuum ranging from preliminary activities/mission need, the concept phase, the demonstration and validation phase, the full-scale development phase, and down to the production phase, different forms of technological collaboration can take place.

They contend that informal and formal meetings, exchanges and discussions are very important during the first two phases of the above mentioned sequence; co-development is of paramount significance during the concept, demonstration and validation, and full-scale development phases; and finally, co-production covers the production phase.

Elaborating on certain extent upon the classification, initially advanced by Contractor and Lorange (1988), of various types of cooperative arrangements, leading from more extensive to intensive forms of collaboration between enterprises, Hagedoorn (1990, 1993) submits his own taxonomy. He suggests the categorisation of the forms of technological cooperation in terms of the extent of organisational interdependence (Hagedoorn 1990). According to him, it is possible to differentiate between six modes of collaboration, namely joint ventures and research corporations (with the largest organisational interdependence), joint R&D, technology exchange agreements, direct investment, customer-supplier relations, and one-directional technology flow (with the smallest organisational interdependence). He defines these various forms of inter-firm agreements, stating that:

"We refer to joint ventures and research corporations as combinations of the economic interests of at least two separate companies in a "distinct" firm; profits and losses are usually shared according to equity investment. Minority equity investment, especially those made by a large company in a smaller "high tech" company, can be understood as a case of cooperation, which in the long run could affect the technological performance of at least one "partner", in particular if such minority sharing is coupled with research contracts.

Joint R&D agreements refer to joint research pacts and joint development agreements which establish joint undertaking of R&D projects with shared resources. Technology exchange agreements cover technology sharing agreements, cross-licensing and mutual second-sourcing of existing technologies. Under the heading of customer-supplier relationships we have joined those categories of agreements through which contract-mediated collaboration in either production or research is established. These customer-supplier relationships can be divided into a number of forms of partnership such as coproduction contracts, comakership relationships, and research contracts that regulate R&D cooperation in which one partner, usually a large company, contracts another company, frequently a small specialized R&D firm, to perform particular research projects. Finally, there are unilateral technology flows such as second-sourcing and licensing agreements" (Hagedoorn 1993: 374-375)

It may be also illustrative to know how the 3,964 inter-firm agreements reported in the MERIT's database were distributed amongst these six modes of technological collaboration. Joint R&D represents over 25% of all cooperative agreements, and joint ventures and research corporations about 22%; in the middle section, with practically 16% in both cases, stand one-directional technology flow, and direct investment; finally, customer-supplier relations (12%), and technology exchange agreements (9%) are the two smallest groups of agreements (Hagedoorn 1990).

Based to a large extent on Hagedoorn's taxonomy, Brockhoff, Gupta and Rotering (1991) found out, in a study of the inter-firm cooperative R&D arrangements of 135 large industrial enterprises in the (then) Federal Republic of Germany, that almost 71% of the companies were engaged in collaborative R&D on individual projects. These agreements frequently comprised both R&D plus manufacturing, and R&D plus marketing, activities. The second most sought-after mode of cooperation was joint ventures, with

the participation of about 20% of the firms. These linkages demand the greatest organisational involvement and interdependence. Finally, 9% of the enterprises were engaged in multiple areas, eg cross-licensing, exchange of patent rights, mutual second-sourcing, etc, all under the heading of **know-how exchange**, which corresponds to the lowest level of complexity. In one of the most seminal studies on technological collaboration, Chesnais (1988a, 1988b) also refers to the extensive modes of inter-firm partnering. Using the **R&D-to-marketing chain**, he presents in his taxonomy the "... range of the main types of agreements established by firms with a view to producing, acquiring and/or commercially exploiting technology in common..." (Chesnais 1988a: 510). He begins by distinguishing between i) a pre-competitive stage, focussed on **research and development cooperation**, and ii) a competitive stage, involving both **technological cooperation** and **manufacturing and/or marketing cooperation**.

The pre-competitive stage's characteristic forms of technological collaboration embrace i) university-based cooperative research financed by associated firms; ii) government-industry cooperative R&D projects with universities and public research institute involvement (both of these forms usually include many partners); and iii) research and development corporations on a private joint-venture basis, normally comprising several partners.

The typical modes of inter-firm agreements during the technological cooperation stage involve i) corporate venture capital in small high-tech firms; ii) non-equity cooperative research and development agreements between two firms in selected areas; and iii) technical agreements between firms concerning completed technology. All of these modes usually encompass few or very few partners, which also applies to the final phase, the manufacturing and/or marketing cooperation stage.

This last stage includes i) industrial joint-venture firms and comprehensive R&D, manufacturing and marketing consortia; ii) customer-supplier agreements; and iii) one-way licensing and/or marketing agreements.

Chesnais (1988a, 1988b) further improves his categorisation,

presenting a taxonomy of types of inter-company agreements which are set against i) government involvement; ii) international supply structure; and iii) technological characteristics.

Alic (1990), based to a significant extent upon Chesnais' work, also advances his own classification. He argues that:

"... collaborative R&D can take many forms.... that extends from precompetitive projects as originally emphasized in ESPRIT to downstream cooperation in production and marketing, where R&D may be only one element in a more comprehensive contractual arrangement" (Alic 1990: 324)

Accordingly, he proposes a three-fold taxonomy of the various forms of cooperative R&D and joint technology development, comprising pre-competitive R&D, downstream technology development, and production and/or marketing, as well as technology development.

We will now introduce the categorisation suggested by Dickson, Smith and Smith (1991) and Smith, Dickson and Smith (1991).

On the basis of the degree of corporate planning involved, they note four distinct forms of technological collaboration. As Smith, Dickson and Smith (1991) write:

"The first is long-term strategic alliances, which are essentially a large firm phenomenon involving a company's long-term strategic plan to improve its competitive position or, in mature industries, to challenge traditional monopolies.... Strategic alliances also incorporate a strong innovation dimension especially in technologically advanced sectors....

The second type of cooperative venture occurs where there are short-term strategic reasons for particular collaborations, which may only cover a specific project....

The third type of venture is where collaboration is largely unplanned, but occurs as a result of opportunity presenting itself. The firms, or rather individuals within firms, are sufficiently enterprising to take advantage of the opportunity....

The final type of collaboration is where firms enter relationships reluctantly as the only means of overcoming long-standing problems, often as a last resort" (Smith, Dickson and Smith 1991: 459)

Finally, we will refer to the taxonomy proposed by Rothwell (Beesley and Rothwell 1987; Dodgson and Rothwell 1991; Rothwell 1991; Rothwell and Beesley 1988; Rothwell and Dodgson 1991).

One important feature of this taxonomy is that it specifically addresses the external linkages established between small and medium sized enterprises. This did not happen with most of the categorisations we have previously discussed, as those were normally concerned with the modes of technological cooperation among large companies.

Furthermore, since the Portuguese industrial sectors are mainly composed of micro and small enterprises, Rothwell's taxonomy is very important for our present study. In fact, the questionnaire we used during our field-work draws to a certain extent on Rothwell's findings.

He identifies five forms of external linkages, which are:

*Contract-out R&D.* This is perhaps the most obvious source of technical expertise for the small firm, either to gain access to technology and skills outside the firm, or simply to stretch scarce resources.

*Joint R&D ventures.* Formal or semi-formal arrangements with other firms jointly to develop a product or process of mutual benefit.

*Marketing relationships.* Agreements to act as agents for other firms' equipment in order to supplement the existing product range, and open up new markets. This was, in some cases, a covert means of gaining access to new technologies.

*Manufacturing relationships.* These take a variety of forms: licensing of another firms' product can be a means of learning about a new area of technology; subcontracting manufacturing is perhaps the most standard way of gaining access to production processes and related skills not possessed by the firm.

*Links with educational establishments, other public sector bodies and research associations.* These can take the form of sponsorship or placement of students during degree courses, and formal or informal access to a variety of facilities and technical expertise" (Rothwell 1991: 103)

Summing up, we may say that the forms of technological collaboration are quite extensive. Authors base their taxonomies upon different criteria, eg the R&D-to-commercialisation chain (Chesnais 1988a, 1988b), the degree of corporate planning (Dickson, Smith and Smith 1991; Smith, Dickson and Smith 1991), the extent of organisational interdependence (Hagedoorn 1990, 1993), etc. Therefore, it is no wonder that we face such a multitude of modes of cooperation.

In order to clarify as much as possible the different categorisations proposed by a large number of researchers and scholars, we present below a summary of the various criteria and forms of technological collaboration as suggested by Barañano (1995b), based on her extensive review of the literature (see TABLE 2).

In the next section, we will analyse a specific form of inter-firm agreements which has attracted significant interest. We refer to informal linkages.

### 3.2.6. A particular mode of technological collaboration: informal networking

The great majority of the forms of cooperation discussed above involved some kind of formalised, contractual relationships between companies. However, another type of arrangement also exists, formed in its chief part by individual, personal networks, which tend to be characterised by a great deal of informality and fluidity, mainly regarding the flow of information.

Such informal modes of technological collaboration are normally established between individual researchers situated in differing institutional environments (universities, governmental laboratories, non-profit institutions, and enterprises), either at a national or international level.

Of particular interest regarding our study are the networks among scientists and engineers engaged in applied research and employed by industrial firms. Indeed, it seems paradoxical that researchers working for private, sometimes competing, enterprises, do exchange information and share the results of their work. In fact, as clearly stated in OECD (1992b):

"... much of the knowledge exchanged and transferred is know-how (the accumulated practical skill which allows one to execute a task smoothly and efficiently) or again "tacit", uncodified (and often uncodifiable) knowledge, e.g. practical craft details never formalised in scientific publications. Such knowledge is implicitly or explicitly proprietary; its possession represents a form of "competitive advantage" for firms and even for public

<b>TABLE 3.2: CRITERIA OF CLASSIFICATION AND FORMS OF TECHNOLOGICAL COLLABORATION</b>	
<b>CRITERIA</b>	<b>FORMS</b>
<b>PHASES OF THE INNOVATION PROCESS</b>	<ul style="list-style-type: none"> <li>• Meetings, exchanges, and discussions</li> <li>• Cooperative R&amp;D projects</li> <li>• Family of technologies agreements</li> <li>• Co-development contracts</li> <li>• Co-production contracts               <ul style="list-style-type: none"> <li>• Fully integrated co-production</li> <li>• Foreign production under license</li> </ul> </li> <li>• Third country sales deals</li> <li>• Licensed production agreements</li> <li>• Offset agreements               <ul style="list-style-type: none"> <li>• Direct offset agreements</li> <li>• Indirect offset agreements</li> </ul> </li> </ul>
<b>FORMALISATION DEGREE</b>	<ul style="list-style-type: none"> <li>• Formal or contractual collaboration</li> <li>• Informal collaboration</li> </ul>
<b>ROLE OF PARTNERS</b>	<ul style="list-style-type: none"> <li>• Horizontal links</li> <li>• Vertical links</li> <li>• Conglomerate links</li> </ul>
<b>INSTITUTIONAL NATURE OF PARTNERS</b>	<ul style="list-style-type: none"> <li>• Homogeneous alliances</li> <li>• Heterogeneous alliances</li> </ul>
<b>GEOGRAPHIC LOCATION OF PARTNERS</b>	<ul style="list-style-type: none"> <li>• Local collaboration</li> <li>• National collaboration</li> <li>• Regional collaboration</li> <li>• International/Worldwide collaboration</li> </ul>

SOURCE: Barañano (1995b)

sector laboratories which may be "competing" for government and industrial contracts" (OECD 1992b: 70) (emphasis added)

Hence, it appears that these scientists and engineers are jeopardising their companies' competitive advantage. Nevertheless, informal trading of know-how is an important feature across a wide range of sectors and technologies, directly involving both competing and non-competing firms. Referring to technology sharing and R&D cooperation, Nelson (1988) points out that:

"Even rivalrous firms may forge agreements to have certain kinds of research carried out cooperatively where the results are difficult to keep proprietary, or where it would be disadvantageous to the group as a whole to do so. Typical examples are industry-wide problems, like learning how better to grade and test raw materials, or to establish appropriate standards for inputs. There is a tradition in some industries of trying to fund this type of work collectively, through some kind of an agreed-upon voluntary tax formula for contribution to a trade association, which can support research at universities, or at independent laboratories" (Nelson 1988: 319)

Discussing the way in which, in a number of industries, companies tacitly pool patents, he also argues that:

"... rivalrous firms apparently have an agreement not to sue each other for infringements. Such arrangements reflect an apparent agreement among a group of firms that they are all better off if they make a common, big pool of at least some of their technological knowledge, than if they all try to keep their individual pools strictly private. It seems that, within limits at least, rivalrous companies can and do recognize the "public good" properties of technology" (Nelson 1988: 318)

The research conducted by von Hippel led to a superior understanding of how informal networks actually function. In an interesting paper, referring to the trading of proprietary process know-how among US steel minimill enterprises, von Hippel (1989) stated:

"The informal proprietary know-how trading behavior which I have observed to date appears to involve informal trading "networks" which develop between engineers having common professional interests. Network formation begins when, at



conferences and elsewhere, an engineer makes private judgements as to the areas of expertise and abilities of those he meets, and builds his personal informal list of possibly useful expert contacts. Later, when "Engineer A" encounters a product or process development problem he finds difficult, he activates his network by calling Engineer B, an appropriately knowledgeable contact who works for a directly competing (or non-competing) firm, for advice.

B makes a judgment as to the competitive value of the information A is requesting. If it seems to him vital to his own firm's competitive position, he will not provide it. However, if it seems useful but not crucial -- and if A seems to be a potentially useful and appropriately knowledgeable expert who may be of future value to B -- B will answer his request as well as he can and/or refer him to other experts of his acquaintance. B may go to considerable lengths to help A: He may, for example, run a special simulation for him on his firm's computer system. At the same time, A realizes that in asking for and accepting the help, he is incurring an obligation to provide similar help to B -- or to another referred by B -- at some future date. No explicit accounting of favors given and received is kept in instances studied to date, but the obligation to return a favor seems strongly felt by recipients" (von Hippel 1989: 158)

Gelsing (1992) suggests that the specialisation process which is at present sweeping several industries may be one of the motives for the development of informal networks. He contends that:

"Even when belonging to the same branch of industry any two firms will tend to differ in the chosen equipment, the market segment, the distribution, the quality control, etc. and thus they may allow engineers to exchange information with colleagues in competing firms. In short the result of specialisation is that the resources of firms differ and therefore two manufacturers of similar products like Volvo and Renault can cooperate in car-engines" (Gelsing 1992: 121)

Interestingly enough, for many years staff at Saab and Volvo have been moving from one firm to another as a promotion mechanism and/or a way of widening their experience. This example may bear strong implications for the Portuguese case and, in particular, for the two industries we are studying.

In a highly comprehensive and detailed study of technological development in enterprises, and their interactions with other companies, Håkansson (1989) examined corporate technological

behaviour by focusing on the technical, purchasing, selling, personnel, and financial characteristics of over 120 small and medium sized firms located in four counties in central Sweden. He noticed that "... half the development work conducted by the 123 companies in our study takes place in collaboration with someone else" (Håkansson 1989: 121). Nevertheless, the degree of formalisation of such inter-firm agreements is very low. In fact, at least 65% of the cooperative arrangements involving customers, suppliers, and competitors, are informal, non-formalised relationships (Håkansson 1989: 113). As he contends:

"Very few of them [corporate collaborative relationships] have any element of formal agreement, and even fewer are entirely based on such agreements. Such legal agreements as do exist generally refer to some other part of the overall relationship (annual agreements on volume or prices, for instance). The long history thus probably acts as a kind of insurance; both parties have had an opportunity to build up confidence in one another. This trust will presumably also mean that expectations on both sides are realistic, that is they are on a scale with which the other partner is able to cope. Both parties know the other's strengths and weaknesses" (Håkansson 1989: 126)

Anyhow, a crucial proviso for the creation and development of a network of informal contacts between scientists and engineers seems to be the existence of trustful relationships among the so-called "invisible college" of peers. In fact, Smith, Dickson and Smith (1991) found out that:

"... the existence of informal, personal networks among the scientific and engineering elite was the key factor in the establishment of collaborative links. In many cases, these links were based on *professional, scientific trust* at the early research stages, which was later formalised when commercial/production possibilities arose. Pre-existing networks are often the basis of collaboration, as personal contacts are used to target key people in potential partner firms, and provide the basis of professional trust on which successful technical collaboration depends" (Smith, Dickson and Smith 1991: 467) (emphasis added)

It could be said that informal collaboration builds upon trust amongst partners. Trust is indeed crucial in a wide number of ways. The final section of this chapter will thus be devoted to trust.

### 3.3. Trust

As argued before, the uncertainty of economic conditions, the complexity of scientific and technological inputs, and the risks associated with uncertain technological trajectories, combined with the acceleration of technological change and the shortening of product life cycles, are forcing enterprises to learn new rules of behaviour, in order to be able to successfully compete under the current market conditions. A possible route to improve their competitiveness relates to the *redefinition of trust* (Sabel 1993) in inter-firm relationships.

Some scholars and researchers have already confirmed that companies are better off working in a more trustful environment. For example, despite the wide variety of the six case studies of technological collaboration reported by Dodgson (1993), it was possible to find some common reasons for the success of such collaborations. Trust and good communications between partners ranked high among the motives. Similarly, Dickson, Smith and Smith (1991), referring to their case studies of 27 pairs of interfirm cooperation, point out that:

"The importance of both professional and business trust in successful collaborations was strongly emphasized by many firms, and particularly by the founders of new firms who frequently depend on former scientific colleagues to collaborate with" (Dickson, Smith and Smith 1991: 150)

The strategic importance of confiding, lasting relationships is confirmed by Saxenian (1991) who, speaking about the close linkages maintained between Silicon Valley's companies and their suppliers, stresses that:

"A network of long-term, trust-based alliances with innovative suppliers represents a source of advantage for a systems producer which is very difficult for a competitor to replicate. Such a network provides both flexibility and a framework for joint learning and technological exchange" (Saxenian 1991: 430)

Trust seems therefore to be a precondition for competitiveness. It is defined as "... the mutual confidence that no party to an exchange will exploit the vulnerabilities of the other" (Sabel

1993: 332). When such exploitation occurs, trust is lost and the partnership almost certainly will come to an end. Smith, Dickson and Smith (1991) provide the following illustrative example:

*"... a large European electronics firm had been working on a data station for use in laboratories. The project needed software inputs which were too sophisticated for in-house capacity. For three years, a company in the US had been contracted to undertake the development work. It was eventually realised that the American company was unable to provide a solution to the problem. This left the company with a major gap in their product range, and a need to find a company which could quickly develop a package. It was decided it would have to be a UK company so that communication and monitoring would be easier. The small company chosen was assessed by in-house people who were impressed by their technical competence. However, problems arose out of the initial advantage the smaller company had seized when a partner heard how desperate the larger one was for a signed formal agreement. With this knowledge, the smaller firm was able to impose terms on the larger. However, this was at the expense of a lack of trust in the longer term. Instead of future collaborations, the larger company has sought alternative partners" (Smith, Dickson and Smith 1991: 465) (emphasis added)*

Intrinsically associated with trust is the notion of trustworthiness. "... an exchange partner is trustworthy when it is worthy of the trust of others" (Barney and Hansen 1994: 176). Nevertheless, it should be mentioned that, while trust is a characteristic of a relationship between partners, trustworthiness is a characteristic of individual partners. Thus, it may be possible to find, within a relationship, both trustworthy and untrustworthy partners.

Specially in this latter case, trustworthiness may become a crucial element of competitiveness. As Lundvall (1988) argues:

*"If a user has a choice between a producer known for low-price and technically advanced products, but also for having a weak record in terms of moral performance, and one well known for trustworthiness, the first will be passed by. This implies limits to opportunistic behaviour. Those limits are reinforced when users pool their information about the reliability of different producers" (Lundvall 1988: 352)*

It has already been suggested that the initial phases of inter-firm collaboration are frequently based upon trusting relations

established between individuals. Nevertheless, this person-to-person interaction also involves a major drawback, meaning that, if for instance those dedicated individuals have to leave their companies, the collaboration may not outlive the discontinuity of personal linkages. To overcome this situation, it is fundamental that enterprises embark on the establishment of *inter-organisational trust* (Dodgson 1993). To "institute" inter-organisational trust takes, however, a long time. Firms need to have full knowledge of the partner's circumstances, and during the process, have to find successful ways of avoiding unsurmountable conflicts of interest among themselves. As Håkansson and Johanson (1988) state:

"Interaction between firms develops over time. It takes time to build functioning relations. The parties have to learn about each other's ways of doing and viewing things and how to interpret each other's acts. Relations are built gradually in a social exchange process through which the parties may come to trust in each other.... Over time, as a consequence of interaction, bonds of various kinds are formed by the parties. There may be technical bonds which are related to the technologies employed by the firms, knowledge bonds related to the parties' knowledge about their business, social bonds in the form of personal confidence, administrative bonds related to the administrative routines and procedures of the firms, and legal bonds in the form of contracts between the firms. These bonds tend to create lasting relationships between the firms" (Håkansson and Johanson 1988: 373)

If successful, this interaction process will eventually bring to the relationship what Håkansson (1989) defines as "mutual trust". According to him:

"... the result can never be guaranteed from the start and unforeseen problems may arise. Taking risks like this calls for mutual trust. Both sides must feel confident that the others are serious and are putting their cards on the table. Without a stock of trust the relationship is likely to be short-lived. Mutual trust is also necessary if the exchange of information and knowledge is to be as free and open as it should be. Mutual trust generally builds up gradually as the two parties first test one another in situations of minor risk (meetings, lesser projects, etc.), and then proceed to more important and more difficult cases" (Håkansson 1989: 146)

With respect to the gradual buildup of trusting relationships and inter-firm cooperation just mentioned, Håkansson (1989) detected a very long duration on his collaborative agreements. On average, development relationships involving customers and suppliers lasted for 13 years, while those with competitors stood for 8 years (Håkansson 1989: 112). This is totally at odds with the situation in the UK, where "... projects rarely lasted more than two years..." (Dickson, Smith and Smith 1991: 147). This discrepancy, we believe, may have to do with the differing cultural and institutional attitudes towards both collaboration and, in particular, trust in the UK *vis-à-vis* the Nordic countries. In the former, a much weaker degree of trust seems to be the rule.

In addition, it could be said that trust contributes to the creation and development of the so-called "industrial districts". Indeed, high levels of trust between local and regional enterprises have been found in such geographically diverse, yet technologically and industrially successful, districts and regions as Baden-Württemberg, Emilia-Romagna, Route 128, Silicon Valley, etc. Sometimes, even new organisational forms are coming into existence, thanks to this networking process.

For example, in her study of the origins and dynamics of production networks in Silicon Valley, Saxenian (1991) points to the fact that "The creation of long-term, trust-based partnerships is blurring the boundaries between interdependent but autonomous firms in the region" (Saxenian 1991: 424).

Moreover, Sabel (1993) suggests that even in declining or threatened economic regions, the "construction" of trust will make inter-firm collaboration possible, thus allowing the economic recovery of those areas. He presents the cases of four traditional, mature industries, the foundry, garment, injection-moulding, and machine-tool industries, located in the American State of Pennsylvania. These industries were characterised by the fact that "... competition among firms, generally considered a fact of business life, had turned cutthroat in the late 1970s and early 1980s" (Sabel 1993: 347). These same companies are currently experimenting a process of economic revitalisation

based essentially upon the switch to a high trust-based economic system.

Sabel's findings are quite relevant to our own study because, as we shall see, the Portuguese mouldmaking industry is today facing a similar set of problems to those experienced by the Pennsylvanian industries. We believe thus that we have here some lessons to be learnt.

### 3.4. Conclusions

In this chapter, we have tried to understand the intricate and interrelated features of industrial collaboration.

Both large companies and small and medium sized firms are increasingly compelled to cooperate among themselves, and with universities, governmental laboratories, and non-profit research institutions. This complex, new *modus vivendi* has its roots, on the one hand, in the particular conditions which have characterised the world economy since the late 1970s, and on the other hand, in the current developments in science and technology. Indeed, the acceleration of technological change and the shortening of product life cycles, associated with economic, financial, and technological uncertainty, plus the profound impact of information technology across existing enterprises and sectors, led to the emergence of new organisational structures, which include greater technological cooperation and networking. Based upon a review of the relevant literature on collaboration, it was possible to notice, firstly, that every firm has its particular motives for cooperating, and they differ for each individual agreement; secondly, though there are many advantages deriving from industrial collaboration, the presence of numerous obstacles makes it very hard to achieve the desired positive outcomes; thirdly, that the focuses of cooperation are manifold, depending, among other points, on the firm's industrial sector, the nature of its R&D activities, the stage of the technology life cycle, and the strategic purpose of its linkages; and finally, that the existence of multiple modes of inter-firm

cooperation does confirm the complexity of the field we are studying.

Nevertheless, and owing to its relevance to the Portuguese case, a distinctive mode of inter-firm agreements, characterised by great informality and fluidity of information, was analysed. Informal networking is normally based on individual, personal contacts between scientists and engineers, working either in competitive or in non-rivalrous companies, who interchange a great amount of information and know-how. It was found that the existence of trusting relationships among these individuals constitute a key factor for the creation and development of such networks.

Furthermore, it appears that enterprises are better off when operating in trustful environments. Confiding partnerships could also contribute to the creation of a new high trust-based economic system, which may have in itself the potential to revitalise declining or threatened economic areas, as is the case of some regions of Portugal.

Having discussed the interrelated, intricate features of industrial collaboration in a global perspective, in the next chapter we will centre our analysis around the particular problems small countries (such as Portugal) are confronted with, owing to the increased internationalisation of technological activities, associated with the current conditions of economic, financial, and technological uncertainty.

#### 4. SMALL COUNTRIES, GOVERNMENT POLICIES, AND NATIONAL SYSTEMS OF INNOVATION: AN INTEGRATED APPROACH

##### 4.1. Introduction

This chapter deals with three topics which, in the light of the previous discussion in Chapters 2 and 3, are of particular relevance to a small less advanced country such as Portugal.

We will start by referring to the problems small countries are facing in their "confrontation" with both large nations and newly industrialised states. Particular attention will be paid to the way small countries have found for catching up on the more technologically competitive nations (*point 2*).

In *point 3* we will discuss a number of different strategies aimed at overcoming the specific problems affecting small countries. Ultimately, the creation and/or improvement of a national system of innovation (NSI) in Portugal, as well as the country's effective catching up process will rest upon this set of government policies.

Finally, we will be mainly interested in finding out how recent research on "national innovation systems" may contribute to the build up of a sound system supporting technical advance. User-producer interaction will also be highlighted, since it is one of the main topics in the research on national systems of innovation (*point 4*).

##### 4.2. The Special Problems of Small Countries

Under the current conditions of economic, financial, and technological uncertainty, associated, on the one hand, with the shortening of product life cycles and the acceleration of technological change and, on the other hand, with an increased internationalisation of firms and globalisation of industries, small nations are facing a whole set of problems.

These problems are, however, dealt with in quite different ways,

depending on the (small) state we are speaking about. Indeed, small countries are very heterogeneous amongst themselves. Focussing solely on Europe, we find nations with a good industrial and technological infrastructure, some of them even possessing their own home-based multinationals, such as the Netherlands, Sweden, or Switzerland. Conversely, other small states have relatively poor industrial and technological infrastructures, as in the case of Greece, Ireland, and Portugal. In a very interesting report commissioned by the National Economic and Social Council of the Irish Republic, Mjøset (1992) analysed the socio-economic development in Ireland, comparing it with that of five other (small) countries, namely Austria, Denmark, Finland, Sweden, and Switzerland.

Portugal was not amongst these contrast nations. We do believe, however, that Mjøset's study is of particular relevance to the Portuguese case. Indeed, we do hold that his overview and conclusions could, generally speaking, also apply to Portugal, since the Irish development experience bears stronger resemblances with Portugal than with the above mentioned states. For example, after introducing the notions of auto-centric development (growth with development) and peripheral development (growth without development), Mjøset (1992) contends that:

"The former is typical of post-war development in the OECD area, while the latter is typical of the poorest third world countries, even in the post-colonial period. The contrast countries are all clear-cut cases of an auto-centric development model, but *how should Ireland be classified?* Ireland is not a third world country, but it is also hard to classify it as a clear-cut auto-centric case. Thus,... Ireland [lies] *in between* the auto-centric and the peripheral types....

As for the pattern of technical change,... Ireland seems closer to the third world type. This is indicated by the characterisation of a *weak national system of innovation*.... As for the standard of living, however, Ireland seems closer to the auto-centric type" (Mjøset 1992: 5-6) (emphasis added)

The reader may notice that equivalent arguments will be advanced in the next chapter, when referring to the Portuguese S&T system (see, for example, Corkill 1993). Further similarities between the two nations may also be found in their birth rates, in the

weight of their primary (agrarian) sectors upon the countries' economies, and in their strong emigration outflows.

Similarly, in a synthesis report prepared for the FAST/MONITOR Programme, O'Doherty and McDevitt (1991) outlined the shared strengths, weaknesses, threats, and opportunities experienced by Greece, Ireland, and Portugal, labelled as small less advanced nations.

They argue that their common strengths basically rest on abundant and relatively high quality labour as well as on a good physical and social environment for industry.

However, the countries' shared weaknesses prevail over their strengths. According to the authors, those are:

- "- "Small firm", non-integrated industrial structures;
  - significant and declining domestic markets;
  - traditional sectors with poor technology and marketing capabilities;
  - lack of both cooperative and entrepreneurial cultures;
  - peripheral locations;
  - the consequent dependence on financial incentives for both indigenous and particularly foreign industry"
- (O'Doherty and McDevitt 1991: 10)

The nations' difficulties of access to new technologies and markets, an increasing loss of market share in domestic markets for both goods and traded services, and a continued reduction in the number and variety of sub-suppliers are referred to as being their common threats.

Finally, the authors maintain that the three states' shared opportunities lay basically on the exploration of niche markets for both goods and traded services, and on a networking process involving other nationally located and foreign based enterprises. To a certain extent, we do not acknowledge the "exploration of niche markets" argument applied to Portugal. On the contrary, we agree with Soete (1988), who suggests that, although small countries may be particularly vulnerable to major changes in technology, they may also have many opportunities for exploiting specialised niches, provided they have a **sustained technological capacity**. As we will show in the next chapters, this does not seem to apply to Portugal.

Still, we do have to point out that, even possessing such

sustained technological capacity, small industrialised nations can not rely heavily on an "exploration of niche markets" strategy. Indeed, these states face an additional, quite important problem, known as "the small-country squeeze". They are increasingly under pressure from both the large economies and the newly industrialised nations, especially those of South East Asia. This squeezing is mainly due to the ever growing complexity of modern technology. As Mjøset (1992) explains:

"... at certain crucial points in time a mastering of generic technologies may still prove crucial. This is a difficult choice for a small country, because such mastery requires enormous costs. If the country chooses to stay out of this field, it may, however, be squeezed between large countries which master the core technologies, and newly industrialising countries which, according to a product cycle logic, are producing very cheaply a number of more simple goods. In such a squeeze, the area of "medium tech" niche products may simply be too narrow" (Mjøset 1992: 41)

Or, as Walsh (1987) argues:

"... improvements in the technological sophistication and R&D intensity of the more traditional sectors in the larger countries have increased the competitive pressure on small country firms in the same sectors, and consequently limited the ability of such firms to lead the way in innovation as they had previously been more able to do. At the same time, the newly industrialised countries (NICs) are increasing the competitive pressure on small industrialised countries in other sectors, where price competition is more important and where the NICs have important cost advantages" (Walsh 1987: 111)

The danger may be even more substantial for small industrialised nations, bearing in mind that South East Asian states are increasingly producing technologically sophisticated products. In fact, as Hobday (1994) suggests, in contrast to conventional analysis of "leaders" and "followers", Asia's latecomers have travelled backwards along the product life cycle from simple, mature technological activities, learning to innovate as they progressed. Today, many engage in early product cycle activities such as product design, process innovation and R&D.

The capacity shown by most of the Asian NICs to close their technological gap encourages us to discuss an issue which has

particular relevance to Portugal ie, how can a small less developed country succeed in catching up on the more technologically competitive nations.

It will be suggested in the next chapters that, contrary to what happens in small advanced industrialised states, Portugal heavily bases its specialisation pattern upon mature, traditional industries, eg clothing, footwear, textiles, etc. Electronics, on the other hand, being at the heart of the new techno-economic paradigm, besides affecting the research, education, and training systems, is pervading all industrial sectors, increasing manufacturing flexibility and enabling high productivity gains even in those traditional, mature industries.

We believe that an important first step towards closing the technological gap is to take as much advantage, and as quickly as possible, of this new techno-economic paradigm. Indeed, as Freeman (1988c) maintains:

"Fears of an inability to catch up or to maintain competitiveness are often based on the idea that it is necessary to become a *producer* of the new key factors and/or of the new leading products in the world economy.... But past experience of changes in techno-economic paradigm suggests that it is not necessary to have a technological and production capability in all the major new products associated with a new techno-economic paradigm in order to catch up or maintain competitiveness. What is necessary is to have the capability to use the new technologies in some industries and to produce a part of the wide range of new products and services appropriate to local conditions, resources and comparative advantages. This will usually require more than the efforts of a single firm to occupy a "niche": the interaction of a group of firms and institutions will be necessary" (Freeman 1988c: 78)

Among the institutions referred to by Freeman, the higher education sector plays quite an important role. In fact, it has been argued (eg Perez 1988; Perez and Soete 1988) that less industrialised countries do have higher opportunities for catching up when a new technological system is still at an early stage, as the main entry requirements are then associated with scientific and technological expertise. As Perez (1988) stresses:

"We are suggesting then that much of the knowledge required to enter a technology system in its early phase is in fact

public knowledge available at universities, and that many of the skills eventually required do not yet exist and all entrants large or small participate in developing them.... This implies that *given the availability of well-qualified university personnel*, a window of opportunity opens for relatively autonomous entry of small firms and of lagging countries into new products in a new technology system in its early phases. This partly explains the cases of innovation outside the main industrialised nations.... *The already developed small countries have usually a highly developed infrastructure, research, higher education and training system, as well as management skills*" (Perez 1988: 92) (emphasis added)

Hence, the occurrence of particular national characteristics (which, as we will argue, are still lacking in the Portuguese scientific and technological infrastructure) may explain the competitive and innovative success of some small advanced nations. Indeed, as Walsh (1987) suggests:

"Historical reasons leading to an early build up of *national scientific and technological capacity... and an early emergence of home-based multinational enterprises* in what were already at the time or soon to become *technologically intensive industries*, help to explain why Switzerland and also to a large extent the Netherlands and Sweden have not experienced many of the "consequence of size" phenomena in science and technology which other countries of similar size have known" (Walsh 1987: 87, 89) (emphasis added)

Similar reasons apply to the cases of Denmark, Finland, and Norway, particularly in respect to their electronics industry (Dalum, Fagerberg and Jørgensen 1988; Lemola and Lovio 1988).

Summing up these arguments, Perez and Soete (1988) contend that:

"What this means for lagging countries is that during periods of paradigm transitions there are two sorts of favourable conditions for catching up. First of all, there is time for learning while everybody else is doing so. Secondly, given a reasonable level of productive capacity and locational advantages and a sufficient endowment of qualified human resources in the new technologies, a temporary window of opportunity is open, with low thresholds of entry where it matters most. ... So early entry into *new technology systems* is the crucial ingredient for the process of catching up" (Perez and Soete 1988: 477)

Small less advanced nations could therefore succeed in catching



up on the more technologically competitive states, if they take (full) advantage of the new techno-economic paradigm. Freeman (1989) provides a particularly illustrative example, when he refers to the case of South Korea. He contends that:

"... one interesting fact should give pause for reflection. The third country in the world to introduce and export 256k memory chips, after Japan and USA was not an OECD or a COMECON country, but South Korea. *Before the 1960s South Korea had only very little industry, and such heavy industry as there was, was concentrated in the North, while both North and South were poor and devastated by the war.... But the fact that it [South Korea] could become a leading player in the world electronics industry within 30 years does give some food for thought*" (Freeman 1989: 2) (emphasis added)

Freeman then goes on warning that short-term solutions are not compatible with the problem of technological catching up. He argues that South Korea's leading industries still have a long way to go before enjoying "... a firm competitive basis in product innovation capacity" (Freeman 1989: 2).

Furthermore, when referring to the Japanese case, Freeman (1987) also maintains that an appropriate combination of factors does contribute to the (technological and scientific) progress of a country with scarce resources. As he rightfully emphasises:

"... the rate of technical change in any country and the effectiveness of companies in world competition in international trade in goods and services, does not depend simply on the scale of their research and development and other technical activities. It depends upon the way in which the available resources are managed and organised, both at the enterprise and at the national level. The national system of innovation may enable a country with rather limited resources, nevertheless, to make very rapid progress through *appropriate combinations of imported technology and local adaptation and development*. On the other hand, weaknesses in the national system of innovation may lead to more abundant resources being squandered by the pursuit of inappropriate objectives or the use of ineffective methods" (Freeman 1987: 2-3) (emphasis added)

The role of the state and of the government policies in supporting technical change is thus of paramount importance in the management and in the organisation of a country's available resources. In the next section we will discuss a number of public

sector policies directed at overcoming some of the above mentioned specific problems which affect small countries. Ultimately, a successful catching up process as well as the build up of a strong national system of innovation will be dependent upon such a set of government policies.

#### 4.3. Government Policies to Promote Innovation

It has been argued (Porter 1990b) that, in spite of the growing internationalisation of scientific and technological activities, the role played by individual nations is becoming increasingly important. This is explained, on the one hand, by the fact that the home nation is the origin of the skills and technology which support competitive advantage and, on the other hand, by the fact that the innovation process involves fundamental uncertainty both in relation to technology and to the marketing of new products. Therefore, one way to overcome market uncertainty is through demand organised by the public sector directly through procurement or indirectly through regulations.

The importance of the public sector in affecting industrial development was already emphasised long ago by Rothwell and Zegveld (1981). They argued that the least important way in which governments influence technical innovation is through subsidy, whereas the most important is through its own demand. As they put it:

"- a strong and clearly expressed government demand has the effect of diminishing risk and uncertainty in the area where it is greatest: the future market. The more radical the innovation, the more important this is" (Rothwell and Zegveld 1981: 51)

Similarly, Gregersen (1988, 1992) maintains that the public sector is involved in direct support of science and development, and its regulations and standards influence the rate and direction of innovation. Furthermore, it is the single most important, and a more or less competent, (first) user of innovations developed in the private sector (Dalpé, DeBresson and

Xiaoping 1992).

A particularly illustrative example of how public sector policies can have quite a positive effect in overcoming some of the small-country disadvantages was highlighted by Dalum, Fagerberg and Jørgensen (1988). Referring specifically to the electronics industry, they argue that it was the lack of adequate support from the Danish and the Swedish governments which prevented a successful production of mainframes or minis in these countries. Conversely, they maintain that in Norway:

"... the case of Norsk Data shows that it is possible, even in small countries, to establish successful computer firms if they are among the first world-wide to exploit possibilities offered by radical changes in component technology, and manage to combine this with software developments for *targeted market segments*. Norsk Data, though not directly supported, survived the initial phase mainly because it *managed to get contracts, some of them technologically very demanding, from the Norwegian public sector*" (Dalum, Fagerberg and Jørgensen 1988: 133) (emphasis added)

Thus, even in small countries, governments and firms can interact to create new, long-term technological capability and competitive advantage.

Generally speaking, governments of small countries may choose amongst a number of different strategies in order to try to overcome the specific problems which affect them.

For example, Corado-Simoes (1991) contends that four main strategies might be followed by Portugal. These are:

- (1) "more of the same", meaning that the country should further increase its specialisation on traditional export industries which still account for a large share in Portugal's exports;
- (2) "integrate in the high-tech world", following a voluntary approach to technological modernisation;
- (3) "building international linkages", forging a network of international relationships, in order to enable Portuguese enterprises to learn and gradually build capabilities to go alone later on; and
- (4) "betting on the difference", assuming that there is room for being different, both at the country and firm levels. The

opportunities lay in "specialised" environments where it is possible to find niches where barriers to entry are modest, economies of scale low, and R&D requirements relatively small. Similarly, based upon a review of the literature on small country strategies, Walsh (1987, 1988) suggests that five different strategic courses might be pursued by those countries. It is important, however, to bear in mind that such courses are not mutually exclusive. She terms them as (1) encouraging MNEs based in the small country; (2) inward investment by foreign MNEs; (3) finding niches in the market; (4) specialisation; and (5) cooperation with other countries. Below, we will briefly characterise these distinct strategies.

(1) encouraging MNEs based in the small country: there is some evidence showing that large companies in small countries can make important contributions to national competitiveness in the world market. This is even more true when there is a significant number of "own" MNEs (multinational enterprises) based in a small country, as in the case of the Netherlands, Sweden, and Switzerland. In fact, since "own" MNEs do spend a large share of the country's R&D expenditures, such countries "... are more successful in dealing with the problems of small resources for innovation and difficulties of breaking into the world market..." (Walsh 1987: 118).

This strategy has certainly not been pursued by Portugal, a country without its own MNEs. However, if a country decides to follow this path, an important point should be kept in the back of the mind ie, although multinationals do most of their R&D in their home country, they may sometimes be tempted to move their R&D to larger countries, benefiting from a wider scientific and technological infrastructure and closeness to larger markets. This was the case, for example, of the Canadian multinational Northern Telecom, which established most of its research laboratories in the United States (Dalpé 1988; McFetridge 1993; Niosi 1991).

(2) inward investment by foreign MNEs: this strategy has been particularly cherished by small countries with weak indigenous R&D capacities. Portugal is such a case.

The most paradigmatic example is probably that of the Republic of Ireland (Mjøset 1992; O'Doherty 1993). This country has offered very big incentives, combining allowances, grants, and tax concessions, to foreign companies to invest in Ireland. This strategy has indeed created many jobs, and the subsidiaries of foreign MNEs have made a big contribution towards increased industrial production and exports although, regarding Irish R&D capacity, their effort has been quite limited.

One should, however, put the technological level of these new jobs in perspective, since most of them are low skill assembly jobs; moreover, Ireland is acting as just a sub-assembly site for multinational corporations, since most of the production is exported back to MNEs' home countries. Irish and American firms have however developed some relatively high-skilled service activities in the telecommunications area.

Though to a lesser degree, Portugal faces quite a similar situation. The Portuguese subsidiaries of foreign MNEs do employ many workers but act only as assembly plants, importing raw materials and exporting assembled products.

Another important point should be referred to ie, the noticeable lack of linkages between many foreign-owned companies and the indigenous enterprises.

We think that this strategy may not be the most suitable as the main instrument for establishing an indigenous capacity in a particular technology; alternative arrangements, such as joint ventures and technological collaboration agreements may be more appropriate for small less advanced countries.

(3) finding niches in the market: small countries may look for specific niches in the market, where economies of scale and barriers to entry are low, and where they are not (yet) facing direct competition from large companies. This strategy, however, may not be the most feasible for small less industrialised countries, particularly if they lack a minimum threshold of expertise and infrastructures. Indeed, as Walsh (1988) argues:

"To permit such a strategy, the small country would need to develop a high-level intelligence-gathering capability in order to identify world trends in output, demand, market potential and scientific and technological developments,

forecast the trajectory, analyse the opportunities and constraints of new development and then direct its limited R&D resources to projects selected for their potential to generate innovations able to fill identified market niches" (Walsh 1988: 53)

Moreover, as Dalpé (1988) suggests, the strategy of niches may turn out to be a hazardous choice, since it is subject to the reaction of large companies. At any moment, these can decide to move in on the market of small firms. Therefore, firms which are active within certain niches must constantly be aware of new products put out by their (larger) competitors.

(4) specialisation: in order to make the most appropriate use of available resources, small countries may also specialise themselves in certain R&D areas. They may exploit their particular advantages, such as natural resources based on an established reputation or technical expertise and market knowledge in certain areas, even though this may not be the "leading edge" high-tech sector. For example, it seems reasonable for Portugal to privilege such technological areas as aquaculture, ocean industries, and seaweed industries, where the country possesses accumulated expertise and knowledge; however, it would be also advisable to be active in other technological areas, such as engineering ceramics, fibre optics, microelectronics, photovoltaics, and wind turbines, where there is high potential for economic growth.

Indeed, the ability of a country to be technologically active in a number of fields is of particular relevance. Walsh (1988) illustrates quite well this point, when she argues that:

"... the extension and continual upgrading of sectors where a country traditionally has been successful, and the development of new industries based on sophisticated technologies, are *not alternative strategies to be counterposed*. They are *parallel strategies*, one for immediate development of a solid industrial base and the other aimed at the long-term development of a strong competitive position in the future" (Walsh 1988: 62) (emphasis added)

A particularly impressive example of this strategy is referred to by Freeman (1987), on his study on Japan. He argues that one

of the factors leading to Japan's competitive success was the promotion by MITI of the most advanced technologies with the widest market potential in the long-term, coupled with the explicit rejection of a strategy based only on the development of such industries as textiles, in which Japan once had a comparative advantage. This example reinforces the importance of a technology policy aimed both at the long-term and at the short-run.

(5) cooperation with other countries: small countries may embrace another strategy, that of cooperating with other small countries. This path has been already followed by the Nordic countries, which were thus able to secure access to a wider, regional market. Cooperation between countries may also favour the creation of a common applied research and technology infrastructure, indispensable for an efficient translation of R&D into commercially exploitable inventions and innovations. This collaboration should, however, be conscientiously worked out. Indeed, as Walsh (1987) contends:

"Co-operative ventures need to be carefully planned, to include not just R&D but marketing and production activity as well, in order to ensure contributions for, and benefits to, each partner in the development of scientific and technological capability on the one hand and the economic exploitation of the R&D on the other hand. By co-operation in production and marketing too, two or more small countries might act together to produce the equivalent of a larger home market for the innovations that result"  
(Walsh 1987: 122)

In our opinion, however, a small (less) developed country can not master its particular weaknesses simply by selecting and/or implementing one, or a mix, of the strategies sketched above. Rather, it needs to be able to create and support a whole set of actors and/or institutions interacting very closely together. Indeed, we think that one of the major factors which may explain the very rapid progress in industrialisation and catching up experienced by South Korea and the other Asian tigers relates to their significant efforts in education and training policies (for a more recent account of these policies see, for example, Hou and Gee 1993; Kim 1993). As Freeman (1989) stresses:

"... former colonial territories of Japan, such as Korea, certainly do not wish to remain dependent upon Japan for capital and technology. They have been making intense efforts to develop their indigenous scientific and technological capability, especially through government initiatives in centralised research and higher education, and now increasingly through enterprise-level R and D. It is particularly striking that several other Asian countries now have a higher annual output of graduate engineers per 100,000 population than Japan.... South Korea is also setting extremely ambitious targets for Research and Development, which (if realised) would mean that the country would have a higher RD/GNP ratio than Japan, USA and EEC by the end of the century" (Freeman 1989: 14) (emphasis added)

In spite of Korea's remarkable achievements in the past few years, Kim (1993) is particularly critical of the role played by the higher education sector in redesigning the nation's innovation system. He maintains that:

"One of the major mistakes made by the Korean government in developing a national system for industrial innovation has been its underinvestment in higher educational institutions.... For example, the student-professor ratio has retrogressed from 22.6 in 1966 to 35.8 in 1985, making all universities primarily undergraduate teaching-oriented rather than research-oriented.... As a result, Korea has failed to develop a stock of highly trained scientists and engineers who will be necessary in the 1990s for Korea to sustain its international competitiveness" (Kim 1993: 371) (emphasis added)

Again, the existence of a research-orientated higher education sector is not, by itself, enough for a small state to overcome its specific disadvantages. As already mentioned above, a whole set of dynamic, flexible institutions should closely interact with each other, thus strongly contributing to the country's development. As Johnson (1988) contends:

"Small developed countries have to be able to adapt to changes in the international competition, primarily by producing for markets with high and rising demand. This means a constant reallocation of resources and a high rate of product innovation. When and where this is not possible, production should stay cost-efficient, which implies a high rate of process innovation. Thus technological innovativeness is at the heart of international competitiveness. This implies that the institutional system should admit and stimulate technological innovation. It

also implies that the institutional system itself should be able to adapt to technical changes; that is, it implies institutional innovativeness. Flexible institutions and technologies are pre-requisites for a flexible economy" (Johnson 1988: 291-292)

Below, he summarises his case, arguing that:

"The point is that the need for an institutional system which stimulates technical innovation is relatively strong for small countries. The possible benefits of such a system are considerable, and so are the potential costs of institutional rigidity" (Johnson 1988: 296)

Therefore, the role played by the institutional system in a nation's economic and technological development will be discussed in greater detail in the next section.

#### 4.4. National Systems Supporting Technical Change

Since the mid-1980s a number of researchers and scholars (Freeman 1987, 1988b; Lundvall 1988, 1992b; Nelson 1988, 1993; Porter 1990a, 1990b;...) have been involved in a search for the origins of national competitiveness. The basic idea is that countries differ in the way they conduct technical change, both at the level of public policies for promoting innovation, and at the level of their socio-economic institutions, eg business enterprises. The researchers' main goal has thus been to tackle the problem of how technology policies, competitiveness, human capital, industrial relations, and economic and political institutions, amongst other factors, influence each other.

As with any new, intertwined (with national, regional, and international levels of innovative activities being integrated), complex concept, that of a "national system of innovation" is necessarily all-encompassing and therefore (still) unclear. Such difficulty has been recognised by Nelson and Rosenberg (1993), who point out that:

"Each of the terms [national innovation system] can be interpreted in a variety of ways, and there is the question of whether, in a world in which technology and business are

increasingly transnational, the concept as a whole makes much sense" (Nelson and Rosenberg 1993: 4)

Those multiple ways of unfolding the concept are fully expressed by the plethora of interpretations surrounding it.

Certainly one of the first definitions of a "national system of innovation" was proposed by Freeman (1987), on his study on Japan. He argues that:

"The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies may be described as "the national system of innovation"" (Freeman 1987: 1)

Freeman goes on to emphasise the importance of the social innovations which accompany a new techno-economic paradigm.

A different approach is followed by the IKE group at Aalborg University (Lundvall 1992b). It accentuates user-producer interactions within the national economy, stressing "... interactive learning anchored in the production structure and in the linkage pattern of the system of production" (Lundvall 1992a: 17).

In an early contribution, Andersen and Lundvall (1988) had already suggested that a national system of innovation is basically a cumulative process of learning-by-doing, learning-by-using, and learning-by-interacting with the market, rather than merely a set of laboratories. They contended that:

"In such a system [of innovation] the fundamental stocks and flows are *knowledge and ideas* rather than tangible products and financial flows. But the system of innovation *is not simply another name* for the "research system" of industrial R&D, public research institutes and universities. On the contrary, we think that an analysis of the system of innovation is greatly strengthened when it takes as its starting-point an analysis of the *system of production and consumption*" (Andersen and Lundvall 1988: 14) (emphasis added)

National innovation systems may also be defined in a broad and/or in a narrow sense. As Freeman (1992) suggests:

"... the concept "National System of Innovation" may be used in two senses: in a *broad* sense it encompasses all

institutions which affect the introduction and diffusion of new products, processes and systems in a national economy; and in a narrow sense it encompasses that set of institutions which are more directly concerned with scientific and technical activities" (Freeman 1992: 169)

This distinction is also subscribed by Lundvall (1992a) who, additionally, pays particular attention to the processes of exploring, searching, and learning. As he puts it:

"The narrow definition would include organisations and institutions involved in searching and exploring - such as R&D departments, technological institutes and universities. The broad definition... includes all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring - the production system, the marketing system and the system of finance present themselves as sub-systems in which learning takes place" (Lundvall 1992a: 12)

Still another interesting classification of innovation systems is the one proposed by Patel and Pavitt (1994). Based upon earlier work (Pavitt and Patel 1988), a distinction between myopic (eg, the UK and the US) and dynamic (eg, Germany and Japan) national systems of innovation is suggested. As Patel and Pavitt (1994) state:

"... myopic systems treat investments in technological activities just like any conventional investment: they are undertaken in response to a well-defined market demand, and include a strong discount for risk and time. As a consequence, technological activities often do not compare favourably with conventional investments. Dynamic national systems of innovation, on the other hand, recognise that technological activities are not the same as any other investment. In addition to tangible outcomes in the form of products, processes and profits, they also entail the accumulation of important but intangible assets, in the form of irreversible processes of technological, organisational and market learning, that enable them to undertake subsequent investments, which they otherwise would not have undertaken due to a lack of the required competencies" (Patel and Pavitt 1994: 23-24)

Finally, two further definitions were recently advanced, which we think bring together most of these different components and emphasise possible linkages amongst various institutions. As Niosi, Saviotti, Bellon and Crow (1993) suggest:

"A national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, inasmuch as the goal of the interaction is the development, protection, financing, or regulation of new science and technology" (Niosi, Saviotti, Bellon and Crow 1993: 212)

Similarly, Edquist and Lundvall (1993) suggest that:

"The national system of innovation is constituted by the institutions and economic structures affecting the rate and direction of technological change in the society. Obviously, the national system of innovation is larger than the R&D system. It must, for example, include not only the system of technology diffusion and the R&D system but also institutions and factors determining how new technology affects productivity and economic growth" (Edquist and Lundvall 1993: 267)

The framework proposed by Porter (1990a, 1990b), although more orientated towards the single firm, is very much in line with the above mentioned studies. He classifies the determinants of national competitive advantage in four broad attributes which, individually and as a system, constitute the so-called "diamond of national advantage":

1. *Factor Conditions*. The nation's position in factors of production, such as skilled labor or infrastructure, necessary to compete in a given industry.
2. *Demand Conditions*. The nature of home-market demand for the industry's product or service.
3. *Related and Supporting Industries*. The presence or absence in the nation of supplier industries and other related industries that are internationally competitive.
4. *Firm Strategy, Structure, and Rivalry*. The conditions in the nation governing how companies are created, organized, and managed, as well as the nature of domestic rivalry" (Porter 1990a: 77)

Interestingly enough, in an era in which business and technology are increasingly transnational, Porter emphasises the role of the individual nation. From his analysis one may conclude that national characteristics do strongly influence the technological activities of domestically-based firms and industries and, ultimately, do also shape the national innovation system itself.

As Porter (1990b) contends:

"... the leaders in particular industries and segments of industries tend to be concentrated in a few nations and sustain competitive advantage for many decades. When firms from different nations form alliances, those firms based in nations which support true competitive advantage eventually emerge as the unambiguous leaders.

Competitive advantage is created and sustained through a highly localized process. Differences in national economic structures, values, cultures, institutions, and histories contribute profoundly to competitive success. The role of the home nation seems to be as strong as or stronger than ever. While globalization of competition might appear to make the nation less important, instead it seems to make it more so.... the home nation takes on growing significance because it is the source of the skills and technology that underpin competitive advantage" (Porter 1990b: 19)

Based upon a study of the technological activities of 686 of the world's largest manufacturing companies, Patel and Pavitt (1991) support Porter's case. They suggest that technological activities essentially remain within firms' home countries, insofar as they found that more than 80 per cent of these activities were domestic.

Patel (1995) further argues that there is no systematic evidence to suggest that widespread internationalisation of technological activities occurred in the 1980s. Based on the US patenting activities of 569 multinationals based in Europe, Japan and the US, and covering 17 industrial product groups, he shows that, for an overwhelming majority, technology production remains close to the home base. Moreover, the most internationalised firms are not in the "high-tech" product groups, but in such product groups as food, drink and tobacco, where adaptation to local markets is important.

One of the most important "elements" of a national system of innovation is the interaction between producers and users. A short overview of these relationships is presented below, since they are pertinent to our research.

User-producer interaction seems to be greatly facilitated by the existence of national linkages. Indeed, the national network of linkages involving producers and users constitutes a basic ingredient for technology upgrading and for the development of



products fully suited to specific customers' needs. This networking process is particularly favoured by such intangible elements as mutual dependence, the sharing of a common culture, and trust. As Andersen and Lundvall (1988) contend:

"At the national level... user-producer relations are facilitated by language, culture, national standardization and a large set of formal and informal organizations" (Andersen and Lundvall 1988: 12)

Equally important are the problems associated with information exchange across cultural and geographical space. Lundvall (1988) maintains that the geographical proximity between groups of producers and users constitutes a comparative advantage, which increases with the complexity of the messages exchanged, having a more significant effect the more radical the innovation. As he puts it:

"The importance of distance will vary with the type of innovative activity involved. When the technology is standardized and reasonably stable, the information exchanged may be translated into standard codes, and long-distance transmission of information can take place and involve low costs. Here, user-producer relationships involving units located far away from each other might be effective.

When the technology is complex and ever changing, a short distance might be important for the competitiveness of both users and producers. Here, the information codes must be flexible and complex, and a common cultural background might be important in order to establish tacit codes of conduct and to facilitate the decoding of the complex messages exchanged. The need for a short distance will be reinforced when user needs are complex and ever changing. When the technology changes rapidly and radically... the need for proximity in terms of geography and culture becomes even more important. A new technological paradigm will imply that established norms and standards become obsolete and that old codes of information cannot transmit the characteristics of innovative activities. In the absence of generally accepted standards and codes able to transmit information, face-to-face contact and a common cultural background might become of decisive importance for the information exchange" (Lundvall 1988: 354-355)

Thus, geographical proximity between groups of producers and users constitutes a comparative advantage, which is particularly important for a small, less technologically advanced country.

Moreover, support and promotion of highly interactive clusters between users and producers should be actively encouraged, as one of the first steps to create and/or improve a national innovation system.

#### 4.5. Conclusions

In this chapter, three issues were discussed, all of them particularly germane to Portugal, a small less advanced country. We started by focussing our attention on the special problems small countries face due to the increased internationalisation of technological activities. It was found that small nations are confronted with many problems. A particularly important one relates to the constant pressure they are enduring, "squeezed" between newly industrialised countries and large economies, due to the increasing complexity of technology. Another big problem concerns the process of catching up on the more technologically competitive nations. An early entry into new technology systems is a crucial ingredient to succeed in this process.

A second issue under discussion focussed on a number of strategies aimed at overcoming the specific problems affecting small countries. The successful implementation of such strategies is reinforced by the existence of a set of institutions working very closely together. In particular, business enterprises and the public sector, which in many nations is the single most important user of innovations developed in the private sector, can and should interact to create national competitive advantage and long-term technological capability.

Finally, the contribution of the "national system of innovation" to the emergence of national technological opportunities was analysed. It was found that national characteristics strongly influence the technological activities of domestically-based firms and industries and, ultimately, also shape the national innovation system itself. The important role played by user-producer linkages in upgrading technology as well as in reinforcing mutual dependence and trust was detected. Moreover,

geographical proximity between groups of producers and users seems to constitute a comparative advantage. Support and promotion of highly interactive clusters between users and producers should therefore be actively encouraged.

In order to better understand the special problems Portugal is currently facing, and in particular the overall situation of its industry regarding collaboration, it is necessary to begin by scrutinising the scientific and technological level of the country. Thus, in the next chapter, our attention will be centred on the latest developments in Portuguese science and technology.

## 5. SCIENCE AND TECHNOLOGY IN PORTUGAL: THE STORY SO FAR

### 5.1. Introduction

In this chapter we will be examining in some detail the Portuguese scientific and technological (S&T) system, focussing especially on its strengths and limitations. Its productive sector will also be carefully analysed, in order to try to understand why it is not performing such a decisive, important role as the one played by the business sector in most of the OECD countries.

As already mentioned in the introductory part of the thesis, we will concentrate on the country's S&T system because, as the evidence in Chapter 8 will show, Portugal is a nation with an incomplete, non-integrated system of innovation. There are virtually no statistics of innovation, reflecting this weakness. Furthermore, although one may consider that most of the actors and/or institutions which shape a country's innovation system (private and public firms (either large or small), universities, government agencies, the system of production and consumption, the marketing system, etc) seem to be already in place, the informal networks of relationships between all of them, which are so important for the creation and/or improvement of a national innovation system, are quite rare.

Focus will also be placed upon Portuguese business firms' expenditures on R&D. Together with statistics on the employment of scientists and engineers, R&D is the only measure of technological level and/or innovative activity which will be discussed. This is mainly because R&D statistics are widely available for almost all OECD countries, and for quite long time-spans, which makes comparisons between nations feasible, despite well-known problems concerning R&D as an indicator of technological level.

On the other hand, no mention will be made to other possible technological indicators, such as bibliometric and citation

analysis, expenditures on education, numbers of innovations and their diffusion, patent statistics, technological balance of payments, etc. This lack of comments is chiefly explained by the very low level of significance of those Portuguese technological indicators, when one analyses them in a broad, general, international context, namely that of OECD's statistics.

Therefore, although we all acknowledge that there is more to innovation than just R&D, important though that might be, our analysis will focus basically upon the four main sectors of the Portuguese S&T system ie, the public, the higher education, the private non-profit, and the business ones.

We will start by presenting a short overview of the country's recent history (*point 2*), since Portugal's political and economic evolution has deeply contributed to shape its scientific and technological system.

The development of the country's S&T system, and in particular the major structural changes recently experienced, are then discussed (*point 3*). To better perceive its intrinsic characteristics, the Portuguese S&T system is placed in the international context ie, it is compared with similar systems of other OECD countries.

Finally, the four distinct sectors which traditionally comprise the institutional infrastructure of a country's scientific and technological system are analysed in some detail, paying particular attention to the Portuguese business sector and to the reasons why it performs such a discrete role in the context of Portugal's S&T system.

## **5.2. A Brief Outline of Portugal's Recent History**

In 1974, the bloodless "Carnation Revolution" put an end to a 48 years old, civilian, right-wing, soft dictatorship in Portugal. Among a number of important characteristics of this regime, a particularly significant one, which carries some relevant implications for our study, refers to the dualistic industrial structure of the country, in which a traditional sector made up

of a very large number of micro and small firms coexisted with a relatively "modern" sector comprising a few oligopolies. As a matter of fact, the Portuguese economy could then be defined as being "oligopolistic-dominated". Economically (as well as financially), the country was "ruled" by a small number of business tycoons who, through their (diversified) economic groups, were in control of a number of key industries (and services), eg, cement, paper, steel, banking and insurance, newspapers, and so on. Moreover, well into the 1960s, these captains of industry had the right to veto the entry, into the Portuguese market, of their business competitors, under the so-called "Lei do Condicionamento Industrial" (Industrial Regulation Law). As a consequence of this veto, facing virtually no industrial challenge, and relying on the existence of a large underpaid labour force, most of them felt no need to technologically modernise their companies.

Interestingly enough, while at the internal level the market shares enjoyed by existing enterprises were protected and the establishment, and the productive capacity, of new firms was controlled, Portugal's membership of EFTA (European Free Trade Association) in 1958, and particularly the 1972 trade agreement with the then European Economic Community (EEC), followed by full membership in 1986, very strongly contributed to a fundamental reorientation in Portugal's trade patterns. Gradually, the country's economy became more outward-looking, yet highly dependent on, and sensitive to, changes in the international economy and world trading conditions, which mirrors the basic characteristics of a small, open economy.

In the aftermath of the 1974 revolution, all the economic conglomerates were nationalised and, suddenly, the Portuguese State (and all the successive governments which ruled the country since then) found itself as the owner of a multitude of enterprises of quite different size, ranging from micro firms to large companies, which used to belong to those economic holdings. A large number of them were not competitive under a free-market economic perspective; consequently, mainly to avoid social costs (such as making workers redundant), as well as social

instability, Portuguese governments started to "throw good money after bad".

The economic situation has only started to better in the beginning of the 1980s, and particularly after 1986, when Portugal formally joined the (then) European Community (EC). One major reason for this improvement relates, to a great extent, to the very large influx of European Union's structural funds which, since then, have been flowing into the country, as a means of paving the way for real economic convergence.

Nevertheless, Portugal's economic structures still require modernisation, and many characteristics of social underdevelopment remain in place.

For a start, international disagreement persists as to how to accurately classify the Portuguese economy. Indeed, indicators of "Third World" status are still evident in any assessment of the economy. Referring to the way Portugal is internationally regarded, Corkill (1993) points out that:

"Usually it is ranked by international organisations either among the poorer First World nations or as being in the front rank of the developing countries. In the 1980s, the World Bank excluded Portugal from its group of "developed market economies" in favour of a "developing country" classification based on its per capita income.... The OECD frequently compares Portugal with other newly industrialising economies (NIEs), while recognising that, as a member of the EC, it also merits being categorised alongside the developed economies" (Corkill 1993: xiii-xiv)

The brief summary of Portugal's recent history sketched above is important for a better understanding of the strengths and weaknesses of its scientific and technological system. This will be the focus of the following section.

### 5.3. Portugal's Scientific and Technological System in Perspective

The Portuguese scientific and technological (S&T) system is a relatively recent one. The first main step towards a national science policy was taken in 1967, with the establishment of

JNICT, the Portuguese Board for Scientific and Technological Research. Initially, its main purpose was the preparation of science policy, the coordination of research at national level, and international cooperation.

According to Ruivo (1991a, 1991b), four different periods of science policy can be clearly identified which, interestingly enough, are closely related to the various models of the innovation process previously discussed.

The first one, from 1969 to 1971, emphasised the so-called linear model of innovation, heavily relying upon basic research, which was believed to be the starting point for a high level of technological research.

The second period, covering the years 1972 to 1974, although still influenced by the linear model of innovation, saw a shift towards a more important role played by applied research activities. This experience was cut short by the 1974 events and subsequent periods of political, economical, and social instability.

The third period, ranging from 1978 to 1985, introduced again a change of direction on science policy. Great relevance was put on the "demand-pull" model of innovation, as a means of matching R&D to the specific needs of Portuguese industry. Additionally, the reduction of technological dependence and the promotion of Portuguese-generated technology was regarded as a country's priority.

Finally, the fourth period, from 1986 to 1989, was strongly associated to Rothwell's third generation innovation process, inasmuch as a number of actions were pursued with the aim of clearly combining the "technology-push" with the "demand-pull" approaches.

It was also during this final stage that the scientific and technological system experienced major changes. Below, we outline the most important of them.

i) In 1987, the incorporation of a specific R&D budget into the national budget was a very important first step in the process of coordinating and planning scientific and technological activities in the public sector;

ii) One year later, the Portuguese Parliament passed a series of important laws. These include:

a) Law 91/88, on Scientific Research and Technological Development, which defined priorities and general objectives and laid down provisions relating to the evaluation of R&D activities, cooperation between enterprises and universities, and the mobility of scientists and technologists;

b) Law 108/88, on the administrative, educational, financial, and scientific autonomy of universities;

c) Decree-Law 374/88, which restructured and strengthened JNICT. Its role was reformulated, to give the Government technical assistance in the field of science and technology. Its new tasks include the preparation of reports and forecasts which can be used as a basis for plans to be approved by the Government; the participation in the overall coordination of science and technology in Portugal; the promotion of research, development, and innovation programmes and projects, in liaison with sectoral implementing bodies, by means of R&D contracts; the promotion of large-scale R&D support facilities and the restructuring of research units; the scrutiny of the development of science and technology in Portugal in the context of world economic developments and their impact on the Portuguese economy; the encouragement and participation in the development of information infrastructure and the promotion of the dissemination of science and technology; the promotion of the awarding of study grants, both in Portugal and abroad, and of research subsidies in accordance with the legislation in force; and the collaboration on the preparation of Government measures to promote international cooperation in the field of science and technology and the development of bilateral relations in this field;

iii) As a direct consequence of the Decree-Law 374/88 JNICT, which had previously been moved from one ministerial department to another, has been placed under the authority of MPAT, the Ministry of Planning and Regional Administration;

iv) The Ministry of Planning and Regional Administration received by law the right to request any relevant information from public research establishments dependent on other ministerial

departments;

- v) Government responsibility for S&T policy has been assigned to SECT, a new Secretariat of State for Science and Technology, under the authority of MPAT, with the responsibility for the overall coordination of science and technology in Portugal, and for international cooperation in the field of R&D;
- vi) The Portuguese Parliament established a Permanent Subcommittee for Science and Technology;
- vii) CSCT, a Higher Council for Science and Technology, has been set up to advise the Government on all matters connected with setting, coordinating, implementing, and assessing S&T policy;
- viii) CSEE, a Council for Higher Education-Enterprises, has been set up to make relations between universities and the production sector easier;
- ix) A large number of R&D centres, institutes, and laboratories have been established, mainly in the form of private non-profit institutions;
- x) Major national advanced research training programmes have been set up.

### 5.3.1. A general overview of the system

Despite the introduction of these new measures and laws, the Portuguese S&T system is still lagging well behind those of other European countries of comparable size, and even very much smaller ones. This situation is mainly the result of a number of structural weaknesses, which have been systematically stressed by researchers and scientists.

For example, Caraça, Gonçalves, Brito, Mateus, Ribeiro, Faisca and Moreno (1993) point out that:

"The main weak points of the Portuguese S&T system can be summarized in the following manner:

- A low technological-intensity profile dominates the productive sector, pulling mainly low professional qualifications from the labour force - thus, a scientific and technological tradition, in particular in industry, is non-existent;
- A technical and industry-prone culture is also non-

existent in most academic circles;

- A general public and political unawareness of the actual situation and perspectives of the S&T system still prevails;
- A low level of formal education and training persists;
- A weak support to the diffusion mechanisms in the S&T system is apparent" (Caraça, Gonçalves, Brito, Mateus, Ribeiro, Faisca and Moreno 1993: 8)

Elsewhere, in a report on incentives to R&D activities in the productive sector, prepared for a Portuguese industrial association (Caraça, Gonçalves, Assis and Gonçalves 1988), we had already mentioned a similar set of reasons.

Ruivo (1991a) also contends that "Some of the obstacles to developing science in Portugal have been the lack of continuity in policies and funds available, and the usual small amount of funds for supporting research" (Ruivo 1991a: 46).

Similarly, in a report on the country's scientific and technological policy, conducted on behalf of the Commission of the European Communities, Spinnato (1993) argues that "One of Portugal's biggest problems, where science and technology are concerned, is the lack of human and financial resources (with figures much lower than the European average)" (Spinnato 1993: 49).

Finally, it is worth mentioning what the examiners of the recent review of Portugal's science and technology policy, conducted on behalf of the OECD, regard as "... the most significant structural and cultural problems..." (OECD 1993b: 101). These include:

- "- lack of R&D capacity in manufacturing industry in terms of both expenditure and skilled personnel - perhaps the *single most important barrier to a technologically dynamic and competitive industry*;
- lack of direct government support for basic pre-competitive industrial R&D;
- shortage of skilled technicians, both in the scientific and technological infrastructures and in industry;
- industrial structures characterised by a large number of SMEs and a bias towards low-technology production in traditional sectors;
- overemphasis on academic research, which itself tends to be overly theoretical;
- an academic culture that resists interaction with industry;

- rigidities within the academic research system which make adaptation to the country's evolving economic needs difficult;
- shortage of modern R&D instrumentation and equipment, and, where up-to-date equipment has been acquired, a general shortage of funds to cover maintenance and operating costs;
- a serious ageing of the research population in some public research establishments (notably in INIA and INIP), due to the freezing of staff levels;
- geographical concentration of national R&D capability, mainly in the Lisbon area" (OECD 1993b: 101-102) (emphasis added)

All these considerations advanced by researchers and scientists are confirmed by the statistical data on science and technology indicators, regularly published by the OECD.

Below, we will present the most recent, relevant data available, comparing Portugal with their counterparts within the European Union (EU), with the EFTA countries, and with Canada, Japan, and the United States. Note that the Portuguese R&D survey is only carried out every second year. Therefore, our analysis covers particularly the five years from 1986 to 1990, a period during which Portugal was already benefiting from its full membership of the EU (and especially from the very large influx of structural funds).

With respect to the gross domestic expenditure on R&D (GERD), measured in terms of million current PPP \$ (purchasing power parities) (TABLE 1), Portugal's GERD in 1990 is approximately less than one-half that of Denmark; less than one-third that of Austria and Finland; less than one-seventh that of Spain; and less than one-ninth that of the Netherlands. Only Greece, Ireland, and Iceland are behind Portugal.

TABLE 5.1: GROSS DOMESTIC EXPENDITURE ON R&D (GERD) (million current PPP \$)				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	1679.7	2034.2	2292.4	-
Denmark	715.2	926.2	1143.4	1383.6
France	13627.7	16608.9	19387.6	23762.1
Germany	-	23661.3	27903.9	32030.6
Greece	176.3	199.8	245.0	-
Ireland	177.8	226.0	259.1	342.6
Italy	5963.4	7920.8	9823.6	11964.3
Netherlands	3059.0	3940.3	4470.6	4826.8
Portugal	202.4	262.9	342.5	501.8
Spain	1318.3	1985.1	2778.2	3888.8
United Kingdom	-	16198.6	17801.2	19955.2
<b>EFTA</b>				
Austria	982.6	1254.5	1470.7	1824.9
Finland	780.1	1014.1	1267.2	1541.8
Iceland	22.0	24.5	-	43.7
Norway	809.0	-	-	-
Sweden	-	-	-	-
Switzerland	-	3160.1	-	-
<b>OTHERS</b>				
Canada	4926.2	5731.5	6314.0	7406.0
Japan	35114.2	42080.2	52109.8	66965.3
United States	103236.0	121629.0	136358.0	149489.0

SOURCE: OECD (1990, 1993a, 1995a)

When expressed in relative terms (GERD as a percentage of gross domestic product - GDP) (TABLE 2), the differences are less striking, but remain nevertheless considerable. Portugal's GERD/GDP ratio in 1990 is less than one-half that of Denmark, Italy, Austria and Canada; and less than one-third that of France, the Netherlands, the United Kingdom and Finland. It is interesting to note that, although Greece still lies behind Portugal, Ireland and Iceland display more favourable GERD/GDP ratios than our country, thus reversing the tendency shown in TABLE 1.

TABLE 5.2: GERD AS A PERCENTAGE OF GROSS DOMESTIC PRODUCT				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	1.60	1.68	1.64	-
Denmark	1.22	1.32	1.49	1.63
France	2.21	2.23	2.28	2.41
Germany	-	2.73	2.86	2.76
Greece	0.31	0.33	0.36	-
Ireland	0.77	0.89	0.84	0.88
Italy	1.01	1.13	1.22	1.30
Netherlands	1.96	2.22	2.22	2.02
Portugal	0.40	0.45	0.50	0.61
Spain	0.47	0.61	0.72	0.85
United Kingdom	-	2.33	2.18	2.19
<b>EFTA</b>				
Austria	1.27	1.31	1.35	1.42
Finland	1.48	1.67	1.80	1.91
Iceland	0.74	0.73	-	1.02
Norway	1.51	-	-	-
Sweden	-	-	-	-
Switzerland	-	2.88	-	-
<b>OTHERS</b>				
Canada	1.36	1.47	1.38	1.45
Japan	2.65	2.75	2.86	3.08
United States	2.77	2.91	2.81	2.72

SOURCE: OECD (1990, 1993a, 1995a)

The relative difference between Portugal and other comparable OECD countries is also found in data on R&D personnel. Referring to the total R&D personnel per thousand labour force (TABLE 3), and to the total R&D scientists and engineers (or university graduates) per thousand labour force (TABLE 4), Portugal shows in both tables the lowest ratio of all the countries displaying data for the year 1990. Spain, which presents the second lowest ratio, employs approximately twice as many R&D personnel as Portugal.

TABLE 5.3: TOTAL R&D PERSONNEL PER THOUSAND LABOUR FORCE				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	8.1	8.8	8.9	-
Denmark	7.0	7.4	8.0	8.6
France	11.3	11.4	11.7	11.8
Germany	-	-	14.3	14.2
Greece	-	-	-	-
Ireland	4.7	4.2	4.4	5.3
Italy	4.8	5.1	5.6	5.9
Netherlands	10.1	10.7	9.7	9.9
Portugal	2.0	2.3	2.4	2.4
Spain	2.8	3.2	3.7	4.5
United Kingdom	-	10.0	10.3	9.6
<b>EFTA</b>				
Austria	-	-	-	-
Finland	-	-	-	-
Iceland	-	-	-	9.3
Norway	8.5	-	-	-
Sweden	-	-	-	-
Switzerland	-	13.1	-	-
<b>OTHERS</b>				
Canada	7.6	8.1	8.3	8.2
Japan	12.3	12.9	13.5	14.1
United States	-	-	-	-

SOURCE: OECD (1992a, 1994, 1995a)

Of some concern is also the fact that, in the period ranging from 1984 to 1990, we have witnessed a really modest increment of only 20% (2.4 / 2.0) in the total number of individuals engaged in R&D activities (TABLE 3); for the same period, Spain has more than trebled Portugal's "improvement" (4.5 / 2.8). With respect to the data presented in TABLE 4, the Portuguese ratio "Total R&D Scientists and Engineers (or University Graduates) per Thousand Labour Force" shows a stronger growth (1.2 / 0.8 = 50%). The increase in the number of researchers has thus outpaced that of the total R&D personnel.

TABLE 5.4: TOTAL R&D SCIENTISTS AND ENGINEERS (OR UNIVERSITY GRADUATES) PER THOUSAND LABOUR FORCE				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	3.4	3.8	4.0	-
Denmark	3.0	3.3	3.6	4.0
France	4.1	4.4	4.8	5.0
Germany	-	-	-	-
Greece	-	-	-	-
Ireland	2.8	2.3	2.7	3.6
Italy	2.7	2.8	3.1	3.2
Netherlands	-	-	-	-
Portugal	0.8	1.0	1.1	1.2
Spain	1.5	1.7	2.1	2.5
United Kingdom	-	4.6	4.8	4.6
<b>EFTA</b>				
Austria	-	-	-	-
Finland	-	-	-	-
Iceland	-	-	-	5.3
Norway	4.4	-	-	-
Sweden	-	-	-	-
Switzerland	-	4.4	-	-
<b>OTHERS</b>				
Canada	3.9	4.4	4.5	4.6
Japan	7.6	8.1	8.7	9.1
United States	6.9	7.4	7.5	-

SOURCE: OECD (1992a, 1994, 1995a)

Traditionally, the institutional infrastructure of a national scientific and technological system comprises four distinct sectors ie, the higher education sector, the private non-profit sector, the public sector, and the business sector.

In almost all OECD countries, the latter two sectors contribute with a lion's share to the financing of the country's gross domestic expenditure on R&D (GERD), although the productive sector usually predominates. Below, we present the percentage of GERD financed by industry (TABLE 5) and by the government (TABLE 6).

TABLE 5.5: PERCENTAGE OF GERD FINANCED BY INDUSTRY				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	66.2	69.2	71.6	-
Denmark	47.9	48.2	47.2	49.3
France	41.1	41.2	43.3	43.5
Germany	-	63.1	63.7	63.3
Greece	25.2	23.2	23.6	-
Ireland	43.3	48.0	50.3	59.1
Italy	43.5	40.3	43.9	43.7
Netherlands	48.3	52.3	53.4	51.1
Portugal	30.8	26.8	27.4	27.0
Spain	51.9	49.3	47.5	47.4
United Kingdom	-	47.0	52.1	50.0
<b>EFTA</b>				
Austria	48.2	48.3	50.7	52.0
Finland	-	-	-	-
Iceland	-	-	-	23.9
Norway	47.5	-	-	-
Sweden	-	-	-	-
Switzerland	-	78.9	-	-
<b>OTHERS</b>				
Canada	36.8	41.8	41.4	41.9
Japan	66.9	68.7	70.5	73.1
United States	50.6	50.2	49.2	50.7

SOURCE: OECD (1990, 1993a, 1995a)

In the case of Portugal, we face a very distinctive, almost unique situation, which mirrors one of the key characteristics of the Portuguese S&T system, namely the problems encountered in funding R&D activities. Indeed, for 1990, while Portuguese industry-funded R&D accounts for no more than 27% of GERD (TABLE 5), for the great majority of all the other OECD countries the figures range from 41.9% (Canada) to 73.1% (Japan). Switzerland even presents a figure of 78.9%, back in 1986. More worrying than this lack of financing by the Portuguese industry is the fact that it has lost almost 4 percentage points since 1984, thus moving against the tide set up by most of the OECD countries, which are increasing their percentage of GERD financed by industry.

TABLE 5.6: PERCENTAGE OF GERD FINANCED BY GOVERNMENT				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	31.8	28.7	26.7	-
Denmark	47.9	46.1	45.7	42.3
France	53.7	52.5	49.9	48.3
Germany	-	35.3	34.2	34.1
Greece	74.8	74.4	67.9	-
Ireland	48.5	43.8	39.5	30.1
Italy	52.9	55.3	51.8	51.5
Netherlands	46.8	44.0	42.7	45.1
Portugal	62.1	63.5	66.1	61.8
Spain	47.3	48.2	48.8	45.1
United Kingdom	-	41.5	35.8	35.2
<b>EFTA</b>				
Austria	49.1	49.1	46.7	44.6
Finland	-	-	-	-
Iceland	-	-	-	65.8
Norway	48.2	-	-	-
Sweden	-	-	-	-
Switzerland	-	21.1	-	-
<b>OTHERS</b>				
Canada	50.9	46.3	43.8	43.8
Japan	22.5	21.3	19.9	18.0
United States	47.7	48.1	48.8	47.0

SOURCE: OECD (1990, 1993a, 1995a)

Obviously, the percentage of GERD financed by government (TABLE 6) displays a virtually mirror-like situation, when we compare it with the data presented in TABLE 5. Again for 1990, while the figures for most of the OECD countries range from 18% (Japan) to 51.5% (Italy), the Portuguese government-funded R&D accounts for 61.8%.

In both tables, only Greece and Iceland show percentages similar to those of Portugal. This may perhaps reflect a specific characteristic of industrialising countries.

In the following sections we will briefly characterise the four sectors which constitute the Portuguese S&T system, paying particular attention to the business sector.

### 5.3.2. The Portuguese public sector.

Most of the relevant information concerning the Portuguese public sector has been already outlined above, namely when speaking about the new institutional infrastructure, set in place since 1986. We may, however, stress a few more points.

For the year 1990, the Portuguese "Government Intramural Expenditure on R&D as a Percentage of GDP" ratio was 0.16%, approximately one-half of the EU's average; the "Government Total R&D Personnel" and the "Government R&D Scientists and Engineers (or University Graduates)" accounted, respectively, for 4,230 and 1,095; finally, the "Government R&D Scientists and Engineers (or University Graduates) as a Percentage of National Total" ratio was 18.5%, 3 percentage points higher than the EU's average in 1989 (OECD 1995a).

A point to be stressed relates to the fact that JNICT currently plays a central, pivotal role in the Portuguese R&D system. Among its new tasks, one is quite relevant, insofar as it pervades the whole national S&T system. We refer to its role as a genuine financing agency for national R&D activities. Indeed, from 1986 to 1991, JNICT's budget has augmented by more than 1,155%, from PTE 1,043.3 million to PTE 13,095.9 million. During the same period, the national S&T budget has only(!) expanded by just over 220% (SECT 1989, 1990).

Besides increasingly financing the country's S&T system, JNICT was able to participate in the launching and implementation of major scientific and technological development programmes. Some of them were financed exclusively through Portuguese funds, eg the PDT (Technological Development Plan) and the PMCT (Science and Technology Mobilisation Programme), others through a very large financial contribution from the EU (always exceeding 50%), eg the CIENCIA, the PEDAP (Specific Programme for the Development of Portuguese Agriculture), the PEDIP (Specific Programme for the Development of Portuguese Industry), the PRODEP (Programme for Educational Development in Portugal), and the STRIDE-Portugal programmes.

The extent of funding by the European Union has been questioned



by the examiners of the recent review of Portugal's science and technology policy. They warn that:

"... it may be unwise on the part of the country not to provide a proportional budgetary increase, which would ensure it more autonomy in science and technology policy and greater power to correct any imbalances between the various disciplines in its R&D programmes" (OECD 1993b: 107)

During the review meeting, Professor Maurel, one of the examiners, clarified their statement. He argued that:

"Most of this increase [in R&D resources in recent years] seemed to have been funded by the European Community. It was to be welcomed that R&D activity was receiving more funding and that Portugal R&D potential was being made available to Europe. However, failure to increase the national R&D budget in the same proportions could jeopardise the stability, safety and independence of R&D programmes. If only a very small part of the R&D budget was of national origin, there was a risk that, in the long run, Portugal would be reduced to implementing decisions that had been taken elsewhere" (OECD 1993b: 137-138)

Another characteristic of the country's S&T system is that research in the Portuguese public sector is mainly performed by state laboratories, which are supposed to "... carry out R&D/provide services for the benefit of firms in the sectors concerned, public authorities and individuals" (Spinnato 1993: 50). An interesting feature is that almost each Ministry has at least one sectoral laboratory. A few of them (LNEC, the National Laboratory for Civil Engineering is a good example) are even regarded as "centres of excellence" of Portuguese research. Very often, however, linkages between laboratories, either belonging to the same Ministry or not, do not exist. The same is true regarding linkages with universities and industry.

This situation has been acknowledged by Portugal's science and technology policy examiners. They stress that:

"The relationship between government laboratories and universities has an important bearing on the strength of the Portuguese S&T system and needs to be carefully examined. As a general policy, the laboratories would be strengthened by closer links with universities,..." (OECD 1993b: 119)

The higher education sector will now be discussed.

### 5.3.3. The Portuguese higher education sector

Let us start with some S&T indicators of the sector. For the year 1990, the Portuguese "Higher Education Expenditure on R&D as a Percentage of GDP" ratio was 0.22%, two-thirds of the EU's average; the "Higher Education Total R&D Personnel" and the "Higher Education R&D Scientists and Engineers (or University Graduates)" accounted, respectively, for 4,840 and 3,755; finally, the "Higher Education R&D Scientists and Engineers (or University Graduates) as a Percentage of National Total" ratio was 63.6%, more than twice the EU's average in 1989 (OECD 1995a). These data reinforce the idea that it is indeed in the higher education sector that one can find the bulk of the Portuguese R&D activities, particularly regarding i) expenditure on R&D and ii) R&D personnel, and not in the business sector, as occurs in most OECD countries.

A few extra points shall now be mentioned.

The Portuguese higher education sector currently includes about 20 public universities and 15 public polytechnics. During the 1970s, a considerable number of new universities were established, all around the country. Their aim was/is to complement the courses offered by the three traditional, older universities of Coimbra, Lisboa, and Porto. These new establishments have tried to include in their *curricula* fields of education and research of particular relevance to the needs and production structures of the regions where they are located. More recently, particularly due to the introduction of restrictions in the access to public higher education establishments, the number of private universities has sprung (there are by now around 15 establishments), especially in the two main Portuguese cities, Lisboa and Porto.

Nevertheless, despite this proliferation of public and private institutions, Spinnato (1993) points to a number of structural weaknesses of the sector, stressing that:

"- higher education enrolment figures are still low, despite noticeable improvements.... In 1987/88 only 11% of 18-24 year-olds were enrolled in higher education, compared with an average of 25% in other Community countries.  
- an imbalance within the higher education sector: in the same period, non-university establishments had only 16% of the total number of students.  
- a marked regional imbalance: the North has 53% of the country's total school-age population but only 28% of university places available" (Spinnato 1993: 23)

The very low percentage of students attending the Portuguese higher education establishments has a direct consequence ie, it aggravates the shortage of human resources available for R&D activities in the country. A key feature of a number of public programmes already mentioned (CIENCIA, PEDAP, PEDIP, and PMCT) is the training of new researchers, who are expected to find jobs in industry, hence ultimately boosting the R&D capabilities of the Portuguese business sector.

Another significant problem is the fact that a large number of university research teams are quite small and do not reach the minimum size to ensure optimal conditions for individual scientific work. To a certain extent, this may be related, on the one hand, to an extreme lack of mobility in the higher education sector "... where scientists and engineers normally remain in the university from which they graduated until retirement" (OECD 1993b: 111) and, on the other hand, to the circumstance that they tend to carry on, sometimes in complete, perfect isolation, their own, "pet" research. One possible way to enhance the creation of such critical masses is to link together a number of laboratories, in which each of them would contribute with what it is best at.

Finally, there is the lack of dialogue between university research and the productive sector. In Portugal, it seems that both sectors are not living in the same world. On the one hand, academic research is too theoretical; on the other hand, industry does not generally express the wish to use scientific findings. To try to overcome this incompatibility, a number of interface organisations, institutionally inserted in the private non-profit sector, have been set up.

#### 5.3.4. The Portuguese private non-profit sector

Internationally, the Portuguese private non-profit sector plays in a league of its own. Indeed, in 1990, the percentage of GERD performed by the sector was 12.4%, which represented almost 9 times the EU's average (OECD 1995a).

Since the middle of the 1980s, the number of private non-profit institutions has been steadily increasing. The main reason behind this growth has been the general assumption (by policy-makers, scientists, technologists, and managers) that it was quite difficult for the country's small and medium sized firms to carry out R&D activities on their own. We may thus argue that, in a certain way, a "niche market" existed for a kind of institution whose purpose is to facilitate relations between the productive sector and the research system. Eventually, their role is to encourage R&D and innovation by Portuguese SMEs.

Ruivo (1991a) succinctly summarises the current situation of the sector. She points out that:

"Most of them [interface institutions] are related to industry and services. They perform several functions such as research, commercialisation of research results, engineering and consulting, technical assistance and training, including advanced education. They have been set up by universities and some government research laboratories. The associations set up by universities are chiefly related to the exploitation of their research results and to co-operative research....

The existing institutions cover many fields, such as biotechnology, fast electronics, information technologies, CAD-CAM and new materials, production engineering and metallomechanics. They have been playing an important role in the regionalisation of the research system and in the utilisation of S&T in regional development" (Ruivo 1991a: 40)

Another reason for launching a private non-profit institution is the wish of certain (still very few) academics to commercialise their own research. They see these interface institutions as the first (commercial) step of a chain reaction which ultimately will transform them in private enterprises, possibly in NTBFs.

Let us now turn our attention to the Portuguese productive sector.

### 5.3.5. The Portuguese business sector

In previous sections we have argued that the Portuguese S&T system as a whole still lags well behind those of other OECD countries of comparable size, and even very much smaller ones. This is even more true with respect to the Portuguese productive sector. A number of studies validate this assertion.

Based on the statistical data published by the OECD, and using the ratios of i) Business Enterprise Expenditure on R&D (BERD) as a Percentage of Domestic Product of Industry (DPI); and ii) Industry-Financed BERD as a Percentage of DPI, Soete and Verspagen (1991) were able to split the OECD countries into three groups, which they defined as high tech, medium tech, and low tech industrial countries. For the year 1990, Portugal was placed, in both cases, in this latter group, showing ratios of 0.20% and 0.18%, respectively; only Greece presented lower ratios (OECD 1995a).

Following in the footsteps of Soete and Verspagen, we have tried to devise a new way of ranking the OECD countries and, as a consequence, Portugal. We believe that the "BERD as a Percentage of GDP" ratio (TABLE 7) provides an interesting ground for analysis.

Using the statistical data for 1990, or going back in time when it is not available for that year, we may thus define four groups of countries: leading-edge technological countries, with a ratio over 1.5; high technology countries, with a ratio of 1.0 to 1.5; middle technology countries, with a ratio of 0.5 to 1.0; and, low technology countries, with a ratio up to 0.5.

The group of leading-edge technological countries comprises Switzerland (2.24), Japan (2.18), Germany (1.98), and the United States (1.91).

The high technology countries' group is formed by the United Kingdom (1.47), France (1.46), Belgium (1.21), Finland (1.19), and the Netherlands (1.14).

The countries in the middle technology group are Denmark (0.93), Norway (0.90), Canada (0.79), Italy (0.76), and Ireland (0.53).

TABLE 5.7: BUSINESS ENTERPRISE EXPENDITURE ON R&D (BERD) AS A PERCENTAGE OF GDP				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	1.14	1.21	1.21	-
Denmark	0.66	0.73	0.82	0.93
France	1.26	1.31	1.35	1.46
Germany	-	2.00	2.07	1.98
Greece	-	0.10	0.10	-
Ireland	0.38	0.48	0.47	0.53
Italy	0.57	0.66	0.70	0.76
Netherlands	1.05	1.30	1.33	1.14
Portugal	0.12	0.12	0.12	0.16
Spain	0.26	0.34	0.41	0.49
United Kingdom	-	1.55	1.47	1.47
<b>EFTA</b>				
Austria	-	-	-	-
Finland	0.86	0.98	1.08	1.19
Iceland	-	-	-	0.20
Norway	0.90	-	-	-
Sweden	-	-	-	-
Switzerland	-	2.24	-	-
<b>OTHERS</b>				
Canada	0.68	0.80	0.77	0.79
Japan	1.72	1.83	1.94	2.18
United States	2.01	2.10	2.02	1.91

SOURCE: OECD (1990, 1993a, 1995a)

Finally, the group of low technology countries comprises Spain (0.49), Iceland (0.20), Portugal (0.16), and Greece (0.10). Again, only Greece lags behind Portugal. Note also the very slow growth of Portugal's BERD as a percentage of GDP, an increase of 33.3% for the period 1984-1990, particularly while comparing with that of Spain, a growth of 88.5% for the same period. The next couple of tables accentuate and complement the view that indeed the Portuguese productive sector lacks, in general terms, R&D capacity.

TABLE 5.8: BERD (million current PPP \$)				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	1193.1	1472.9	1686.2	-
Denmark	389.0	513.7	632.1	787.5
France	7788.8	9751.6	11528.8	14356.8
Germany	-	17317.6	20190.5	22988.5
Greece	-	57.2	69.0	-
Ireland	87.6	121.1	144.5	205.7
Italy	3361.8	4622.0	5680.3	6977.0
Netherlands	1644.8	2306.4	2683.7	2712.7
Portugal	59.9	69.0	84.2	131.0
Spain	725.1	1108.0	1577.7	2248.8
United Kingdom	-	10775.6	12048.5	13446.8
<b>EFTA</b>				
Austria	-	-	-	-
Finland	452.3	597.5	758.7	964.6
Iceland	-	-	-	8.5
Norway	480.2	-	-	-
Sweden	-	-	-	-
Switzerland	-	2454.2	-	-
<b>OTHERS</b>				
Canada	2452.0	3117.8	3532.1	4024.6
Japan	22849.1	28014.8	35398.3	47450.9
United States	74800.0	87823.0	97889.0	104606.0

SOURCE: OECD (1990, 1993a, 1995a)

With respect to the business enterprise expenditure on R&D (BERD), measured in terms of million current PPP \$ (TABLE 8), Portugal's BERD in 1990 is approximately less than one-third that of Norway (back in 1984); less than one-sixth that of Denmark; and less than one-seventh that of Finland. Again, only Greece and Iceland are behind Portugal.

This very bleak panorama is better perceived through the analysis of TABLE 9, which illustrates a quite serious weakness of the Portuguese scientific and technological system, namely the extremely low level of expenditure on R&D by the productive sector.

TABLE 5.9: PERCENTAGE OF GERD PERFORMED BY THE BUSINESS ENTERPRISE SECTOR				
	1984	1986	1988	1990
<b>EU</b>				
Belgium	71.0	72.4	73.6	-
Denmark	54.4	55.5	55.3	56.9
France	57.2	58.7	59.5	60.4
Germany	-	73.2	72.4	71.8
Greece	-	28.6	28.2	-
Ireland	49.3	53.6	55.8	60.0
Italy	56.4	58.4	57.8	58.3
Netherlands	53.8	58.5	60.0	56.2
Portugal	29.6	26.3	24.6	26.1
Spain	55.0	55.8	56.8	57.8
United Kingdom	-	66.5	67.7	67.4
<b>EFTA</b>				
Austria	-	-	-	-
Finland	58.0	58.9	59.9	62.6
Iceland	-	-	-	19.4
Norway	59.3	-	-	-
Sweden	-	-	-	-
Switzerland	-	77.7	-	-
<b>OTHERS</b>				
Canada	49.8	54.4	55.9	54.3
Japan	65.1	66.6	67.9	70.9
United States	72.5	72.2	71.8	70.0

SOURCE: OECD (1990, 1993a, 1995a)

Indeed, for 1990, while the Portuguese business enterprise sector has only performed 26.1% of GERD (TABLE 9), for the great majority of all the other OECD countries the figures range from 54.3% (Canada) (more than doubling the Portuguese percentage) to 71.8% (Germany). Switzerland has even presented a figure of 77.7% back in 1986. Furthermore, and certainly quite worrying for policy-makers and politicians, the Portuguese figure has lost 3.5 percentage points since 1984, thus moving against the tide set up by most of the OECD countries, which are increasing their percentage of GERD performed by industry.

Regarding the number of R&D personnel employed by the Portuguese productive sector, we again face big disparities between our

country and other OECD countries.

For 1990, the "Total Business Enterprise R&D Personnel as a Percentage of National Total" ratio is, for Portugal 16.6%, for the EU 55.2% (in 1991), and for the Nordic countries 57.0% (in 1991); while the "Business Enterprise R&D Scientists and Engineers (or University Graduates) as a Percentage of National Total" ratio is, for Portugal 7.4%, for the EU 50.5% (in 1991), and for the Nordic countries 45.8% (in 1991) (OECD 1995a). R&D data for 1992 have been very recently released (JNIC 1995b). Below, we present some relevant R&D indicators (TABLE 10).

Gross Domestic Expenditure on R&D (GERD) (million current PPP \$)	678.50	(501.80)
GERD as a Percentage of Gross Domestic Product (GDP)	0.63	(0.61)
Percentage of GERD Financed by Industry	20.20	(27.00)
Percentage of GERD Financed by Government	59.40	(61.80)
Percentage of GERD Performed by the Business Enterprise Sector	21.70	(26.10)
Business Enterprise Expenditure on R&D (BERD) (million current PPP \$)	147.30	(131.00)
BERD as a Percentage of GDP	0.14	(0.16)
Total R&D Personnel per Thousand Labour Force	2.80	(2.40)
Total R&D Scientists and Engineers (or University Graduates) per Thousand Labour Force	1.60	(1.20)

\* Data between brackets (last column) refer to the year 1990  
SOURCE: JNIC (1995b)

These data reinforce the already very weak position of the Portuguese business sector in the context of the country's

scientific and technological system, notwithstanding the very large influx of EU's structural funds, which were also directed towards Portugal's productive sector. Indeed, from 1990 to 1992, a significant fall is noticeable, both in the "Percentage of GERD financed by industry" and the "Percentage of GERD performed by the business enterprise sector". Furthermore, although the "GERD as a percentage of GDP" shows a very slight increase, the "BERD as a percentage of GDP" has decreased.

A number of possible explanations may be put forward to try to explain the above presented statistical data, although we do believe that probably one of the most important reasons relates to how science and technology in general, and innovation in particular, are regarded by most of the Portuguese entrepreneurs and managers.

For example, an extensive study on innovation in the Portuguese industry has been recently conducted under the aegis of the Ministry of Industry (GEPIE 1992). A questionnaire was sent to around 25% of the Portuguese manufacturing firms employing 10 or more persons. The number of useful replies was 1,026.

Among other pertinent questions, it was asked to rank 5 factors which have contributed the most to the introduction of innovations in the enterprises. A list of 23 possible factors was presented.

Not surprisingly, "R&D activities" ranked 13th place, and "Linkages with universities and with non-profit research institutions" (a main focus of our research) has only ranked 20th place!

The most important factor contributing to the introduction of innovations in the companies was "Purchase of equipment", followed by "Development and improvement of products", "Adaptation to customer's tastes", and "Pressure from competition". Definitely, the innovation strategy in the Portuguese industry seems to be rather passive.

Another possible explanation for the very low level of R&D capacity in the Portuguese productive sector is advanced by Godinho and Caraça (1990). They contend that the lack of very large corporations in the Portuguese business sector does not

generate the need for a reorganisation of the industrial system towards the institutional framework in which large international corporations work, both in their home markets and abroad.

Furthermore, based on OECD's statistical data, they argue that the weight of certain multinational corporations is very important in some European countries. They claim, for example, that in the Netherlands, 78% of the business expenditure on R&D (BERD) is performed by the top 4 Dutch companies, while in Switzerland the same number of enterprises perform 69% of the Swiss BERD.

Interestingly enough, if we translate these findings to the Portuguese case, we find that, in 1990, the top 4 Portuguese firms performed only 32.7% of the Portuguese BERD; even the top 10 performed only 52.0% (JNICT 1993). Similarly, in 1992, a mere 47.8% of the country's BERD was performed by the top 10 enterprises (JNICT 1995a), which again reinforces the idea of the absence of large R&D performing companies in Portugal.

Another peculiar characteristic of the country's productive system, closely associated with the lack of Portuguese-owned big corporations, is the multitude of micro and small firms which constitute the major part of that system. This proliferation of very small companies forces researchers and scientists studying the Portuguese case to adopt a quite distinctive taxonomy with respect to the ranking of enterprises according to their size.

In fact, as Barañano (1995a) points out, although there is not a unique, internationally agreed-upon classification, it is usually accepted that small enterprises employ up to 99 employees, in a medium sized enterprise there are between 100 and 499 workers, and large companies employ 500 and more people.

However, if we apply these rankings to the Portuguese situation, we will end up with 99.95% of the country's businesses employing less than 500 workers; furthermore, in the category "micro" (firms with less than 10 employees), Portugal has the highest percentage (95.19%) among all the EU countries (CEC 1990). Hence, it would make much more sense, for example, to establish the "50 workers" mark as the divide between a small and a medium sized company, in Portugal.

The characterisation of the country as a small business orientated economy is reinforced when we establish a comparison between the relative numbers of micro, small, medium, and large enterprises and their contribution to employment. Indeed, more than a third (35.7%) of the Portuguese workforce is employed in micro firms (26.9% is the EU's average); conversely, large Portuguese companies only provide 19.0% of employment, compared with a European Union's average of 28.1% (CEC 1990).

The very high percentage of Portuguese micro and small enterprises may additionally be a major reason for the low statistical weight of the productive sector in the whole of the country's S&T system.

Indeed, as Pavitt, Robson and Townsend (1987a, 1989) have found, R&D statistics do not reflect the volume of technological activities in small firms. For example, they argue that, although enterprises with fewer than 1,000 employees account for 3.3% of the business enterprise R&D expenditure, they have produced 34.9% of significant innovations (Pavitt, Robson and Townsend 1989). Similarly, Soete and Verspagen (1991) point out that:

"... official R&D expenditure data represent according to our "best" estimates a mere 35 to 45 per cent of total efforts devoted to technological advance. Officially reported R&D expenditures tend to significantly underestimate the actual technological effort in such areas as production engineering, software and design; in *small firms* and in services" (Soete and Verspagen 1991: 267) (emphasis added)

Further evidence regarding the underestimation by official statistics of R&D activities in small firms is presented by Kleinknecht (1987) and Kleinknecht and Reijnen (1991). They contend that official surveys are mainly concerned with the so-called formal R&D. This is normally performed, in a continuous way, in the established R&D departments and laboratories of medium and large companies. However, they argue that:

"... there are many small and medium-sized firms which (occasionally) undertake small R&D projects. Such projects are often rather informal, i.e. there is no formal R&D department and perhaps not even a formal budget. Most of this R&D work is likely to be "D" rather than "R". It is

conceivable that such firms do not report their R&D in the official survey, either because they think it is not worth filling in a complicated questionnaire for such little amounts of R&D, and/or because their internal accounting system is not sufficiently detailed in order to give information on *budgets* (as opposed to time) spent on R&D. In other words, the complexity of the official R&D survey questionnaires as well as the fact that one asks for money spent on R&D may function as a filter against reporting small-scale R&D activities" (Kleinknecht and Reijnen 1991: 582-583)

From our own work on the R&D statistics of the Portuguese business sector, we may advance a third explanation why, at least in the case of the Portuguese small and medium-sized companies, their R&D activities are not being fully reported in the official survey ie, most of them do not know that they are indeed performing (mainly "D") activities, which are covered by the so-called "Frascati Manual".

In an attempt to overcome this undercounting of small firm R&D, Kleinknecht (1987) and Kleinknecht and Reijnen (1991) introduced, in their own survey, a very simple indicator, man-years of R&D. As a consequence, they have found a considerable larger amount of R&D in small companies (less than 500 employees) compared to the official Dutch survey. They contend that:

"... there is only little difference in the size class of firms which have 500 and more employees.... However, in the smaller size classes there are remarkable differences. Among firms which have 10-499 employees, we measure roughly four times as much, i.e. 19,418 man years as opposed to 4,820 man years in the survey by the Statistical Office" (Kleinknecht and Reijnen 1991: 584-585) (emphasis added)

Bearing in mind such findings, it seems very important to find new, more adequate ways of capturing this small-scale and informal R&D, notably in small and medium-sized firms. This is important for international organisations responsible for collecting and disseminating statistical data on science and technology indicators, such as the EU and the OECD, but it is of particular relevance for a small country like Portugal, where the above discussed weaknesses of its S&T system are also hindering the data collecting process. Elsewhere (Assis 1985, 1989), a couple of suggestions for a better statistical coverage of the

Portuguese business sector, in particular regarding the micro and small firm's universe, have already been advanced.

#### 5.4. Conclusions

In this chapter, we have described the main characteristics of the Portuguese scientific and technological system.

As a result of our analysis, we got the impression that its structural weaknesses (which outnumber its strengths) are deeply rooted in the country's history.

During the past 10 years, a large amount of legislation has been introduced, aiming at modernising the Portuguese S&T system, ultimately trying to bridge the gap between Portugal and its European partners. Unfortunately, these new laws are not transforming the system as quickly as everyone wishes. Much more important than (good or bad) laws is certainly a change of mentalities. Two decades have already passed since the end of the regime which ruled the country over 48 years, yet its basic philosophical principles can still be found quite easily. It is rather common for a Portuguese entrepreneur to think alongside these lines: "My firm is making an after-tax profit of PTE.... Therefore, why should I innovate? Innovation costs money!".

Excessive bureaucracy is also hampering R&D activities performed by the public and by the higher education sectors, since researchers and scientists spend a lot of their valuable time applying for fresh money for research and dealing with red tape. This particular situation seems to be a little less cumbersome in the private non-profit sector, which has been showing a great deal of dynamism, with the launching of a large number of institutions dedicated to performing and commercialising their own research.

Bearing in mind what we have just said, and after comparing the Portuguese science and technology indicators with those of other selected OECD countries, it is not surprising to find that, alongside Greece and Iceland, Portugal plays a very modest role amongst those OECD countries.

Portuguese scientific and technological activities are mainly performed by the public sector, the higher education sector and, to a lesser extent, by the private non-profit sector. A similar set of big, structural problems have been found in all of them. Apart from the already mentioned bureaucratic burden, we may refer the general lack of funding and of R&D equipment and instrumentation, the very low rotation of researchers in some public R&D institutions (due to the freezing of staff levels), and the geographical imbalance of national R&D capabilities across the country.

A low level of formal education, coupled with an insufficient and inadequate training, constitutes one of the major shortcomings of the higher education sector. It was also found that technical courses taught at polytechnics were only attended by a handful of students; if this trend continues, in a few years-time the shortage of specialised human resources may become a serious issue. Furthermore, academic research tends to be excessively theoretical, away from the more practical needs of Portuguese industry.

The new private non-profit R&D establishments have been fulfilling an important role as interface institutions, acting as intermediaries between public research organisations and industry. Indeed, a noticeable lack of linkages between the four institutional sectors which comprise the Portuguese S&T system is probably one of its most (negative) characteristics. Finally, the business sector plays a minimal role in the context of the country's R&D activities. Generally speaking, it is characterised by a rather low level of R&D capacity, both in terms of expenditures and of skilled personnel. A very large number of micro and small firms are concentrated in traditional, low-technology industries. Furthermore, the purchase of external technology is widely disseminated across industries, thus contributing to the country's strong technological dependence. Summing up, we may argue that the absence of linkages between, and the weaknesses of, the actors and/or institutions which shape Portugal's S&T system, makes it very difficult for such bodies to support the innovative capacity of companies in a satisfactory

way. Hence, the strong need for (policy) measures aimed at facilitating the creation and/or improvement of the technological networking between all those different actors.

What we have learned in this chapter about the Portuguese scientific and technological system, and in particular the specific features of its business sector, will be of great help for the study of the industries we have selected for our research.

The general characteristics of those industries will be the focus of the next chapter.

## 6. THE PORTUGUESE INDUSTRIES UNDER SCRUTINY

### 6.1. Introduction

In this chapter we will introduce the Portuguese industrial sectors which we are going to analyse in our research. To begin with, we tried to cover a wide spectrum of the country's industry. Therefore, adapting the taxonomy of sectoral patterns of innovation proposed by Pavitt (1984), we initially selected three Portuguese industries, biotechnology (a *science-based* industry), electronics (a *technology-based* industry), and mouldmaking (a *traditional* industry).

These particular industries were chosen because of the interest in finding out the extent and quality of their linkages with other enterprises, with academic research, and with public sector institutions.

However, right at the start, after conducting a small number of preliminary interviews, it was found that industrial biotechnology, like other science-based industries (for example, engineering ceramics, optoelectronics, or parallel computing), scarcely exists in Portugal. Research in these industries is predominantly concentrated in the laboratories of universities and polytechnics, in private non-profit institutions, and in some specialised government laboratories.

Therefore, the research had to focus exclusively on both the electronics and mouldmaking industries. In spite of that, the current situation of the Portuguese biotechnology industry will also be very briefly discussed in the present chapter, since some investigation had already been conducted on this issue and, in any case, its under-developed embryonic nature is itself an illustration of our main theme.

In order to properly study these industries, it is initially necessary to carefully assess the differences and similarities which exist amongst the various industrial branches of the Portuguese productive sector (*point 2*). Furthermore, the analysis

of the levels of technological specialisation of the different industrial branches will allow us to ascertain their weaknesses and strengths.

Subsequently, we will be addressing the particulars of each of the selected Portuguese industries (point 3).

### 6.2. A Close Examination of the Portuguese Business Sector

It was argued in the previous chapter that the Portuguese scientific and technological system, and in particular its business sector, still lags well behind those of other European countries of comparable size, and even very much smaller ones. Referring specifically to the Portuguese productive sector, broad differences do exist amongst differing industrial branches. The following two tables present, for the year 1990, the Portuguese Business Enterprise Expenditure on R&D (BERD), according to the International Standard Industrial Classification (ISIC). It was found that the four branches of the business sector with the highest R&D expenditure per enterprise were, in descending order, "Communications" ( $496.1 \times 10^6$  PTE), "Paper & Printing" ( $213.2 \times 10^6$  PTE), "Electrical Machinery & Electronic Equipment and Components" ( $158.3 \times 10^6$  PTE), and "Commercial & Engineering Services" ( $150.2 \times 10^6$  PTE) (TABLE 1.1).

TABLE 6.1.1: PORTUGUESE BERD ACCORDING TO ISIC BRANCHES, IN 1990: R&D EXPENDITURE PER ENTERPRISE (Current Prices x 10<sup>6</sup> PTE)

ISIC BRANCHES	NUMBER OF FIRMS (1)	BERD (2)	(2)/(1)
<b>AGRICULTURE</b>	1	1.3	1.3
<b>MINING</b>	3	109.0	36.3
· Electrical Machinery & Electronic Equipment and Components	24	3,799.0	158.3
· Chemicals & Drugs	36	1,882.8	52.3
· Motor Vehicles, Ships & Other Transport Equipment	3	141.6	47.2
· Ferrous Metals	5	150.3	30.1
· Non-Ferrous Metals	2	12.3	6.2
· Fabricated Metal Products	8	221.8	27.7
· Instruments	2	27.1	13.6
· Office & Computing Machinery	23	659.7	28.7
· Food, Drink & Tobacco	21	472.8	22.5
· Textiles, Footwear & Leather	9	368.6	41.0
· Rubber & Plastic Products	8	123.5	15.4
· Stone, Clay & Glass	10	164.0	16.4
· Paper & Printing	7	1,492.6	213.2
· Wood, Cork & Furniture	5	97.8	19.6
<b>TOTAL MANUFACTURING</b>	163	9,613.9	59.0
· Utilities	2	148.3	74.2
· Construction	1	12.2	12.2
· Transport & Storage	4	97.7	24.4
· Communications	3	1,488.4	496.1
· Commercial & Engineering Services	14	2,102.9	150.2
· Other Activities	3	11.9	4.0
<b>TOTAL SERVICES</b>	27	3,861.4	143.0
<b>TOTAL BUSINESS ENTERPRISE</b>	194	13,585.6	70.0

SOURCE: JNICT (1993)

Although the manufacturing sector was responsible in 1990 for almost 71% of the total Portuguese BERD (TABLE 1.2), it is nevertheless interesting to notice that, amongst the above mentioned top-four business branches, there is only one which is usually labelled as a "high-technology intensity industry" ie, "Electrical Machinery & Electronic Equipment and Components". The

TABLE 6.1.2: PORTUGUESE BERD ACCORDING TO ISIC BRANCHES, IN 1990: PERCENTAGE PER BRANCH (Current Prices x 10 <sup>6</sup> PTE)			
ISIC BRANCHES	NUMBER OF FIRMS	BERD	%
<b>AGRICULTURE</b>	1	1.3	0.01
<b>MINING</b>	3	109.0	0.80
· Electrical Machinery & Electronic Equipment and Components	24	3,799.0	27.96
· Chemicals & Drugs	36	1,882.8	13.86
· Motor Vehicles, Ships & Other Transport Equipment	3	141.6	1.04
· Ferrous Metals	5	150.3	1.11
· Non-Ferrous Metals	2	12.3	0.09
· Fabricated Metal Products	8	221.8	1.63
· Instruments	2	27.1	0.20
· Office & Computing Machinery	23	659.7	4.86
· Food, Drink & Tobacco	21	472.8	3.48
· Textiles, Footwear & Leather	9	368.6	2.71
· Rubber & Plastic Products	8	123.5	0.91
· Stone, Clay & Glass	10	164.0	1.21
· Paper & Printing	7	1,492.6	10.99
· Wood, Cork & Furniture	5	97.8	0.72
<b>TOTAL MANUFACTURING</b>	<b>163</b>	<b>9,613.9</b>	<b>70.77</b>
· Utilities	2	148.3	1.09
· Construction	1	12.2	0.09
· Transport & Storage	4	97.7	0.72
· Communications	3	1,488.4	10.95
· Commercial & Engineering Services	14	2,102.9	15.48
· Other Activities	3	11.9	0.09
<b>TOTAL SERVICES</b>	<b>27</b>	<b>3,861.4</b>	<b>28.42</b>
<b>TOTAL BUSINESS ENTERPRISE</b>	<b>194</b>	<b>13,585.6</b>	<b>100.00</b>

SOURCE: JNICT (1993)

weight of "Paper & Printing" is explained by the existence of a handful of large paper mills, arguably performing R&D activities. Finally, two branches belonging to the services sector are also represented. In a certain sense, this proves the importance of this sector in the whole of the Portuguese BERD. Its significance is reinforced by the fact that, on average, each enterprise belonging to the services sector carries out almost 2.5 times as

much R&D as its manufacturing sector's counterparts (TABLE 1.1). To better clarify the strengths and weaknesses of the Portuguese business sector, it is important to find out which are the levels of technological specialisation of its different industrial branches.

Patel and Pavitt (1992) used a measure labelled as "Revealed Technology Advantage" to establish the sectoral patterns of technological specialisation of 18 Western countries. They explain that:

"Revealed Technology Advantage (RTA) is defined as a country's or region's share of all US patenting in a technological field, divided by its share of all US patenting in all fields. An RTA of more than one therefore shows a country's or region's relative strength in a technology, and less than one its relative weakness" (Patel and Pavitt 1992: 10)

During the period 1984-88, and considering Patel and Pavitt's division of technologies into 11 specified fields, it was found that Portugal shows only a relative strength in Industrial Chemicals (1.99), in Electrical Machinery (1.88), and in Mechanical Engineering (1.42). Much more worrying than this concentration of the country's relative technological advantage in only three technologies is the fact that Portugal had totally and completely lost (RTA = 0.00, in 1984-88) its relative strength in three other technologies. Indeed, during the 1963-68 period, Portugal's RTA in Fine Chemicals, in Defence, and in Raw Materials were, respectively, 10.61, 3.40, and 0.98 (TABLE 2). Similarly, in a thorough report to the Commission of the European Communities on international science and technology activities, Archibugi and Pianta (1992) have also found that Portugal presents a very low level of technological specialisation, measured on patent data. They contend that:

"The only sector where a high index of specialization is obtained from a substantial number of patents and citations for Portugal is Organic chemicals. In the other classes the absolute numbers are too low to produce a reliable indicator of technological strength and weakness" (Archibugi and Pianta 1992: 77)

TABLE 6.2: SECTORAL PATTERNS OF RELATIVE TECHNOLOGICAL ADVANTAGE: 1963-88

	Fine Chem	Indu Chem	Mate-rials	Mech Eng	Motor Vehic	Elect Mach	Elec-tron Cap	Tele-comm	Elec-tron Cons	Raw Mat	Defence
<b>AUSTRIA:</b>											
1963-8	1.42	0.80	1.06	1.25	1.21	0.62	0.28	0.38	1.69	0.39	0.17
1984-8	0.38	0.59	0.64	1.49	1.43	0.94	0.30	0.41	0.48	0.79	0.59
<b>BELGIUM:</b>											
1963-8	1.23	1.37	4.03	0.71	0.44	0.91	0.66	1.02	3.96	0.42	0.78
1984-8	1.82	1.55	2.07	0.75	0.19	0.80	0.14	0.53	1.55	1.14	1.53
<b>DENMARK:</b>											
1963-8	3.07	0.77	0.98	1.11	0.39	0.87	0.47	0.55	1.17	0.92	0.12
1984-8	2.10	0.86	0.79	1.22	0.18	0.74	0.27	0.48	0.41	1.02	0.64
<b>FINLAND:</b>											
1963-8	0.00	0.62	0.00	1.30	2.18	0.72	0.00	0.32	0.20	1.33	0.47
1984-8	1.04	0.62	0.72	1.47	0.64	0.80	0.17	0.33	0.14	1.35	1.72
<b>FRANCE:</b>											
1963-8	1.87	1.01	1.06	1.02	2.10	1.22	0.83	1.15	0.80	0.49	1.10
1984-8	1.40	0.95	0.77	1.06	0.70	1.15	0.84	1.69	0.53	0.77	1.77
<b>GERMANY:</b>											
1963-8	1.13	1.48	0.67	0.96	1.43	0.77	0.93	0.73	1.88	0.54	1.03
1984-8	1.13	1.29	0.91	1.16	1.35	0.81	0.60	0.80	0.55	0.61	1.36
<b>GREECE:</b>											
1963-8	0.00	1.01	0.00	1.00	3.08	0.38	0.93	0.67	1.69	0.56	1.98
1984-8	0.83	2.83	0.00	0.55	3.41	0.98	0.00	0.00	0.00	1.64	4.08
<b>IRELAND:</b>											
1963-8	0.00	0.39	0.00	1.28	2.99	0.00	0.00	0.65	0.00	0.55	0.00
1984-8	1.54	1.68	0.00	0.69	0.00	1.06	0.90	0.00	0.76	1.27	0.00
<b>ITALY:</b>											
1963-8	1.29	1.93	0.52	0.93	1.25	0.67	0.87	0.69	0.53	0.71	0.78
1984-8	2.11	1.00	0.71	1.14	1.24	0.65	0.58	1.06	0.39	0.76	0.86

TABLE 6.2: SECTORAL PATTERNS OF RELATIVE TECHNOLOGICAL ADVANTAGE: 1963-88 (continued)

	Fine Chem	Indu Chem	Materials	Mech Eng	Motor Vehic	Elect Mach	Elec- tron Cap	Tele- comm	Elec- tron Cons	Raw Mat	Defence
<b>JAPAN:</b>											
1963-8	2.95	1.61	1.01	0.77	0.83	1.17	1.46	1.06	1.99	0.44	0.35
1984-8	0.81	0.91	1.41	0.86	2.41	1.13	1.59	0.86	2.53	0.35	0.10
<b>NETHERLANDS:</b>											
1963-8	1.71	1.45	1.23	0.75	0.15	1.34	1.90	1.09	1.93	1.15	0.15
1984-8	0.53	1.02	0.73	0.84	0.42	1.21	1.24	1.48	2.03	1.21	0.35
<b>NORWAY:</b>											
1963-8	0.94	0.61	0.00	1.24	0.36	1.15	0.65	0.46	0.29	0.91	0.46
1984-8	0.69	0.70	0.44	1.09	0.53	1.07	0.23	0.64	0.51	2.06	2.14
<b>PORTUGAL:</b>											
1963-8	10.61	1.40	0.00	0.98	0.00	0.67	0.00	0.00	0.00	0.98	3.40
1984-8	0.00	1.99	0.00	1.42	0.00	1.88	0.00	0.00	0.00	0.00	0.00
<b>SPAIN:</b>											
1963-8	0.85	0.56	0.48	1.18	2.99	0.85	0.13	1.02	0.47	0.47	1.93
1984-8	1.46	0.74	0.15	1.25	2.64	0.54	0.08	0.34	0.07	0.64	0.90
<b>SWEDEN:</b>											
1963-8	0.94	0.44	0.44	1.22	1.12	1.13	0.71	1.37	0.38	0.67	2.34
1984-8	0.53	0.50	0.69	1.46	0.79	0.90	0.34	0.72	0.27	0.96	2.17
<b>SWITZERLAND:</b>											
1963-8	2.61	2.00	0.23	0.89	0.56	0.84	0.57	0.73	0.63	0.47	1.44
1984-8	1.86	1.44	0.65	1.09	0.50	0.88	0.45	0.71	0.52	0.61	1.04
<b>UNITED KINGDOM:</b>											
1963-8	0.87	1.03	1.09	1.02	1.99	1.22	1.03	1.02	0.92	0.68	1.28
1984-8	1.92	1.05	1.07	1.03	1.01	0.94	0.68	1.00	0.68	0.87	1.05
<b>UNITED STATES:</b>											
1963-8	0.89	0.93	1.04	1.01	0.89	1.00	1.02	1.03	0.94	1.09	1.00
1984-8	0.91	1.00	0.95	0.98	0.56	1.01	1.01	1.06	0.71	1.29	1.16

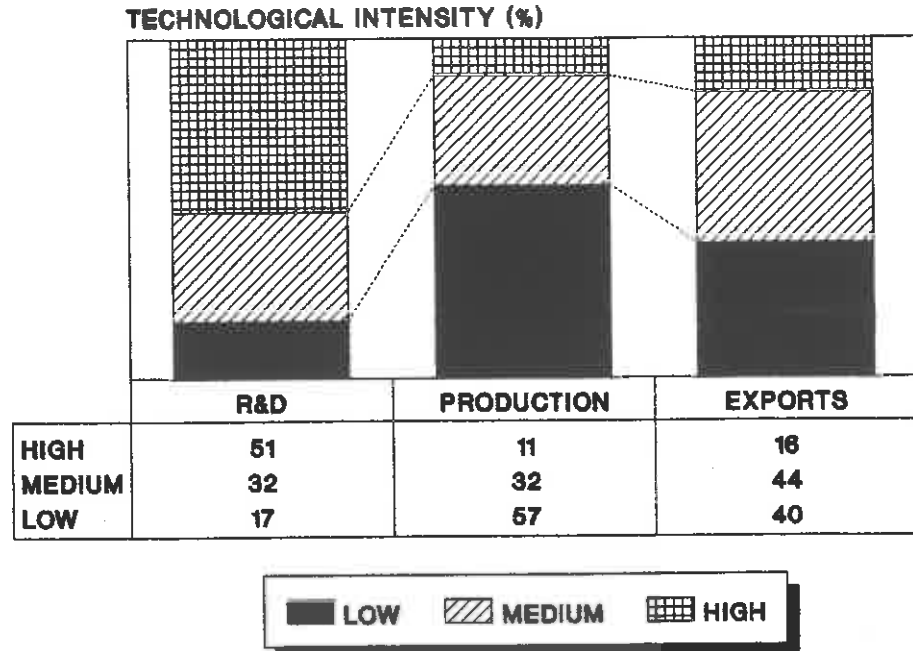
SOURCE: Patel and Pavitt (1992)

The existence of such different national levels of technological specialisation contributes to the establishment of flows of technology amongst countries. The vast majority of these flows correspond to situations where the countries with higher potential act as suppliers of technology. Apart from some paradigmatic cases (for instance Japan, and more recently, Korea), the relations thus established tend to increase the (technological) dependence of the recipient countries with regard to the producers of technology.

In a report prepared for the FAST Programme of the (then) EEC, Gonçalves, Caraça, Assis and Proença (1987a, 1987b) - based on an early article by Gonçalves and Caraça (1986) - attempted to rank the various branches of the Portuguese manufacturing industry according to their levels of technological intensity. The researchers' underlying premise was the assumption that different industries incorporate technology in different ways, in line with their own specific requirements and goals; therefore, various levels of technological intensity may thus be defined.

Gonçalves and Caraça (1986) mention an OECD study in which the manufacturing sectors of 11 developed countries - Australia, Belgium, Canada, the Federal Republic of Germany, France, Italy, Japan, the Netherlands, Sweden, the UK, and the USA - were classified in three levels ie, high, medium, and low, according to their technological intensity (FIGURE 1). The OECD's classification criterion was based exclusively on the "BERD/Volume of Production" ratio.

FIGURE 6.1: AVERAGE WEIGHTS OF MANUFACTURING SECTORS OF 11 DEVELOPED OECD COUNTRIES (1970-80)

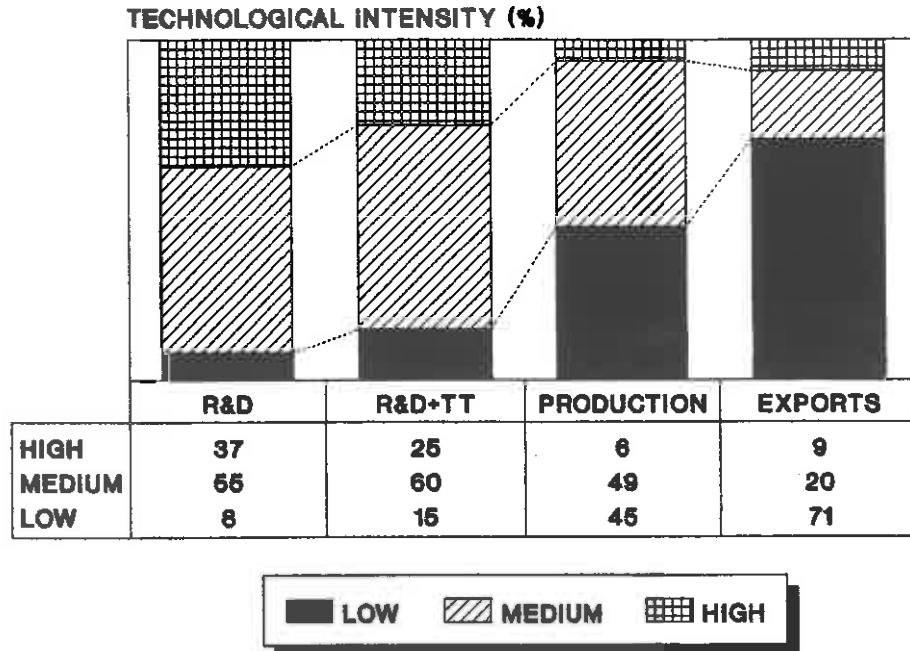


SOURCE: Gonçalves and Caraça (1986)

A relevant feature of this study, which covers the period from 1970 to 1980, was the fact that high technology intensity industries accounted for 51% of R&D expenditures, while their share in Production and Exports was only 11% and 16%, respectively. Conversely, low and medium technology intensity industries accounted for 89% and 84% of Production and Exports, respectively.

Taking into account the major role played by imported technology in the Portuguese manufacturing sector, an extra column, which measures the R&D expenditures plus the costs of imported technology, was introduced in FIGURE 2. In fact, the Portuguese productive sector is well-known for spending more on purchasing technology than on R&D, thus aggravating the country's technological dependence. Indeed, according to statistical data just released, the 203 Portuguese enterprises with R&D activities in 1992 spent  $30,220 \times 10^6$  PTE on purchasing technology and only

FIGURE 6.2: TECHNOLOGICAL INTENSITY OF THE PORTUGUESE MANUFACTURING SECTOR IN 1982



SOURCE: Gonçalves and Caraça (1986)

17,452.2 x 10<sup>6</sup> PTE on expenditure on R&D (JNICIT 1995a).

The contrast between the two Figures is quite suggestive. Indeed, as Gonçalves, Caraça, Assis and Proença (1987a) stress:

"Comparing diagrams of Figures 1 and 2, it can be stated that the modernization effort of the Portuguese manufacturing sector is significantly lower in what respects [sic] its associated high technology intensity industries, even in relative terms. In absolute terms, the manufacturing sector has directed a shallow 1,122.6 million PTE towards R&D activities in 1982, while all firms presented an expenditure on R&D of about 2,043.6 million PTE, that is 0.11% of GDP. Costs of imported technology are: 6,273.4 million PTE in the manufacturing sector and 10,129.1 million PTE in the sector of firms. It should also be noted the small share of high technology intensity activities in the total amount of Production and of Exports, though they seem to display some trend towards competitiveness in foreign markets. Even more disturbing is the fact that over 70% of our Exports are supported by only 15% of our effort of modernization (8% of expenditure on R&D) proving, in yet



another way, the vulnerability of our economic structure" (Gonçalves, Caraça, Assis and Proença 1987a: 14)

Based on our taxonomy of technological intensity levels, combined with the most relevant features (to our line of study) of the already discussed i) Dodgson and Rothwell's (1989a) and Rothwell's (1991) taxonomy of small and medium sized firms in manufacturing industry; ii) Imai and Baba's (1991) taxonomy; and, in particular, iii) Pavitt's (1984) taxonomy of sectoral patterns of innovation, we are now able to define which specific Portuguese industrial sectors we are going to analyse in our research.

It may be useful to summarise again the main features of the country's S&T system. Its business sector is characterised by the existence of a large number of micro and small firms, dominated by a low-technology production in traditional sectors. Additionally, high technology R&D activities tend to be mainly concentrated on the public sector, the higher education sector, and the private non-profit sector.

Thus, the initial purpose of our study was the differentiation amongst three distinct sectors of the Portuguese manufacturing industry, which we have labelled as i) science-based sector (biotechnology); ii) technology-based sector (electronics); and iii) traditional sector (mouldmaking).

These particular industries were chosen because of the interest in finding out the extent and quality of their linkages with other enterprises, with academic research, and with public sector institutions.

We have already mentioned the methodological impediment which prevented us from involving the Portuguese biotechnology industry in our field work. Nevertheless, we think that it is still important to present a brief overview of the current situation of this industry in Portugal, at least for the benefit of the reader who might not be familiar with its peculiarities.

### 6.3. The Selected Portuguese Industries

#### 6.3.1. The Portuguese biotechnology industry

Biotechnology, and in particular the set of phenomena linked to its emergence and early developmental stages, has been thoroughly studied at the international level (Dodgson 1990, 1991, 1993; Faulkner 1986; Fransman 1991; Oakey, Faulkner, Cooper and Walsh 1990; Orsenigo 1989, 1993; Pisano, Shan and Teece 1988; Sharp 1989b, 1989c;...).

Fundamentally, biotechnology has emerged from basic research discoveries made in the research laboratories of universities. Small, new enterprises, which were generally spin-offs from these laboratories, were set up to carry on this basic inventive activity. Established, large chemical and pharmaceutical companies have then started to invest in, to buy-out, or to constitute joint ventures with those spin-offs, as a means of maintaining a "watching brief" on the most recent, promising developments of this new technology, without heavy investment. Finally, a growing network of relationships between the large companies and the small firms was established, in which the latter provided state-of-the-art technical expertise to the former, which in turn possessed the resources for manufacturing, marketing and distributing the new technologies/products.

In brief, the initial scientific breakthroughs which had occurred inside the academic world were very quickly transferred to a multitude of newly established small enterprises, dedicated to the development and exploitation of such (radical) innovations. In Portugal, the situation is totally different. In a report prepared for JNICT on the country's strengths and weaknesses in the fields of biotechnology and fine chemicals, Sant'Ana and Chopplet (1991) refer the existence of only three dedicated biotechnology firms (DBFs). They list a further 26 companies which, they argue, may have some potential interest in biotechnology and/or fine chemicals. These (older) enterprises, mainly of medium and large size, are active in the fields of pharmaceuticals, food, beverages, agro-chemicals, cosmetics, and

paper.

We believe, however, that their interest is chiefly theoretical, far from practical applications. Indeed, the R&D activities carried out in some of those companies are related to their core businesses, and only marginally to biotechnology. Even so, the panorama is not brilliant. Indeed, the examiners of the recent review of Portugal's science and technology policy reported that "... there were no more than two pharmaceutical firms that had an R&D laboratory" (OECD 1993b: 125).

Referring again to the (lack) of involvement in biotechnology by the Portuguese business sector, two additional surveys (Malcata and Mota 1991; Novais 1992) give an exact representation of the reality. Both aim at listing the institutions which are carrying out R&D activities in the biotechnology field, the former only in the north of Portugal, the latter covering the whole country. In both surveys we find the same statement, little industrial R&D has been performed in this field. Conversely, Portuguese biotechnology is heavily concentrated in the laboratories of universities and polytechnics, and in a number of private non-profit institutions. Additionally, some government laboratories are also engaged in R&D activities in the field.

Regardless of everything mentioned above, we have conducted interviews in four Portuguese "biotechnology" enterprises during our field-work (see Appendix 2). We thought it could be of interest to try to find out the reasons behind the absence of industrial involvement in biotechnology, and why no spin-offs are occurring. We present below a short summary of our findings.

The core business of three of those "biotechnology" companies was beverages, chemicals, and pharmaceuticals, respectively. Their R&D activities were thus focused on these industries. They were only marginally interested in biotechnology to the degree that it could improve their products. Moreover, those were large, well established enterprises, with a significant percentage of foreign participation in the share capital, which contributed to a certain degree of technological dependence. This is certainly one of the reasons for the lack of Portuguese industrial involvement in the field. Indeed, research in biotechnology is carried out

abroad, and their results are then transferred to Portugal. The fourth company was a very young "would-be" dedicated biotechnology firm, still trying to sell its products for the very first time, after overcoming a series of major drawbacks. Turning now to the absence of academic spin-offs, it may be argued that it is quite natural, owing to the Portuguese circumstances. For a start, as mentioned above, employee mobility is a (structural) problem in Portugal. In addition to this, it surely is safer for researchers and scientists to work in the laboratories of universities and of private non-profit institutions than to launch his/her own DBF. These research institutions are in general very well equipped, some of the Portuguese groups are carrying out state-of-the-art research, and their collaborative R&D linkages with the foreign academic and industrial world are expanding.

Bearing in mind this short summary, we have to point out that Portuguese biotechnology industry is still in a very embryonic stage, and there is the need to assemble a critical mass (substantially increasing the number of enterprises and, in particular, overcoming the current shortage of highly qualified technicians) before we really can start speaking about a truly biotechnology industry in Portugal.

### 6.3.2. The Portuguese electronics industry

The electronics industry has also been extensively studied by researchers and scientists, eg Freeman (1982), Hobday (1992), Sharp (1989a), and Soete (1985), to cite but a few.

The emergence and early growth stages of electronics was based upon basic research discoveries, which were then very rapidly developed and commercially exploited by a large number of newly founded small innovative enterprises. As Oakey and Cooper (1991) have noticed, this pattern is very similar to that of biotechnology. Despite some significant differences, for example the longer time-span needed for a biotechnology firm to be self-sufficient through profits, the role played by small high

technology companies in both industries is quite important. In fact, referring specifically to electronics, Oakey (1984) contends that:

"... the broadly defined electronics and control instrumentation sectors are areas of high technology production where constantly evolving products and overall growth facilitates the continuing entry of many small firms to fill emerging new production niches.... Because the bulk of these evolving product niches are high technology, constant research and development is indicated by the need to keep internal product development at the leading edge of advancing technology" (Oakey 1984: 238)

Below, he adds that:

"... the small firm remains a particularly efficient vehicle for innovation in high technology electronics based industries where the informal juxtaposition of production with development ensures close interaction between concept and construction" (Oakey 1984: 238)

As was suggested by Oakey (1984), many small Portuguese electronics enterprises, besides carrying out R&D activities and linking with research laboratories of universities and of non-profit research institutions, are quite active exploring new market niches. Their major attributes will be examined below. For the time being, we will briefly characterise the Portuguese electronics industry.

ANIMEE is the Portuguese industrial association which represents most of the country's electronics, as well as electrical, companies. Two assumptions derive from this "combination" of two different, although closely related, industries. The first points to the (yet) relatively little importance of electronics in the context of Portuguese industry, inasmuch as there is no apparent need to constitute an independent electronics industrial association. The second point to bear in mind relates to the statistical data we will be presenting below. The statistical grouping of the two industries made it sometimes difficult to isolate the Portuguese electronics industry data.

In 1992, the Portuguese electrical and electronics industries accounted for 1.14% of the country's GDP, well below the world's

average of 3.4%; conversely, the fact that they accounted for 10.1% of Portugal's total manufacturing exports indicate the strong propensity of these industries to sell abroad (ANIMEE 1994).

Nevertheless, during the period 1989-1992, the exports of the Portuguese electronics industry have always accounted for less than 3% of the country's total exports (TABLE 3), which again illustrates the industry's secondary position when compared to the Portuguese electrical industry.

TABLE 6.3: EXPORTS OF PORTUGUESE ELECTRONICS INDUSTRY VERSUS TOTAL PORTUGUESE EXPORTS			
YEAR	TOTAL EXPORTS (10 <sup>9</sup> PTE)	EXPORTS OF ELECTRONICS (10 <sup>9</sup> PTE)	%
1989	2,015.71	55.4	2.75
1990	2,335.80	62.2	2.66
1991	2,354.10	69.2	2.94
1992	2,475.20	64.0	2.59

SOURCE: ANIMEE (1991, 1993, 1994) and ICEP (1995)

TABLE 4 and TABLE 5 display the turnover of the electronics industry, and the turnover of the electrical and the electronics industries, respectively.

TABLE 6.4: PORTUGUESE ELECTRONICS INDUSTRY: TURNOVER (Current Prices x 10 <sup>6</sup> PTE)	
YEAR	TURNOVER
1989	79,643
1990	98,774
1991	102,254
1992	111,244

SOURCE: ANIMEE (no date, 1991, 1993, 1994)

TABLE 6.5: PORTUGUESE ELECTRICAL AND  
ELECTRONICS INDUSTRIES  
TURNOVER (Current Prices x 10<sup>9</sup> PTE)

YEAR	TURNOVER
1983	78
1984	110
1985	127
1986	133
1987	158
1988	196
1989	239
1990	315
1991	350
1992	371
1993*	393

\* ANIMEE's Forecast

SOURCE: ANIMEE (1991, 1994)

During the 1989-1992 period, the turnover of the Portuguese electronics industry was approximately 1/3 of the total turnover of the two industries. Its annual growth, however, was lower than that of the two industries taken together. In fact, for the period mentioned above, the turnover of these two industries showed an increase of 55.2%, versus an increase of only 39.7% for the electronics industry.

TABLE 6 and TABLE 7 exhibit the employment in the electronics industry, and in the electrical and the electronics industries, respectively.

TABLE 6.6: PORTUGUESE ELECTRONICS INDUSTRY  
EMPLOYMENT

YEAR	EMPLOYMENT
1989	12,331
1990	12,058
1991	9,675
1992	9,452

SOURCE: ANIMEE (1991, 1994)

TABLE 6.7: PORTUGUESE ELECTRICAL AND ELECTRONICS INDUSTRIES EMPLOYMENT	
YEAR	EMPLOYMENT
1983	31,100
1984	30,600
1985	29,140
1986	29,480
1987	29,000
1988	32,200
1989	34,000
1990	34,135
1991	34,398
1992	34,937
1993*	33,190

\* ANIMEE's Forecast

SOURCE: ANIMEE (1991, 1994)

For the period 1989-1992, and taking both industries together, an annual average growth of approximately 1% was noticeable. However, if we consider only the Portuguese electronics industry, in the same period a remarkable reduction of more than 23% in the number of employees was recorded. This decline was particularly evident from 1990 to 1991, when employment in the electronics industry fell by almost 20%. The main reason was the increasing mechanisation and/or automation of production, both in new and in already established firms, which inevitably led to the dismissal of a large number of workers. A process of technological change was/is thus taking place in this industry. TABLE 8 and TABLE 9 show the exports/imports ratio of the electronics industry, and of the electrical and the electronics industries, respectively. During the 1989-1992 period, a significant feature of their evolution should be emphasised. In fact, while the electrical and electronics industries' ratio remained more or less stable (between 0.47 and 0.51), the electronics industry's ratio revealed an ever increasing tendency to diminish. On the one hand, this trend reflects the fact that the Portuguese electronics industry strongly relies on imports

(raw materials and components) to manufacture its finished products, thus increasing its technological dependence. On the other hand, the same industry has not been able to keep pace with the increasing rhythm of global technological production. In other words, bearing in mind that the electronics industry is generally termed as a high technology industry, which is not the case of the electrical industry, the fact that, in terms of export/import ratio, the Portuguese electrical industry is performing better than the electronics industry demonstrates that Portugal is not closing the technological gap.

TABLE 6.8: PORTUGUESE ELECTRONICS INDUSTRY: EXPORTS / IMPORTS RATIO (Current Prices x 10 <sup>6</sup> PTE)			
YEAR	EXPORTS	IMPORTS	RATIO
1989	55,363	137,103	0.40
1990	62,265	158,702	0.39
1991	69,210	186,137	0.37
1992	64,026	191,160	0.33

SOURCE: ANIMEE (no date, 1991, 1993, 1994)

TABLE 6.9: PORTUGUESE ELECTRICAL AND ELECTRONICS INDUSTRIES EXPORTS / IMPORTS RATIO (Current Prices x 10 <sup>9</sup> PTE)			
YEAR	EXPORTS	IMPORTS	RATIO
1986	79	142	0.56
1987	96	190	0.51
1988	110	247	0.45
1989	151	317	0.48
1990	208	405	0.51
1991	225	477	0.47
1992	251	494	0.51

SOURCE: ANIMEE (no date, 1991, 1994)

Finally, the geographical distribution, by economic area, of the Portuguese electrical and electronics industries' exports (TABLE 10) and imports (TABLE 11) will be analysed.

TABLE 6.10: PORTUGUESE ELECTRICAL AND ELECTRONICS INDUSTRIES EXPORTS BY ECONOMIC AREA (%)				
ECONOMIC AREA	1989	1990	1991	1992
EU	86	84	87	84
EFTA	4	4	4	5
Former Portuguese Colonies	3	4	4	5
South East Asia	1	2	1	1
USA	4	3	2	2
Others	2	3	2	3
TOTAL	100	100	100	100

SOURCE: ANIMEE (1991, 1993, 1994)

TABLE 6.11: PORTUGUESE ELECTRICAL AND ELECTRONICS INDUSTRIES IMPORTS BY ECONOMIC AREA (%)				
ECONOMIC AREA	1989	1990	1991	1992
EU	76	78	78	79
EFTA	5	6	5	6
Japan	7	5	4	4
South East Asia	5	5	6	4
USA	6	5	6	5
Others	1	1	1	2
TOTAL	100	100	100	100

SOURCE: ANIMEE (1991, 1993, 1994)

Both the exports, and the imports, of the Portuguese electrical and electronics industries confirm the extremely strong links with Europe, especially in the case of exports. Indeed, the

future European Economic Area (EU plus EFTA) were, in 1992, responsible for 89% of the exports and for 85% of the imports of these Portuguese industries. To a certain extent, this share reflects Portugal's accession to Europe, as a full member of the EU. However, it also points to the significant influence of European multinationals upon the country's economic tissue. Indeed, the examiners of the recent review of Portugal's science and technology policy revealed that "In electronics, over 90 per cent of output comes from foreign-owned companies which perform very little R&D in Portugal" (OECD 1993b: 125).

This statement illustrates particularly well the above discussed situation of the Portuguese electronics industry. Let us now move to the country's mouldmaking industry.

### 6.3.3. The Portuguese mouldmaking industry

We will start by presenting a short overview of this industry in Portugal, since we assume the reader may not be familiar with its specificities.

The mouldmaking industry is a sector which is traditionally part of toolmaking, a skilled branch of engineering. In Portugal, the moulds produced are mostly destined for the plastics industry. Household appliances (32%), automobile (20%), electrical equipment (10%), electronics and telecommunications (9%), packaging (9%), and toys (8%), are the industries which absorb most of the output of this sector (ICEP 1995).

Mouldmaking is one of the most important traditional industries in Portugal. There are two major mouldmaking industrial poles in the country, Marinha Grande (to the north of Lisboa) and Oliveira de Azeméis (to the south of Porto). They are located not far from coastal areas, and are inserted in larger industrial districts. The Portuguese mouldmaking industry started in Marinha Grande. This region is well-known for its two-centuries old glass industry. Moulds were needed to manufacture glass products. At the beginning, moulds were imported from Europe, especially from Austria and Germany. Finally, at the turn of this century, the

first moulds for glass were produced in Marinha Grande, thus enabling the formation of a highly specialised workforce, which has greatly contributed towards the launching of the industry we are now studying.

The first mouldmaking enterprise, established half a century ago, acted as a genuine "university" for the mouldmaking industry, insofar as many of its blue-collar employees, after acquiring a high level of training and experience, left the company to launch their own small firms. The second major mouldmaking industrial pole at Oliveira de Azeméis was thus established.

The middle of the 50s witnessed the beginning of exports, initially for the UK, and later for other European countries and the US. During the 60s and the 70s, foreign customers started to press for improved technical quality of the moulds. Therefore, mouldmaking firms had to acquire foreign technology, as a means of technologically upgrading their equipment; for instance, at the beginning of the 80s, the first CAD/CAM system of the mouldmaking industry was installed.

The introduction of this system, associated with the far-reaching possibilities opened up by information technology, gave the company that purchased it an early technological lead. Indeed, as Perrin (1989) contends:

"... with the diffusion of information technology it has been possible:

- to increase automation in the production area with CAM (computer-aided manufacturing);
- to introduce automation in the drawing and design area with CAD (computer-aided design) and in the production planning area with CAPP (computer-aided production planning).

Now, with information technology it is possible to link the automation of two or more functions: production and design with a CAD/CAM system for instance, or production + design + production planning + marketing" (Perrin 1989: 351)

Similarly, referring to the pervasiveness of information technology, Freeman (1991) argues that:

"Not only has it found applications in every manufacturing and service sector, often changing profoundly both products and processes, but it also

affects every *function* within each firm: design (CAD); manufacture (robotics, instrumentation, FMS, control systems, CIM, etc); marketing (computer-based inventory and distribution systems) accounts and administration (management information systems, etc). Finally, it affects, through its convergence with the telecommunications system, the network of communications within the firm and between the firm and its supplier networks, technology networks, customer networks, etc. In this last area it provides entirely new possibilities for rapid interchange of information, data, drawings, advice, specifications, and so on between geographically dispersed sites via fax, VANS, electronic mail, teleconferencing, distance learning, etc. It is hardly surprising, therefore, that taking into account both the pervasiveness of IT and its systemic characteristics, most of the new developments in networking in the 1980s have been associated in one way or another with the diffusion of this technology" (Freeman 1991: 509)

A practical application, which shows how information technology can (positively) affect the above mentioned network of communications between the enterprise and the outside world, is found in the Portuguese mouldmaking industry. CET, a research centre on telecommunications, which belongs to the state telecommunications company, supported the first experiments in the modernisation of the country's telecommunications infrastructure, through the construction of a fibre-optic link between the towns of Leiria and Marinha Grande and the respective digitalisation of the central commutation exchanges. The mouldmaking enterprises located at Marinha Grande immediately took advantage of the new infrastructure, drastically reducing the time needed to contact their customers and suppliers. Ultimately, their goal will be to reach the point described by Mowery (1989), who stresses that:

"Recent innovations in the technologies of information transmission, storage, and analysis have lowered information costs still further, and appear to facilitate interfirm cooperation in product development, manufacture, and marketing in some industries. The exchange of technical, testing, and other data between development teams and the use of computer-aided design and manufacturing technologies in both development and production have simplified the "spinning off" of numerous tasks to other foreign or domestic firms in product design and manufacture" (Mowery 1989: 25)

Let us now briefly characterise the Portuguese mouldmaking industry.

Portugal is one of the main mould exporting countries. Although its worldwide share is rather low, it was nevertheless ranked 8th place in 1993, having slightly improved its position with regard to 1990 (TABLE 12).

COUNTRY	1990		1993	
	EXPORTS	%	EXPORTS	%
Austria	-	-	55,051	1.30
Belgium	204,781	6.13	127,957	3.02
Denmark	21,101	0.63	-	-
Finland	4,804	0.14	3,004	0.07
France	163,301	4.89	256,754	6.05
Germany	706,373	21.15	786,508	18.54
Italy	191,826	5.74	245,076	5.78
Japan	850,661	25.47	1,648,934	38.86
Korea	97,004	2.91	145,693	3.43
Netherlands	108,434	3.25	70,558	1.66
Portugal	95,083	2.85	133,885	3.15
Spain	125,569	3.80	132,896	3.13
Sweden	25,845	0.77	36,385	0.86
Switzerland	193,701	5.80	205,181	4.84
UK	68,568	2.05	64,779	1.53
USA	483,083	14.46	330,286	7.78
TOTAL	3,340,134	100.00	4,242,947	100.00

SOURCE: ISTA (1992, 1995)

Similarly, the industry's exports are gaining weight in terms of the country's total exports. Indeed, from 1989 (0.69%) to 1993 (0.89%), the Portuguese mouldmaking industry has steadily improved its importance (TABLE 13). An additional feature to bear in mind is the overly export-orientated nature of this industry in as far as, from 1989 to 1993, at least 81.6% of its production was exported (TABLE 14).

TABLE 6.13: EXPORTS OF PORTUGUESE MOULDMAKING INDUSTRY VERSUS TOTAL PORTUGUESE EXPORTS			
YEAR	TOTAL EXPORTS (10° PTE)	EXPORTS OF MOULDS (10° PTE)	%
1989	2,015.71	13.88	0.69
1990	2,335.80	18.80	0.80
1991	2,354.10	20.47	0.87
1992	2,475.20	22.11	0.89
1993	2,474.40	22.10	0.89
1994*	2,810.60	25.25	0.90

\* ICEP's Forecast  
SOURCE: ICEP (1995)

TABLE 6.14: EXPORTS OF PORTUGUESE MOULDS AS A PERCENTAGE OF PRODUCTION OF PORTUGUESE MOULDS			
YEAR	EXPORTS (10° PTE)	PRODUCTION (10° PTE)	%
1989	13.88	17.00	81.6
1990	18.80	20.70	90.8
1991	20.47	23.60	86.7
1992	22.11	25.20	87.7
1993	22.10	25.80	85.7
1994*	25.25	28.70	88.0

\* ICEP's Forecast  
SOURCE: ICEP (1995)

The exports of this industry are mainly directed towards two large economic areas, Europe and North America. In fact, during the period 1989-1993, at least 72% of the Portuguese mouldmaking production was annually exported to both areas (TABLE 15). However, a trend should be emphasised, ie the growing importance of countries located outside these two economic areas, which are becoming clients of the Portuguese mouldmaking industry. This recent diversification into new foreign markets was, to a large extent, a direct consequence of the economic recession which

TABLE 6.15: PORTUGUESE MOULDMAKING INDUSTRY EXPORTS BY (MAIN) ECONOMIC AREAS (%)		
YEARS	CANADA + USA	EU
1989	35.0	46.0
1990	23.7	52.9
1991	21.0	57.5
1992	20.1	56.9
1993	25.3	46.7
1994*	25.7	45.8

\* ICEP's Forecast  
SOURCE: ICEP (1995)

still affects most of the Western developed countries. This was the main reason why, from 1989 (35.0%) to 1993 (25.3%), the Portuguese exports to the Canadian and to the United States markets have fallen off sharply; similarly, between 1991 and 1993, exports to the European Union decreased by almost 11% (TABLE 15). Their shares have been "captured" by countries like Israel, Turkey and, especially, the so-called "Others" (TABLE 16).

TABLE 6.16: MAIN IMPORTERS OF PORTUGUESE MOULDS (%)				
COUNTRY	1991	1992	1993	1994*
Canada + USA	21.0	20.1	25.3	25.7
France	11.9	12.9	9.0	9.2
Germany	16.1	17.4	14.7	11.8
Israel	2.4	3.5	3.7	4.1
Netherlands	6.7	6.5	4.8	4.6
Spain	8.7	7.0	4.9	3.7
Sweden	5.8	5.7	4.8	3.8
Turkey	1.8	2.2	3.8	2.9
UK	7.9	7.2	9.4	6.7
Others	17.7	17.5	19.6	27.5
TOTAL	100.0	100.0	100.0	100.0

\* ICEP's Forecast  
SOURCE: ICEP (1995)

Referring now more specifically to the distinctive features of the Portuguese mouldmaking industry, it has to be pointed out that, as a general rule, they are far from being brilliant. For example, we have mentioned before that, during the 60s and the 70s, foreign customers have "forced" Portuguese mouldmaking enterprises to technologically upgrade their equipment. More recently, with the large influx of EU's structural funds and of PEDIP's funds, the time was ripe for a second wave of modern, technologically up-to-date equipment to be purchased abroad, as a means of further improving the technical quality of the Portuguese moulds and, ultimately, becoming more competitive in the foreign arena. In fact, in 1990, Portugal spent twice as much as the average of all the mouldmaking countries both in all kinds of expenses for investment purposes (TABLE 17) and in new machines and mechanical installations (TABLE 18), as a percentage of turnover. The figures for 1993, although lower, are still well above average.

TABLE 6.17: TOTAL INVESTMENT AS A PERCENTAGE OF TURNOVER (SALES)		
COUNTRY	1990	1993
Austria	-	6.0
Belgium	11.0	9.0
Finland	6.5	3.8
France	11.2	6.5
Germany	9.8	6.6
Ireland	-	27.5
Italy	15.3	8.4
Japan	7.0	11.0
Korea	19.7	13.0
Netherlands	-	12.1
Portugal	20.5	12.0
Spain	10.2	4.0
Switzerland	13.0	5.5
United Kingdom	4.1	9.2
United States	4.7	4.9
AVERAGE	10.6	9.0

SOURCE: ISTA (1992, 1995)

TABLE 6.18: INVESTMENT IN NEW MACHINES AND MECHANICAL INSTALLATIONS AS A PERCENTAGE OF TURNOVER (SALES)		
COUNTRY	1990	1993
Austria	-	5.0
Belgium	9.0	-
Finland	4.5	1.2
France	7.4	5.2
Germany	6.3	5.2
Ireland	-	16.0
Japan	5.0	5.0
Korea	15.2	11.0
Netherlands	-	7.9
<i>Portugal</i>	15.7	10.0
Spain	8.5	2.2
Switzerland	10.0	4.6
United Kingdom	3.5	7.2
United States	3.8	3.9
AVERAGE	7.2	6.3

SOURCE: ISTA (1992, 1995)

However, in spite of all this investment in modern equipment, the truth is that it is not paying off. In fact, in 1990 as well as in 1993, Portugal presents both the lowest turnover per employee (TABLE 19) and the lowest value added per employee (TABLE 20) of all the mouldmaking countries. Moreover, the figures for Portugal are only equivalent to slightly more than 1/3 of the average of all those countries.

TABLE 6.19: TURNOVER (SALES) PER EMPLOYEE IN ECU		
COUNTRY	1990	1993
Austria	-	88,081
Belgium	79,669	82,033
Finland	47,423	38,828
France	75,064	80,625
Germany	67,672	66,789
Ireland	-	42,618
Italy	72,274	70,605
Japan	81,215	127,133
Korea	28,803	42,341
Netherlands	-	65,247
Portugal	21,043	24,155
Spain	59,624	68,914
Switzerland	88,068	87,749
United Kingdom	43,128	48,206
United States	67,080	86,147
AVERAGE	61,798	69,222

SOURCE: ISTA (1992, 1995)

TABLE 6.20: VALUE ADDED PER EMPLOYEE IN ECU		
COUNTRY	1990	1993
Austria	-	60,923
Belgium	48,320	46,453
Finland	29,278	24,641
France	42,377	42,019
Germany	38,789	43,019
Ireland	-	26,921
Italy	53,220	52,682
Japan	29,860	91,028
Korea	14,184	20,394
Netherlands	-	44,840
Portugal	12,760	15,050
Spain	34,526	33,339
Switzerland	49,432	48,852
United Kingdom	25,750	33,847
United States	43,401	58,321
AVERAGE	35,402	43,014

SOURCE: ISTA (1992, 1995)

In order to try to understand why the very high level of the industry's expenditures in i) all kinds of expenses for investment purposes, and in ii) new machines and mechanical installations is not in tune with both its turnover per employee and its value added per employee, we have looked at the various special tools produced by ISTA's members (TABLE 21).

COUNTRY	PUNCHING AND STAMPING DIES	MOULDS FOR RUBBER AND PLASTICS	DIECASTING DIES	JIGS AND FIXTURES	STANDARD TOOLING COMPONENTS	OTHER MOULDS AND DIES	TOTAL
Austria	-	73,401	13,212	-	-	-	86,613
Belgium	31,131	92,349	5,212	1,012	105,949	-	235,653
Finland	12,056	10,935	4,124	5,488	381	-	32,984
France	282,226	612,582	60,922	-	-	-	955,730
Germany	1,147,685	956,125	93,021	249,092	143,655	-	2,589,578
Italy	-	-	-	-	-	-	1,031,919
Japan	1,467,833	1,372,110	158,536	-	-	364,980	3,363,459
Korea	492,883	388,306	23,086	-	-	143,620	1,047,895
Netherlands	11,217	10,987	-	-	-	-	22,204
Portugal	-	146,924	10,214	-	-	-	157,138
Spain	234,570	194,301	34,441	-	16,698	-	480,010
Switzerland	80,916	170,502	20,229	54,329	12,715	-	338,691
UK	237,391	219,482	21,359	188,316	32,693	-	699,241
USA	1,658,611	1,603,129	350,684	663,444	568,667	-	4,844,535
TOTAL							15,885,650

SOURCE: ISTA (1995)

A significant feature was distinctively noticeable ie, only two countries, Austria and Portugal, were active in only two areas, "moulds for rubber and plastics" (84.7% and 93.5% of turnover, respectively) and "diecasting dies" (15.3% and 6.5% of turnover, respectively). Both France (64.1%) and Switzerland (50.3%) also presented more than 50% of turnover in the area "moulds for rubber and plastics".

However, when we compare the performance of Portugal with that of these other three countries, in terms of their turnover per employee (TABLE 19) and value added per employee (TABLE 20), we notice that, generally speaking, their performance is well above average. This is particularly conspicuous in the case of Austria. We do believe that such figures are explained by the fact that, although the Portuguese mouldmaking blue-collar workers are in general highly specialised in a complex set of specific tasks,

these usually tend to be very labour-intensive. In addition to that, the training of the mouldmaking employees is normally directed towards the operation of conventional machines. Indeed, the typical equipment of the Portuguese mouldmaking industry still comprises 66% of conventional machines and only 34% of CNC machines (CEFAMOL *no date*). Hence, we are confronted with a really odd situation insofar as, on the one hand many mouldmaking enterprises do have modern, new machines while, on the other hand they lack the well-trained workers to operate them.

An additional reason for the extremely low level of productivity of the Portuguese mouldmaking industry may be related to the equally very low level of wages and salaries paid in this industry. For example, it was pointed out to us that, when a graduate engineer joins a mouldmaking firm, her/his initial monthly salary is around PTE 120,000 (roughly £480). Indeed, only Korea shows a lower total personnel cost as a percentage of turnover, both in 1990 and in 1993 (TABLE 22).

COUNTRY	1990	1993
Austria	-	52.0
Belgium	42.0	50.0
Finland	57.4	58.0
France	46.0	47.1
Germany	49.5	55.5
Ireland	-	40.5
Italy	42.5	46.6
Japan	47.9	42.4
Korea	32.3	33.4
Netherlands	-	50.1
Portugal	37.5	39.0
Spain	43.5	47.8
Switzerland	44.0	46.6
United Kingdom	52.0	56.5
United States	55.0	49.4
AVERAGE	45.9	47.4

SOURCE: ISTA (1992, 1995)

TABLE 23 further illustrates in a very detailed way how low the wages and salaries paid in the Portuguese mouldmaking industry are. It presents an international comparison of the effective wages paid per hour to a skilled mould or tool maker, and to a skilled tool designer. Additionally, it also displays a foreman's monthly salary.

The two countries with the highest levels of wages and salaries are Switzerland and the United States. Once again, on the opposite side of the spectrum lay Korea and Portugal. The Portuguese wages and salaries only account for about 1/5 of those of Switzerland and the United States.

COUNTRY	SKILLED MOULD OR TOOL MAKER		SKILLED TOOL DESIGNER		FOREMAN	
	EFFECTIVE WAGES PER HOUR IN ECU				SALARY PER MONTH IN ECU	
	1991	1994	1991	1994	1991	1994
Austria	-	11.43	-	14.75	-	2,138
Belgium	9.92	12.34	13.09	14.20	2,256	2,662
Finland	10.08	7.44	14.29	9.86	2,020	1,566
France	8.31	9.11	9.03	10.31	-	2,578
Germany	10.50	11.84	14.68	16.55	2,465	2,851
Ireland	-	9.03	-	14.70	-	2,243
Italy	7.83	7.30	9.95	8.30	2,227	1,766
Korea	3.17	4.45	2.80	3.47	1,065	1,078
Netherlands	8.75	10.36	9.71	11.32	1,656	1,969
Portugal	3.30	3.70	3.69	4.13	834	938
Spain	9.74	8.76	13.31	10.97	2,136	2,087
Switzerland	14.86	17.65	16.57	20.73	3,543	4,224
UK	8.47	9.18	10.86	9.98	2,064	2,141
US	17.27	19.51	16.99	19.01	3,460	3,875

SOURCE: ISTA (1992, 1995)

Finally, a particular feature of the mouldmaking industry worldwide should be mentioned, ie the important role played by subcontracting work. In TABLE 24, Portugal occupies the third highest place in terms of the value of parts and technical

services purchased outside the enterprise as a percentage of turnover, below France and Japan (1990) and Korea and Japan (1993).

COUNTRY	1990	1993
Austria	-	11.0
Belgium	4.0	-
Finland	4.0	2.8
France	19.1	11.1
Germany	8.5	8.0
Ireland	-	11.0
Italy	7.0	12.1
Japan	17.4	14.6
Korea	14.7	15.4
Netherlands	-	5.8
Portugal	15.5	14.0
Spain	13.5	9.4
Switzerland	12.0	11.9
United Kingdom	0.7	6.6
United States	7.6	8.5
AVERAGE	10.7	10.5

SOURCE: ISTA (1992, 1995)

In the Portuguese case, a relevant motive for such high percentage lies in the fact that most of the country's (small) mouldmaking firms still base their "competitive" strategy in terms of price. Therefore, in order to capture a large volume of manufacturing orders for moulds, as a means of making their investment in machines and in mechanical installations more profitable, they lower their selling prices. However, as soon as those orders are assigned to them, they realise that, even working at full capacity, they are not able to fulfil their contractual obligations only by themselves. Thus, the solution is to subcontract the work to other (small) enterprises. Particularly in the *Marinha Grande* area, this strategy is facilitated by cultural and historical reasons. The Portuguese

Communist Party was (is) very active in this industrial pole, and a long history of blue-collar unions fighting for their rights still holds the workers, and many managers, together.

#### 6.4. Conclusions

In this chapter we have presented the Portuguese industries which are at the centre of our research.

Based upon earlier contributions by renowned researchers and scientists, we have proposed our own taxonomy of technological intensity levels, in which we differentiated amongst three distinct sectors of the country's manufacturing industry, ie a technology-based sector, a traditional sector, and a science-based sector. In accordance with this taxonomy, three industries were initially selected for analysis, electronics, mouldmaking, and biotechnology, respectively.

It was found that the Portuguese electronics industry is currently experiencing a process of technological change, characterised on the one hand by an increasing mechanisation and/or automation of production and on the other hand by the dismissal of a large number of its workers. Despite that process, it appears that the industry has not been able to keep pace with the increasing rhythm of global technological production.

Generally speaking, the Portuguese electronics companies may be grouped into three main categories.

First, the manufacturing subsidiaries of the big international corporations produce according to specifications, assemble the components, and export the final products back to their parent's home country. These subsidiaries rely upon the existence of a qualified, yet underpaid (in European terms), workforce.

Then, apart from a multitude of small and medium sized firms carrying out none or very little R&D, the presence of a number of newly founded, research-intensive, small enterprises, which are exploring new market niches and establishing close linkages with university laboratories and private non-profit research institutions may be the biggest hope for the Portuguese

electronics industry to bridge its technological gap.

The Portuguese mouldmaking industry is a traditional industry which has been intensely pervaded by electronics. However, apart from a small number of enterprises which are taking full advantage of, and benefiting the most from, this technology, the majority of its firms are still producing their moulds in a very conventional way. Most of their workers simply do not know how to put the new equipment acquired abroad to good use.

Furthermore, in international terms, the productivity of the Portuguese mouldmaking workforce is generally rather low, which is in tune with the low wages and salaries paid in the industry. Finally, it should be pointed out that industrial biotechnology scarcely exists in Portugal. Indeed, only a very small number of large, well established companies, with a significant percentage of foreign participation in the share capital, have some marginal interest in the field. Research in biotechnology is still predominantly concentrated in the laboratories of universities and polytechnics, in private non-profit institutions and, to a lesser extent, in some specialised government laboratories.

As a direct consequence of this situation, biotechnology will be excluded from the statistical analysis. Therefore, in the next chapters, we will be focussing our attention exclusively on the electronics and on the mouldmaking industries.

## 7. THE METHODOLOGY

### 7.1. Introduction

In this chapter we will very briefly describe the various steps we have taken in order to be able to conduct our field-work. We will start by explaining how we have selected the enterprises in our sample (*point 2*). It was necessary to follow two distinct paths, since the number, the geographical location, and the services delivered by electronics and by mouldmaking firms were quite dissimilar. We will then explain how we got in touch with our selected companies.

In *point 3* we will be introducing our questionnaire. Firstly, we will describe its main topics, and then the processes by which some of the basic variables which have derived from its questions were recodified and regrouped.

### 7.2. The Selection of the Sample

As referred to above, our research's target population were the Portuguese enterprises active in the electronics and in the mouldmaking industries.

Our very first step towards the identification of the universe of such companies was the gathering and consultation of various directory sources, from which firms were eventually drawn.

According to a Directory published by the electrical and electronics association (ANIMEE 1991), there were 60 enterprises in the Portuguese electronics industry. They were overwhelmingly located in the Greater Lisboa area (40), followed by the Greater Porto area (7), with the remaining 13 companies scattered all over the country (TABLE 1). All those firms were eligible for an initial contact.

TABLE 7.1: PORTUGUESE ELECTRONICS INDUSTRY COMPANIES BREAKDOWN PER GEOGRAPHICAL LOCATION		
LOCATION	COMPANIES	%
Braga	4	6.66
Greater Lisboa	40	66.67
Greater Porto	7	11.67
Vila Nova de Famalicão	3	5.00
Others	6	10.00
<b>TOTAL</b>	<b>60</b>	<b>100.00</b>

SOURCE: ANIMEE (1991)

A quite distinctive situation characterised the Portuguese mouldmaking industry. Indeed, an issue published by its association (CEFAMOL 1991) listed a total of 309 mouldmaking enterprises in Portugal (TABLE 2).

TABLE 7.2: PORTUGUESE MOULDMAKING INDUSTRY COMPANIES BREAKDOWN PER GEOGRAPHICAL LOCATION		
LOCATION	COMPANIES	%
Greater Lisboa	18	5.83
Greater Porto	36	11.65
Marinha Grande	168	54.37
Oliveira de Azeméis	56	18.12
Others	31	10.03
<b>TOTAL</b>	<b>309</b>	<b>100.00</b>

SOURCE: CEFAMOL (1991)

More than half of all those companies were located in the Marinha Grande area. The industrial pole around Oliveira de Azeméis was the second largest in the country.

However, research on such a large number of firms was definitely impossible to put into practice, due to severe time and budget constraints. A selection process was therefore necessary.

In order to achieve this goal, we have used a second Directory published by CEFAMOL (CEFAMOL no date). There, the Portuguese mouldmaking enterprises are listed according to 11 different types of moulds and services which they deliver. These comprise:

- injection moulds for plastics;
- compression and transfer moulds;
- blow moulds;
- moulds for rubber;
- moulds for glass;
- die casting;
- other type of moulds;
- mouldbases (bolsters);
- patterns and models;
- engineering, design and export;
- special tooling and features

We have already mentioned that the Portuguese mouldmaking industry still produces a considerable number of its moulds in a very conventional way, despite being recently pervaded by electronics. We were thus interested in finding out how some of the most technologically advanced firms were dealing with this process of technological change. Therefore, we have decided to select for analysis the enterprises which were active in three of the above mentioned types of moulds and services, namely i) patterns and models; ii) engineering, design and export; and iii) special tooling and features. TABLE 3 presents the companies thus selected, according to their geographical location.

TABLE 7.3: PORTUGUESE MOULDMAKING INDUSTRY COMPANIES SELECTED FOR THE RESEARCH BREAKDOWN PER GEOGRAPHICAL LOCATION		
LOCATION	COMPANIES	%
Greater Lisboa	4	10.81
Greater Porto	2	5.41
Marinha Grande	19	51.35
Oliveira de Azeméis	8	21.62
Others	4	10.81
TOTAL	37	100.00

SOURCE: CEFAMOL (no date)

Note that the geographical distribution of this sample was quite similar to its universe (TABLE 2). All these 37 enterprises were thus eligible for an initial contact.

The next step was to get in touch with our 97 selected companies (60 from electronics plus 37 from mouldmaking).

First of all, a letter addressed to the managing director was sent via fax, carefully explaining the aim of our study and requesting a face-to-face meeting in order to collect information (general reports, promotional booklets, etc) and to fill-in a questionnaire. After receiving a reply, a second contact was made, by telephone, to arrange the interview.

We have ended up with a set of 28 interviews, evenly distributed between electronics and mouldmaking enterprises. This represents a response rate of 28.9 percent, which we believe is reasonably satisfactory for this kind of exercise.

The interviews were conducted in mid-1992. They all involved personnel having senior executive responsibility, lasted around 2 hours, and were usually followed by a visit to the premises.

### 7.3. The Questionnaire

As mentioned above, the interviews were conducted using a questionnaire, which was designed by the author. It was partly based upon some earlier studies (Beesley and Rothwell 1987; Rothwell and Beesley 1988, 1989) and partly on the author's own experience and ideas. Amongst its 77 questions it included a few open ones.

The questionnaire was 14 pages long (see Appendix 1) and requested information on a series of 8 main topics:

- background of the enterprise (15 questions);
- the R&D structure (13 questions);
- linkages with other enterprises (17 questions);
- linkages with academic research (9 questions);
- linkages with public sector institutions (7 questions);
- technological innovations in the enterprise (8 questions);
- technology transfer (6 questions);
- extent and quality of the enterprise's inter-institutional linkages (2 questions)

The questionnaire's 77 questions have originated 202 basic variables. It should be mentioned that, during the statistical analysis, some of those basic variables were recodified. For instance, the overall data concerning question 3 (year of foundation) and question 8 (total turnover, total personnel, and total salary costs) were divided into three regular intervals, according to their observed frequencies.

Furthermore, all the questions in which the interviewee had to use a weighted scale to ponder over the importance of various topics (eg questions 10, 30, 32,...) were also recodified. Hence, the initial six-points weighted scale was regrouped into three categories, namely "major importance", "average importance", and "minor importance". Our purpose was to obtain a more reliable, representative information.

In order to better understand the (possible) shared relationship or connection of cause and effect amongst a number of our variables, we had also employed some measures of correlation. Thus, we had calculated the coefficients of correlation between i) a number of variables which we considered to be representative of our firms' structure (location of the enterprise, year of foundation of the enterprise, total turnover in 1991, total personnel in 1991, total gross expenditures in 1991, and Portuguese participation in the share capital) and ii) a number of variables assumed as typical of our companies' R&D structure; of their linkages with other enterprises, with academic research, and with public sector institutions; of their technological innovations; and of their technology transfer policies. In this second group, the variables were the following:

- existence of R&D activities in the enterprise;
- importance of collaborative R&D linkages;
- importance of collaborative marketing linkages;
- importance of subcontracting-out manufacturing links;
- importance of subcontracting-in manufacturing links;
- existence of collaborative agreements;
- existence of linkages with academic research;
- contacts with R&D activities at universities;
- contacts with R&D activities at polytechnics;
- existence of links with public sector institutions;
- contacts with governmental R&D laboratories;
- contacts with non-profit R&D institutions;
- patent technological innovations;

- develop technological innovations;
- acquisition of technology;
- selling of technology

Finally, two-dimensional and three-dimensional cross-tabulations were also calculated (see *Appendix 4* and *Appendix 5*). We have thus obtained contingency tables, which included statistics (for example, Pearson's R) showing the shared relationship among some of our basic variables.

It should also be pointed out that, in all our statistical analysis, we have used SPSS - Statistical Package for Social Sciences.

In the next chapter we present the results of our field-work.



## 8. THE RESEARCH

### 8.1. Introduction

In this chapter we will be dealing with the statistical analysis of the data gathered during our fieldwork in Portugal, carried out in the Spring and Summer months of 1992.

*Point 2* explains how the hypotheses which we seek to test emerged from our initial literature survey, theoretical framework, and experience of the Portuguese S&T system.

The statistical analysis (*point 3*) closely follows the structure of the questionnaire (see *Appendix 1*). We start by characterising the enterprises in the study in terms of their location, year of foundation, total turnover, total personnel, total salary costs, the Portuguese participation in the share capital, the ownership by an economic group, and the number, academic background, and age group of their senior managers (*section 1*). In *section 2* we briefly focus on the R&D activities in the enterprises, namely in terms of the existence (or not) of R&D activities, as well as on the importance of inter-departmental linkages.

Sections 3 to 5 constitute the bulk of the research. In *section 3* (linkages with other enterprises) we analyse the degree of importance, and the location, of suppliers, customers and competitors; the importance of past, present, and future linkages; and the existence, and the importance, of scientific and technological collaborative agreements. *Section 4* deals with the linkages with academic research, particularly regarding the importance of past, present, and future linkages (both formal and informal); the main reasons for networking with academic research, and for contacts with R&D activities at universities and polytechnics. *Section 5* follows the footsteps of the previous section, only now focusing on the linkages with non-academic public sector institutions, ie, governmental laboratories and non-profit institutions.

In *section 6* (technological innovations in the enterprises) we

are interested in finding out whether the firms in the sample patent and/or develop technological inventions, and what are the focus, the purpose, the costs, and the major obstacles to the introduction of technological innovations. Finally, in section 7 we briefly speak about the technology transfer process, namely regarding the acquisition and the selling of technology by the companies.

The reader should bear in mind that we are dealing with a small sample. In fact, the 28 cases we have reported in our research are evenly distributed between the two industries we are studying: electronics (14 cases), and mouldmaking (14 cases). To try, in a certain way, to overcome the smallness of our sample, in our statistical analysis we will also use cross-tabulations (by location, by year of foundation, by personnel, and by Portuguese participation in the share capital). Hence, we believe we will be able to improve, and better clarify, our understanding of the two industries.

## 8.2. The Hypotheses

Based upon an extensive literature survey on the theory of innovation, focussing particularly on the role played by large and small enterprises in the process of innovation, as well as in the motives behind the growing importance of industrial cooperation, coupled with the analysis and experience of the Portuguese S&T system, we attempt to validate a set of hypotheses which can be derived from this integrated framework.

The uncertainty of economic conditions, the complexity of scientific and technological inputs, and the risks associated with uncertain technological trajectories, combined with the acceleration of technological change and the shortening of product life cycles, are forcing enterprises to learn new rules of behaviour, in order to be able to successfully compete under the current market conditions. These include greater technological collaboration and networking.

What makes the recent spate of cooperative associations original

is their extent. Indeed, it is argued that firms establish both horizontal linkages with competitors (Nelson 1988; von Hippel 1989) and with firms performing similar activities in other industrial branches, and vertical linkages with suppliers and customers (Lundvall 1988, 1991, 1992c, 1993) in complementary activities. Collaboration can either take place between enterprises of equal or near equal strength or of very different size and financial power (Chesnais 1988b). It can also involve big, high technology firms which operate in global markets (Hergert and Morris 1988; Hladik and Linden 1989; Kleinknecht and Reijnen 1992; Mowery 1989), companies working in the newer technologies of information and communications, in biotechnology, and in new materials (Hagedoorn and Schakenraad 1990, 1991, 1992), small and medium sized enterprises (Furukawa, Teramoto and Kanda 1990), and industries which are increasingly using sophisticated technologies (Gugler 1992). The focus and scope of these collaborations vary widely, with broad differences between and within industrial sectors. They can range from simple and brief contracts to large-scale, long-term joint ventures (CEST 1991).

Moreover, companies work jointly with universities, polytechnics, independent research and technology organisations, and government laboratories. However, one can also notice that certain kinds of enterprises preferentially link either with academic research or with public sector institutions.

For example, Dodgson and Rothwell (1989a) and Rothwell (1991) argue that, in order to complement their commonly limited in-house R&D resources, modern, niche strategy SMEs need a frequent access to external sources of scientific and technological expertise, thus establishing formal and informal linkages with other enterprises, with academic research, and with public sector institutions. Conversely, NTBFs put particular emphasis on their external linkages with academic research, insofar as most of them started as spin-offs from university departments, aiming at exploring radical product innovations.

Finally, the importance of the public sector in affecting industrial development has been particularly emphasised (Dalpé,

DeBresson and Xiaoping 1992; Gregersen 1988, 1992; Rothwell and Zegveld 1981). It is argued that small, high technology firms are better able to successfully overcome the first stages of their evolutionary process when they manage to get contracts from the public sector (Dalum, Fagerberg and Jørgensen 1988). Thus:

*Hypothesis 1: Although the extent and quality of linkages with other enterprises is significantly important across (Portuguese) industries, there is a distinctive weakness in the pattern regarding the extent and quality of their linkages with academic research, and with public sector institutions.*

Portugal heavily bases its specialisation pattern upon mature, traditional industries, eg clothing, footwear, textiles, etc. As a consequence, a low technological-intensity profile characterises its productive sector, which is further dominated by a very large number of SMEs (Caraça, Gonçalves, Assis and Gonçalves 1988; Caraça, Gonçalves, Brito, Mateus, Ribeiro, Faisca and Moreno 1993; OECD 1993b).

Conversely, Portuguese high technology R&D activities are mainly concentrated on the public sector, the higher education sector, and the private non-profit sector (Assis 1985, 1989; JNICT 1995b; OECD 1990, 1992a, 1993a, 1994, 1995a).

It is thus with no surprise that one finds that links between industrial production, on the one hand, and R&D institutes and/or universities, on the other hand, are particularly weak (Caraça, Gonçalves, Brito, Mateus, Ribeiro, Faisca and Moreno 1993; Corado-Simoes 1991; Fontes and Coombs 1994; GEPIE 1992; OECD 1993b; Ruivo 1991a, 1991b; Simões 1993; Spinnato 1993).

Notwithstanding, although an academic culture that resists interaction with industry still prevails in Portugal (OECD 1993b), one may expect that a number of linkages between modern, niche strategy Portuguese SMEs and academic research will eventually occur.

Indeed, as suggested by Oakey (1984), Utterback and Abernathy (1975), and Vernon (1966), in the early phases of the product cycle, constant research and development is needed in order to keep internal product development at the leading edge of advancing technology. This requires the presence of high-level

scientific skills, which may only be found inside the academic world.

*Per contra*, due to a lack of R&D capacity in most of the Portuguese manufacturing firms, in terms of both expenditure and skilled personnel (OECD 1993b), one may expect that these low-medium technology enterprises will establish linkages with institutions belonging to the public sector, with the aim at obtaining advice and (technical) support. Hence, the country's public sector institutions may ultimately play an important role in establishing and strengthening linkages with Portuguese firms. We might thus argue:

***Hypothesis 2: Portuguese high technology enterprises (in the electronics industry) preferentially link with academic research rather than with public sector institutions; the opposite trend characterises a low-medium technology industry (mouldmaking).***

Small and large firms play different, yet complementary, roles in the process of innovation (Acs and Audretsch 1990; Rothwell 1983, 1989). It is a symbiotic relationship, which may be seen as an attempt to blend the behavioural advantages of small firms in innovation with the resource-related advantages enjoyed by large companies (Rothwell 1983; Rothwell and Zegveld 1982).

Small firms have made important contributions to innovation and growth in specific high technology based industries (Oakey 1984; Rothwell 1989). For example, Pavitt, Robson and Townsend (1987a) argue that companies with fewer than 200 employees accounted for a significant percentage of the innovations in instruments, in machinery, in textiles, leather and clothing, and in electronics. They also contend that the ratio of the share of manufacturing firms' innovations to their shares of employment for the period 1981 to 1983 was greatest for enterprises with between 100 and 199 employees.

Additionally, the volume of technological activities in small companies is also underestimated by official statistics of R&D activities (Kleinknecht 1987; Kleinknecht and Reijnen 1991; Soete and Verspagen 1991).

Therefore, it is no wonder that many large companies, including major US corporations such as 3M, tried to blend their material

advantages with the behavioural advantages of the small firms, relocating their innovatory activity in comparatively small units (Rothwell 1989).

On the other hand, as already mentioned, collaboration between enterprises is currently a widespread phenomenon, engulfing not only large companies, but also small and medium sized firms, even in medium and low tech sectors (Gugler 1992; Kleinknecht and Reijnen 1992). However, in a study into technology strategies in innovative small and medium sized enterprises, Beesley and Rothwell (1987) and Rothwell and Dodgson (1991) contend that few innovative SMEs formed linkages with large companies, and they also preferred to establish strong "near-to-market" interactions involving product development along the vertical supplier-manufacturer-customer chain. Dodgson (1990) further refers the case of a medium sized, independent biotechnology firm, whose external linkages are so impressive that include long-term collaboration with universities, with research institutes, and with some of the world's biggest pharmaceutical corporations. We therefore hypothesise:

***Hypothesis 3: In general terms, small and medium sized firms tend to establish more linkages than large enterprises.***

To the extent that the empirical research reported in this chapter and Chapter 9 substantiates and elaborates these hypotheses, it will further validate some of the main findings of the earlier international literature as well as contributing original insights on the special distinctive features of the Portuguese national system.

### **8.3. The Statistical Analysis**

#### **8.3.1. The general background of the enterprises**

The firms in the sample are mainly located in four regions (TABLE 1).

TABLE 8.1: LOCATION OF THE ENTERPRISE

LOCATION	ELECTRONICS		MOULDMAKING	
	No.	%	No.	%
Greater Lisboa	8	57.1	-	-
Greater Porto	4	28.6	2	14.3
Marinha Grande	-	-	3	21.4
Oliveira de Azeméis	-	-	8	57.1
Others	2	14.3	1	7.1
TOTAL	14	100.0	14	100.0

There is a dichotomy between the cities and the countryside, which correlates well with the location of high tech, versus low-medium tech industries. While more than 85% of the electronics companies are located in the Greater Lisboa area and the Greater Porto area, almost 80% of the mouldmaking enterprises are clustered around Marinha Grande and Oliveira de Azeméis. There are historical, as well as institutional reasons which explain this tendency: the mouldmaking industry started as a supplier to the glass-blowing industry (Marinha Grande) and to the shoe industry (Oliveira de Azeméis), developing later as an industry in its own right, while high-tech industries, such as electronics, tend to be located close to the centres of knowledge, particularly universities and research institutions, which still have their hard core at Lisboa and Porto.

With respect to the year of foundation (TABLE 2), more than 60% of the electronics firms in the sample were founded after 1986 (5 of them in, or after, 1989), which is mainly explained by the surge of New Technology Based Firms (NTBFs), spinning-off from the leading engineering school in Portugal (Instituto Superior Técnico - Higher Technical Institute), located in Lisboa.

The newness of these enterprises almost certainly has a big effect upon collaboration which, as seen before, develops gradually over time.

TABLE 8.2: YEAR OF FOUNDATION OF THE ENTERPRISE

YEAR	ELECTRONICS		MOULDMAKING	
	No.	%	No.	%
Before 1965	1	7.7	6	42.9
From 1965 to 1986	4	30.8	5	35.7
After 1986	8	61.5	3	21.4
TOTAL	13 <sup>1</sup>	100.0	14	100.0

<sup>1</sup> 1 missing case in Electronics

The situation in the mouldmaking industry is quite different. Only 3 companies were founded after 1986; almost half of the sample (6 out of 14 enterprises) was set up before 1965, with 2 of these firms being launched during the 1950s.

The total turnover in 1991 (TABLE 3) and the total personnel in 1991 (TABLE 4) are highly correlated.

TABLE 8.3: TOTAL TURNOVER IN 1991

TURNOVER (x 10 <sup>6</sup> PTE)	ELECTRONICS		MOULDMAKING	
	No.	%	No.	%
Less than 110	5	41.7	3	21.4
110 - 400	5	41.7	5	35.7
More than 400	2	16.7	6	42.9
TOTAL	12 <sup>1</sup>	100.0	14	100.0

<sup>1</sup> 2 missing cases in Electronics

TABLE 8.4: TOTAL PERSONNEL IN 1991

PERSONNEL	ELECTRONICS		MOULDMAKING	
	No.	%	No.	%
Less than 25	6	46.2	3	21.4
Between 25 and 70	5	38.5	5	35.7
More than 70	2	15.4	6	42.9
TOTAL	13 <sup>1</sup>	100.0	14	100.0

<sup>1</sup> 1 missing case in Electronics

In the sample there is a predominance of small/medium sized companies in the electronics industry. This is due to the existence of an appreciable number of recent enterprises (the NTBFs which spun-off from the universities), which are mainly dependent on the technical expertise and know-how of a very small number of highly qualified employees (note that 6 of the electronics firms have at least one researcher/doctoral engineer or scientist among their staff). As these are recent companies, they are still in the early stages of their development, trying to find new market niches for their new products, sometimes depending upon one product only. Therefore, it is natural that in this stage, their profits are not yet very high. In fact, only 2 enterprises, employing more than 70 staff, have a total turnover of more than PTE 400,000,000 (roughly £1,600,000). These 2 firms are Portuguese subsidiaries of multinational corporations, and are the only ones in the sample engaging more than 1,000 persons each (just to prove how truly "micro", in general, are companies in Portugal, in our sample of 28 enterprises we only have 2 with more than 250 employees and 6 with more than 100).

In contrast, the mouldmaking industry is dominated by medium/large firms. Only 3 out of 14 companies have a total turnover of less than PTE 110,000,000 (around £440,000), and also just 3 enterprises employ less than 25 workers. We can explain this by the fact that every mould is unique, it is not mass-

produced, it is manufactured according to rigid specifications and parameters (therefore, its selling price is high), and it is also labour-intensive, thus the need for engaging a substantial number of specialised blue-collar workers.

Turning now to the total salary costs in 1991 (TABLE 5), we can identify two trends in the sample: generally speaking, the employees of electronics firms are well paid, in contrast to those working in the mouldmaking industry.

TABLE 8.5: TOTAL SALARY COSTS IN 1991

SALARY COSTS (x 10 <sup>6</sup> PTE)	ELECTRONICS		MOULDMAKING	
	No.	%	No.	%
Less than 59	3	27.3	6	42.9
59 - 100	5	45.5	3	21.4
More than 100	3	27.3	5	35.7
TOTAL	11 <sup>1</sup>	100.0	14	100.0

<sup>1</sup> 3 missing cases in Electronics

In the electronics industry, while almost half of the companies employ less than 25 people (a small enterprise, according to our taxonomy - Table 4), a similar percentage of firms spends between PTE 59,000,000 and PTE 100,000,000 in salaries - £236,000 to £400,000 - (a medium sized company, according to the same taxonomy - Table 5).

Quite opposite is the panorama in the mouldmaking industry. With respect to employment (Table 4), only 3 out of 14 enterprises are classified as small firms; however, this number increases two-fold when considering total salary costs (Table 5).

The reader may also remember that the initial monthly salary of a graduate engineer who joins a mouldmaking firm is around PTE 120,000 (roughly £480), which is below the level of salaries paid to a graduate engineer in the electronics industry.

24 out of 28 companies have 100% Portuguese participation in their share capital (TABLE 6).

TABLE 8.6: PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

	0%	23%	50%	75%	100%
Electronics	2	-	-	-	12
Mouldmaking	1	-	1	-	12

With respect to foreign ownership, the electronics and the mouldmaking firms enjoy a virtually identical situation, each industry having only 2 out of 14 firms with foreign participation in their share capital. These trends will be better clarified if we also analyse the distribution of the enterprises in the sample according to the ownership by an economic group (TABLE 7).

TABLE 8.7: OWNERSHIP BY AN ECONOMIC GROUP

	YES	%	NO	%	TOTAL	%
Electronics	9	64.3	5	35.7	14	100.0
Mouldmaking	4	28.6	10	71.4	14	100.0

While less than 30% of the mouldmaking companies are owned by an economic group, pointing to one of the main characteristics of the industry (the independence of its enterprises), the electronics industry presents a curious tendency: 9 out of 14 firms belong to an economic group. Bearing in mind that only 2 of these are subsidiaries of multinational corporations, we find out that the majority of the remaining 7 belong to AITEC, the first BIC (Business Innovation Centre) launched in Portugal, in 1986. It resulted from the association of IPE (Investments and State Shareholders) with INESC, a private non-profit university-based research institute, working in the area of engineering and computing systems. It is important to stress this association, as it explains the strong cooperation shown later, when we focus on the electronics industry's linkages with academic research and

with non-profit R&D institutions.

We also believe it is worth considering the number, academic background, and age group of the senior managers of the companies in the sample (TABLES 8.1, 8.2 and 8.3). In Portuguese enterprises, the active participation of the workers in management decisions is very rare. These usually rest with the managers and/or owners of the firms. In the electronics industry in particular, and based upon our set of interviews, its young managers seem more keen to take and accept risks, more inclined to gamble on new products or technologies which have not yet been fully tested but, if successful, will bring a bright (and profitable) future to their companies. Furthermore, although one can learn a lot by running an enterprise day after day, nowadays it is more and more crucial to be endowed with the necessary theoretical instruments, which can often be obtained only by pursuing a postgraduate degree at a University.

From the analysis of the tables, we immediately notice two things. The first is that, on average, the number of senior managers *per firm* varies from 3.54 in electronics, down to 3.29 in mouldmaking (TABLE 8.1).

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TABLE 8.8.1: NUMBER OF SENIOR MANAGERS

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	ENTERPRISES	SENIOR MANAGERS	AVERAGE
Electronics <sup>1</sup>	13	46	3.54
Mouldmaking	14	46	3.29

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<sup>1</sup> 1 missing case in Electronics

Hence, across industries, there seems to exist a certain convergence. The total number of senior managers, both in electronics and in mouldmaking, is 46.

There are some striking differences regarding the academic background (TABLE 8.2) and the age group (TABLE 8.3) of the senior managers of the electronics and the mouldmaking companies in the sample.

TABLE 8.8.2: ACADEMIC BACKGROUND OF SENIOR MANAGERS

ACADEMIC BACKGROUND	ELECTRONICS <sup>1</sup>		MOULDMAKING	
	No.	%	No.	%
Postgraduate Degree	12	26.1	-	-
Degree Level	32	69.6	14	30.4
Pre-Degree Level	2	4.3	32	69.6
TOTAL	46	100.0	46	100.0

<sup>1</sup> 1 missing case in Electronics

TABLE 8.8.3: AGE GROUP OF SENIOR MANAGERS

AGE GROUP	ELECTRONICS <sup>1</sup>		MOULDMAKING	
	No.	%	No.	%
20 - 29 years	10	25.6	1	2.2
30 - 39 years	17	43.6	16	34.8
40 - 49 years	10	25.6	10	21.7
50 - 59 years	2	5.1	11	23.9
60 - 69 years	-	-	6	13.0
More than 69 years	-	-	2	4.3
TOTAL	39	100.0	46	100.0

<sup>1</sup> 2 missing cases in Electronics

In electronics, while more than 25% hold a postgraduate degree (a Master's or a Doctorate), only 4.3% have no degree from a University. In contrast, in mouldmaking, no senior manager holds a postgraduate degree, and almost 70% of them have only a pre-degree level.

Regarding their age group, we find that in electronics 25.6% of senior managers are under 30 years of age, and almost 70% under 40 years (there are no senior managers over 60 years); in mouldmaking, only 1 senior manager is under 30 years of age,

while more than 60% are at least 40 years old (there are even 2 over 69 years of age).

In conclusion, we may state that:

The ELECTRONICS enterprises in the sample are mainly located in the two major cities in the country; they are fairly recent; they are small/medium size in terms of total turnover and total personnel, and of medium size in terms of total salary costs; almost all the firms have 100% Portuguese participation in their share capital, though more than 60% of them are linked to an economic group; and their senior managers are highly qualified academically, with almost 70% of them under 40 years of age;

The MOULDMAKING enterprises in the sample are mainly located around Marinha Grande and Oliveira de Azeméis, in the Portuguese countryside; they were predominantly founded before 1986; they are of medium/large size in terms of total turnover and of total personnel, and of small/large size in terms of total gross expenditures; almost all the firms have 100% Portuguese participation in their share capital, nearly 75% of them being independent from economic groups; and their senior managers are poorly qualified academically, with more than 60% of them over 40 years of age.

### 8.3.2. R&D activities in the enterprises

In general, Portuguese firms do not pay great attention to R&D (Research and Development) (this point was dealt with in more detail in previous chapters). Although R&D activities are developed across all the Portuguese industrial sectors, the distribution of such activities is not even among sectors (or among companies within a sector).

This assertion is well illustrated when analysing TABLE 9.

TABLE 8.9: EXISTENCE OF R&amp;D ACTIVITIES IN THE ENTERPRISE

	YES	%	NO	%	TOTAL	%
Electronics	10	71.4	4	28.6	14	100.0
Mouldmaking	1	7.1	13	92.9	14	100.0

While 10 out of 14 enterprises in electronics perform R&D activities, only 1 out of 14 does the same in the mouldmaking industry. We may be able to explain these different tendencies. The senior managers of the electronics companies are young, highly qualified people. They know that their small/medium sized enterprises have to be very competitive in the marketplace, where they are facing competition from older, well-established, bigger firms. They know they have to find new niches in the market, and they often need to find new products for those niches. Also, technology is changing rapidly in the electronics sector. It is by doing R&D within their companies that they are able to fulfil these goals.

On the other hand, the senior managers of the mouldmaking enterprises are older, and often poorly qualified academically (even though not necessarily so from a managerial perspective). Until recently, the industry was experiencing a "boom" in businesses, sales and profits. Portuguese moulds were (and still are) well-regarded abroad, and the fine finishing of moulds by skilled Portuguese shop floor workers is highly valued. A business philosophy is, as a result of this craft orientation, deeply embedded in many of the Portuguese industries, regarding why firms should embark on formal R&D - which is costly - when competitiveness has been based on fine craft skills.

Cross-tabulating the existence of R&D activities in the enterprise by location, by year of foundation, by firm size, and by the Portuguese participation in the share capital, we obtain a better understanding of the companies in the sample.

In electronics (see Appendix 4), 87.5% of the enterprises located in the Greater Lisboa area (7 out of 8) perform R&D, while 3 out

of 4 firms in the Greater Porto area do not develop R&D activities; 70% of the companies which have R&D activities are quite young (founded after 1986); the small and medium sized enterprises, both in terms of total personnel and of total turnover, are mainly the ones which perform R&D; and 90% of the firms developing R&D activities have 100% Portuguese participation in their share capital.

The only company in the mouldmaking industry which performs R&D is located in Marinha Grande; it was founded in 1975; according to our taxonomy of firms, in terms of total personnel it is a medium sized enterprise; and, the Portuguese participation in its share capital is 100%.

At this stage, let us briefly analyse how the 10 electronics enterprises which develop R&D activities "organise" them. While 8 of the firms have a formal R&D department, and carry out research in a continuous, steady way, a formal, hierarchical structure exists solely in one company. Only 3 enterprises fully support (financially) their R&D activities from internal funds, although it is worth pointing out that 7 out of 10 firms self-finance at least 50% of their own research. Financial support from the Government (particularly from the PEDIP programme) comes second in importance, followed by EU (European Union) R&D programmes (2 companies are 100% backed by these funds). Not less than 65% of R&D is carried out in the research departments of the 10 enterprises, half of these being entirely responsible for their research activities. The number of R&D projects developed by the electronics firms has been also increasing over the years: in 1989, 7 companies carried out 15 research projects; one year later, the same number of enterprises were engaged in 20 R&D projects; and, in 1991, 9 firms were involved in 35 research projects.

Finally, it is interesting to see how the electronics companies in the sample regard the importance of their inter-departmental R&D linkages (TABLE 10) (note that the 4 enterprises which are not performing R&D activities are also included in the table, under the columns "MINOR IMPORTANCE").

TABLE 8.10: IMPORTANCE OF INTER-DEPARTMENTAL LINKAGES

ELECTRONICS	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
R&D/Production and Engineering	10	71.4	-	-	4	28.6
R&D/Marketing and Sales	7	50.0	2	14.3	5	35.7
R&D/Administrative-Financial	4	28.6	4	28.6	6	42.9
R&D/Design	2	14.3	2	14.3	10	71.4

All the firms with R&D activities class the "R&D/Production and Engineering" linkages as of MAJOR IMPORTANCE, and 50% of the companies attribute the same degree of importance to "R&D/Marketing and Sales" links. This is quite natural, bearing in mind that the Portuguese electronics enterprises in the sample are normally of small/medium size in terms of personnel, who in turn are highly qualified. During our research, we found out that the employees in the various departments of these firms (especially in the NTBFs) tend to be interactive, exchanging information frequently. In addition, the same individuals are often simultaneously responsible for the R&D and for the Production and Engineering divisions. Likewise, the close interaction between the R&D and Marketing and Sales departments is one of the basic conditions for a company to become truly competitive in the marketplace. NTBFs, in particular, need to generate cash as quickly as possible, and an aggressive marketing strategy, firmly linked to the launching of new products (or services) developed in the R&D department, is seen as very important. Conversely, almost 75% of the enterprises grade as of MINOR IMPORTANCE the linkages between the R&D and the Design departments. This is because in most, if not all of these firms, R&D and Design are essentially carried out in the same department.

### 8.3.3. Linkages with other enterprises

The present section, as well as the next two, aggregate the major findings of our research. We will be analysing the kind of linkages the firms in the sample establish with other companies. No enterprise produces for itself alone, it is not isolated in the marketplace, it has to pay great attention to a multitude of other agents which interrelate, in quite different ways (sometimes positively, others negatively), with the firm. Some of the main agents influencing the life of a company are its suppliers, customers and competitors. The following tables show how the enterprises in the sample perceive the importance of their suppliers, customers, and competitors.

Suppliers (and particularly customers) are very important for almost all the firms we are studying. In fact, while 78.6% of the companies across the two industries rank as of MAJOR IMPORTANCE their relations with suppliers (TABLE 11), all impute the same importance to their ties with customers (TABLE 12).

TABLE 8.11: DEGREE OF IMPORTANCE OF SUPPLIERS

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	11	78.6	2	14.3	1	7.1
Mouldmaking	11	78.6	2	14.3	1	7.1

TABLE 8.12: DEGREE OF IMPORTANCE OF CUSTOMERS

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	14	100.0	-	-	-	-
Mouldmaking	14	100.0	-	-	-	-

*Per contra*, competitors are only classified as of AVERAGE IMPORTANCE by 57.1% of the firms across-the-board (TABLE 13).

TABLE 8.13: DEGREE OF IMPORTANCE OF COMPETITORS

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	2	14.3	8	57.1	4	28.6
Mouldmaking	2	14.3	8	57.1	4	28.6

These different degrees of importance are quite natural. For any individual company, one of its main goals has to be to sell its products (or services), increasing its market share and gaining as many new customers as possible, while trying not to loose the old ones. It is the only way it can survive and prosper in such a competitive business world as the current one. Obviously, its suppliers are also very important, as they provide the enterprise with all the necessary (raw) materials it needs in order to manufacture its own products. It seems to us that competitors are ranked lower than customers and suppliers just because, in general, firms (particularly in Portugal) tend to undervalue the competition, assuming that their own products (or services) are better, more customer-friendly if you wish, than those of their competitors.

It is interesting to find out that 4 electronics, and 3 mouldmaking companies impute MAJOR IMPORTANCE to "Others" (TABLE 14).

TABLE 8.14: DEGREE OF IMPORTANCE OF "OTHERS"

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	4	28.6	-	-	10	71.4
Mouldmaking	3	21.4	-	-	11	78.6

In the electronics industry, these are **Partners**, enterprises working in the same field (or business), and often closely interacting together (each developing different components of a product for the same customer, for instance). In the mouldmaking industry, on the other hand, "Others" are mainly **Subcontracted Firms**, hired to manufacture a mould (or part of it), in order to shorten production lead times.

Let us now find out where the main suppliers, customers and competitors of the companies in the sample are located (TABLE 15, TABLE 16 and TABLE 17, respectively).

TABLE 8.15: LOCATION OF MAIN SUPPLIERS

LOCATION	ELECTRONICS		MOULDMAKING	
	No.	%	No.	%
Less than 5 kms	2	14.3	-	-
Between 5 - 20 kms	2	14.3	2	14.3
In the District	3	21.4	1	7.1
In Portugal	5	35.7	11	78.6
Abroad	2	14.3	-	-
TOTAL	14	100.0	14	100.0

TABLE 8.16: LOCATION OF MAIN CUSTOMERS

LOCATION	ELECTRONICS		MOULDMAKING	
	No.	%	No.	%
Less than 5 kms	1	7.1	-	-
Between 5 - 20 kms	3	21.4	-	-
In the District	1	7.1	-	-
In Portugal	5	35.7	2	14.3
Abroad	4	28.6	12	85.7
TOTAL	14	100.0	14	100.0

TABLE 8.17: LOCATION OF MAIN COMPETITORS

LOCATION	ELECTRONICS		MOULDMAKING	
	No.	%	No.	%
Less than 5 kms	1	7.1	1	7.1
Between 5 - 20 kms	1	7.1	1	7.1
In the District	1	7.1	2	14.3
In Portugal	5	35.7	6	42.9
Abroad	6	42.9	4	28.6
TOTAL	14	100.0	14	100.0

With respect to electronics, it appears the industry does not have a clearly defined, locational focus regarding its main suppliers, customers and competitors. On the other hand, if we take into account that almost half of the firms in the sample are NTBFS clustered around Instituto Superior Técnico (Higher Technical Institute), in Lisboa, and that they closely interact together, it is not at all surprising that nearly 30% of the companies locate both their main suppliers and customers within a distance of 20 kms. What is interesting, and demonstrates how Portuguese electronics enterprises are becoming more and more competitive in the marketplace, is the fact that 28.6% of them

locate their main customers "Abroad"; furthermore, 6 out of 14 regard as their main competitors foreign firms also located "Abroad". It was clear during the interviews that they do not fear this foreign competition in terms of losing Portuguese market share, but as an obstacle they need to master to conquer new (foreign) markets and customers.

78.6% of the main suppliers of the Portuguese mouldmaking companies are located "In Portugal". The former are enterprises which supply steel to manufacture the moulds, and usually they are Portuguese subsidiaries of German or US multinationals. The reason why, in TABLE 15, they are located "In Portugal", is because they are based far from the two main mouldmaking regions in the country, Marinha Grande and Oliveira de Azeméis. As Portuguese mouldmaking is an export-orientated industry, it is normal to find out that 85.7% of the firms in the sample locate their main customers "Abroad" (this percentage correlates very well with the one reflecting the exports of the whole industry, as we pointed out in a preceding chapter). For more than 70% of the companies in the sample, their main competitors are other Portuguese mouldmaking enterprises. Abroad, Portuguese moulds are well-regarded, well-paid for and, since there are many firms working in this industry, it is only natural to find major competitors in close precincts. It is also worth mentioning that nearly 30% of the companies regard as their main competitors mouldmaking enterprises in Spain, Italy, France and in Germany, as well as some of the Southeast Asian NICs, although for the moment the quality and the finishing of the latter's moulds is quite low if compared with the Portuguese.

In the questionnaire, we asked our interviewees to grade the R&D, the marketing, and the manufacturing relationships of their enterprises with other firms, through time. They were requested to give details regarding past (during the last three years), present (in 1992), and future linkages (for the next three years).

In electronics (TABLE 18), we find four main types of linkage: **Collaborative R&D Linkages** (from no enterprise graduating them as of MAJOR IMPORTANCE in TABLE 18.1, up to 7 in TABLE 18.3);

**Collaborative Marketing Linkages** (from 11 firms rating them as of MINOR IMPORTANCE in TABLE 18.1, down to 5 in TABLE 18.3); **Subcontracting-out Manufacturing Links** (from 8 companies classing them as of MINOR IMPORTANCE in TABLE 18.1, down to 3 in TABLE 18.3); and **Subcontracting-in Manufacturing Links** (from 6 enterprises grading them as of MAJOR IMPORTANCE in TABLE 18.1, up to 9 in TABLE 18.3). This changing pattern characterises well this young, dynamic industry. Below, we will be analysing, in depth, these four types of linkages.

TABLE 8.18.1: IMPORTANCE OF PAST LINKAGES

ELECTRONICS	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
	Contracted-out R&D Linkages	-	-	1	7.1	13
Subcontracted R&D Linkages	3	21.4	2	14.3	9	64.3
Collaborative R&D Linkages	-	-	7	50.0	7	50.0
Agency Linkages	2	14.3	-	-	12	85.7
Collaborative Marketing Linkages	2	14.3	1	7.1	11	78.6
Subcontracting-out Manufacturing Links	2	14.3	4	28.6	8	57.1
Subcontracting-in Manufacturing Links	6	42.9	2	14.3	6	42.9
Licensing Linkages	2	14.3	1	7.1	11	78.6

TABLE 8.18.2: IMPORTANCE OF PRESENT LINKAGES

ELECTRONICS	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
	Contracted-out R&D Linkages	-	-	2	14.3	12
Subcontracted R&D Linkages	3	21.4	3	21.4	8	57.1
Collaborative R&D Linkages	2	14.3	7	50.0	5	35.7
Agency Linkages	3	21.4	1	7.1	10	71.4
Collaborative Marketing Linkages	3	21.4	3	21.4	8	57.1
Subcontracting-out Manufacturing Links	3	21.4	5	35.7	6	42.9
Subcontracting-in Manufacturing Links	7	50.0	1	7.1	6	42.9
Licensing Linkages	2	14.3	1	7.1	11	78.6

TABLE 8.18.3: IMPORTANCE OF FUTURE LINKAGES

ELECTRONICS	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
	Contracted-out R&D Linkages	1	7.1	2	14.3	11
Subcontracted R&D Linkages	5	35.7	2	14.3	7	50.0
Collaborative R&D Linkages	7	50.0	3	21.4	4	28.6
Agency Linkages	3	21.4	4	28.6	7	50.0
Collaborative Marketing Linkages	5	35.7	4	28.6	5	35.7
Subcontracting-out Manufacturing Links	5	35.7	6	42.9	3	21.4
Subcontracting-in Manufacturing Links	9	64.3	2	14.3	3	21.4
Licensing Linkages	3	21.4	1	7.1	10	71.4

In mouldmaking (TABLE 19), only two types of linkages are noticeable: **Subcontracting-out Manufacturing Links** (from 3 firms ranking them as of MAJOR IMPORTANCE in TABLE 19.1, up to 5 in TABLE 19.3); and **Subcontracting-in Manufacturing Links** (although the number of companies classifying them as of MINOR IMPORTANCE actually increases from 6 in TABLE 19.1, up to 7 in TABLE 19.3). We will be also examining these two types of linkages in more detail, below.

TABLE 8.19.1: IMPORTANCE OF PAST LINKAGES

MOULDMAKING	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
	Contracted-out R&D Linkages	-	-	-	-	14
Subcontracted R&D Linkages	-	-	-	-	14	100.0
Collaborative R&D Linkages	-	-	2	14.3	12	85.7
Agency Linkages	-	-	1	7.1	13	92.9
Collaborative Marketing Linkages	-	-	2	14.3	12	85.7
Subcontracting-out Manufacturing Links	3	21.4	9	64.3	2	14.3
Subcontracting-in Manufacturing Links	2	14.3	6	42.9	6	42.9
Licensing Linkages	1	7.1	-	-	13	92.9

TABLE 8.19.2: IMPORTANCE OF PRESENT LINKAGES

MOULDMAKING	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Contracted-out R&D Linkages	-	-	-	-	14	100.0
Subcontracted R&D Linkages	-	-	-	-	14	100.0
Collaborative R&D Linkages	-	-	2	14.3	12	85.7
Agency Linkages	-	-	1	7.1	13	92.9
Collaborative Marketing Linkages	-	-	2	14.3	12	85.7
Subcontracting-out Manufacturing Links	4	28.6	8	57.1	2	14.3
Subcontracting-in Manufacturing Links	1	7.1	7	50.0	6	42.9
Licensing Linkages	1	7.1	-	-	13	92.9

TABLE 8.19.3: IMPORTANCE OF FUTURE LINKAGES

MOULDMAKING	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Contracted-out R&D Linkages	-	-	-	-	14	100.0
Subcontracted R&D Linkages	-	-	1	7.1	13	92.9
Collaborative R&D Linkages	-	-	2	14.3	12	85.7
Agency Linkages	2	14.3	1	7.1	11	78.6
Collaborative Marketing Linkages	1	7.1	7	50.0	6	42.9
Subcontracting-out Manufacturing Links	5	35.7	8	57.1	1	7.1
Subcontracting-in Manufacturing Links	2	14.3	5	35.7	7	50.0
Licensing Linkages	1	7.1	-	-	13	92.9

It is really interesting to note the similarity between TABLE 19.1 (the importance of mouldmaking linkages in the past three years) and the present situation, as shown in TABLE 19.2. Apart from a very small increase in the relevance of **Subcontracting-out Manufacturing Links**, counterbalanced by an equal minimum decrease in the significance of **Subcontracting-in Manufacturing Links**, the linkages among mouldmaking enterprises did not evolve at all. This stable pattern illustrates well this mature industry. It also seems to indicate that, exclusive of "Subcontracting Manufacturing Links" (a major characteristic of the industry), other types of linkages have a very weak importance. Furthermore, the sharp overall increment in the importance of future linkages

(TABLE 19.3), almost certainly reflects a "face-to-face interview" phenomenon (confronted with direct, eyeball-to-eyeball questions, the interviewees tend to point to an idealistic, far better situation in the future).

TABLE 20 and TABLE 21 (discussed right away) are based on the data displayed in TABLE 18.2 and TABLE 19.2, respectively.

TABLE 20.1 shows the nature of collaborative R&D linkage among the electronics firms in the sample.

TABLE 8.20.1: NATURE OF COLLABORATIVE R&D LINKAGES

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Active technical participation	3	33.3	6	66.7	-	-
"Joint-venture"	2	22.2	2	22.2	5	55.6
Customer prototype testing	1	11.1	4	44.4	4	44.4
Temporary transfer of technical staff	-	-	5	55.6	4	44.4
Permanent transfer of technical staff	-	-	-	-	9	100.0
Others	-	-	-	-	9	100.0

<sup>1</sup> 5 missing cases in Electronics

"Active technical participation" is regarded as quite important by all the 9 valid cases. Additionally, more than half of the companies grade as of AVERAGE IMPORTANCE the "Temporary transfer of technical staff". This ranking is natural, if one ponders the weight of NTBFS in the sample, as well as their close, strong interrelationships. Conversely, while only one enterprise attach MAJOR IMPORTANCE to "Customer prototype testing", 4 attribute MINOR IMPORTANCE to it, which indicates that, in terms of collaborative R&D, downstream linkages (with customers) are not yet viewed by the electronics firms in the sample as particularly important.

To discover more about collaborative R&D linkages in electronics, we can use cross-tabulations (see Appendix 4). The 2 companies imputing MAJOR IMPORTANCE (as well as more than half of the enterprises attaching AVERAGE IMPORTANCE) to this type of linkages are located in the Greater Lisboa area, while 60% of the

firms attributing MINOR IMPORTANCE to them are in the Greater Porto area; only companies founded after 1986 rate them as of MAJOR IMPORTANCE; small enterprises, both in terms of total personnel and of total turnover, are mainly the ones which impute AVERAGE/MAJOR IMPORTANCE to them, while the medium and large size firms generally tend to attach MINOR IMPORTANCE to this type of linkages (note that no large company attributes MAJOR IMPORTANCE to them); and only enterprises which have 100% Portuguese participation in their share capital impute MAJOR IMPORTANCE to collaborative R&D linkages.

In TABLE 20.2 we only have 6 valid cases of electronics firms with collaborative marketing linkages; nevertheless, as this type of linkages is steadily increasing through time, we have also decided to examine it.

TABLE 8.20.2: MAIN REASONS FOR COLLABORATIVE MARKETING LINKAGES

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Gain access to new market areas	4	66.7	2	33.3	-	-
Gain knowledge about new market areas	3	50.0	2	33.3	1	16.7
Avoid falling behind competitors	3	50.0	1	16.7	2	33.3
Gain access to complementary products	2	33.3	3	50.0	1	16.7
Gain access to new technical know-how	1	16.7	4	66.7	1	16.7
Others	-	-	-	-	6	100.0

<sup>1</sup> 8 missing cases in Electronics

"Gain access to new market areas", alongside with "Gain knowledge about new market areas" (which acts as a complement to the former) are the main reasons for the Portuguese electronics companies in the sample to engage in collaborative marketing linkages. These enterprises seem to be following a rather determined business strategy, trying to conquer new markets through marketing alliances. It is worth pointing out that "Avoid falling behind competitors", as well as "Gain access to complementary products", are also significant reasons for the firms (and we have been mainly speaking about the NTBFS clustered

in the Greater Lisboa area) to enter in such a type of linkages. Turning again to the cross-tabulations (see Appendix 4), we register, as expected, that more than 50% of the companies class collaborative marketing linkages as of MINOR IMPORTANCE. It is in the Great Porto area that this tendency is particularly strong (75% of enterprises), while 66.7% of the firms grading these linkages as of AVERAGE/MAJOR IMPORTANCE are located in the Greater Lisboa area; companies founded after 1965 are the ones which, predominantly, attach AVERAGE/MAJOR IMPORTANCE to them; similarly, the same classification is correlated with small enterprises (less than 25 employees), while medium and large sized firms mainly attribute MINOR IMPORTANCE to them; in terms of total turnover, the smaller the company, the greater the importance it imputes to collaborative marketing linkages; and, only enterprises with 100% Portuguese participation in their share capital impute AVERAGE/MAJOR IMPORTANCE to this type of linkages.

TABLE 20.3 shows the main reasons why the electronics firms in the sample subcontract manufacturing to other companies.

TABLE 8.20.3: REASONS FOR SUBCONTRACTING-OUT MANUFACTURING LINKS

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Lack of in-house production capacity	4	50.0	2	25.0	2	25.0
Lack of in-house skills	3	37.5	3	37.5	2	25.0
Shorten development lead times	3	37.5	3	37.5	2	25.0
Access to technology new to the firm	3	37.5	1	12.5	4	50.0
Others	-	-	-	-	8	100.0

<sup>1</sup> 6 missing cases in Electronics

The dominant argument is "Lack of in-house production capacity", closely followed by "Lack of in-house skills" and "Shorten development lead times". These are chiefly explained by the fact that 8 out of the 14 enterprises we are studying are quite young (established after 1986) and lack sufficient production capacity (and skills) to satisfy demand. On the other hand, it is worth

pointing out the relatively strong importance of "Access to technology new to the firm" (although 50% of the companies rank it as of MINOR IMPORTANCE, 37.5% attach MAJOR IMPORTANCE to it). This clearly reveals that around half of these electronics enterprises are engaged in a "learning process", linking with other firms with the intention of obtaining knowledge on manufacturing know-how new to them.

Cross-tabulating the importance of subcontracting-out manufacturing links (see Appendix 4), we find out that, while 75% of the companies classifying these linkages as of AVERAGE/MAJOR IMPORTANCE are located in the Greater Lisboa area, 3/4 of the enterprises in the Greater Porto area graduate them as of MINOR IMPORTANCE; the younger firms (founded after 1986) are the ones which, predominantly, attribute AVERAGE/MAJOR IMPORTANCE to this type of linkage; in terms of total turnover, the bigger the company, the smaller the importance it imputes to them; and, only enterprises with 100% Portuguese participation in their share capital impute AVERAGE/MAJOR IMPORTANCE to subcontracting-out manufacturing links.

Finally, let us analyse TABLE 20.4, which lists the reasons why the electronics firms in the sample perform subcontract manufacturing for other companies.

TABLE 8.20.4: REASONS FOR SUBCONTRACTING-IN MANUFACTURING LINKS

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Existence of strong in-house know-how	8	100.0	-	-	-	-
Others	1	12.5	-	-	7	87.5
External managerial influence	-	-	2	25.0	6	75.0
Existence of external pressure factors	-	-	2	25.0	6	75.0
Lack of self managerial autonomy	-	-	1	12.5	7	87.5

<sup>1</sup> 6 missing cases in Electronics

All of them rate as of MAJOR IMPORTANCE the "Existence of strong in-house know-how". The reader should bear in mind that we are referring to 8 enterprises which, in Portuguese terms, are very

high-tech orientated, employing highly qualified staff. It is also worth pointing out that one firm regards "Imports substitution" as a major reason for performing subcontract manufacturing for other companies (we will be dealing in more detail with this medium sized enterprise, when addressing the topic of patenting technological innovations). There are also 2 firms attaching AVERAGE IMPORTANCE to both "External managerial influence" and "Existence of external pressure factors". These are Portuguese subsidiaries of multinational corporations and their top managers are influenced by strategic decisions emanating from their parent-houses.

In our cross-tabulations of the importance of subcontracting-in manufacturing links (see Appendix 4), we notice an almost even dichotomy between the number of companies classing them, on one hand as of MAJOR IMPORTANCE and, on the other hand, as of MINOR IMPORTANCE. However, we have to stress again that, as in all the other cross-tabulations, the missing cases are included under the columns "MINOR IMPORTANCE". Hence, while 50% of the enterprises founded before 1986 attribute MINOR IMPORTANCE to this type of linkages, half of the firms established after that date impute MAJOR IMPORTANCE to them (from all the companies grading the linkages as of MAJOR IMPORTANCE, 2/3 were also founded after 1986); in terms of total personnel, the smaller the enterprise, the greater the importance it imputes to them; small and medium sized firms (by total turnover) are also the ones which tend to rank their linkages as of MAJOR IMPORTANCE, in contrast to large companies, which all classify them as of MINOR IMPORTANCE; and, only 33.3% of enterprises with 100% Portuguese participation in their share capital attach MINOR IMPORTANCE to subcontracting-in manufacturing links.

Let us now turn our attention to the Portuguese mouldmaking firms in the sample, and to their manufacturing relationships.

TABLE 21.1 ranks their main reasons for subcontracting-out manufacturing links.

TABLE 8.21.1: REASONS FOR SUBCONTRACTING-OUT MANUFACTURING LINKS

MOULDMAKING <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Shorten development lead times	9	75.0	2	16.7	1	8.3
Lack of in-house production capacity	7	58.3	3	25.0	2	16.7
Others	3	25.0	-	-	9	75.0
Lack of in-house skills	-	-	3	25.0	9	75.0
Access to technology new to the firm	-	-	1	8.3	11	91.7

<sup>1</sup> 2 missing cases in Mouldmaking

75% of the companies attribute MAJOR IMPORTANCE to "Shorten development lead times", while almost 60% attach the same degree of importance to "Lack of in-house production capacity". These reasons are closely linked together, and characterise pretty well this mature industry. Indeed, the Portuguese mouldmaking industry can basically be defined as an industry depending heavily upon subcontracting linkages. The competition among its enterprises is fierce; in order to gain as many production orders as possible, managers usually tell customers they can manufacture more moulds than they can actually produce. Hence, the "Lack of in-house production capacity", leading to the necessity to subcontract manufacturing to other firms, in order to "Shorten development lead times", thus trying to honour their delivery deadlines. The reason why 3 companies impute MAJOR IMPORTANCE to "Others" is related to this lack of time to fulfil their obligations. It is interesting to note that for 25% of the enterprises, the "Lack of in-house skills" is ranked as of AVERAGE IMPORTANCE. More important than that, 11 out of 12 firms rate "Access to technology new to the firm" as of MINOR IMPORTANCE, which seems to indicate that their senior managers/owners do not require to buy-in manufacturing know-how or technology, but rely upon well-established technology. Frequently, however, this technology is out-of-date, compared with state-of-the-art technology.

In Appendix 5 we present the cross-tabulations of the mouldmaking companies in the sample. Regarding the importance of

subcontracting-out manufacturing links, while 75% of the enterprises located in Oliveira de Azeméis attach MAJOR IMPORTANCE to them, none of the firms in Marinha Grande rank them with the same degree of importance; the small firms (less than 25 employees) are the ones which tend to class this type of linkages as of MAJOR IMPORTANCE, while medium and large size companies grade them as of AVERAGE IMPORTANCE; all the enterprises with foreign participation in their share capital attribute MAJOR IMPORTANCE to subcontracting-out manufacturing links.

When we analyse TABLE 21.2, which refers to subcontracting-in manufacturing links, we find once more the main characteristics of this mature, traditional industry.

TABLE 8.21.2: REASONS FOR SUBCONTRACTING-IN MANUFACTURING LINKS

MOULDMAKING <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Existence of strong in-house know-how	5	50.0	1	10.0	4	40.0
Others	2	20.0	2	20.0	6	60.0
Existence of external pressure factors	-	-	3	30.0	7	70.0
External managerial influence	-	-	2	20.0	8	80.0
Lack of self managerial capability	-	-	-	-	10	100.0

<sup>1</sup> 4 missing cases in Mouldmaking

As many as 40% of the firms impute MINOR IMPORTANCE to the "Existence of strong in-house know-how", which apparently means that their workforce is not highly qualified. Furthermore, 60% of the companies acknowledge the same degree of importance to "Others" (this item consisting mainly of "Lack of in-house production capacity" of other mouldmaking enterprises, as we have explained before). This picture is also the cause for the AVERAGE IMPORTANCE some firms attach to both the "Existence of external pressure factors" and to the "External managerial influence". To find more about the importance of subcontracting-in manufacturing links among the mouldmaking companies in the sample, we use again the cross-tabulations (see Appendix 5).

While all the enterprises located in Marinha Grande attribute AVERAGE IMPORTANCE to this type of linkage, 83.3% of the firms imputing MINOR IMPORTANCE to them are based in Oliveira de Azeméis; the younger the company, the greater the importance it attributes to them; on the other hand, the smaller the enterprise (both in terms of total personnel and in terms of total salary costs), the smaller the importance of these linkages; and, all the firms with foreign participation in their share capital always attach MINOR IMPORTANCE to subcontracting-in manufacturing links.

Finally, we think it is worthwhile to examine the extent of the scientific and technological agreements in which the companies in the sample are engaged in. We believe that the existence of these collaborative contracts are a good measure of how much an enterprise can be truly competitive in the marketplace, particularly if its partners are close to the technological edge of its industry, and especially if it can learn from this collaborative process. TABLE 22 reflects the present situation (in 1992), by industry.

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TABLE 8.22: EXISTENCE OF COLLABORATIVE AGREEMENTS

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	YES	%	NO	%	TOTAL	%
Electronics	6	42.9	8	57.1	14	100.0
Mouldmaking	3	21.4	11	78.6	14	100.0

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In electronics, there is some kind of an equilibrium, with 6 firms cooperating with other companies, while 8 are not (yet) collaborating. *Per contra*, the existence of scientific and technological accords seems to be the exception rather than the rule, in the mouldmaking industry (only just over 20% of its enterprises embark on scientific and technological cooperation). Using cross-tabulations to improve our understanding of how scientific and technological agreements are distributed *per industry*, we notice that, in electronics (see Appendix 4), half

of the companies located in the Greater Lisboa area have this type of contract (66.7% of all the enterprises with these accords are also in this region), while 75% of the firms based in the Greater Porto area do not collaborate (scientifically and technologically) with others; the older the company, the more agreements it establishes (while 60% of the enterprises founded before 1986 cooperate, 62.5% of the younger ones - created after that date - do not), which is not at all a surprising feature, bearing in mind that collaboration, as mentioned above, develops gradually over time; in terms of total turnover, while all the large firms have these contracts, 60% of the small and medium sized companies do not participate in them; and, all the Portuguese subsidiaries of multinational corporations embark in scientific and technological agreements, while 2/3 of the enterprises with 100% Portuguese participation in their share capital do not.

In the mouldmaking industry (see *Appendix 5*), only 3 of the firms in the sample have signed scientific and technological agreements. One is located in *Marinha Grande*, and is also the only one developing R&D activities, while the remaining two are situated in the Greater Porto area, of which one has very strong and close upstream linkages (with suppliers). While the majority of the older companies (because their technological level is very low) and all the younger ones (still with not enough time to initiate them) do not contract this type of accord, 66.7% of all the enterprises cooperating (scientifically and technologically) with others were founded between 1965 and 1986; in terms of total personnel, as well as of total salary costs, the small firms are the ones which, predominantly, are collaborating in scientific and technological agreements; and, more than 80% of the companies with 100% Portuguese participation in their share capital do not embark in this type of contracts.

We can get a better picture of these scientific and technological agreements if we analyse their evolution through time, focussing on the period covering the last three years and the forecast for the next three. In electronics (*TABLE 23*), we find out a sharp increase in the importance and the extent of agreements.

TABLE 8.23.1: IMPORTANCE OF PAST COLLABORATIVE AGREEMENTS

ELECTRONICS	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Portugal	1	7.1	2	14.3	11	78.6
European Union	1	7.1	1	7.1	12	85.7
USA	1	7.1	-	-	13	92.9
EFTA	-	-	-	-	14	100.0
Multilateral Agreements	-	-	-	-	14	100.0
Others	-	-	-	-	14	100.0

TABLE 8.23.2: IMPORTANCE OF FUTURE COLLABORATIVE AGREEMENTS

ELECTRONICS	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
European Union	5	35.7	4	28.6	5	35.7
Portugal	4	28.6	4	28.6	6	42.9
USA	1	7.1	1	7.1	12	85.7
Others	1	7.1	-	-	13	92.9
EFTA	-	-	1	7.1	13	92.9
Multilateral Agreements	-	-	1	7.1	13	92.9

In the past, more than 75% of the companies ranked all types of partnerships as of MINOR IMPORTANCE. They are now forecasting a clear growth across-the-board, and particularly in the agreements with European Union-based enterprises, and with those established in Portugal (note that the European Union overtakes Portugal in the importance of future collaborative agreements, and that one firm is even initiating a scientific and technological partnership with a South Korean company...). This change is mainly explained by the emergence in very recent years of a number of quite aggressive, competitive NTBFs, which have been (successfully) trying to enter (and conquer) new markets, in Portugal and abroad.

In our sample of the mouldmaking industry (TABLE 24), the importance of collaborative agreements was rather small in the past, and its future situation does not seem to be much changed.

TABLE 8.24.1: IMPORTANCE OF PAST COLLABORATIVE AGREEMENTS

MOULDMAKING	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
	European Union	2	14.3	-	-	12
Portugal	1	7.1	-	-	13	92.9
USA	1	7.1	-	-	13	92.9
Others	1	7.1	-	-	13	92.9
EFTA	-	-	1	7.1	13	92.9
Multilateral Agreements	-	-	-	-	14	100.0

TABLE 8.24.2: IMPORTANCE OF FUTURE COLLABORATIVE AGREEMENTS

MOULDMAKING	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
	European Union	3	21.4	2	14.3	9
Others	2	14.3	-	-	12	85.7
Portugal	1	7.1	2	14.3	11	78.6
USA	1	7.1	2	14.3	11	78.6
EFTA	-	-	1	7.1	13	92.9
Multilateral Agreements	-	-	-	-	14	100.0

During the last three years, more than 85% of its enterprises classified them as of MINOR IMPORTANCE, for all types of partnerships. And for the next three, the forecast is... more than 60% of the firms will again rank all of them as of MINOR IMPORTANCE. As explained before, the companies clustered around Marinha Grande traditionally export moulds mostly to the USA, while those in the Oliveira de Azeméis region largely to Europe. Therefore, the weight of the European Union agreements (compared with those established with USA companies) is dependent upon the fact that, while studying 8 enterprises clustered around Oliveira de Azeméis, we only have 3 in the Marinha Grande region. It is also interesting to see that two firms are establishing collaborative agreements, rated as of MAJOR IMPORTANCE, with companies in Israel and Japan.

In conclusion, we may state that:

The ELECTRONICS enterprises in the sample locate both their main suppliers and their main customers "In Portugal", and their main competitors "Abroad"; "Active technical participation" is regarded as the leading driving force for embarking in collaborative R&D linkages; "Gain access to new market areas" and "Gain knowledge about new market areas" (for collaborative marketing linkages), "Lack of in-house production capacity" plus both "Lack of in-house skills" and "Shorten development lead times" (for subcontracting-out manufacturing links), and "Existence of strong in-house know-how" (for subcontracting-in manufacturing links) are the main reasons for electronics firms establishing linkages with other companies. In general, the younger (founded after 1986), small sized enterprises, with 100% Portuguese participation in their share capital, and situated in the Greater Lisboa region, are the ones imputing major importance to their linkages with other firms; and, almost half of the companies are engaged in scientific and technological agreements, with the bigger weight being, predominantly, played by the older, large sized electronics enterprises, with foreign participation in their share capital, and established in the Greater Lisboa area;

The MOULDMAKING enterprises in the sample locate both their main suppliers and their main competitors "In Portugal", and their main customers "Abroad". "Shorten development lead times" and "Lack of in-house production capacity" (for subcontracting-out manufacturing links), and "Existence of strong in-house know-how" (for subcontracting-in manufacturing links) are the main reasons behind their manufacturing relationships; and, they normally do not engage in scientific and technological agreements with other firms.

#### 8.3.4. Linkages with academic research

Considering Portuguese industry as a whole, there are very few linkages with academic research. Furthermore, it seems that academics and business managers do not speak the same language.

The former often "blame" the latter of being only interested in short-term solutions to their problems, disregarding more basic research because it takes time and money. On the other hand, business managers "accuse" academic researchers of being mainly concerned with academic research questions and not being prepared to solve practical problems, like those an enterprise has to face day by day. Essentially, they are both right. The level of R&D expenditures in the Portuguese business sector is extremely low (the sector accounts for less than 30% of the total R&D spending of the country, which is around 50% the average level of R&D disbursements of the European Union business sector). On the other hand, Portuguese universities have been traditionally more teaching-orientated than research-orientated, and the research that has been done has been mainly concerned with basic science. Looking at specific Portuguese industries shows that the extent of their linkages with academic research vary from industry to industry. We will argue that Portuguese high-tech industries (and firms) tend to network more with academic research than the low-tech ones, despite the fact that both high- and low-tech industries (and companies) can ultimately benefit from these linkages (for instance, the assistance of a university metallurgy professor, with her/his knowledge of metals, their chemical structures, and the ways in which they behave and can be used, can be of invaluable importance to a mouldmaking enterprise, particularly knowing that its employers and managers are, as previously shown, usually poorly qualified academically). TABLE 25 shows how the firms in the sample link with academic research.

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TABLE 8.25: EXISTENCE OF LINKAGES WITH ACADEMIC RESEARCH

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	YES	%	NO	%	TOTAL	%
Electronics	11	78.6	3	21.4	14	100.0
Mouldmaking	4	28.6	10	71.4	14	100.0

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78.6% of the companies in the high-tech electronics industry network with academic research, while an almost similar percentage (71.4%) of enterprises in the low-tech mouldmaking industry do not have this type of relationship.

We can use again the cross-tabulations to improve our understanding of the pattern of linkages with academic research. In electronics (see *Appendix 4*), 87.5% of the firms located in the Greater Lisboa area have linkages with academic research; recently founded firms link strongly with academic research (only 1 out of 8 companies launched after 1986 does not have academic contacts); all of the large sized enterprises (both in terms of total personnel and of total turnover) have linkages with academic research, while there is one small and one medium sized firm without them; and, all the companies with foreign participation in their share capital, as well as 75% of the ones with 100% Portuguese participation in it, have linkages with academic research.

In the mouldmaking industry (see *Appendix 5*), only 4 out of 14 enterprises have linkages with academic research; half of them are located in the Greater Porto area, while 87.5% of the firms in Oliveira de Azeméis do not have these type of linkages; none of the younger companies (founded after 1986) has established links with academic research; in terms of total personnel, the enterprises which are, predominantly, collaborating with academic research, are of small and medium size; and, one of the 4 firms with linkages has a foreign participation in its share capital, while 90% of the companies without linkages have 100% Portuguese participation in it.

We can get a better picture of how the linkages with academic research work *per industry* if we analyse the importance of formal, and informal linkages, as well as the main reasons for establishing them.

"Consultancies" are regarded by more than 80% of the electronics companies as the most significant category of formal linkage (TABLE 26.1).

TABLE 8.26.1: IMPORTANCE OF FORMAL LINKAGES

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Consultancies	4	36.4	5	45.5	2	18.2
Use of facilities/scientific equipment	2	18.2	5	45.5	4	36.4
Contracted research	4	36.4	-	-	7	63.6
Support of studentships	2	18.2	3	27.3	6	54.5
Exchange of personnel	1	9.1	4	36.4	6	54.5
Others	-	-	1	9.1	10	90.9

<sup>1</sup> 3 missing cases in Electronics

Many of these enterprises are recently founded NTBFs, spinning-off from an engineering university, and clustered around it. They employ few, young, although highly qualified people (at the very least, they hold a university graduate degree), and they keep in touch with university professors. Therefore, it is not surprising to discover that "Consultancies" are of vital importance to these firms. This reasoning can also be applied to the other categories of formal linkage. Indeed, almost 2/3 of the companies grade the university's "Use of facilities/scientific equipment" as of AVERAGE/MAJOR IMPORTANCE (the laboratories and research departments of a university tend to be better equipped than those of a small, very young, NTBF...). Moreover, this is also why "Contracted research" is ranked as of MAJOR IMPORTANCE by 4 out of 11 enterprises, and why "Support of studentships" and "Exchange of personnel" (from the university to the firm and/or vice-versa) have some relative importance.

With respect to informal linkages (TABLE 26.2), "Personal contacts" have an overwhelming relevance, as more than 90% of the companies classified them as of MAJOR IMPORTANCE (it shows once more how the close relationships between academics and business managers - the simple fact that they know, and talk to, each other personally - can prove to be instrumental, eg, in the solution of problems).

TABLE 8.26.2: IMPORTANCE OF INFORMAL LINKAGES

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Personal contacts	10	90.9	1	9.1	-	-
Attendance of conferences	6	54.5	4	36.4	1	9.1
Membership of professional bodies	2	18.2	6	54.5	3	27.3
Others	-	-	-	-	11	100.0

<sup>1</sup> 3 missing cases in Electronics

Also ranked by 54.5% of the enterprises as of MAJOR IMPORTANCE is the "Attendance of conferences", while the same percentage rates the "Membership of professional bodies" as of AVERAGE IMPORTANCE. It is undeniable that these two categories of informal linkage function as a "forum", where both academics and business managers (most of them sharing the same academic background) exchange information and ideas.

Bearing in mind what we have just said, it is no surprise at all to find out that the two main reasons why the electronics firms link with academic research (TABLE 26.3), classed by all the companies as of AVERAGE/MAJOR IMPORTANCE, are "Contribute to the solution of problems" and "Suggest new ways of solving problems".

TABLE 8.26.3: MAIN REASONS FOR LINKAGES WITH ACADEMIC RESEARCH

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Contribute to the solution of problems	3	27.3	8	72.7	-	-
Suggest new ways of solving problems	2	18.2	9	81.8	-	-
Generate new lines of research	3	27.3	5	45.5	3	27.3
Give advice for use in routine work	2	18.2	6	54.5	3	27.3
Others	-	-	-	-	11	100.0

<sup>1</sup> 3 missing cases in Electronics

It seems that, despite their strong in-house know-how, the

electronics firms sometimes face certain specific challenges they can not overcome by themselves, hence they resort to academic research. Small and medium sized enterprises can have great depth in certain areas, but they also suffer from diseconomies of scope. It is also worth mentioning that around 50% of the firms grade "Generate new lines of research" as of AVERAGE IMPORTANCE, which seems to indicate that they do not depend exclusively upon university laboratories to carry out R&D activities.

In the mouldmaking industry, only 4 companies (in a sample of 14) have linkages with academic research bodies. Thus, the data in the next three tables will refer solely to those enterprises. The most significant category of formal linkages (TABLE 27.1) is "Use of facilities/scientific equipment" (only 1 firm ranks it as of MINOR IMPORTANCE), immediately followed by "Consultancies" (half of the valid cases attribute MAJOR/AVERAGE IMPORTANCE to it).

TABLE 8.27.1: IMPORTANCE OF FORMAL LINKAGES

MOULDMAKING <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Use of facilities/scientific equipment	1	25.0	2	50.0	1	25.0
Consultancies	1	25.0	1	25.0	2	50.0
Contracted research	-	-	2	50.0	2	50.0
Exchange of personnel	-	-	1	25.0	3	75.0
Support of studentships	-	-	-	-	4	100.0
Others	-	-	-	-	4	100.0

<sup>1</sup> 10 missing cases in Mouldmaking

It indicates that these companies are not very well equipped technologically, hence their need for the facilities/scientific equipment the universities place at their disposal. Coming only as second best, "Consultancies" are nevertheless still quite important, as well as "Contracted research", classified by two enterprises as of AVERAGE IMPORTANCE (we have to stress again that, in the whole sample, only one firm is carrying out R&D activities). The panorama outlined above is a visible sign of the

very low-tech stage in which the Portuguese mouldmaking industry still is.

When we analyse the informal linkages with academic research (TABLE 27.2), it seems to us that the business managers are acting more in a passive, rather than in an active way.

TABLE 8.27.2: IMPORTANCE OF INFORMAL LINKAGES

MOULDMAKING <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Attendance of conferences	2	50.0	2	50.0	-	-
Personal contacts	1	25.0	3	75.0	-	-
Membership of professional bodies	1	25.0	-	-	3	75.0
Others	-	-	-	-	4	100.0

<sup>1</sup> 10 missing cases in Mouldmaking

Although the difference between "Attendance of conferences" and "Personal contacts" is minimal, they attach more importance to the former *vis-à-vis* the latter (they tend to listen instead of talking face-to-face with academic researchers).

The main reasons for the mouldmaking enterprises to link with academic research (TABLE 27.3) are basically motivated by the contribution of academia towards the solution of their day-to-day problems.

TABLE 8.27.3: MAIN REASONS FOR LINKAGES WITH ACADEMIC RESEARCH

MOULDMAKING <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Contribute to the solution of problems	1	25.0	3	75.0	-	-
Suggest new ways of solving problems	-	-	4	100.0	-	-
Give advice for use in routine work	-	-	2	50.0	2	50.0
Generate new lines of research	-	-	-	-	4	100.0
Others	-	-	-	-	4	100.0

<sup>1</sup> 10 missing cases in Mouldmaking

It is worth considering that all 4 companies rank "Generate new lines of research" as of MINOR IMPORTANCE.

It is instructive to find out (among the companies with linkages with academic research) how strong are their contacts with R&D activities carried out at academic research bodies. We believe this can be a good indicator of the degree of involvement of the industries (and their enterprises) in R&D activities.

In Portugal, basic research is mainly carried out at the university, and at the polytechnic, level. In electronics, more than 80% of the firms with linkages with academic research have contacts with R&D activities at universities (TABLE 28.1).

TABLE 8.28.1: CONTACTS WITH R&D ACTIVITIES AT UNIVERSITIES

	YES	%	NO	%	TOTAL	%
Electronics <sup>1</sup>	9	81.8	2	18.2	11	100.0
Mouldmaking <sup>2</sup>	-	-	4	100.0	4	100.0

<sup>1</sup> 3 missing cases in Electronics

<sup>2</sup> 10 missing cases in Mouldmaking

This looks quite intuitive, taking into account the percentage of NTBFs in the sample. Conversely, none of the mouldmaking companies develop contacts with R&D activities at universities, which again demonstrates how very low-tech orientated this particular Portuguese industry is.

Polytechnics in Portugal have a lower standard than universities. Hence, it is hardly surprising to find out that, across industries, and among the 15 companies with linkages with academic research, only 3 electronics enterprises have established contacts with R&D activities at polytechnics (TABLE 28.2).

TABLE 8.28.2: CONTACTS WITH R&amp;D ACTIVITIES AT POLYTECHNICS

	YES	%	NO	%	TOTAL	%
Electronics <sup>1</sup>	3	27.3	8	72.7	11	100.0
Mouldmaking <sup>2</sup>	-	-	4	100.0	4	100.0

<sup>1</sup> 3 missing cases in Electronics

<sup>2</sup> 10 missing cases in Mouldmaking

Regarding the sponsorship of engineering/science students (TABLE 29), more than 60% of the enterprises in electronics, and 75% of the mouldmaking ones, do not support students.

TABLE 8.29: SPONSORSHIP OF ENGINEERING/SCIENCE STUDENTS

	YES	%	NO	%	TOTAL	%
Electronics <sup>1</sup>	4	36.4	7	63.6	11	100.0
Mouldmaking <sup>2</sup>	1	25.0	3	75.0	4	100.0

<sup>1</sup> 3 missing cases in Electronics

<sup>2</sup> 10 missing cases in Mouldmaking

In electronics, there is positively no necessity (every year a large number of well-prepared engineering graduates leave the universities, ready to join the Portuguese workforce), while what the mouldmaking industry really needs is to enhance the skills and technical qualifications of its shop floor workers (as well as finding ways of attracting qualified engineers and business managers to the countryside, away from the big city centres, which is indeed a pivotal problem).

Finally, let us find how both formal and informal linkages with academic research have evolved over time, focussing on the period covering the last three years (past linkages) and the forecast for the next three (future linkages).

TABLE 30 presents the evolution of formal linkages.

TABLE 8.30.1: IMPORTANCE OF PAST FORMAL LINKAGES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	4	28.6	5	35.7	5	35.7
Mouldmaking	-	-	2	14.3	12	85.7

TABLE 8.30.2: IMPORTANCE OF FUTURE FORMAL LINKAGES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	6	42.9	7	50.0	1	7.1
Mouldmaking	1	7.1	3	21.4	10	71.4

In electronics, for the last three years period, there was an even distribution, with 4 firms classing their linkages as of MAJOR IMPORTANCE, while the 10 remaining companies graded them as of AVERAGE/MINOR IMPORTANCE. For the next three years we are confronted with a sharp increase in the importance of formal linkages, with only one enterprise imputing MINOR IMPORTANCE to them, compared with 6 firms attaching MAJOR IMPORTANCE to their formal linkages.

In the mouldmaking industry, a slight increase is expected. During the previous three years, 85.7% of companies ranked their formal linkages as of MINOR IMPORTANCE, while for the next three years 71.4% of the enterprises impart the same degree of importance to them.

In terms of informal linkages (TABLE 31), the panorama is rather similar to that of formal linkages, the difference being the former are generally regarded by the companies as more important

than the latter.

TABLE 8.31.1: IMPORTANCE OF PAST INFORMAL LINKAGES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	8	57.1	2	14.3	4	28.6
Mouldmaking	1	7.1	3	21.4	10	71.4

TABLE 8.31.2: IMPORTANCE OF FUTURE INFORMAL LINKAGES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	11	78.6	1	7.1	2	14.3
Mouldmaking	5	35.7	4	28.6	5	35.7

Thus, in electronics, while in the last three years 57.1% of its firms classified their past informal linkages as of MAJOR IMPORTANCE, the percentage related to future informal linkages will rise to 78.6%.

Similarly, in the mouldmaking industry, we find a substantial increase in the importance of informal linkages over time. The number of its companies graduating them as of MINOR IMPORTANCE was 10 in the last three years, while for the next three, that figure will be halved. On the other hand, the number of enterprises attributing MAJOR IMPORTANCE to their informal linkages will be multiplied by five (from 1 to 5).

In conclusion, we may state that:

The ELECTRONICS enterprises in the sample largely link with academic research; they are chiefly located in the Greater Lisboa

area, fairly young (founded after 1986), and mainly of small and medium size, both in terms of total personnel and of total turnover; and, they have 100% Portuguese participation in their share capital (note, however, that all the large sized firms, with 100% foreign participation in their share capital, have linkages with academic research). "Consultancies", followed by "Use of facilities/scientific equipment" and by "Contracted research" are the most important categories of formal linkages, while "Personal contacts" and "Attendance of conferences" stand out in terms of informal linkages. The main reasons for linking with academic research are "Contribute to the solution of problems" and "Suggest new ways of solving problems"; electronics companies frequently establish contacts with R&D activities at universities, but not at polytechnics and, at times, they sponsor engineering/science students; and, they attribute more importance to their informal, than to their formal linkages with academic research;

The MOULDMAKING enterprises in the sample seldom have linkages with academic research; the few which network are mainly located in the Greater Porto area; they are not very young (founded before 1986); and, in terms of total personnel, they are small and medium sized firms. "Use of facilities/scientific equipment" and "Consultancies" are the most important categories of formal linkages, while the most significant informal linkages are "Attendance of conferences" and "Personal contacts". Their main reason for linking with academic research is, basically, the help the latter brings to the solution of their day-to-day problems. Mouldmaking companies do not forge contacts with R&D activities, either at universities or at polytechnics, and they rarely sponsor engineering/science students. They impute more importance to their informal, than to their formal linkages with academic research.

#### 8.3.5. Linkages with public sector institutions

In a previous chapter, we have briefly described the recent

evolution of the Portuguese economy. Well into the 1980s, the public sector played a very important role in the economy, particularly because of the large number of nationalised enterprises, which were then (and some of them still are) owned by the State, as a consequence of the 1974 "Carnation Revolution". As many of those firms were not, under a free-market perspective, (technologically) competitive, Portuguese Governments, mainly to avoid social costs (such as making workers redundant, which would certainly have led to political and social instability), began to spend large amounts of money, massively supporting those burdensome companies. Consequently, many Portuguese nationalised companies (and industries), facing a whole set of quite distinct problems, started to rely heavily upon the country's public sector institutions.

It was not until the 1980s, and particularly after 1986, when Portugal joined the (then) European Community, that the economic situation began to better. Being one of its poorer member states, the country was/is "inundated" with European Union's structural funds, aiming at the improvement of its economy, as a means of bridging the gap which separates Portugal from its northern, wealthier partners. Comprehensive programmes, such as STRIDE (Science and Technology Research into Innovative Developments in Europe) and PEDIP (Programa Específico de Desenvolvimento da Indústria Portuguesa - Specific Programme for the Development of Portuguese Industry) as well as industry-orientated initiatives, like PITIE (Programa Integrado para as Tecnologias da Informação e Electrónica - Integrated Programme for the Information and the Electronics Technologies) were implemented. At last, Governments were able to introduce rational measures regarding the upgrading of Portuguese industry.

This succinct overview was necessary, because we think it is interesting to discover whether or not the two industries (and the firms) we are studying are applying for, and benefiting from, the proposals and programmes launched by the Portuguese Governments and the Commission of the European Communities. We will argue that, in general, the companies are indeed establishing linkages with public sector organisations, although

they seem to be more interested in the inputs they have from public sector institutes, like access to equipment, training facilities, advice, etc, rather than in the available government schemes for assessing external technological know-how.

TABLE 32 shows how the enterprises in the sample link with public sector agencies.

TABLE 8.32: EXISTENCE OF LINKS WITH PUBLIC SECTOR INSTITUTIONS

	YES	%	NO	%	TOTAL	%
Electronics	13	92.9	1	7.1	14	100.0
Mouldmaking	10	71.4	4	28.6	14	100.0

More than 90% of the electronics firms, as well as more than 70% of the mouldmaking ones, network with public sector institutions. In electronics, the only enterprise without linkages with public sector organisations is located in the Greater Lisboa area; it is quite recent (founded after 1986); it is a medium sized firm, in terms of total personnel (employing between 25 and 70 people) and, it has 100% Portuguese participation in its share capital. In the mouldmaking industry (see *Appendix 5*), only 4 out of 14 companies do not have linkages with public sector institutes; half of them are located in Marinha Grande, while 75% of the enterprises in Oliveira de Azeméis have established this type of linkages; all the older firms (founded before 1965) have links with public sector agencies; both in terms of total personnel and of total turnover, the large sized companies are, predominantly, collaborating with public sector institutions; and, one of the enterprises without linkages has a 50% foreign participation in its share capital, while 90% of the firms with linkages have 100% Portuguese participation in it.

It is interesting to discover (among the companies with linkages with public sector agencies) how strong their contacts are with R&D activities carried out at these institutions. This can be a good indicator of the degree of involvement of the industries

(and their enterprises) in R&D activities.

Within Portuguese public sector organisations, R&D activities are mainly carried out at both governmental R&D laboratories, and at non-profit R&D institutes. The latter are a kind of "interface" agencies, associating individual university professors, wishing to pursue research activities (remember that Portuguese universities are mainly teaching-orientated, not research-orientated), alongside full-time scientists employed there, thus enabling the creation of an active, challenging environment, a (theoretically) ideal place for research. The most representative Portuguese non-profit R&D institutions, keeping in mind the industries we are studying, are INESC (Instituto de Engenharia de Sistemas e Computadores - Systems and Computer Engineering Institute), ISQ (Instituto de Soldadura e Qualidade - Welding and Quality Institute), and CATIM (Centro de Apoio Tecnológico à Indústria Metalomecânica - Technological Support Centre for the Metalmechanical Industry), while INETI (Instituto Nacional de Engenharia e Tecnologia Industrial - National Engineering and Industrial Technology Institute) is the most outstanding governmental R&D laboratory.

According to TABLE 33.1, the firms do not particularly favour contacts with governmental R&D laboratories (only 30.8% of the electronics companies and 20% of the mouldmaking ones have contacts with them).

TABLE 8.33.1: R&D CONTACTS WITH GOVERNMENTAL LABORATORIES

	YES	%	NO	%	TOTAL	%
Electronics <sup>1</sup>	4	30.8	9	69.2	13	100.0
Mouldmaking <sup>2</sup>	2	20.0	8	80.0	10	100.0

<sup>1</sup> 1 missing case in Electronics

<sup>2</sup> 4 missing cases in Mouldmaking

Conversely, the electronics enterprises massively contact with non-profit R&D organisations (TABLE 33.2).

TABLE 8.33.2: R&amp;D CONTACTS WITH NON-PROFIT INSTITUTIONS

	YES	%	NO	%	TOTAL	%
Electronics <sup>1</sup>	11	84.6	2	15.4	13	100.0
Mouldmaking <sup>2</sup>	2	20.0	8	80.0	10	100.0

<sup>1</sup> 1 missing case in Electronics

<sup>2</sup> 4 missing cases in Mouldmaking

This trend is explained by the close linkages many of these firms have established with INESC, the private non-profit university-based research institute, associated with the leading engineering university in the country (and a large number of these companies are spin-offs from that university). On the other hand, only 2 mouldmaking enterprises have developed contacts with non-profit R&D agencies, which again demonstrates how low-tech orientated this particular Portuguese industry is.

It is only when we examine the technical inputs from public sector institutions (TABLE 34), that we notice how important they are for the firms which have linkages with public sector organisations, and that they probably are the main reason for the companies establishing this type of linkages (if we exclude the contacts between the electronics enterprises and non-profit R&D institutes).

TABLE 8.34: TECHNICAL INPUTS FROM PUBLIC SECTOR INSTITUTIONS

	YES	%	NO	%	TOTAL	%
Electronics <sup>1</sup>	9	69.2	4	30.8	13	100.0
Mouldmaking <sup>2</sup>	7	70.0	3	30.0	10	100.0

<sup>1</sup> 1 missing case in Electronics

<sup>2</sup> 4 missing cases in Mouldmaking

Around 70% of both the electronics and the mouldmaking firms have

technical inputs from public sector agencies (such as access to equipment, training facilities, advice, and so on).

In contrast, and despite all the programmes and measures launched by the Portuguese Governments and by the Commission of the European Communities, the companies do not seem to take advantage of government schemes in order to assist them to gain access to external technical expertise (TABLE 35).

TABLE 8.35: GOVERNMENT SCHEMES FOR EXTERNAL TECHNICAL EXPERTISE

	YES	%	NO	%	TOTAL	%
Electronics <sup>1</sup>	5	38.5	8	61.5	13	100.0
Mouldmaking <sup>2</sup>	3	30.0	7	70.0	10	100.0

<sup>1</sup> 1 missing case in Electronics

<sup>2</sup> 4 missing cases in Mouldmaking

Of the 23 enterprises which have linkages with public sector institutions, only 8 firms utilise government linkage schemes. It is interesting to note why the remaining 15 companies do not take-up government schemes: they are all aware of their existence; 13 of them are convinced of their usefulness, but consider the application procedures too complicated; 8 enterprises lack resources to handle applications; and, only 6 firms have actually felt the need for the schemes.

Finally, the following tables indicate how both formal and informal linkages with public sector organisations are evolving over time.

TABLE 36 presents the evolution of formal linkages.

TABLE 8.36.1: IMPORTANCE OF PAST FORMAL LINKAGES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	3	21.4	9	64.3	2	14.3
Mouldmaking	2	14.3	7	50.0	5	35.7

TABLE 8.36.2: IMPORTANCE OF FUTURE FORMAL LINKAGES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	7	50.0	6	42.9	1	7.1
Mouldmaking	3	21.4	8	57.1	3	21.4

In electronics, in the last three years, 64.3% of the companies rated their formal linkages as of AVERAGE IMPORTANCE, but indicated a sharp future increase in importance, with only one enterprise imparting MINOR IMPORTANCE to them.

In the mouldmaking industry a small increase is indicated. In the last three years, only 2 companies have classed their formal linkages as of MAJOR IMPORTANCE, while 7 graded them as of AVERAGE IMPORTANCE. For the next three years, 3 enterprises attribute MAJOR IMPORTANCE to them, while 8 attribute AVERAGE IMPORTANCE to them.

In terms of informal linkages (TABLE 37), the panorama is rather similar to that of formal linkages, the difference being the former are generally regarded by the companies as more important than the latter.

TABLE 8.37.1: IMPORTANCE OF PAST INFORMAL LINKAGES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	6	42.9	6	42.9	2	14.3
Mouldmaking	4	28.6	6	42.9	4	28.6

TABLE 8.37.2: IMPORTANCE OF FUTURE INFORMAL LINKAGES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	9	64.3	4	28.6	1	7.1
Mouldmaking	6	42.9	5	35.7	3	21.4

Thus, in electronics, while in the last three years 42.9% of firms ranked their past informal linkages as of MAJOR IMPORTANCE, the percentage related to future informal linkages rises to 64.3%.

Similarly, in the mouldmaking industry, we find an increase in the importance of informal linkages over time. The number of companies rating them as of MAJOR IMPORTANCE was 4 in the last three years, while for the next three, there are 6 enterprises attaching MAJOR IMPORTANCE to them.

In conclusion, we may state that:

Most of the ELECTRONICS enterprises in the sample link with public sector institutes; the only one without this type of linkage is located in the Greater Lisboa area; it is quite recent (founded after 1986); in terms of total personnel, it is a medium sized firm; and, it has 100% Portuguese participation in its share capital. Electronics companies frequently establish R&D

contacts with non-profit agencies, but not with governmental laboratories; they also pay much more attention to technical inputs from public sector institutions than to the available government schemes for external technical expertise; and, they give more importance to their informal, rather than to their formal linkages with public sector organisations;

The majority of the MOULDMAKING enterprises in the sample link with public sector institutes. The firms located at Oliveira de Azeméis predominantly establish this type of linkage. All the older companies (founded before 1965) have linkages with public sector agencies; both in terms of total personnel and of total turnover, the large sized enterprises network with them; and, almost all the firms with 100% Portuguese participation in their share capital link with public sector institutions. Mouldmaking companies do not particularly favour R&D contacts either with governmental laboratories or with non-profit organisations, and they rarely apply for government schemes for external technical expertise; however, most of them have technical inputs from public sector institutes; and, they impute more importance to their informal, than to their formal linkages with public sector agencies.

#### 8.3.6. Technological innovations in the enterprises

Technological innovations generated by a firm are the most valuable indicator of its degree of creativeness and competitiveness. In principle, the more inventive a company is, the more technological innovations it engenders. One important indicator of this process is the patenting of technological inventions by the enterprise. TABLE 38 shows how many of the firms in the sample have taken out patents, during the previous five years.

TABLE 8.38: PATENT TECHNOLOGICAL INVENTIONS

	YES	%	NO	%	TOTAL	%
Electronics	3	21.4	11	78.6	14	100.0
Mouldmaking	-	-	14	100.0	14	100.0

During that period, only 3 electronics companies (10.7% of the whole sample) have patented technological inventions (these enterprises are all located in the Greater Lisboa area; they were founded after 1986; in terms of total personnel, of total turnover, and of total salary costs, and according to our taxonomy of firms, 2 of them are of small size, the remaining being a medium-sized company; and, they all have 100% Portuguese participation in their share capital). Among them, they were responsible for 5 patents, all of them registered in the Portuguese Patent Office only. This paints a rather dismal picture, particularly bearing in mind that electronics is a high-tech industry. However, there is an explanation for this situation. Many of the recent NTBFs are working in the area of Software and Information Services, and software is not usually patented. Furthermore, as we will be showing later, the electronics firms in the sample regard patenting costs as the second most important cost associated with the introduction of technological innovations.

Obviously, if the company is engaged in a process of technological collaboration, either with other enterprises, or with academic research, or with public sector institutions, the conception and development of technological innovations tend to be fostered further afield. This situation is clearly shown in TABLE 39, where we can see that, in the last three years, only one electronics firm has not developed technological innovations (it is located in the Greater Lisboa area, and was founded before 1965; in terms of total personnel, of total turnover, and of total gross expenditures, it is a large enterprise; and, it has 100% foreign participation in its share capital).

TABLE 8.39: DEVELOP TECHNOLOGICAL INNOVATIONS

	YES	%	NO	%	TOTAL	%
Electronics	13	92.9	1	7.1	14	100.0
Mouldmaking	2	14.3	12	85.7	14	100.0

Conversely, in the mouldmaking industry, and during the same period of time, only 2 out of 14 companies have generated technological innovations, which once again points to the very low-tech profile of this Portuguese industry. One of these enterprises is located in Marinha Grande, the other in Oliveira de Azeméis; one was established before 1965, the other between 1965 and 1986; according to our taxonomy of firms, in terms of total personnel, they are of medium, and of large size, respectively, while regarding the total turnover, they are large sized companies; and, they both have 100% Portuguese participation in their share capital.

Since technological innovations are developed by just 2 mouldmaking companies (which is not statistically significant), we are henceforth going to focus our attention on the electronics enterprises in the sample.

TABLE 40 shows the distribution of the technological innovations by **Process Innovation**, by **Product Innovation**, and by **Services Innovation**.

TABLE 8.40: FOCUS OF TECHNOLOGICAL INNOVATIONS

ELECTRONICS <sup>1</sup>	YES		NO		TOTAL	
	No.	%	No.	%	No.	%
New manufacturing/processing techniques	5	38.5	8	61.5	13	100.0
Automation	4	30.8	9	69.2	13	100.0
New organisational structure	5	38.5	8	61.5	13	100.0
New radical products	7	53.8	6	46.2	13	100.0
New "incremental" products	12	92.3	1	7.7	13	100.0
New materials	3	23.1	10	76.9	13	100.0
New consume services	4	30.8	9	69.2	13	100.0
New services to other enterprises	7	53.8	6	46.2	13	100.0
Others	1	7.7	12	92.3	13	100.0

<sup>1</sup> 1 missing case in Electronics

We can easily confirm the outstanding importance of Product Innovation among the electronics firms (more than 90% of them develop technological innovations related to "New "incremental" products" and, for more than half of the companies, their technological innovations generate "New radical products"). However, one has to pay particular attention to the notion of "radical" because, in the Portuguese case, these are products developed essentially by very young NTBFs, which have defined their market niches, and are conceiving specific products (until recently not available in the Portuguese market, mainly as a result of lack of demand) for their particular customers. This does not mean that the same product (or a similar one) can not be obtained in the international market. This accounts for the fact that, for more than half of the electronics enterprises, their technological innovations are associated with "New services to other enterprises" (Services Innovation). Process Innovation, on the other hand, clearly has minor importance (only 5 out of 13 electronics firms relate their technological innovations to "New manufacturing/processing techniques" and to "New organisational structure").

It may be interesting, before analysing the next table, to discover how the technological innovations among these electronics companies are funded. Not surprisingly, more than 60% of the enterprises fully finance them; furthermore, 11 out of 13

firms (almost 85%) back at least half of the cost of their technological innovations (thus, these are heavily self-financed by the companies themselves). In a decreasing order of importance, we can also find technological innovations funded by the Portuguese public sector, by the financial market and, finally, by the private sector (a 20% share in one enterprise) and by the European Union (a 10% share in two firms).

TABLE 41 presents the main reasons for the introduction of technological innovations by the electronics companies.

TABLE 8.41: AIM OF THE INTRODUCTION OF TECHNOLOGICAL INNOVATIONS

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Enter new markets	12	92.3	1	7.7	-	-
Develop new products	10	76.9	1	7.7	2	15.4
Improve existing products	9	69.2	2	15.4	2	15.4
Improve existing equipment's performance	7	53.8	4	30.8	2	15.4
Maintain its market share	7	53.8	4	30.8	2	15.4
Increase productivity	7	53.8	3	23.1	1	7.7
Decrease number of employees	6	46.2	4	30.8	3	23.1
Improve working conditions and safety	3	23.1	4	30.8	6	46.2
Use new (raw) materials	3	23.1	4	30.8	6	46.2
Save energy consumption	3	23.1	3	23.1	7	53.8
Reduce/Eliminate environmental pollution	2	15.4	4	30.8	7	53.8
Others	2	15.4	-	-	11	84.6

<sup>1</sup> 1 missing case in Electronics

"Enter new markets" is classed by all but one enterprise as of MAJOR IMPORTANCE, which shows the degree of dynamism (chiefly led by the NTBFs) presently sweeping the industry (note that only 7 firms attribute the same degree of importance to "Maintain its market share"). Closely associated with that outstanding reason, graded by at least 69% of the companies as of MAJOR IMPORTANCE, are "Develop new products" and "Improve existing products" (remember the prominent importance of Product Innovation, in Table 40). It is also interesting to point out that 53.8% of the enterprises rank as of MAJOR IMPORTANCE both "Improve existing equipment's performance" and its obvious outcome "Increase productivity", while "Decrease number of employees" (classified by 77% of the firms as of MAJOR/AVERAGE IMPORTANCE) is also a

reason for the introduction of technological innovations. Conversely (and quite understandably, attending to the characteristics of the industry), more than half of the electronics companies rank as of MINOR IMPORTANCE both "Save energy consumption" and "Reduce/Eliminate environmental pollution". Finally, 2 enterprises attach MAJOR IMPORTANCE to "Optimise production" (under "Others").

"Development costs" are regarded by the electronics firms as the most important costs associated with the introduction of technological innovations by the companies (TABLE 42).

TABLE 8.42: COSTS OF INTRODUCING TECHNOLOGICAL INNOVATIONS

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Development costs	10	76.9	3	23.1	-	-
Licensing and patenting costs	6	46.2	7	53.8	-	-
Personnel expenditures	6	46.2	6	46.2	1	7.7
Training expenditures	6	46.2	6	46.2	1	7.7
Production equipment costs	4	30.8	8	61.5	1	7.7
Research costs	5	38.5	4	30.8	4	30.8
Commercialisation costs	4	30.8	4	30.8	5	38.5
Design costs	2	15.4	5	38.5	6	46.2
Others	-	-	1	7.7	12	92.3

<sup>1</sup> 1 missing case in Electronics

10 out of 13 enterprises rate this as of MAJOR IMPORTANCE, the remaining 3 class them as of AVERAGE IMPORTANCE. This situation is mainly justified by the relevance the firms attribute to Product Innovation (particularly to "New "incremental" products" and to "New radical products"), which suggests the allocation of substantial amounts of money to carry out the development of those new products. As previously pointed out, "Licensing and patenting costs" are also highly valued by the companies, with none of them grading these costs as of MINOR IMPORTANCE, while 6 enterprises rank them as of MAJOR IMPORTANCE (this is one of the reasons why, during the last five years, only 3 electronics firms have patented technological innovations). A practical example will clarify this problem. A medium-sized company (it

employs 47 staff), located in the Greater Porto area, had devised a new, cheaper process for assembling the electronic parts, and their connections, of silicon chips. Mainly because of patenting costs, as well as to the firm's lack of in-house production capacity, and shortage of (human) resources to handle (complicated) application procedures, at the end of the day that new process was bought, and patented, by a large European corporation, working in the same technological field. Yet, the latter is not producing its chips in accordance with the new process, since it had already allocated huge amounts of money to production facilities, which were designed for its established assembling process. The corporation was concerned with the possibility that a competitor would eventually buy (and patent) the new and superior assembling process devised by the Portuguese enterprise. Personnel-related costs ("Personnel expenditures" and "Training expenditures"), as well as "Production equipment costs" are also quite important, with only one firm attributing MINOR IMPORTANCE to these type of costs. On the other hand, we find no particular trend regarding the importance of both "Research costs" and "Commercialisation costs", while "Design costs" are clearly classified by the companies as of MINOR/AVERAGE IMPORTANCE.

When discussing the main reasons for the introduction of technological innovations by the electronics enterprises (Table 41), we referred to the dynamism, mainly headed by the NTBFs, presently sweeping the industry. It is worth mentioning again how young, and highly qualified academically, their senior managers are, as well as how these high-tech, R&D-orientated firms strongly link with both academic research and non-profit R&D institutions. Even so, those same senior managers clearly adopt a passive stance on the obstacles to the introduction of technological innovations by their companies (TABLE 43).

TABLE 8.43: OBSTACLES TO INTRODUCING TECHNOLOGICAL INNOVATIONS

ELECTRONICS <sup>1</sup>	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Lack of financial support	7	53.8	4	30.8	2	15.4
Lack of fiscal incentives	6	46.2	3	23.1	4	30.8
Lack of governmental support	4	30.8	6	46.2	3	23.1
Market uncertainty	3	23.1	6	46.2	4	30.8
Lack of qualified staff	3	23.1	5	38.5	5	38.5
Difficulty in initiating organic changes	2	15.4	3	23.1	8	61.5
No collaboration from public R&D labs	1	7.7	4	30.8	8	61.5
No collaboration from private R&D labs	-	-	3	23.1	10	76.9
Others	1	7.7	-	-	12	92.3

<sup>1</sup> 1 missing case in Electronics

In fact, the three most important reasons, ranked as of MAJOR/AVERAGE IMPORTANCE by at least 9 out of 13 enterprises ("Lack of financial support", "Lack of fiscal incentives" and "Lack of government support"), are all associated with external financing and external support (from the government). We can thus argue that the Portuguese electronics industry is indeed quite dynamic, and yet it is also very passive. A market-related argument ("Market uncertainty") comes in fourth place, and is rated as of MAJOR IMPORTANCE by 3 firms only, while an equal number of companies attribute the same degree of importance to "Lack of qualified staff". In general, "Difficulty in initiating organic changes", "No collaboration from public R&D labs" and, particularly, "No collaboration from private R&D labs" are not viewed by the electronics enterprises in the sample as significant obstacles to the introduction of technological innovations. Lastly, there is one firm which gives MAJOR IMPORTANCE to "Internal red-tape" (under "Others").

In conclusion, we may state that, between the two industries we are studying, ELECTRONICS shows a certain degree of creativeness. The three very young, small and medium sized companies which, during the last five years, patented technological inventions, all belong to this industry. There is only one electronics enterprise (among 14) which has not developed technological innovations during the last three years. These are primarily

related to Product Innovation ("New "incremental" products" and "New radical products") and, to a lesser degree, to Services Innovation ("New services to other enterprises") and to Process Innovation; the purpose of the introduction of technological innovations is chiefly "Enter new markets", "Develop new products" and "Improve existing products", while their main costs are associated with development, as well as with licencing and patenting; and, the most important obstacles to the introduction of technological innovations by the electronics firms relate to external financing and external support (from the government).

### 8.3.7. Technology transfer in the enterprises

Being a less-developed, peripheral, small, open economy, Portugal is strongly influenced by what happens *chez* its main economic partners, which traditionally have been other European Union countries and the USA. As previously stated, the Portuguese industry is, in general, lagging behind the better equipped, more advanced industries of the developed economies. At present, it is confronted with a big challenge, that is, of technologically catching up with them; this is particularly relevant in the case of the mature, traditional Portuguese industries (like mouldmaking). One way of closing that gap is importing a lot of technology. TABLE 44 shows the acquisition of technology among the 28 companies in the sample, during the last three years.

TABLE 8.44: ACQUISITION OF TECHNOLOGY

	YES	%	NO	%	TOTAL	%
Electronics	4	28.6	10	71.4	14	100.0
Mouldmaking	5	35.7	9	64.3	14	100.0

Only 32.1% of them did embark in the process of buying technology. In essence, at least around 65% of the firms in the

electronics and in the mouldmaking industries do not acquire it. We regard the situation of this second industry with deep concern, since it is quite obvious the urgent need for its technological upgrading.

It is interesting to find out where this technology is coming from (note that one company may buy technology from more than one source).

In electronics, only one enterprise purchased it from European Union countries; 2 firms acquired their technology from other Portuguese companies, while Portuguese universities and non-profit R&D institutions sold technology to one enterprise. This trend points again to the intimate relationships the electronics firms share among themselves, as well as to their close linkages with academic research and with public sector organisations (especially non-profit R&D institutes). All technology transfer contracts involve "transfer of technical knowledge" and "technical assistance"; furthermore, 3 companies have also signed "licencing contracts" and "engineering services and projects", which reveals that they are not merely buying equipment.

On the other hand, in the mouldmaking industry, all contracts of acquisition of technology were celebrated with foreign enterprises (5 of these are established in European Union countries, while 2 USA firms and an equal number of companies based in the EFTA countries transferred their technology to Portuguese mouldmaking enterprises), which again shows the extreme dependence of this mature industry on its (foreign) suppliers of technology. The weight of their technology transfer contracts rests upon "transfer of technical knowledge" and "technical assistance", which proves once more that Portuguese mouldmaking firms basically purchase equipment.

Resorting again to the cross-tabulations (see *Appendix 4*), we find out that all the electronics firms which bought technology are located in the Greater Lisboa area; the year of foundation of the companies seems to have a good correlation with the purchase of technology (all the enterprises established between 1965 and 1986 did not acquire it, while 75% of the buyers were founded after 1986); in terms of total turnover, it is evident

that the small and medium sized firms did not normally purchase technology; and, 75% of the companies with 100% Portuguese participation in their share capital did not acquire technology, as opposed to half of the enterprises with 100% foreign participation in it.

In the mouldmaking industry (see Appendix 5), though around 65% of its firms did not buy technology (which is well proved by the companies based in Oliveira de Azeméis), 2/3 of the enterprises established in Marinha Grande did purchase it, as well as a subsidiary of a multinational corporation, located in the Greater Porto area; with respect to the year of foundation, what is really worrying is the fact that 66.7% of the firms established before 1965 did not acquire technology during the last three years; in terms of total turnover, 2/3 of the companies which did not buy technology are of small and medium size; and, while half of the enterprises with foreign participation in their share capital purchase technology, 66.7% of the companies with 100% Portuguese participation in it did not.

If we now turn our attention to the selling of technology by the firms in the sample, during the last three years (TABLE 45), we face a bleaker panorama.

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TABLE 8.45: SELLING OF TECHNOLOGY

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	YES	%	NO	%	TOTAL	%
Electronics	4	28.6	10	71.4	14	100.0
Mouldmaking	1	7.1	13	92.9	14	100.0

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Only one mouldmaking enterprise (out of 14) supplied it. Even in electronics, less than 30% of its firms sold technology. This situation suggests the negligible capability of Portuguese companies to integrate themselves in the international flows of technology, which leads to the chronic deficit of the Portuguese technology balance of payments.

When we analyse the different recipients of the selling of

technology, we find once more the intimate ties the electronics enterprises in the sample share among themselves, as well as their close relationships with both academic research and public sector institutions (especially with non-profit R&D organisations). All 4 firms supplied technology to other Portuguese companies and to the Government; 2 of them sold technology to non-profit R&D institutes, while universities and even the former Portuguese colonies were buyers of technology supplied by one enterprise (note that one firm may sell technology to more than one customer). The technology transfer contracts celebrated by 3 of these electronics companies involve "licencing contracts", "transfer of technical knowledge" and "technical assistance"; furthermore, 2 of the firms also supplied technology related to "engineering services and projects", which reveals that they are not just selling equipment. These 4 enterprises are all located in the Greater Lisboa area; they are young (founded after 1986); both in terms of total personnel and of total turnover, half of them are small firms, the remaining 2 being medium sized companies; and, they all have 100% Portuguese participation in their share capital.

Not surprisingly, the only mouldmaking enterprise in the sample carrying out R&D activities also sells technology. The purchasers of its technology were not located in Portugal, but in European Union countries, in the former Portuguese colonies, and even in Tunisia. The technology transfer contracts celebrated by the Portuguese firm involve "transfer of technical knowledge", "technical assistance" and "engineering services and projects". This company is located in Marinha Grande; it was founded between 1965 and 1986; according to our taxonomy of enterprises, in terms of total personnel it is a medium sized firm, while in terms of total turnover, it is a large company; and, it has 100% Portuguese participation in its share capital.

#### **8.4. Conclusions**

In the final section of the questionnaire, we asked our

interviewees to ponder over the extent and quality of the linkages their enterprises have established with other firms, with academic research, and with public sector institutions. The following tables reflect their personal views on the issue. Regarding the quality of their linkages with other companies (TABLE 46.1), an overwhelming majority of enterprises across industries class them as of MAJOR IMPORTANCE.

TABLE 8.46.1: QUALITY OF LINKAGES WITH OTHER ENTERPRISES

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	12	85.7	2	14.3	-	-
Mouldmaking	12	85.7	2	14.3	-	-

It shows how strong, close links with suppliers and customers are perceived by the firms as critically relevant to their business strategies.

TABLE 46.2 truly reveals the current state of the two Portuguese industries we are analysing.

TABLE 8.46.2: QUALITY OF LINKAGES WITH ACADEMIC RESEARCH

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	8	57.1	3	21.4	3	21.4
Mouldmaking	2	14.3	1	7.1	11	78.6

We referred above to the intimate, close linkages the electronics firms (particularly the recent NTBFs, spinning-off from an engineering university) have established with academic research;

we also found only one mouldmaking company performing research (moreover, the industry has no contacts at all with R&D activities at universities and at polytechnics). As one would expect, 57.1% of the electronics firms grade as of MAJOR IMPORTANCE their linkages with academic research, while 78.6% of the mouldmaking companies attribute MINOR IMPORTANCE to them. Finally, more than half of the electronics firms classify their linkages with public sector institutions as of MAJOR IMPORTANCE (TABLE 46.3).

TABLE 8.46.3: QUALITY OF LINKAGES WITH PUBLIC SECTOR INSTITUTIONS

	MAJOR IMPORTANCE		AVERAGE IMPORTANCE		MINOR IMPORTANCE	
	No.	%	No.	%	No.	%
Electronics	8	57.1	5	35.7	1	7.1
Mouldmaking	4	28.6	6	42.9	4	28.6

Again, this tendency is explained by the strong linkages many of these companies have established with INESC, the private non-profit university-based research organisation, associated with the leading engineering university in the country. Conversely, 6 out of 14 mouldmaking enterprises impute AVERAGE IMPORTANCE to their linkages with public sector institutes, what is chiefly accounted for by the significant role played by the technical inputs from public sector agencies.

What other main conclusions can we draw from the statistical analysis of the data herein presented?

We may contend that our research hypotheses were validated. Indeed, a distinctive pattern emerged, regarding the extent and quality of the companies' linkages with academic research, and with public sector institutions: Portuguese high technology enterprises (in the electronics industry) preferentially linked with academic research rather than with public sector organisations, while the opposite trend characterised the low-

medium technology mouldmaking firms. In addition, small and medium sized companies were often more likely to establish more linkages than large enterprises.

In view of the density of data presented in this chapter, and the need to highlight the main conclusions, we shall discuss these key points further in the next chapter, and illustrate them with comments made during the interviews.

## 9. HIGHLIGHTS OF THE RESEARCH

In this chapter we shall supplement the analysis given in Chapter 8 with some further observations. These are mainly based on comments made during the interviews. They both confirm the analysis of Chapter 8 and give some additional insights.

Let us start our discussion by focussing on the characteristics of the founders/senior managers of the firms we are studying. It was found that, in electronics, senior managers are highly qualified academically (only a couple of them have no degree from a University), and they are also fairly young (almost 70% of them are less than 40 years of age). This is mainly explained by the fact that many are recent graduates from Técnico, the leading engineering school in Portugal. These characteristics bear important consequences for the networking process of the electronics enterprises in the sample, insofar as the extent of internal technological competences, particularly the quality and quantity of in-house employment of technical specialists, is one of the most significant reasons influencing the willingness and capability to establish external technological links (de Vet and Scott 1992; Dodgson 1993).

Conversely, in mouldmaking, founders/senior managers are poorly qualified academically (less than a third have a University degree), and almost two thirds are over 40 years of age. Their (technical) expertise has been acquired while working as shop-floor workers at (other) mouldmaking firms, usually from a quite tender age. In fact, what may be interesting to stress here is the relevant role which the first mouldmaking enterprise established in Portugal has played in the launching of the industry. Indeed, many managers have told us that they have left that company (Aníbal H. Abrantes) to found their own firms, after having acquired there a high level of training and experience. For example, one interviewee explained that:

"Our firm was founded by 10 partners, who were shop-floor workers at Aníbal H. Abrantes. This number has been

decreasing, and now there are only 4 partners, who are also the owners" (M-09)

This high number of initial partners also relates to a locational dichotomy which can be detected in the Portuguese mouldmaking industry. Indeed, the basic characteristics of the industry at Marinha Grande are different from those at Oliveira de Azeméis. The latter is known by its low employment fluctuation, and by the fact that the firms, which are in general big (in Portuguese terms), tend to be independent from each other, both horizontally and vertically. The companies have few owners, who are inclined to be highly individualistic.

On the other hand, the enterprises located at Marinha Grande are owned by a larger number of persons who, as seen above, have frequently left other mouldmaking companies in the area to start their own business. There is also a strong community spirit, although a high employment fluctuation is noticeable. Finally, many small and medium sized firms are dependent on the larger ones, as well as on the intermediaries, for orders and for selling abroad.

After having conducted our field-work, we think that we are in a position to propose a taxonomy of the Portuguese mouldmaking firms. Enterprises belonging to this traditional industry could be split into five different categories, according to their distinct characteristics at the time of our interviews:

- i) **Globally Integrated Service** firms, are those which have introduced a totally new organisation in their production process, with the help of new technologies;
- ii) **Computing Systems** firms, are those which have introduced CAD/CAM machines in their production process;
- iii) **Production Systems** firms, are those which have only introduced CNC machines in their production process;
- iv) **Technical Consulting** firms, are those which, with the help of new technologies (for example, computer-controlled CNC machines), are assisting other enterprises in their production process; and,
- v) **Conventional** firms, are those which still produce their moulds in a very traditional way.

In spite of such a diverse categorisation of enterprises, we could only find, in our sample, one mouldmaking company which was performing R&D. We think that it would be informative to outline the particular features of this firm.

This small sized firm is part of the world's largest mould engineering group, which comprises a total of 15 companies. These cover a wide range of specific fields of activity, including trading, engineering, training, production, as well as some specialised enterprises. Our firm is one of such specialised companies.

Benefiting from the introduction of new technologies (for instance, it was the first company to install, at the beginning of the 80s, the first CAD/CAM system of the Portuguese mouldmaking industry), associated with the far-reaching possibilities opened up by information technology (Freeman 1991; Mowery 1989; Perrin 1989), it started to work in close cooperation with its customers (the importance of this particular networking process has been emphasised by Lundvall 1988, 1991, 1992c, 1993), in order to design the final product. The use of its CAD/CAM systems further enabled the firm to perform on computer screens, in three dimensions, all conception, modelling, prototype production, design, tooling, and plastic flow testing of the mould, thus achieving the optimum performance of the mould under design, as well as significantly reducing the cost and the delivery time of the moulds it produces.

As the owner of the company explained: "Our clients' technological requirements/specifications have forced us to develop technological innovations in-house" (M-12).

Paying thus particular attention to the technical specifications its customers require for their moulds, and always aiming at producing high-quality moulds, as well as conforming exactly to pre-established delivery dates, the firm has been able to gain its clients' loyalty and trust, which is of paramount importance in successful technological cooperation, as stressed by a number of researchers and scholars (Andersen and Lundvall 1988; Barney and Hansen 1994; Dickson, Smith and Smith 1991; Dodgson 1993; Håkansson 1989; Håkansson and Johanson 1988; Lundvall 1988; Sabel

1993; Saxenian 1991; Smith, Dickson and Smith 1991).

As a consequence, the company seems to be in a very good position for enjoying further market penetration of the higher priced, better quality niche in the market for mouldmaking.

Another interesting feature of the Portuguese mouldmaking industry relates to the distribution of its exports. We had already mentioned in a previous chapter that these are mainly directed towards two large economic areas, Europe and North America. However, one can also notice the dependence of the industry (and consequently of its firms) on a small number of large multinationals.

For example, the senior manager of a mouldmaking firm explained that:

"All our moulds are sold abroad. 2/3 of our exports are directed towards the US market. HASBRO, a big American toy maker absorbs half of our exports to that market. So far as I know, around 15-20 Portuguese mouldmaking firms are working almost exclusively for this client. Our relationship with our biggest client (HASBRO) started while we were still workers at Aníbal H. Abrantes. When we founded this enterprise, HASBRO became one of our first customers" (M-09)

Similarly, the manager of a company which produces moulds for the automobile, electrical equipment, electronics and telecommunications, household appliances, and packaging industries, contended that:

"Our company is specialised in the production of very large moulds. For example, we have produced the moulds for the "Renault Clio" motorcar" (M-13)

The only firm performing R&D activities has amongst its main customers a number of major multinationals in a wide range of industries (automobile, electronics and telecommunications, household appliances, packaging, and toys). In order to further increase user-producer linkages, it has located two of its sales offices abroad, in Sweden and in the UK, where its main clients are based.

Turning to the linkages with other enterprises, it was possible to observe that, while the electronics firms had established

linkages across-the-board (ie, they were active in terms of collaborative R&D linkages, collaborative marketing linkages, subcontracting-out manufacturing links, and subcontracting-in manufacturing links), the networking activities of the mouldmaking companies were restricted to their manufacturing relationships ie, both subcontracting-out, and subcontracting-in, manufacturing links (TABLE 1).

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TABLE 9.1: LINKAGES WITH OTHER ENTERPRISES

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	ELECTRONICS	MOULDMAKING
Collaborative R&D Linkages	*	
Collaborative Marketing Linkages	*	
Subcontracting-out Manufacturing Links	*	*
Subcontracting-in Manufacturing Links	*	*

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We can further enumerate the main reasons why the enterprises in our sample established such kinds of linkages (TABLE 2).

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TABLE 9.2: MAIN REASONS FOR LINKAGES WITH OTHER ENTERPRISES

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	ELECTRONICS	MOULDMAKING
Active technical participation	*	
Gain access to new market areas	*	
Gain knowledge about new market areas	*	
Lack of in-house production capacity	*	*
Lack of in-house skills	*	
Shorten development lead times	*	*
Existence of strong in-house know-how	*	*

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All the electronics firms were involved in active technical participation, not necessarily on a formal basis. This was quite natural, bearing in mind the weight of NTBFs in the sample. In

fact, as Rothwell (1984) had already suggested, the presence of a number of newly founded, research-intensive, small enterprises, is proving to be quite decisive in the emergence of the Portuguese electronics industry. However, taking into account that a considerable percentage of the firms' resources (ranging from 2% to 70% of sales) are allocated to their in-house R&D activities, which is indeed very costly, a valuable supplement to those activities is inter-firm agreements, particularly when involving a complementary mix of in-house R&D coupled to the results of R&D performed elsewhere (Dodgson 1993; Link and Tassej 1987).

Referring now to the collaborative marketing linkages of the electronics firms, it was found that these enterprises seemed to be following a rather determined business strategy, trying to conquer new markets through marketing alliances. Although marketing-based agreements represent the lowest degree of control over technology (IEE 1992), Portuguese electronics companies are actively establishing agreements to act as agents for other firms' equipment in order to supplement the existing product range, and thus gain access to, and knowledge about, new market areas. Such strategy had already been identified by several authors (Beesley and Rothwell 1987; Dodgson and Rothwell 1991; Rothwell 1991; Rothwell and Beesley 1988; Rothwell and Dodgson 1991). For example, the manager of a small (5 employees) electronics firm, specialised in interactive information booths and in computer and multimedia training, told us that: "In Portugal, we represent more than 30 foreign brands" (E-06). Similarly, another enterprise, which develops information management systems and auctions' electronic systems "... depends very much on its marketing agreements" (E-07).

Moving now to the manufacturing relationships of the companies under study, it is interesting to notice that Portuguese mouldmaking firms fully comply with the characteristics of SMEs in traditional industries, proposed by Dodgson and Rothwell (1989a) and Rothwell (1991). As they, alongside with Hobday (1994), Mjøset (1992), and Walsh (1987, 1988) have pointed out, SMEs in traditional industries are currently facing strong

competition from the developing countries, particularly in terms of low labour costs. This was acknowledged by one manager, who argued that:

"East Asian mould producing countries are now competing with the Portuguese mouldmaking industry in terms of price, while Germany is competing in terms of technology" (M-03)

Furthermore, as these enterprises are not expected to generate significant product technological innovations (Pavitt 1984), they are forced to upgrade the quality of their products through an optimal access to existing technology, which normally is exogenously produced.

For example, we have mentioned before that, during the 60s and the 70s, foreign customers started to press for improved technical quality of the moulds. Therefore, mouldmaking firms had to acquire foreign technology, as a means of technologically upgrading their equipment. More recently, with the large influx of EU's structural funds and of PEDIP's funds, the time was ripe for a second wave of modern, technologically up-to-date equipment to be purchased abroad, as a means of further improving the technical quality of the Portuguese moulds and, ultimately, becoming more competitive in the foreign arena.

As was also argued by Freeman (1991), Mowery (1989), and Perrin (1989), the possibility of benefiting from the many opportunities modern microelectronics devices can offer is of paramount importance for these small firms. We have already referred to the case of the Portuguese mouldmaking company which installed the first CAD/CAM system of the industry, at the beginning of the 80s. The introduction of this system, associated with the far-reaching possibilities opened up by information technology, gave the company that purchased it an early technological lead.

This technological complexity and novelty (Barañano 1995b; Dodgson 1989; Mowery 1989; Saxenian 1991), associated with the introduction of new technologies in the Portuguese mouldmaking industry, was extensively reported by several of our interviewees. The owner of a firm which produces moulds for the electronics and telecommunications, and toys industries, argued that:

"We now have 4 CNC machines as well as 2 CAD/CAM machines. We decided to purchase them because our clients started sending their technical specifications for the moulds in "diskette". With this new machinery it was also possible to introduce new products into the market" (M-05)

The manager of another enterprise, specialised in moulds for the electronics and telecommunications, household appliances, automobile, and toys industries, pointed out that:

"At the beginning of the 70s, to comply with an increase in technical complexity of our clients' orders, we had to acquire foreign, newer technology" (M-10)

Finally, the senior manager of a company which produces moulds for the household appliances, electrical equipment, electronics and telecommunications, automobile, and cutlery industries, contended that:

"In 1986, as a response to the technological upgrading of our competitors, both in Portugal and abroad (eg, South Korea and Taiwan), it was decided to follow a similar path. Thus, our factory equipment now comprises 60 machines for producing moulds; 10 of them are CNC machines. We also have 3 CAD/CAM machines" (M-14)

Despite this positive tendency in the industry, it is still possible to find an appreciable number of small mouldmaking firms which have been left out of the picture. They generally lack in-house production capacity, and are thus (heavily) dependent upon subcontracting linkages. This is the case of a company which

"... produces only 40 moulds *per annum*, due to a lack of in-house production capacity. The factory equipment comprises 24 machines for producing moulds; only 1 is a CNC machine" (M-09)

Turning now our attention to the reasons why the enterprises in our sample established linkages with academic research (TABLE 3), it is interesting to note that the mouldmaking firms, besides not contracting research (which is not surprising, in view of the above-mentioned general characteristics of the industry), also do not approach *academia* for the solution of the problems of the industry.

TABLE 9.3: MAIN REASONS FOR LINKAGES WITH ACADEMIC RESEARCH

	ELECTRONICS	MOULDMAKING
Consultancies	*	*
Use of facilities/scientific equipment	*	*
Contracted research	*	
Personal contacts	*	*
Attendance of conferences	*	*
Contribute to the solution of problems	*	
Suggest new ways of solving problems	*	

This situation was clearly expressed by the senior manager of a mouldmaking company, who argued that:

"To solve our day-to-day problems we primarily contact other firms, not academia, and only from time to time we approach public institutions for help" (M-14)

In fact, in Portuguese technical universities there are normally no experts in the production process of moulds for the plastics industry. Such expertise and know-how rest within the mouldmaking enterprises, as well as within CATIM and CENFIM, which are technological support centres for the industry.

On the other hand, one may wonder why one of the main reasons for academic linkage by electronics firms is problem solving, bearing in mind what we have said earlier, that the perception was that academic work was too theoretical, while universities thought that enterprises are only interested in short-term solutions.

For a start, our position is supported by similar opinions advanced by a number of researchers and scientists (Caraça, Gonçalves, Brito, Mateus, Ribeiro, Faisca and Moreno 1993; Corado-Simoes 1991; Fontes and Coombs 1994; GEPIE 1992; OECD 1993b; Ruivo 1991a, 1991b; Simões 1993; Spinnato 1993). However, many of the electronics firms in our sample are modern, niche strategy SMEs. These enterprises, as suggested by Dodgson and Rothwell (1989a), Oakey (1984), and Rothwell (1991), have to perform some in-house R&D, as they need to be innovative in order

to survive. Notwithstanding, to complement their commonly limited in-house R&D resources, the companies also need a frequent access to external sources of scientific and technological expertise, thus establishing formal and informal linkages with academic research (not to mention with other firms and with public sector institutions).

Additionally, many of these enterprises were recently founded NTBFs, spinning-off from an engineering university, and clustered around it. They employ few, young, although highly qualified people (at the very least, they hold a university graduate degree), and they keep in close touch with university professors. Therefore, due to an easy access to universities, it is not surprising to discover the existence of such linkages.

Moreover, universities often are (important) customers of the electronics firms. For example, the manager of a small electronics enterprise told us that:

"We are all graduates from Técnico. We have established strong linkages with the Institute, insofar as it is one of our main clients" (E-06)

Or, again, in the case of another small company which produces and develops equipments in the areas of energy, data communication, and software:

"We have established very close linkages with the Universities of Aveiro and of Coimbra, as well as with LNEC (Laboratório Nacional de Engenharia Civil - National Laboratory for Civil Engineering)" (E-12)

Similarly, when analysing the linkages of the electronics firms with public sector institutions, and in line with what was already suggested by several authors (Dalpé, DeBresson and Xiaoping 1992; Dalum, Fagerberg and Jørgensen 1988; Gregersen 1988, 1992; Rothwell and Zegveld 1981), we confirmed the extremely important role played by these organisations in influencing technical innovation, as well as the role played by the public sector as the single most important (first) user of innovations developed in the private sector. In other words, large, leading-edge customers play an important role both in

"pulling" innovations from their suppliers (Rothwell 1986) and in diminishing the risk and uncertainty associated with the introduction of new products in the marketplace.

For example, the manager of a small firm (23 employees) specialised in software production, told us that:

"We are working very closely with INESC in our core business, software production and development for well-defined markets. Our major clients are the Portuguese parish councils and boroughs" (E-05)

Or, again,

"We produce and develop professional printed circuit boards for large customers eg, banks, the Portuguese electricity and telecommunications companies, etc" (E-12)

Likewise, the manager of a small company (10 employees) which produces equipment for data communication, explained that:

"Our firm has established a strong interaction with CET, which is located nearby. CET is a research centre on telecommunications, and belongs to the State's telecommunications company. We have a small number of clients, although they are all large enterprises, like Portugal Telecom, a number of banks and of insurance companies, hypermarkets, etc" (E-14)

The manager of an electronics enterprise which develops information systems has summarised quite well the strategy pursued by many of the firms in our sample:

"Until very recently, our major clients were some of the larger departments of the Portuguese Public Administration. Now that we are well-established in the market, we are trying to attract other clients, in particular those from the private sector" (E-08)

Finally, we should point out that the involvement in a process of technological collaboration has proved quite important for an electronics company which produces small domestic appliances. Indeed, as the manager of that firm explained:

"We have developed a totally new product, a plastic grill, in cooperation with INESC/Porto. An ASIC (application-specific integrated circuit) has been incorporated into

this new product, thus significantly reducing its production costs.

As a direct consequence of the collaboration with INESC/Porto, we have considerably increased our in-house know-how, upgraded our product portfolio, and conquered new markets" (E-09)

Let us now focus upon an issue of particular relevance to the Portuguese industry in general, one which obviously affects both the electronics and the mouldmaking industries, ie training.

As we have already stressed in a previous chapter, we think that one of the major factors which may explain the very rapid progress in industrialisation and catching up experienced by South Korea and the other Asian tigers relates to their significant efforts in education and training policies (Hou and Gee 1993; Kim 1993).

Conversely, in Portugal, a low level of training persists (Caraça, Gonçalves, Brito, Mateus, Ribeiro, Faísca and Moreno 1993; Corkill 1993), although successive Governments have launched a number of public programmes trying to overcome this situation.

However, the business sector shows a certain disbelief *vis-à-vis* the efficacy and efficiency of such measures. As the manager of a small (31 employees) electronics firm, specialised in educational software, maintains: "In the area of professional training, the PEDIP Programme is poorly managed" (E-03).

Likewise, the only mouldmaking company performing R&D activities was forced to establish its own training organisation, which has now as its sole business the training of all the employees of the group, aiming at developing a world-class labour force capable of taking full advantage of state-of-the-art technology.

Therefore, one may question whether these Government schemes are actually designed to meet the specific needs of the enterprises or, on the contrary, are so generic that they do not provide a solution to the requirements of particular industries (and their individual firms).

In conclusion, and in line with the results of our research, we may contend that the Portuguese electronics firms should try to engage themselves in the exploration of new market niches and in

the strengthening of their close linkages with *academia* and private non-profit research institutions.

On the other hand, the Portuguese mouldmaking enterprises need, first of all, to fully explore the (technological) possibilities of their in-house technology, namely their CAD/CAM and CNC machines. They should also try to lessen the (important) role played by intermediaries, through the establishment and/or improvement of the companies' marketing capabilities. The geographical diversification of exports, and a more balanced portfolio of customers, should also be looked for.

In a second stage, they may consider the introduction of a new philosophy in the human resources, the production, and the marketing departments of the firms, focusing upon their flexibility, in the areas of design, prototype, and production of moulds. Finally, a formal, institutional networking amongst individual companies, as well as their specialisation, producing only for particular industries, eg the household appliances or the automobile ones, may be one of the strategies pursued by the Portuguese mouldmaking industry in the next few years.

Above all, Portuguese firms should be in permanent contact with their clients, should try to constantly upgrade their technological level, through the introduction of new technologies, and should persevere in closing both their productivity and technological gap *vis-à-vis* foreign competitors. In the next chapter we will present the main findings of the thesis, and suggest a number of policy measures and areas for further research.

## 10. CONCLUSIONS

### 10.1. Introduction

This final chapter of the thesis is structured in four parts. We will start by presenting a detailed summary of the thesis, reviewing the main findings of the previous chapters (*point 2*). In *point 3* we will mention some methodological implications. Then, based upon the ideas generated by the research, we will suggest a number of policy measures which might be considered for implementation (*point 4*). Finally, a few areas for future research will be proposed (*point 5*).

### 10.2. Main Findings of the Thesis

The starting point of this thesis was the evidence provided by the earlier literature (eg Corado-Simoes 1991; Fontes and Coombs 1994; Simões 1993) on the relative weakness of the Portuguese national system of innovation (NSI) and, in particular, the weak network of relationships between those institutions which are generally considered to be important for a national system (universities, research institutes, government agencies, firms, etc).

Empirical research in other countries had already stressed the great importance of external linkages. Hence, in this thesis, it was decided to thoroughly analyse the current situation of the external linkages of Portuguese enterprises at the national level, with the intention of improving our knowledge on this issue in order to, on the one hand, consolidate the linkages which already exist and, on the other hand, to generate new linkages which are essential for the establishment of the Portuguese system of innovation.

To achieve that objective, an extensive, detailed analysis of the external linkages of a representative sample of Portuguese firms

was carried out.

We have tried to cover a wide spectrum of the country's industry in our study. Therefore, adapting the taxonomy of sectoral patterns of innovation proposed by Pavitt (1984), we have initially selected three Portuguese industries, biotechnology (a science-based industry), electronics (a technology-based industry), and mouldmaking (a traditional industry).

These particular industries were chosen because of the interest in finding out the extent and quality of their linkages with other enterprises, with academic research, and with public sector institutions.

However, when conducting our field-work, we were immediately confronted with a methodological impediment. Industrial biotechnology, like other science-based industries (for example, engineering ceramics, optoelectronics, or parallel computing), scarcely exists in Portugal. Research in these industries is predominantly concentrated in the laboratories of universities and polytechnics, in private non-profit institutions, and in some specialised government laboratories. In any case, its under-developed embryonic nature is itself an illustration of our main theme.

Such evidence was only empirically substantiated after conducting a set of interviews in a small number of enterprises with marginal interests in the biotechnology field. As a result, the research had to focus exclusively on both the electronics and mouldmaking industries.

To be able to fully comprehend the empirical results from our field-work, it was firstly necessary to be "equipped" with a sound theoretical framework. An extensive survey of the literature in the fields of the theory of innovation, of technological collaboration, and of the recent Portuguese economic, as well as scientific and technological, history was thus conducted.

In Chapter 2 we reviewed previous research on general theories of innovation, focussing on the two leading schools of economic thought, the neo-classical and the evolutionary ones. It was found that the former postulates an over-simplified economic

model, insofar as it maintains that all kinds of firms, large and small, have equal access to credible information and to a freely and effortlessly available technology. Enterprises would thus be able to act with absolute knowledge and foresight.

On the contrary, the evolutionary school provides a far better interpretation of the process of innovation. It strongly stresses the cumulative aspects of technology, the great importance of both incremental and radical innovations, the multiple inputs to innovation from various sources within and outside the firm, and the important role of diffusion in economic growth.

It was also shown that small and large firms contribute in different ways towards the innovation process. The extent of that contribution differs between industries, and is in a continuous process of evolution and change. In some areas, the relative contribution of small enterprises is declining, whereas in other areas it is growing. Furthermore, it also varies with the diffusion, throughout the system, of generic technologies, namely information and communications technology, as well as with the various stages of the industry's life cycle.

In Chapter 3 we concentrated on a survey of the relevant literature on technological collaboration. It was noticed that cooperation between enterprises, and with universities, governmental laboratories, and non-profit research institutions, is a widespread phenomenon. Current developments in science and technology and the changes in the world economy are at the heart of such all-encompassing, structural changes. Indeed, the acceleration of technological change and the shortening of product life cycles, associated with economic, financial, and technological uncertainty, plus the profound impact of information technology across existing enterprises and sectors, led to the emergence of new organisational structures, which include greater technological cooperation and networking.

It was also found, firstly, that every firm has its particular motives for cooperating, and they differ for each individual agreement; secondly, though there are many advantages deriving from industrial collaboration, the presence of numerous obstacles makes it very hard to achieve the desired positive outcomes;

thirdly, that the focuses of cooperation are manifold, depending, among other points, on the firm's industrial sector, the nature of its R&D activities, the stage of the technology life cycle, and the strategic purpose of its linkages; and finally, that the existence of multiple modes of inter-firm cooperation does confirm the complexity of the field of technological collaboration.

It was also shown that increased industrial collaboration is forcing companies to learn new rules of behaviour. In this context, it appears that firms are better off when operating in trustful environments. Trusting relationships between partners may thus turn out to be a crucial element of competitiveness.

In Chapter 4 we discussed a number of issues which are particularly germane to Portugal, a small less advanced country. To start with, it was found that small countries are facing a particular set of problems, due to the increased internationalisation of technological activities. They are being squeezed between large nations which master the world's core technologies, and newly industrialising states which are increasingly producing technologically sophisticated products. Under these conditions, the small country's traditional area of "medium tech" niche products may simply be too narrow.

Another problem concerns the process of catching up on the more technologically competitive nations. It was found that an early entry into new technology systems is a crucial ingredient to succeed in this process, coupled with the existence of a set of institutions interacting very closely together in order to create national competitive advantage and long-term technological capability.

Finally, regarding the contribution of the "national innovation system" to the emergence of national technological opportunities, it was concluded that national characteristics strongly influence the technological activities of domestically-based firms and industries. The important role played by supplier-customer linkages in upgrading technology as well as in reinforcing mutual dependence and trust was also detected.

In Chapter 5 we examined the main characteristics of the

Portuguese scientific and technological (S&T) system, rather than its innovation system, simply because Portugal is a country with an incomplete, non-integrated innovation system. One of the major findings was the remarkable lack of linkages between the four institutional sectors ie, the public, the higher education, the private non-profit, and the business sectors.

Furthermore, and contrary to the majority of OECD countries, it was noticed that Portuguese scientific and technological activities are mainly performed by the public sector, by the higher education sector, and by the private non-profit sector. Nonetheless, a similar set of problems pervades all of them, namely excessive bureaucracy, a general lack of funding and of R&D equipment and instrumentation, a very low rotation of researchers in a number of public R&D institutions, and a geographical imbalance of national R&D capabilities across the country. Moreover, academic research tends to be excessively theoretical, away from the more practical needs of the country's industry.

On the other hand, it was observed that the business sector performs a rather discrete role within the whole of Portugal's S&T system. It is characterised by a rather low level of R&D capacity, both in terms of expenditures and of skilled personnel. Most of its enterprises are concentrated in traditional, low-technology industries. Additionally, purchase of external technology is widely disseminated across industries, which contributes to the country's strong technological dependence.

In Chapter 6 we analysed in greater detail the Portuguese business sector, paying special attention to the Portuguese industries selected for the research, electronics and mouldmaking. A brief overview of the current situation of biotechnology in Portugal was also provided.

It was found that the Portuguese electronics industry is currently experiencing a process of technological change characterised, first, by an increasing mechanisation and/or automation of production and, second, by the dismissal of a large number of its workers. Despite that process, it appears that the industry has not been able to keep pace with the increasing

rhythm of global technological production.

On the other hand, the Portuguese mouldmaking industry has been intensely pervaded by electronics. However, apart from a small number of enterprises which took full advantage of, and benefited the most from, the introduction and diffusion of this technology, the majority of its firms still produce their moulds in a very conventional way. Two further weaknesses were also detected ie, the low productivity of the workforce, and an insufficient and (sometimes) inadequate training in the new technologies.

In Chapter 7 we explained the various steps taken in the process of selecting the enterprises in the sample, and introduced and then described the questionnaire used in the field-work.

Chapter 8 started by explaining how the hypotheses which we sought to test have emerged from the initial literature survey, theoretical framework, and experience of the Portuguese S&T system. Afterwards, it was entirely devoted to the statistical analysis of the data gathered during the field-work. It was found that, with regard to their linkages with other enterprises, an overwhelming majority of both electronics and mouldmaking firms view them as very important, which showed how close, strong links with customers and suppliers were perceived by the firms as critically relevant to their business strategies. Concerning their linkages with academic research, two quite distinct trends were observed. While a significant number of electronics companies (particularly some recent NTBFs) established intimate relationships with academic research (and to a lesser extent with public sector institutions), the mouldmaking enterprises in the sample had no contacts at all with R&D activities carried out at universities and at polytechnics.

With reference to their linkages with public sector institutions, a close interaction between the mouldmaking firms and those institutions was noted, chiefly due to the role of *technical* inputs from the public sector agencies.

In addition, it should be emphasised that, generally speaking, small and medium sized enterprises showed a greater propensity to establish more linkages than the larger companies.

Finally, in Chapter 9 we supplemented the statistical analysis

with comments made during the interviews.

To sum up, in the case of the Portuguese electronics industry, we have learned that a close liaison with a source of science and technology could have positive effects, bearing in mind that the generation of knowledge and technology is, in Portugal, still very reduced. This was especially evident in the case of a number of newly founded, research-intensive, small enterprises, which are exploring new market niches and establishing close linkages with a number of big departments of the Portuguese Public Administration, as well as with some large companies, university laboratories, and private non-profit research institutions, like INESC.

Interestingly enough, a study focussing on the problems of technology access confronted by Portuguese NTBFs has reached a similar set of conclusions. Indeed, after conducting interviews in 28 enterprises, Fontes and Coombs (1994) found that most firms concentrated their efforts on product technology; others used quite extensively external consultants in order to compensate for their limited in-house resources and competences; finally, collaboration with external organisations was of paramount importance for other companies. Moreover, they argue that a large number of the enterprises which use technology transferred from research centres are clustered in fields related to information technologies. This is in tune with our own findings regarding the electronics firms we have contacted.

In the case of the Portuguese mouldmaking industry, it bears, generally speaking, strong resemblances to what Malerba (1993) designates as "the small firms network". It was found that this industry is mainly located in two regions (Marinha Grande and Oliveira de Azeméis), characterised by cultural and social homogeneity, which developed historically on a vocational basis. In those areas, technical change occurs through horizontal linkages amongst a large number of small and medium sized firms. This process has been put into practice by a particular cluster of companies, possessing complementary skills and belonging to a technology-orientated group located in Marinha Grande. Their effective networking gave them (and the group) a distinct

competitive advantage *vis-à-vis* other mouldmaking enterprises outside the network, both in Portugal and abroad.

### 10.3. Methodological Implications

A number of methodological limitations have prevented us from further improving this thesis. We will now briefly elaborate on this subject.

To start with, a particular focus was placed upon the symbiotic relationship between large and small firms. We were hoping to find, during our field-work, evidence supporting the existence of such relationship amongst the enterprises of our sample, in particular at the level of subcontracting manufacturing relationships. It was therefore necessary to be "equipped" with a sound theoretical framework.

Furthermore, even if that relationship was not confirmed in the field, we still think that it was important to study it, bearing in mind its relevance for Portugal, a country which needs to build and strengthen the linkages between the institutions which shape the national system of innovation.

We have already mentioned that the Portuguese business sector is, in general terms, characterised by the existence of a very large percentage of small firms. The same trend also applies to both the electronics and the mouldmaking industries.

Only two large companies, both belonging to the electronics industry, have accepted to participate in the field-work. No large mouldmaking company was part of the study. Consequently, a (comparative) inter-industry analysis of the symbiotic relationship between small and large enterprises could not be addressed in our research.

A second methodological limitation relates to the size of our sample. Due to severe time and budget constraints, we have ended up with a set of (only) 28 enterprises. This may be regarded as a small sample. Moreover, there were only 2 companies with more than 250 employees and 6 with more than 100. Therefore, although we may argue that the industries under study are relatively

homogeneous (at least in relation to firm size), we should be careful when drawing the conclusions of our statistical analysis. A further methodological limitation can be pointed out, ie the non-existence of industrial biotechnology in Portugal. Since we have discussed this issue in previous chapters, as well as its implications for our research, we will not address it again.

#### 10.4. Policy Implications

Based upon the main findings of the thesis, we will try in this section to suggest a number of measures directly related to (public) technology policy, which might be considered for implementation.

The importance of clearly defining a national technology policy was already stressed by Nelson and Rosenberg (1993), who maintain that a country will progressively fall behind if it does not have an explicit technology policy. Moreover, they argue, economic, industrial, and technology policies should be integrated into a coherent framework.

We think that the main issue regarding Portugal's development problem relates to the weak development of its indigenous industry. Portuguese enterprises are relatively passive, normally adopting a reactive attitude towards external influences. Most of them are active in traditional industries, and favour competitive strategies based on cost rather than on product differentiation. Marketing activities are generally viewed as unimportant, and long-term linkages with customers tend to be infrequent..

At a different level, the informal networks of relationships between scientists, entrepreneurs, bankers, government officials and industrialists (Walsh 1988), which often exist in small industrialised countries, are also quite rare in Portugal.

One may thus argue that the country's scientific and technological gap corresponds to its failure to build its own "development blocks" (Dahmén 1989). Indeed, a development block typically involves several domestic sectors (eg producers and

users of goods, private and public organisations, etc) coupled by strong qualitative and quantitative linkages.

This is why the arguments advanced by Lundvall (1988) regarding the geographical proximity between groups of producers and users do have important implications for such a small, less technologically advanced country as Portugal. We have already mentioned that the country's enterprises prefer "to go it alone", since cooperative culture is, in general, lacking in Portugal. However, as technology is constantly changing, there is the strong need to overcome this structural competitive disadvantage, in order to remain competitive in, at least, a few industries. An important first step in this direction would be the reinforcement of the user-producer linkages which already exist in a (small) number of Portuguese industries, as highlighted by our research. We do believe that electronics enterprises (namely the NTBFs clustered around Instituto Superior Técnico, in Lisboa), as well as some of the mouldmaking firms from Marinha Grande, do have the potential for strengthening the already initiated process of close customer-supplier linkages.

In fact, the support and promotion of highly interactive clusters (between local research centres, users and producers, etc) would be important for the improvement of the still incipient Portuguese innovation system, and should therefore be actively encouraged.

A major task for Portugal in the years ahead must thus be to further integrate and consolidate its "development blocks" and to build up a solid Portuguese system of innovation. Only this may solve some of the problems identified in this research.

Portugal faces a particularly complicated set of problems. To a large extent it did not develop its own national version of the "Fordist" mass production/mass consumption model, which proved to be of utmost importance in the reorganisation of European manufacturing industries after World War II.

However, in order to overcome the challenges of the new techno-economic paradigm, Portugal does not need to develop itself into a "Fordist" latecomer. On the contrary, it needs to find its position in the restructuring race, on the grounds of having

missed those "Fordist" opportunities, which could even give the country certain advantages. Ultimately, whether Portugal can grasp the new techno-economic paradigm will largely depend on its (improved) national system of innovation.

Furthermore, being a small less advanced country, with an open economy, Portugal also needs to find the best strategy to overcome the specific problems associated with smallness.

A number of strategies were already proposed by Corado-Simoes (1991) and Walsh (1987, 1988). We do believe that a mix of three strategies, namely "finding niches in the market", "specialisation", and "cooperation with other countries" (with the prevalence of one over the others according to specific circumstances, industries, and technological areas) may be the most appropriate way for Portugal to initiate a process of catching up in technology and, ultimately, to build up a strong national innovation system.

Portuguese policy-makers should consider in earnest the latter strategy. Cooperation with Portugal's sole neighbour, Spain (which itself is a small less developed country) will offer Portuguese enterprises the possibility of entering a wider market, that of the Iberian Peninsula, as well as the chance to catch up in some technological areas where Spanish companies are more advanced. A significant increase in intra-Iberian trade is already reported, following the accession of both countries to the (then) European Community.

The establishment of closer, stronger (trade) linkages with more advanced industrial nations (as is the case of Spain) may also facilitate Portugal's progressive integration in a network of intra-industry trade between some of the most dominant industrial countries.

Mjøset (1992) illustrates this point quite well in his study. He maintains that, when Germany became one of the world's leading industrial economies at the beginning of the 1900s, Switzerland and the Nordic countries moved quickly to increase their ties with Germany. They were thus able to absorb not only technologies, but also management strategies and organisational forms pioneered in Germany (for a detailed account of the

evolution of the German innovation system see, for example, Keck 1993). Conversely, Ireland's almost exclusive reliance upon (a declining) Britain only aggravated its structural dependence. However, this was offset by much closer links with US multinationals.

This example reinforces our idea that one of the possible strategies which Portugal (and Portuguese-based enterprises) may follow in order to overcome some of its specific disadvantages lies in strengthening its linkages with Spain (and Spanish-based firms). A first step would be to consider the Iberian Peninsula as its "home" market.

To sum up, we would argue that it is no longer enough for a country to have an explicit S&T policy, a system of competent institutions with some centres of excellence, a few enterprises performing R&D and collaborating with universities, even a few successful exporters with mastery of technology. Improving the Portuguese system of innovation goes far beyond just strengthening the current Portuguese S&T infrastructure. It requires the enhancement of its linkages, as well as acting upon the whole spectrum of policies and upon such intangible factors as national attitudes and values. Under the new world conditions, economic success requires widespread innovativeness, and the engagement of the whole society in innovation, not just a selected group of experts or some first-class companies or institutions.

#### 10.5. Further Research

Finally, let us suggest a few topics for future research: Firstly, the replication of the methodology herein used in i) other Portuguese traditional industries, eg clothing, cork, footwear, or textiles, and in ii) other Portuguese technology-based industries, eg chemicals, or mechanical engineering, to confirm whether our results apply to those industries; Secondly, the comparison between ours and similar studies carried out abroad, namely the comparison with other studies on national

innovation systems, particularly those related to small less advanced European countries, eg Greece, Ireland, or Spain, identifying the ways and means by which those countries overcome their structural disadvantages;

Thirdly, additional research on the Portuguese system of innovation, focussing on national advantages, and linking them to an evaluation of industrial policy measures.

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**QUESTIONNAIRE**

RESEARCH PROJECT

**THE INTER-INSTITUTIONAL LINKAGES  
OF PORTUGUESE SMES**

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The confidentiality of the interviewee and/or its enterprise as well as the data collected is guaranteed. The latter will only be used in aggregate and for statistical purposes.

**INSTRUCTIONS**

A weighted scale (1 to 5) is employed in the questionnaire. It reflects the importance the interviewees attribute to the various questions they are requested to answer.

The value zero (0) indicates that the respondent "does not know/does not reply".

**Weighted scale:**

- 1: Irrelevant
- 2: Minor importance
- 3: Average importance
- 4: Major importance
- 5: Extremely important

A) BACKGROUND OF THE ENTERPRISE

1.- NAME OF THE ENTERPRISE \_\_\_\_\_

2.- LOCATION:

- Place \_\_\_\_\_  
- District \_\_\_\_\_

3.- YEAR OF FOUNDATION \_\_\_\_\_

4.- PRINCIPAL CLASSIFICATION OF ECONOMIC ACTIVITIES \_\_\_\_\_

5.- MAIN PRODUCTS \_\_\_\_\_

6.- HOW MANY ESTABLISHMENTS HAS THE ENTERPRISE? \_\_\_\_\_

7.- WHERE IS LOCATED ITS MAIN ESTABLISHMENT? \_\_\_\_\_

8.- SIZE OF THE ENTERPRISE:

- ⇒ Total Turnover (x 10<sup>6</sup> PTE)
- ⇒ Total Personnel, of which:
  - Researchers/Postgraduates
  - University graduates
  - Other qualified technicians
  - Administrative staff
  - Shop floor workers
- ⇒ TOTAL SALARY COSTS (x 10<sup>6</sup> PTE)

	91	90	89

9.- HOW MANY EMPLOYEES WORK IN THE FOLLOWING DEPARTMENTS:

- ⇒ Production and engineering?
- ⇒ R&D?
- Design?
- Marketing and sales?
- ⇒ Administrative-financial?

	91	90	89

10.- PONDER OVER THE IMPORTANCE OF THE INTER-DEPARTMENTAL LINKAGES BETWEEN THE R&amp;D DEPARTMENT AND THOSE OF:

- Production and engineering
- Design
- Marketing and sales
- Administrative-financial

	0	1	2	3	4	5

11.- DIVISION OF THE SHARE CAPITAL (IN PERCENTAGE):

- ⇒ Portuguese participation: \_\_\_\_\_ %
  - Cooperative sector \_\_\_\_\_ %
  - Private sector \_\_\_\_\_ %
  - Public sector \_\_\_\_\_ %
- ⇒ Foreign participation \_\_\_\_\_ %

12.- IS THE ENTERPRISE OWNED BY AN ECONOMIC GROUP?

Which one? \_\_\_\_\_ Y / N

13.- TOTAL NUMBER OF SENIOR MANAGERS \_\_\_\_\_



22.- IS THERE A FORMAL, INSTITUTIONALISED, RESEARCH CAREER IN THE ENTERPRISE?

Y / N

23.- SIZE OF THE R&D DEPARTMENT OF THE ENTERPRISE:

Total Personnel, of which:

- Researchers/Postgraduates
- University graduates
- Other qualified technicians
- Administrative staff
- Shop floor workers

	91	90	89

24.- EXPENDITURE ON R&D ACTIVITIES (x 10<sup>3</sup> PTE), OF WHICH:

TOTAL

- Salaries
- Other current expenditures
- Facilities
- Scientific and technical equipment

	91	90	89

25.- NUMBER OF R&D PROJECTS DEVELOPED BY THE ENTERPRISE:

	91	90	89

26.- WHAT PERCENTAGE OF ITS TOTAL R&D EXPENDITURES DEVOTE THE ENTERPRISE TO ITS R&D PROJECTS? \_\_\_\_\_ %

27.- DOES THE ENTERPRISE PERFORM R&D WORK FOR OTHER COMPANIES (SUBCONTRACTING)?

Y / N

28.- DOES THE ENTERPRISE HAVE ANY OTHER KIND OF RELATIONSHIP WITH THESE COMPANIES?

- Customers
- Suppliers
- Competitors
- Others (specify) \_\_\_\_\_

Y / N

Y / N

Y / N

Y / N

### C) LINKAGES WITH OTHER ENTERPRISES

29.- DOES YOUR ENTERPRISE HAVE ANY KIND OF FORMAL OR INFORMAL LINKAGES WITH OTHER COMPANIES?  
(If N, go to question 46)

Y / N

30.- ARE THOSE COMPANIES MAINLY:

- Suppliers to your enterprise?
- Customers of your enterprise?
- Competitors of your enterprise?
- Others? (specify) \_\_\_\_\_

0 1 2 3 4 5

0 1 2 3 4 5

0 1 2 3 4 5

0 1 2 3 4 5

31.- ARE THOSE COMPANIES MAINLY LOCATED (IN RELATION TO YOUR ENTERPRISE):

- Less than 5 Kms.?
- Between 5 - 20 Kms.?
- In the District?
- In Portugal?
- Abroad?

SUP. CUS. COM.

Y / N Y / N Y / N

Y / N Y / N Y / N

Y / N Y / N Y / N

Y / N Y / N Y / N

Y / N Y / N Y / N

## 32.- PONDER OVER THE IMPORTANCE OF THE LINKAGES BETWEEN YOUR ENTERPRISE AND OTHER COMPANIES AS:

- |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| - Contracted-out R&D Linkages               | 0 | 1 | 2 | 3 | 4 | 5 |
| - Subcontracted R&D Linkages                | 0 | 1 | 2 | 3 | 4 | 5 |
| - Collaborative R&D Linkages                | 0 | 1 | 2 | 3 | 4 | 5 |
| - Marketing relationships:                  |   |   |   |   |   |   |
| - Agency Linkages                           | 0 | 1 | 2 | 3 | 4 | 5 |
| - Collaborative Marketing Linkages          | 0 | 1 | 2 | 3 | 4 | 5 |
| - Manufacturing relationships:              |   |   |   |   |   |   |
| - Subcontracting-out Manufacturing Linkages | 0 | 1 | 2 | 3 | 4 | 5 |
| - Subcontracting-in Manufacturing Linkages  | 0 | 1 | 2 | 3 | 4 | 5 |
| - Licencing Linkages                        | 0 | 1 | 2 | 3 | 4 | 5 |

## 33.- THE MAIN REASONS UNDERLYING THE ENTERPRISE'S CONTRACTED-OUT R&amp;D LINKAGES ARE:

- |  |   |   |   |   |   |   |
|--|---|---|---|---|---|---|
| - To gain access to technology new to the enterprise | 0 | 1 | 2 | 3 | 4 | 5 |
| - To shorten development lead times                  | 0 | 1 | 2 | 3 | 4 | 5 |
| - Lack of in-house skills                            | 0 | 1 | 2 | 3 | 4 | 5 |
| - Lack of in-house R&D capacity                      | 0 | 1 | 2 | 3 | 4 | 5 |
| - Others (specify) _____                             | 0 | 1 | 2 | 3 | 4 | 5 |

## 34.- THE MAIN REASONS UNDERLYING THE ENTERPRISE'S SUBCONTRACTED R&amp;D LINKAGES ARE:

- |  |   |   |   |   |   |   |
|--|---|---|---|---|---|---|
| - Existence of strong in-house know-how  | 0 | 1 | 2 | 3 | 4 | 5 |
| - External managerial influence          | 0 | 1 | 2 | 3 | 4 | 5 |
| - Existence of external pressure factors | 0 | 1 | 2 | 3 | 4 | 5 |
| - Lack of self managerial autonomy       | 0 | 1 | 2 | 3 | 4 | 5 |
| - Others (specify) _____                 | 0 | 1 | 2 | 3 | 4 | 5 |

## 35.- THE NATURE OF THE ENTERPRISE'S COLLABORATIVE R&amp;D LINKAGES IS:

- |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| - Active technical participation        | 0 | 1 | 2 | 3 | 4 | 5 |
| - "Joint-venture"                       | 0 | 1 | 2 | 3 | 4 | 5 |
| - Customer prototype testing            | 0 | 1 | 2 | 3 | 4 | 5 |
| - Temporary transfer of technical staff | 0 | 1 | 2 | 3 | 4 | 5 |
| - Permanent transfer of technical staff | 0 | 1 | 2 | 3 | 4 | 5 |
| - Others (specify) _____                | 0 | 1 | 2 | 3 | 4 | 5 |

## 36.- THE MAIN REASONS UNDERLYING THE ENTERPRISE'S AGENCY LINKAGES ARE:

- |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| - Gain access to new market areas       | 0 | 1 | 2 | 3 | 4 | 5 |
| - Gain knowledge about new market areas | 0 | 1 | 2 | 3 | 4 | 5 |
| - Avoid falling behind competitors      | 0 | 1 | 2 | 3 | 4 | 5 |
| - Gain access to complementary products | 0 | 1 | 2 | 3 | 4 | 5 |
| - Gain access to new technical know-how | 0 | 1 | 2 | 3 | 4 | 5 |
| - Others (specify) _____                | 0 | 1 | 2 | 3 | 4 | 5 |

## 37.- THE MAIN REASONS UNDERLYING THE ENTERPRISE'S COLLABORATIVE MARKETING LINKAGES ARE:

- |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| - Gain access to new market areas       | 0 | 1 | 2 | 3 | 4 | 5 |
| - Gain knowledge about new market areas | 0 | 1 | 2 | 3 | 4 | 5 |
| - Avoid falling behind competitors      | 0 | 1 | 2 | 3 | 4 | 5 |
| - Gain access to complementary products | 0 | 1 | 2 | 3 | 4 | 5 |
| - Gain access to new technical know-how | 0 | 1 | 2 | 3 | 4 | 5 |
| - Others (specify) _____                | 0 | 1 | 2 | 3 | 4 | 5 |

## 38.- THE MAIN REASONS UNDERLYING THE ENTERPRISE'S SUBCONTRACTING-OUT MANUFACTURING LINKAGES ARE:

- |  |   |   |   |   |   |   |
|--|---|---|---|---|---|---|
| - Lack of in-house production capacity | 0 | 1 | 2 | 3 | 4 | 5 |
| - Lack of in-house skills              | 0 | 1 | 2 | 3 | 4 | 5 |
| - Shorten development lead times       | 0 | 1 | 2 | 3 | 4 | 5 |
| - Access to technology new to the firm | 0 | 1 | 2 | 3 | 4 | 5 |
| - Others (specify) _____               | 0 | 1 | 2 | 3 | 4 | 5 |

## 39. - THE MAIN REASONS UNDERLYING THE ENTERPRISE'S SUBCONTRACTING-IN MANUFACTURING LINKAGES ARE:

- Existence of strong in-house know-how	0	1	2	3	4	5
- External managerial influence	0	1	2	3	4	5
- Existence of external pressure factors	0	1	2	3	4	5
- Lack of self managerial autonomy	0	1	2	3	4	5
- Others (specify) _____	0	1	2	3	4	5

## 40. - THE MAIN REASONS UNDERLYING THE ENTERPRISE'S LICENCING LINKAGES ARE:

- Gain access to new market areas	0	1	2	3	4	5
- Gain knowledge about new market areas	0	1	2	3	4	5
- Avoid falling behind competitors	0	1	2	3	4	5
- Gain access to complementary products	0	1	2	3	4	5
- Gain access to new technical know-how	0	1	2	3	4	5
- Others (specify) _____	0	1	2	3	4	5

## 41. - DOES THE ENTERPRISE BENEFIT FROM THE EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS?

Are its partners located in:	Y	/	N
- Portugal?	Y	/	N
- European Union?	Y	/	N
- EFTA?	Y	/	N
- United States of America?	Y	/	N
- Multilateral agreements?	Y	/	N
- Others? (specify) _____	Y	/	N

## 42. - PONDER THE IMPORTANCE, DURING THE LAST THREE YEARS, OF YOUR ENTERPRISE'S LINKAGES WITH OTHER COMPANIES IN THE FOLLOWING AREAS:

- Contracted-out R&D Linkages	0	1	2	3	4	5
- Subcontracted R&D Linkages	0	1	2	3	4	5
- Collaborative R&D Linkages	0	1	2	3	4	5
- Marketing relationships:						
- Agency Linkages	0	1	2	3	4	5
- Collaborative Marketing Linkages	0	1	2	3	4	5
- Manufacturing relationships:						
- Subcontracting-out Manufacturing Linkages	0	1	2	3	4	5
- Subcontracting-in Manufacturing Linkages	0	1	2	3	4	5
- Licencing Linkages	0	1	2	3	4	5

## 43. - PONDER THE IMPORTANCE, DURING THE LAST THREE YEARS, OF YOUR ENTERPRISE'S SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS IN:

- Portugal	0	1	2	3	4	5
- European Union	0	1	2	3	4	5
- EFTA	0	1	2	3	4	5
- United States of America	0	1	2	3	4	5
- Multilateral agreements	0	1	2	3	4	5
- Others (specify) _____	0	1	2	3	4	5

## 44. - DURING THE NEXT THREE YEARS, HOW DO YOU FORECAST THE EVOLUTION OF YOUR ENTERPRISE'S LINKAGES WITH OTHER COMPANIES IN THE FOLLOWING AREAS:

- Contracted-out R&D Linkages?	0	1	2	3	4	5
- Subcontracted R&D Linkages?	0	1	2	3	4	5
- Collaborative R&D Linkages?	0	1	2	3	4	5
- Marketing relationships:						
- Agency Linkages?	0	1	2	3	4	5
- Collaborative Marketing Linkages?	0	1	2	3	4	5
- Manufacturing relationships:						
- Subcontracting-out Manufacturing Linkages?	0	1	2	3	4	5
- Subcontracting-in Manufacturing Linkages?	0	1	2	3	4	5
- Licencing Linkages?	0	1	2	3	4	5

45.- DURING THE NEXT THREE YEARS, HOW DO YOU FORECAST THE EVOLUTION OF YOUR ENTERPRISE'S SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS IN:						
- Portugal?	0	1	2	3	4	5
- European Union?	0	1	2	3	4	5
- EFTA?	0	1	2	3	4	5
- United States of America?	0	1	2	3	4	5
- Multilateral agreements?	0	1	2	3	4	5
- Others? (specify) _____	0	1	2	3	4	5

**D) LINKAGES WITH ACADEMIC RESEARCH**

46.- DOES YOUR ENTERPRISE HAVE ANY KIND OF FORMAL OR INFORMAL LINKAGES WITH ACADEMIC RESEARCH? Y / N  
*(If N, go to question 55)*

47.- PONDER THE IMPORTANCE FOR YOUR ENTERPRISE OF ITS FORMAL LINKAGES WITH ACADEMIC RESEARCH:						
- Consultancies	0	1	2	3	4	5
- Use of facilities/scientific equipment	0	1	2	3	4	5
- Contracted research	0	1	2	3	4	5
- Support of studentships	0	1	2	3	4	5
- Exchange of personnel	0	1	2	3	4	5
- Others (specify) _____	0	1	2	3	4	5

48.- PONDER THE IMPORTANCE FOR YOUR ENTERPRISE OF ITS INFORMAL LINKAGES WITH ACADEMIC RESEARCH:						
- Personal contacts	0	1	2	3	4	5
- Attendance of conferences	0	1	2	3	4	5
- Membership of professional bodies	0	1	2	3	4	5
- Others (specify) _____	0	1	2	3	4	5

49.- THE MAIN REASONS FOR LINKAGES WITH ACADEMIC RESEARCH ARE:						
- Contribute to the solution of problems	0	1	2	3	4	5
- Suggest new ways of solving problems	0	1	2	3	4	5
- Generate new lines of research	0	1	2	3	4	5
- Give advice for use in routine work	0	1	2	3	4	5
- Others (specify) _____	0	1	2	3	4	5

50.- DOES YOUR ENTERPRISE HAVE REGULAR CONTACTS WITH R&D ACTIVITIES BEING CARRIED OUT AT:  
 - Universities? Y / N  
 - Polytechnics? Y / N

51.- WHAT PERCENTAGE OF THE ENTERPRISE'S R&D EXPENDITURE IS BEING CONTRACTED OUT TO:  
 - Universities? \_\_\_\_\_ %  
 - Polytechnics? \_\_\_\_\_ %

52.- DOES YOUR ENTERPRISE SPONSOR ENGINEERING/SCIENCE STUDENTS? Y / N

53.- PONDER THE IMPORTANCE, DURING THE LAST THREE YEARS, OF YOUR ENTERPRISE'S LINKAGES WITH ACADEMIC RESEARCH:						
- Formal linkages	0	1	2	3	4	5
- Informal linkages	0	1	2	3	4	5

54.- DURING THE NEXT THREE YEARS, HOW DO YOU FORECAST THE EVOLUTION OF YOUR ENTERPRISE'S LINKAGES WITH ACADEMIC RESEARCH:						
- Formal linkages?	0	1	2	3	4	5
- Informal linkages?	0	1	2	3	4	5

**E) LINKAGES WITH PUBLIC SECTOR INSTITUTIONS**

- 55.- DOES YOUR ENTERPRISE HAVE ANY KIND OF FORMAL OR INFORMAL LINKAGES WITH PUBLIC SECTOR INSTITUTIONS?  
(If N, go to question 62) Y / N
- 56.- DOES YOUR ENTERPRISE HAVE REGULAR CONTACTS WITH R&D ACTIVITIES BEING CARRIED OUT AT:  
- Governmental laboratories? Y / N  
- Non-profit institutions? Y / N  
- Others? (specify) \_\_\_\_\_ Y / N
- 57.- WHAT PERCENTAGE OF THE ENTERPRISE'S R&D EXPENDITURE IS BEING CONTRACTED OUT TO:  
- Governmental laboratories? \_\_\_\_\_ %  
- Non-profit institutions? \_\_\_\_\_ %  
- Others? (specify) \_\_\_\_\_ %
- 58.- DOES YOUR ENTERPRISE HAVE TECHNICAL INPUTS FROM PUBLIC SECTOR INSTITUTIONS? (Access to equipment, training facilities, advice, etc) Y / N
- 59.- DOES YOUR ENTERPRISE TAKE ADVANTAGE OF ANY GOVERNMENT SCHEMES FOR EXTERNAL TECHNICAL EXPERTISE? Y / N  
Which ones? \_\_\_\_\_  
Why not?  
- Not aware of their existence Y / N  
- Application procedures too complicated Y / N  
- Lack of resources to handle application Y / N  
- Not convinced of their usefulness Y / N  
- Need has not arisen Y / N  
- Others (specify) \_\_\_\_\_ Y / N
- 60.- PONDER THE IMPORTANCE, DURING THE LAST THREE YEARS, OF YOUR ENTERPRISE'S LINKAGES WITH PUBLIC SECTOR INSTITUTIONS:  
- Formal linkages 0 1 2 3 4 5  
- Informal linkages 0 1 2 3 4 5
- 61.- DURING THE NEXT THREE YEARS, HOW DO YOU FORECAST THE EVOLUTION OF YOUR ENTERPRISE'S LINKAGES WITH PUBLIC SECTOR INSTITUTIONS:  
- Formal linkages? 0 1 2 3 4 5  
- Informal linkages? 0 1 2 3 4 5

**F) TECHNOLOGICAL INNOVATIONS IN THE ENTERPRISE**

- 62.- DURING THE LAST FIVE YEARS, HAS YOUR ENTERPRISE PATENTED ANY TECHNOLOGICAL INVENTION? Y / N  
How many? \_\_\_\_\_  
Where? \_\_\_\_\_  
- Portugal Y / N  
- European Patent Office Y / N  
- USA Patent Office Y / N  
- Others (specify) \_\_\_\_\_ Y / N
- 63.- DOES YOUR ENTERPRISE DEVELOP (OR HAS DEVELOPED) ANY KIND OF TECHNOLOGICAL INNOVATION? Y / N  
(If N, go to question 70)

64.- IS (OR WAS) THE TECHNOLOGICAL INNOVATION FOCUSED ON:

- Process innovation:
  - New manufacturing/processing techniques? Y / N
  - Automation? Y / N
  - New organisational structure? Y / N
- Product innovation:
  - New radical products? Y / N
  - New "incremental" products? Y / N
  - New materials? Y / N
- Services innovation:
  - New consume services? Y / N
  - New services to other enterprises? Y / N
- Others? (specify) \_\_\_\_\_ Y / N

65.- IN WHAT PERCENTAGE IS (OR WAS) THE TECHNOLOGICAL INNOVATION FUNDED BY:

- The enterprise itself? \_\_\_\_\_ %
- The banking system? \_\_\_\_\_ %
- The private sector? \_\_\_\_\_ %
- The public sector? \_\_\_\_\_ %
- The European Union? \_\_\_\_\_ %
- Non-European Union funds? \_\_\_\_\_ %
- Others? (specify) \_\_\_\_\_ %

66.- PONDER THE IMPORTANCE OF THE INTRODUCTION OF TECHNOLOGICAL INNOVATIONS TO YOUR ENTERPRISE

0 1 2 3 4 5

67.- REASONS FOR THE INTRODUCTION OF TECHNOLOGICAL INNOVATIONS BY THE ENTERPRISE:

- Enter new markets 0 1 2 3 4 5
- Develop new products 0 1 2 3 4 5
- Improve existing products 0 1 2 3 4 5
- Improve existing equipment's performance 0 1 2 3 4 5
- Maintain its market share 0 1 2 3 4 5
- Increase productivity 0 1 2 3 4 5
- Decrease number of employees 0 1 2 3 4 5
- Improve working conditions and safety 0 1 2 3 4 5
- Use new (raw) materials 0 1 2 3 4 5
- Save energy consumption 0 1 2 3 4 5
- Reduce/Eliminate environmental pollution 0 1 2 3 4 5
- Others (specify) \_\_\_\_\_ 0 1 2 3 4 5

68.- MAJOR COSTS OF THE INTRODUCTION OF TECHNOLOGICAL INNOVATIONS BY THE ENTERPRISE:

- Development costs 0 1 2 3 4 5
- Licencing and patenting costs 0 1 2 3 4 5
- Personnel expenditures 0 1 2 3 4 5
- Training expenditures 0 1 2 3 4 5
- Production equipment costs 0 1 2 3 4 5
- Research costs 0 1 2 3 4 5
- Commercialisation costs 0 1 2 3 4 5
- Design costs 0 1 2 3 4 5
- Others (specify) \_\_\_\_\_ 0 1 2 3 4 5

69. - OBSTACLES TO THE INTRODUCTION OF TECHNOLOGICAL INNOVATIONS BY THE ENTERPRISE:

- Lack of financial support
- Lack of fiscal incentives
- Lack of governmental support
- Market uncertainty
- Lack of qualified staff
- Difficulty in initiating organic changes
- No collaboration from public R&D laboratories
- No collaboration from private R&D laboratories
- Others (specify) \_\_\_\_\_

0	1	2	3	4	5
0	1	2	3	4	5
0	1	2	3	4	5
0	1	2	3	4	5
0	1	2	3	4	5
0	1	2	3	4	5
0	1	2	3	4	5
0	1	2	3	4	5
0	1	2	3	4	5
0	1	2	3	4	5

G) TECHNOLOGY TRANSFER

70. - DURING THE LAST THREE YEARS, DID THE ENTERPRISE BUY ANY TECHNOLOGY?  
(If N, go to question 73)

Y / N

71. - THE ENTERPRISE BOUGHT TECHNOLOGY FROM:

- Portugal:
  - Other enterprises?
  - Government?
  - Universities?
  - Non-profit institutions?
- Abroad:
  - European Union?
  - EFTA?
  - United States of America?
  - Others? (specify) \_\_\_\_\_

Y / N  
Y / N  
Y / N  
Y / N  
Y / N  
Y / N  
Y / N  
Y / N  
Y / N

72. - WHAT TYPES OF TECHNOLOGY TRANSFER CONTRACTS (BUYING) HAS THE ENTERPRISE SIGNED?

- Licencing contracts
- "Franchising" contracts
- Transfer of technical knowledge
- Technical assistance
- Engineering services and projects
- Others (specify) \_\_\_\_\_

Y / N  
Y / N  
Y / N  
Y / N  
Y / N  
Y / N

73. - DURING THE LAST THREE YEARS, DID THE ENTERPRISE SELL ANY TECHNOLOGY?  
(If N, go to question 76)

Y / N

74. - THE ENTERPRISE SOLD TECHNOLOGY TO:

- Portugal:
  - Other enterprises?
  - Government?
  - Universities?
  - Non-profit institutions?
- Abroad:
  - European Union?
  - EFTA?
  - Former Portuguese colonies?
  - Others? (specify) \_\_\_\_\_

Y / N  
Y / N  
Y / N  
Y / N  
Y / N  
Y / N  
Y / N





**LIST OF THE ENTERPRISES  
PARTICIPATING IN THE RESEARCH PROJECT**

**A) ELECTRONICS INDUSTRY**

- \* ALCATEL PORTUGAL - Sistemas de Comunicação, SA
- \* CRASI - Controlo, Automação, Sistemas de Informação, Lda
- \* DIACOMA - Projectos, Produtos e Tecnologias de Comunicação, SA
- \* FRAEP - Fábrica de Aparelhagem de Precisão e Electrónica de Potência, SA
- \* INIX - Desenvolvimento e Comercialização de Tecnologias de Informação, SA
- \* MEGAMEDIA - Soluções Multimedia, SA
- \* MICROPROCESSADOR - Sistemas Digitais, SA
- \* NOVABASE - Sistemas de Informação e Bases de Dados, SA
- \* SOLICA
- \* STONE - Circuitos Impressos, Lda
- \* TECMIC - Tecnologias de Microelectrónica
- \* TECNOPARQUE
- \* TEXAS INSTRUMENTS - Equipamento Electrónico (Portugal), Lda
- \* VEGATRON - Electrónica e Sistemas, SA

**B) MOULDMAKING INDUSTRY**

- \* A. SILVA, GODINHO & COMP, Lda
- \* ALFAMOLDE - Moldes para Plásticos, Lda
- \* CIDACOS - Moldes Industriais, Lda
- \* CONSULMOLDE - Importação e Exportação, Lda
- \* ERNESTO SÃO SIMÃO, Lda
- \* EUROMEC - Moldes, Automatismos e Serviços de Manutenção Industrial, SA
- \* MOLDITE - Indústria de Moldes, SA
- \* MOLDOPLASTICO, Lda
- \* NOVATECA - Sociedade Industrial de Ser. e Moldes, Lda
- \* PINHOS & RIBEIRO, Lda
- \* ROEHLLEN-MARTIN Limited
- \* SET - Sociedade de Engenharia e Transformação, SA
- \* SIMOLDES Aços, Lda
- \* TECNIMOPLAS - Indústria Técnica de Moldes, Lda

**C) BIOTECHNOLOGY INDUSTRY**

- \* BIOROPE - Sociedade Europeia de Biotecnologia, SA
- \* CENTRALCER - Central de Cervejas, SA
- \* CIPAN
- \* HOVIONE - Sociedade Química, SA

**LIST OF EXPERTS INTERVIEWED  
DURING THE RESEARCH PROJECT**

**A) ELECTRONICS INDUSTRY**

- \* Professor Luís Ramos da Silva Vidigal  
INESC - Instituto de Engenharia de Sistemas e Computadores
- \* Professor Pedro Guedes de Oliveira  
Departamento de Electrónica e de Telecomunicações  
Universidade de Aveiro
- \* Eng. Themudo de Castro  
Departamento de Electrónica  
INETI - Instituto Nacional de Engenharia e Tecnologia Industrial

**B) BIOTECHNOLOGY INDUSTRY**

- \* Professor Augusto G. Medina  
Escola Superior de Biotecnologia  
Universidade Católica Portuguesa
- \* Professor Carvalho Guerra  
Cons. para a Cooperação Ensino Superior/Empresa
- \* Professora Cecília Arraiano  
CTQB - Centro de Tecnologia Química e Biológica
- \* Doutor F. Xavier D. Domingos A. Malcata  
Escola Superior de Biotecnologia  
Universidade Católica Portuguesa
- \* Professor Júlio Maggiolly Novais  
Centro de Engenharia Biológica  
IST - Instituto Superior Técnico
- \* Professor Manuel José Teixeira Carrondo  
IBET - Instituto de Biologia Experimental e Tecnológica

**CROSS-TABULATIONS  
ELECTRONICS INDUSTRY**

EXISTENCE OF R&D ACTIVITIES IN THE ENTERPRISE  
by  
LOCATION OF THE ENTERPRISE

LOCATION	Count Row Pct Col Pct	R&D ACTIVITIES		Row Total
		NO	YES	
GREAT LISBOA	1 12.5 25.0	7 87.5 70.0	8 57.1	
GREAT PORTO	3 75.0 75.0	1 25.0 10.0	4 28.6	
OTHERS		2 100.0 20.0	2 14.3	
Column Total	4 28.6	10 71.4	14 100.0	

Statistic	Value
Pearson's R	.05000

Number of Missing Observations: 0

EXISTENCE OF R&D ACTIVITIES IN THE ENTERPRISE  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

YEAR	Count Row Pct Col Pct	R&D ACTIVITIES		Row Total
		NO	YES	
BEFORE 1965			1 100.0 10.0	1 7.7
1965 TO 1986	2 50.0 66.7	2 50.0 20.0		4 30.8
AFTER 1986	1 12.5 33.3	7 87.5 70.0		8 61.5
	Column Total	3 23.1	10 76.9	13 100.0

Statistic	Value
Pearson's R	.17712

Number of Missing Observations: 1

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EXISTENCE OF R&D ACTIVITIES IN THE ENTERPRISE  
by  
TOTAL PERSONNEL IN 91

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PERSONNEL	Count Row Pct Col Pct	R&D ACTIVITIES		Row Total
		NO	YES	
LESS THAN 25	1 16.7 33.3	5 83.3 50.0	6 46.2	
25 TO 70	1 20.0 33.3	4 80.0 40.0	5 38.5	
MORE THAN 70	1 50.0 33.3	1 50.0 10.0	2 15.4	
	Column Total	3 23.1	10 76.9	13 100.0

Number of Missing Observations: 1

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EXISTENCE OF R&D ACTIVITIES IN THE ENTERPRISE  
by  
TOTAL TURNOVER IN 91 ( $\times 10^6$  PTE)

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TURNOVER	Count Row Pct Col Pct	R&D ACTIVITIES		Row Total
		NO	YES	
LESS THAN 110	1 20.0 33.3	4 80.0 44.4	5 41.7	
110 - 400	1 20.0 33.3	4 80.0 44.4	5 41.7	
MORE THAN 400	1 50.0 33.3	1 50.0 11.1	2 16.7	
	Column Total	3 25.0	9 75.0	12 100.0

Number of Missing Observations: 2

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EXISTENCE OF R&D ACTIVITIES IN THE ENTERPRISE  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	R&D ACTIVITIES		Row Total
		NO	YES	
0	1	1	1	2
	50.0	50.0	50.0	14.3
	25.0	10.0		
100	3	9		12
	25.0	75.0		85.7
	75.0	90.0		
Column Total	4	10	14	
	28.6	71.4	100.0	

Number of Missing Observations: 0

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IMPORTANCE OF COLLABORATIVE R&D LINKAGES  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
GREAT LISBOA	2 25.0 40.0	4 50.0 57.1	2 25.0 100.0	8 57.1	
GREAT PORTO	3 75.0 60.0	1 25.0 14.3		4 28.6	
OTHERS		2 100.0 28.6		2 14.3	
Column Total	5 35.7	7 50.0	2 14.3	14 100.0	

<i>Statistic</i>	<i>Value</i>
----- Pearson's R	----- -.03352

Number of Missing Observations: 0

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IMPORTANCE OF COLLABORATIVE R&D LINKAGES  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

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YEAR	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
BEFORE 1965			1 100.0 14.3		1 7.7
1965 TO 1986		2 50.0 50.0	2 50.0 28.6		4 30.8
AFTER 1986		2 25.0 50.0	4 50.0 57.1	2 25.0 100.0	8 61.5
	Column Total	4 30.8	7 53.8	2 15.4	13 100.0

Number of Missing Observations: 1

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IMPORTANCE OF COLLABORATIVE R&D LINKAGES  
by  
TOTAL PERSONNEL IN 91

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PERSONNEL	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 25	1	4	1	6	
	16.7 25.0	66.7 57.1	16.7 50.0	46.2	
25 TO 70	2	2	1	5	
	40.0 50.0	40.0 28.6	20.0 50.0	38.5	
MORE THAN 70	1	1		2	
	50.0 25.0	50.0 14.3		15.4	
Column Total	4	7	2	13	
	30.8	53.8	15.4	100.0	

Number of Missing Observations: 1

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IMPORTANCE OF COLLABORATIVE R&D LINKAGES  
by  
TOTAL TURNOVER IN 91 ( $\times 10^6$  PTE)

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TURNOVER	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 110	1	20.0	60.0	20.0	5 41.7
	25.0	50.0	50.0		
110 - 400	2	40.0	40.0	20.0	5 41.7
	50.0	33.3	50.0		
MORE THAN 400	1	50.0	50.0		2 16.7
	25.0	16.7			
	Column Total	4 33.3	6 50.0	2 16.7	12 100.0

Number of Missing Observations: 2

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IMPORTANCE OF COLLABORATIVE R&D LINKAGES  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
0	1 50.0 20.0	1 50.0 14.3	1 50.0 14.3		2 14.3
100	4 33.3 80.0	6 50.0 85.7	2 16.7 100.0		12 85.7
Column Total	5 35.7	7 50.0	2 14.3		14 100.0

Statistic	Value
----- Pearson's R	----- .17310

Number of Missing Observations: 0

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IMPORTANCE OF COLLABORATIVE MARKETING LINKAGES  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
GREAT LISBOA		4	2	2	8
		50.0	25.0	25.0	57.1
		50.0	66.7	66.7	
GREAT PORTO		3		1	4
		75.0		25.0	28.6
		37.5		33.3	
OTHERS		1	1		2
		50.0	50.0		14.3
		12.5	33.3		
	Column Total	8 57.1	3 21.4	3 21.4	14 100.0

<i>Statistic</i>	<i>Value</i>
----- <i>Pearson's R</i>	----- -.11137

Number of Missing Observations: 0

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IMPORTANCE OF COLLABORATIVE MARKETING LINKAGES  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

YEAR	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
BEFORE 1965	1 100.0 14.3				1 7.7
1965 TO 1986	2 50.0 28.6	1 25.0 33.3	1 25.0 33.3		4 30.8
AFTER 1986	4 50.0 57.1	2 25.0 66.7	2 25.0 66.7		8 61.5
	Column Total	7 53.8	3 23.1	3 23.1	13 100.0

Statistic	Value
----- Pearson's R	----- .17037

Number of Missing Observations: 1

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IMPORTANCE OF COLLABORATIVE MARKETING LINKAGES  
by  
TOTAL PERSONNEL IN 91

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PERSONNEL	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 25	2 33.3 28.6	2 33.3 66.7	2 33.3 66.7	2 33.3 66.7	6 46.2
25 TO 70	3 60.0 42.9	1 20.0 33.3	1 20.0 33.3	1 20.0 33.3	5 38.5
MORE THAN 70	2 100.0 28.6				2 15.4
	Column Total	7 53.8	3 23.1	3 23.1	13 100.0

Number of Missing Observations: 1

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IMPORTANCE OF COLLABORATIVE MARKETING LINKAGES  
by  
TOTAL TURNOVER IN 91 (x 10<sup>6</sup> PTE)

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TURNOVER	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 110	2 40.0 33.3	1 20.0 33.3	2 40.0 66.7	5 41.7	
110 - 400	2 40.0 33.3	2 40.0 66.7	1 20.0 33.3	5 41.7	
MORE THAN 400	2 100.0 33.3			2 16.7	
	Column Total	6 50.0	3 25.0	3 25.0	12 100.0

Number of Missing Observations: 2

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IMPORTANCE OF COLLABORATIVE MARKETING LINKAGES  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
0	2 100.0 25.0				2 14.3
100	6 50.0 75.0		3 25.0 100.0	3 25.0 100.0	12 85.7
Column Total	8 57.1	3 21.4	3 21.4	14 100.0	

Number of Missing Observations: 0

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IMPORTANCE OF SUBCONTRACTING-OUT MANUFACTURING LINKS  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
GREAT LISBOA	2		4	2	8
	25.0 33.3		50.0 80.0	25.0 66.7	57.1
GREAT PORTO	3			1	4
	75.0 50.0			25.0 33.3	28.6
OTHERS	1		1		2
	50.0 16.7		50.0 20.0		14.3
	Column Total	6 42.9	5 35.7	3 21.4	14 100.0

Number of Missing Observations: 0

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IMPORTANCE OF SUBCONTRACTING-OUT MANUFACTURING LINKS  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

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YEAR	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
BEFORE 1965	1 100.0 20.0				1 7.7
1965 TO 1986	2 50.0 40.0		1 25.0 20.0	1 25.0 33.3	4 30.8
AFTER 1986	2 25.0 40.0		4 50.0 80.0	2 25.0 66.7	8 61.5
	Column Total	5 38.5	5 38.5	3 23.1	13 100.0

Number of Missing Observations: 1

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IMPORTANCE OF SUBCONTRACTING-OUT MANUFACTURING LINKS  
by  
TOTAL TURNOVER IN 91 ( $\times 10^6$  PTE)

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TURNOVER	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 110	2		2	1	5
	40.0		40.0	20.0	41.7
	40.0		40.0	50.0	
110 - 400	1		3	1	5
	20.0		60.0	20.0	41.7
	20.0		60.0	50.0	
MORE THAN 400	2				2
	100.0				16.7
	40.0				
Column Total		5	5	2	12
		41.7	41.7	16.7	100.0

Number of Missing Observations: 2

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IMPORTANCE OF SUBCONTRACTING-OUT MANUFACTURING LINKS  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

PORTUGUESE SHARE	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
0	2 100.0 33.3				2 14.3
100	4 33.3 66.7	5 41.7 100.0	3 25.0 100.0		12 85.7
Column Total	6 42.9	5 35.7	3 21.4		14 100.0

Number of Missing Observations: 0

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IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

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YEAR	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
BEFORE 1965	1				1
	100.0 16.7				7.7
1965 TO 1986	2			2	4
	50.0 33.3			50.0 33.3	30.8
AFTER 1986	3		1	4	8
	37.5 50.0		12.5 100.0	50.0 66.7	61.5
	Column Total	6 46.2	1 7.7	6 46.2	13 100.0

Number of Missing Observations: 1

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IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
TOTAL PERSONNEL IN 91

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PERSONNEL	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 25	2 33.3 33.3			4 66.7 66.7	6 46.2
25 TO 70	2 40.0 33.3		1 20.0 100.0	2 40.0 33.3	5 38.5
MORE THAN 70	2 100.0 33.3				2 15.4
	Column Total	6 46.2	1 7.7	6 46.2	13 100.0

Number of Missing Observations: 1

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IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
TOTAL TURNOVER IN 91 (x 10<sup>6</sup> PTE)

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TURNOVER	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 110	2 40.0 40.0			3 60.0 50.0	5 41.7
110 = 400	1 20.0 20.0		1 20.0 100.0	3 60.0 50.0	5 41.7
MORE THAN 400	2 100.0 40.0				2 16.7
	Column Total	5 41.7	1 8.3	6 50.0	12 100.0

Number of Missing Observations: 2

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IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
0	2 100.0 33.3				2 14.3
100	4 33.3 66.7	1 8.3 100.0	7 58.3 100.0		12 85.7
Column Total	6 42.9	1 7.1	7 50.0		14 100.0

Number of Missing Observations: 0

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
LOCATION OF THE ENTERPRISE

LOCATION	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
GREAT LISBOA		4	4	8
		50.0	50.0	57.1
GREAT PORTO		3	1	4
		75.0	25.0	28.6
OTHERS		1	1	2
		50.0	50.0	14.3
		12.5	16.7	
	Column Total	8	6	14
		57.1	42.9	100.0

<i>Statistic</i>	<i>Value</i>
<i>Pearson's R</i>	<i>-.01521</i>

Number of Missing Observations: 0

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

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YEAR	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
BEFORE 1965			1 100.0 16.7	1 7.7
1965 TO 1986		2 50.0 28.6	2 50.0 33.3	4 30.8
AFTER 1986		5 62.5 71.4	3 37.5 50.0	8 61.5
	Column Total	7 53.8	6 46.2	13 100.0

Number of Missing Observations: 1

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
TOTAL TURNOVER IN 91 (x 10<sup>6</sup> PTE)

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TURNOVER	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
LESS THAN 110	3 60.0 50.0	2 40.0 33.3	5 41.7	
110 - 400	3 60.0 50.0	2 40.0 33.3	5 41.7	
MORE THAN 400		2 100.0 33.3	2 16.7	
	Column Total	6 50.0	6 50.0	12 100.0

Number of Missing Observations: 2

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

PORTUGUESE SHARE	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
0			2 100.0 33.3	2 14.3
100		8 66.7 100.0	4 33.3 66.7	12 85.7
Column Total		8 57.1	6 42.9	14 100.0

Number of Missing Observations: 0

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
GREAT LISBOA	1	7	8	
	12.5	87.5	57.1	
	33.3	63.6		
GREAT PORTO	2	2	4	
	50.0	50.0	28.6	
	66.7	18.2		
OTHERS		2	2	
		100.0	14.3	
		18.2		
	Column Total	3 21.4	11 78.6	14 100.0

<i>Statistic</i>	<i>Value</i>
----- Pearson's R	----- .07340

Number of Missing Observations: 0

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

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YEAR	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
BEFORE 1965			1 100.0 9.1	1 7.7
1965 TO 1986		1 25.0 50.0	3 75.0 27.3	4 30.8
AFTER 1986		1 12.5 50.0	7 87.5 63.6	8 61.5
	Column Total	2 15.4	11 84.6	13 100.0

<i>Statistic</i>	<i>Value</i>
----- Pearson's R	----- .02585

Number of Missing Observations: 1

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
TOTAL PERSONNEL IN 91

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PERSONNEL	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
LESS THAN 25	1 16.7 50.0	5 83.3 45.5	6 46.2	
25 TO 70	1 20.0 50.0	4 80.0 36.4	5 38.5	
MORE THAN 70		2 100.0 18.2	2 15.4	
	Column Total	2 15.4	11 84.6	13 100.0

Statistic	Value
----- Pearson's R	----- .11364

Number of Missing Observations: 1

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
TOTAL TURNOVER IN 91 (x 10<sup>6</sup> PTE)

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TURNOVER	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
LESS THAN 110	1 20.0 50.0	4 80.0 40.0	5 41.7	
110 - 400	1 20.0 50.0	4 80.0 40.0	5 41.7	
MORE THAN 400		2 100.0 20.0	2 16.7	
	Column Total	2 16.7	10 83.3	12 100.0

Statistic	Value
Pearson's R	.15492

Number of Missing Observations: 2

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
0			2 100.0 18.2	2 14.3
100		3 25.0 100.0	9 75.0 81.8	12 85.7
Column Total		3 21.4	11 78.6	14 100.0

Number of Missing Observations: 0

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ACQUISITION OF TECHNOLOGY BY THE ENTERPRISE  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	ACQUISITION		Row Total
		NO	YES	
GREAT LISBOA	4	4		8
	50.0	50.0		57.1
	40.0	100.0		
GREAT PORTO	4			4
	100.0			28.6
	40.0			
OTHERS	2			2
	100.0			14.3
	20.0			
	Column Total	10 71.4	4 28.6	14 100.0

Number of Missing Observations: 0

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ACQUISITION OF TECHNOLOGY BY THE ENTERPRISE  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

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YEAR	Count Row Pct Col Pct	ACQUISITION		Row Total
		NO	YES	
BEFORE 1965			1 100.0 25.0	1 7.7
1965 TO 1986		4 100.0 44.4		4 30.8
AFTER 1986		5 62.5 55.6	3 37.5 75.0	8 61.5
	Column Total	9 69.2	4 30.8	13 100.0

<i>Statistic</i>	<i>Value</i>
----- Pearson's R	----- -.04042

Number of Missing Observations: 1

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ACQUISITION OF TECHNOLOGY BY THE ENTERPRISE  
by  
TOTAL TURNOVER IN 91 (x 10<sup>6</sup> PTE)

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TURNOVER	Count Row Pct Col Pct	ACQUISITION		Row Total
		NO	YES	
LESS THAN 110	4 80.0 44.4	1 20.0 33.3	5 41.7	
110 - 400	4 80.0 44.4	1 20.0 33.3	5 41.7	
MORE THAN 400	1 50.0 11.1	1 50.0 33.3	2 16.7	
	Column Total	9 75.0	3 25.0	12 100.0

Number of Missing Observations: 2

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ACQUISITION OF TECHNOLOGY BY THE ENTERPRISE  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

PORTUGUESE SHARE	Count Row Pct Col Pct	ACQUISITION		Row Total
		NO	YES	
0	1 50.0 10.0	1 50.0 25.0	2 14.3	
100	9 75.0 90.0	3 25.0 75.0	12 85.7	
Column Total	10 71.4	4 28.6	14 100.0	

<i>Statistic</i>	<i>Value</i>
<i>Pearson's R</i>	<i>-.19365</i>

Number of Missing Observations: 0

**CROSS-TABULATIONS**  
**MOULDMAKING INDUSTRY**

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IMPORTANCE OF SUBCONTRACTING-OUT MANUFACTURING LINKS  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
GREAT PORTO			1 50.0 12.5	1 50.0 25.0	2 14.3
MARINHA GRANDE		1 33.3 50.0	2 66.7 25.0		3 21.4
OLIVEIRA AZEMÉIS		1 12.5 50.0	4 50.0 50.0	3 37.5 75.0	8 57.1
OTHERS			1 100.0 12.5		1 7.1
	Column Total	2 14.3	8 57.1	4 28.6	14 100.0

<i>Statistic</i>	<i>Value</i>
----- <i>Pearson's R</i>	----- -.01946

Number of Missing Observations: 0

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IMPORTANCE OF SUBCONTRACTING-OUT MANUFACTURING LINKS  
by  
TOTAL PERSONNEL IN 91

PERSONNEL	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 25	1 33.3 50.0			2 66.7 50.0	3 21.4
25 TO 70	1 20.0 50.0		3 60.0 37.5	1 20.0 25.0	5 35.7
MORE THAN 70			5 83.3 62.5	1 16.7 25.0	6 42.9
	Column Total	2 14.3	8 57.1	4 28.6	14 100.0

<i>Statistic</i>	<i>Value</i>
Pearson's R	-.06202

Number of Missing Observations: 0

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IMPORTANCE OF SUBCONTRACTING-OUT MANUFACTURING LINKS  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
0				1 100.0 25.0	1 7.1
50				1 100.0 25.0	1 7.1
100		2 16.7 100.0	8 66.7 100.0	2 16.7 50.0	12 85.7
Column Total		2 14.3	8 57.1	4 28.6	14 100.0

Number of Missing Observations: 0

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IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
LOCATION OF THE ENTERPRISE

LOCATION	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
GREAT PORTO	1 50.0 16.7	1 50.0 14.3			2 14.3
MARINHA GRANDE			3 100.0 42.9		3 21.4
OLIVEIRA AZEMÉIS	5 62.5 83.3	3 37.5 42.9			8 57.1
OTHERS			1 100.0 100.0		1 7.1
	Column Total	6 42.9	7 50.0	1 7.1	14 100.0

<i>Statistic</i>	<i>Value</i>
<i>Pearson's R</i>	<i>.12225</i>

Number of Missing Observations: 0

IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

YEAR	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
BEFORE 1965		3	3		6
		50.0	50.0		42.9
		50.0	42.9		
1965 TO 1986		2	3		5
		40.0	60.0		35.7
		33.3	42.9		
AFTER 1986		1	1	1	3
		33.3	33.3	33.3	21.4
		16.7	14.3	100.0	
	Column Total	6 42.9	7 50.0	1 7.1	14 100.0

Number of Missing Observations: 0

IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
TOTAL PERSONNEL IN 91

PERSONNEL	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 25	2 66.7 33.3	1 33.3 14.3			3 21.4
25 TO 70	2 40.0 33.3	3 60.0 42.9			5 35.7
MORE THAN 70	2 33.3 33.3	3 50.0 42.9	1 16.7 100.0		6 42.9
	Column Total	6 42.9	7 50.0	1 7.1	14 100.0

Number of Missing Observations: 0

IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
TOTAL GROSS EXPENDITURES IN 91 ( $\times 10^6$  PTE)

GROSS EX PENDITURES	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
LESS THAN 59	3 50.0 50.0	3 50.0 42.9	3 50.0 42.9		6 42.9
59 - 100	1 33.3 16.7	2 66.7 28.6	2 66.7 28.6		3 21.4
MORE THAN 100	2 40.0 33.3	2 40.0 28.6	1 20.0 100.0		5 35.7
	Column Total	6 42.9	7 50.0	1 7.1	14 100.0

Number of Missing Observations: 0

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IMPORTANCE OF SUBCONTRACTING-IN MANUFACTURING LINKS  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	IMPORTANCE			Row Total
		MINOR	AVERAGE	MAJOR	
0	1 100.0 16.7				1 7.1
50	1 100.0 16.7				1 7.1
100	4 33.3 66.7	7 58.3 100.0	1 8.3 100.0		12 85.7
Column Total	6 42.9	7 50.0	1 7.1		14 100.0

Number of Missing Observations: 0

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
GREAT PORTO			2 100.0 66.7	2 14.3
MARINHA GRANDE	2 66.7 18.2		1 33.3 33.3	3 21.4
OLIVEIRA AZEMÉIS	8 100.0 72.7			8 57.1
OTHERS	1 100.0 9.1			1 7.1
	Column Total	11 78.6	3 21.4	14 100.0

Number of Missing Observations: 0

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

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YEAR	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
BEFORE 1965	5	1	6	
	83.3	16.7	42.9	
	45.5	33.3		
1965 TO 1986	3	2	5	
	60.0	40.0	35.7	
	27.3	66.7		
AFTER 1986	3		3	
	100.0		21.4	
	27.3			
	Column Total	11 78.6	3 21.4	14 100.0

Statistic	Value
----- Pearson's R	----- -.08047

Number of Missing Observations: 0

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
TOTAL PERSONNEL IN 91

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PERSONNEL	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
LESS THAN 25		2	1	3
		66.7	33.3	21.4
		18.2	33.3	
25 TO 70		4	1	5
		80.0	20.0	35.7
		36.4	33.3	
MORE THAN 70		5	1	6
		83.3	16.7	42.9
		45.5	33.3	
	Column Total	11 78.6	3 21.4	14 100.0

<i>Statistic</i>	<i>Value</i>
----- <i>Pearson's R</i>	----- -.14484

Number of Missing Observations: 0

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
TOTAL GROSS EXPENDITURES IN 91 (x 10<sup>6</sup> PTE)

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GROSS EX PENDITURES	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
LESS THAN 59	4 66.7 36.4	2 33.3 66.7	6 42.9	
59 - 100	3 100.0 27.3		3 21.4	
MORE THAN 100	4 80.0 36.4	1 20.0 33.3	5 35.7	
	Column Total	11 78.6	3 21.4	14 100.0

Statistic	Value
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Pearson's R	-.15481

Number of Missing Observations: 0

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EXISTENCE OF SCIENTIFIC AND TECHNOLOGICAL AGREEMENTS  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	AGREEMENTS		Row Total
		NO	YES	
0			1 100.0 33.3	1 7.1
50		1 100.0 9.1		1 7.1
100		10 83.3 90.9	2 16.7 66.7	12 85.7
	Column Total	11 78.6	3 21.4	14 100.0

Number of Missing Observations: 0

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
GREAT PORTO			2 100.0 50.0	2 14.3
MARINHA GRANDE		2 66.7 20.0	1 33.3 25.0	3 21.4
OLIVEIRA AZEMÉIS		7 87.5 70.0	1 12.5 25.0	8 57.1
OTHERS		1 100.0 10.0		1 7.1
	Column Total	10 71.4	4 28.6	14 100.0

Number of Missing Observations: 0

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

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YEAR	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
BEFORE 1965	4	2	6	
	66.7	33.3	42.9	
	40.0	50.0		
1965 TO 1986	3	2	5	
	60.0	40.0	35.7	
	30.0	50.0		
AFTER 1986	3		3	
	100.0		21.4	
	30.0			
Column Total	10 71.4	4 28.6	14 100.0	

Number of Missing Observations: 0

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
TOTAL PERSONNEL IN 91

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PERSONNEL	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
LESS THAN 25	2 66.7 20.0	1 33.3 25.0	3 21.4	
25 TO 70	3 60.0 30.0	2 40.0 50.0	5 35.7	
MORE THAN 70	5 83.3 50.0	1 16.7 25.0	6 42.9	
	Column Total	10 71.4	4 28.6	14 100.0

<i>Statistic</i>	<i>Value</i>
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<i>Pearson's R</i>	-.17541

Number of Missing Observations: 0

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EXISTENCE OF FORMAL/INFORMAL LINKAGES WITH ACADEMIC RESEARCH  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
0			1 100.0 25.0	1 7.1
50	1 100.0 10.0			1 7.1
100	9 75.0 90.0	3 25.0 75.0		12 85.7
Column Total		10 71.4	4 28.6	14 100.0

Number of Missing Observations: 0

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EXISTENCE OF LINKAGES WITH PUBLIC SECTOR INSTITUTIONS  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
GREAT PORTO			2 100.0 20.0	2 14.3
MARINHA GRANDE		2 66.7 50.0	1 33.3 10.0	3 21.4
OLIVEIRA AZEMÉIS		2 25.0 50.0	6 75.0 60.0	8 57.1
OTHERS			1 100.0 10.0	1 7.1
	Column Total	4 28.6	10 71.4	14 100.0

<i>Statistic</i>	<i>Value</i>
----- Pearson's R	----- .05505

Number of Missing Observations: 0

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EXISTENCE OF LINKAGES WITH PUBLIC SECTOR INSTITUTIONS  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

YEAR	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
BEFORE 1965			6 100.0 60.0	6 42.9
1965 TO 1986		3 60.0 75.0	2 40.0 20.0	5 35.7
AFTER 1986		1 33.3 25.0	2 66.7 20.0	3 21.4
	Column Total	4 28.6	10 71.4	14 100.0

Number of Missing Observations: 0

EXISTENCE OF LINKAGES WITH PUBLIC SECTOR INSTITUTIONS  
by  
TOTAL PERSONNEL IN 91

PERSONNEL	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
LESS THAN 25	1 33.3 25.0	2 66.7 20.0	3 21.4	
25 TO 70	2 40.0 50.0	3 60.0 30.0	5 35.7	
MORE THAN 70	1 16.7 25.0	5 83.3 50.0	6 42.9	
Column Total	4 28.6	10 71.4	14 100.0	

<i>Statistic</i>	<i>Value</i>
----- <i>Pearson's R</i>	----- .17541

Number of Missing Observations: 0

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EXISTENCE OF LINKAGES WITH PUBLIC SECTOR INSTITUTIONS  
by  
TOTAL TURNOVER IN 91 (x 10<sup>6</sup> PTE)

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TURNOVER	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
LESS THAN 110	1 33.3 25.0	2 66.7 20.0	3 21.4	
110 - 400	2 40.0 50.0	3 60.0 30.0	5 35.7	
MORE THAN 400	1 16.7 25.0	5 83.3 50.0	6 42.9	
	Column Total	4 28.6	10 71.4	14 100.0

<i>Statistic</i>	<i>Value</i>
----- <i>Pearson's R</i>	----- .17541

Number of Missing Observations: 0

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EXISTENCE OF LINKAGES WITH PUBLIC SECTOR INSTITUTIONS  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

PORTUGUESE SHARE	Count Row Pct Col Pct	LINKAGES		Row Total
		NO	YES	
0			1 100.0 10.0	1 7.1
50		1 100.0 25.0		1 7.1
100		3 25.0 75.0	9 75.0 90.0	12 85.7
	Column Total	4 28.6	10 71.4	14 100.0

<i>Statistic</i>	<i>Value</i>
----- Pearson's R	----- .04049

Number of Missing Observations: 0

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ACQUISITION OF TECHNOLOGY BY THE ENTERPRISE  
by  
LOCATION OF THE ENTERPRISE

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LOCATION	Count Row Pct Col Pct	ACQUISITION		Row Total
		NO	YES	
GREAT PORTO	1	1		2
	50.0	50.0		14.3
	11.1	20.0		
MARINHA GRANDE	1	2		3
	33.3	66.7		21.4
	11.1	40.0		
OLIVEIRA AZEMÉIS	6	2		8
	75.0	25.0		57.1
	66.7	40.0		
OTHERS	1			1
	100.0			7.1
	11.1			
Column Total	9	5	14	
	64.3	35.7	100.0	

Number of Missing Observations: 0

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ACQUISITION OF TECHNOLOGY BY THE ENTERPRISE  
by  
YEAR OF FOUNDATION OF THE ENTERPRISE

YEAR	Count Row Pct Col Pct	ACQUISITION		Row Total
		NO	YES	
BEFORE 1965	4	2	6	
	66.7	33.3	42.9	
	44.4	40.0		
1965 TO 1986	2	3	5	
	40.0	60.0	35.7	
	22.2	60.0		
AFTER 1986	3		3	
	100.0		21.4	
	33.3			
Column Total	9	5	14	
	64.3	35.7	100.0	

<i>Statistic</i>	<i>Value</i>
----- <i>Pearson's R</i>	----- -.17916

Number of Missing Observations: 0

ACQUISITION OF TECHNOLOGY BY THE ENTERPRISE  
by  
TOTAL TURNOVER IN 91 (x 10<sup>6</sup> PTE)

TURNOVER	Count Row Pct Col Pct	ACQUISITION		Row Total
		NO	YES	
LESS THAN 110	2	1	3	
	66.7	33.3	21.4	
	22.2	20.0		
110 - 400	4	1	5	
	80.0	20.0	35.7	
	44.4	20.0		
MORE THAN 400	3	3	6	
	50.0	50.0	42.9	
	33.3	60.0		
Column Total	9	5	14	
	64.3	35.7	100.0	

Statistic	Value
Pearson's R	.17916

Number of Missing Observations: 0

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ACQUISITION OF TECHNOLOGY BY THE ENTERPRISE  
by  
PORTUGUESE PARTICIPATION IN THE SHARE CAPITAL

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PORTUGUESE SHARE	Count Row Pct Col Pct	ACQUISITION		Row Total
		NO	YES	
0			1 100.0 20.0	1 7.1
50		1 100.0 11.1		1 7.1
100		8 66.7 88.9	4 33.3 80.0	12 85.7
Column Total		9 64.3	5 35.7	14 100.0

Number of Missing Observations: 0

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