4. Ensaios: Innovation diffusion and technological competition: the case of Portuguese industries [2]

ABSTRACT. In this article, that is based on the paper: "Patterns of innovation diffusion and technological competition in Portuguese manufacturing and service industries", to be published by the *International Review of Applied Economics,* we analyse the inter-industry heterogeneity in the diffusion of innovations and level of technological competition in Portuguese manufacturing and service industries. The industries are classified with reference to the relationship between the level of participation in innovation and the strategies of innovative firms. Methods of multivariate statistics are used to synthesize the data and to group the observations into subsets. Four distinctive innovation patterns are identified, defined along the following dimensions: output-orientation of innovation, importance of disembodied innovation, role of technologically advanced innovation and level of innovation opportunities. It is also found that high levels of technological competition tend to occur in sectors with relatively low dimension, productivity and overall investment.

4.1. Introduction

Empirical evidence suggests that there are significant inter-industry differences in the firms' innovation behaviour. This evidence is often understood as a sign of technological or economic determinism in innovation: different industries will follow different innovation patterns and these patterns depend on structural characteristics specific to each industry.

The study of sectoral-specific innovation patterns and its determinants is relevant for policy purposes, since the recognition of substantial differences in innovation patterns implies the necessity of introducing selective technological policies, suitable to the specific needs of each industry. General policies may not have an impact on the innovation behaviour of the firms in some industries.

Innovation patterns at the industry level are often explained with reference to the concept of technological regimes (Nelson & Winter, 1982; Winter, 1984), according to which the firms' decision to innovate and subsequent innovation behaviour are determined by the environment in which they operate. Technological regimes have been characterized by aspects such as the level of technological opportunities (Klevorick *et al.* , 1995), continuity of innovation through time (Malerba & Orsenigo, 2000; Cefis & Orsenigo, 2001) and appropriability conditions of the innovation (Cohen *et al.* , 2002).

The evolution of innovation patterns in time may also follow a path characterized by certain industry-specific technological trajectories (Nelson & Winter, 1977; Dosi, 1982). It is argued that firms in each industry tend to follow similar innovation strategies, as they have the same perceptions of the available alternatives. Several empirical studies have studied dimensions of sectoral technological trajectories, such as orientation towards product or process innovation (Pianta, 2000; Nascia & Perani, 2002), sources of information (Audretsch, 1997), type of innovation input (Sellenthin & Hommen, 2002; Veugelers & Cassiman, 1999) and degree and type of interaction between firms (Malerba, 2002).

A stream of literature has focused on the classification of industries according to their innovation patterns. The primary source of reference for many studies is the work developed by Pavitt (Pavitt, 1984, Pavitt *et*

2 Por Maria Rosário Oliveira Martins. O texto é da responsabilidade da autora e não coincide necessariamente com a posição do Ministério da Economia e da Inovação.

al., 1989), who developed an industry taxonomy based on type of innovations (product *vs* process innovation), objectives of R&D, sources of information and appropriability mechanisms. Other studies have also classified industries according to a mix of indicators of technological regimes or technological trajectories. Recently, Castellacci (2004) systematized a series of dimensions related to both technological regimes and technological trajectories and developed an alternative to Pavitt's taxonomy.

Most of the recent studies on the identification of sectoral innovation patterns use formal statistical methods, first introduced by Evangelista (2000), where the industries are classified using clustering methods applied on a series of variables related to the firms' average innovation behaviour.

This paper attempts to identify for the Portuguese economy the inter-sectoral patterns of innovation with reference to two specific (and inter-related) dimensions: the level of innovation diffusion and the level of technological competition. These dimensions may be considered as a characteristic of the industries' technological regime (if understood as constraints to the firms' decision to innovate and to their innovative behaviour) or technological trajectory (if understood as explaining the firms' strategic choices in terms of innovation).

Either way, it is expected that the relations between the levels of innovation diffusion and technological competition in an industry and the behaviour of the firms that innovate will follow some patterns. The aim is to classify industries according to these innovation patterns.

The second objective of this study is to investigate the relations between innovation diffusion, technological competition and innovation environment. The innovation environment of an industry is defined as the set of conditions that firms face when deciding to innovate or engaging in innovation activities. It is assumed that the innovation environment can be assessed by the firms' perceived obstacles to innovation and the industries' structural characteristics.

The study uses Portuguese Community Innovation Survey (CIS III), at the sector level, covering the period 1998-2000 and considers both manufacturing and services in the same framework of analysis, in order to test whether there are distinctive patterns of innovation in those industries, given the increased opportunities for introduction of information technologies in services during the last decade (Coombs & Miles, 2000).

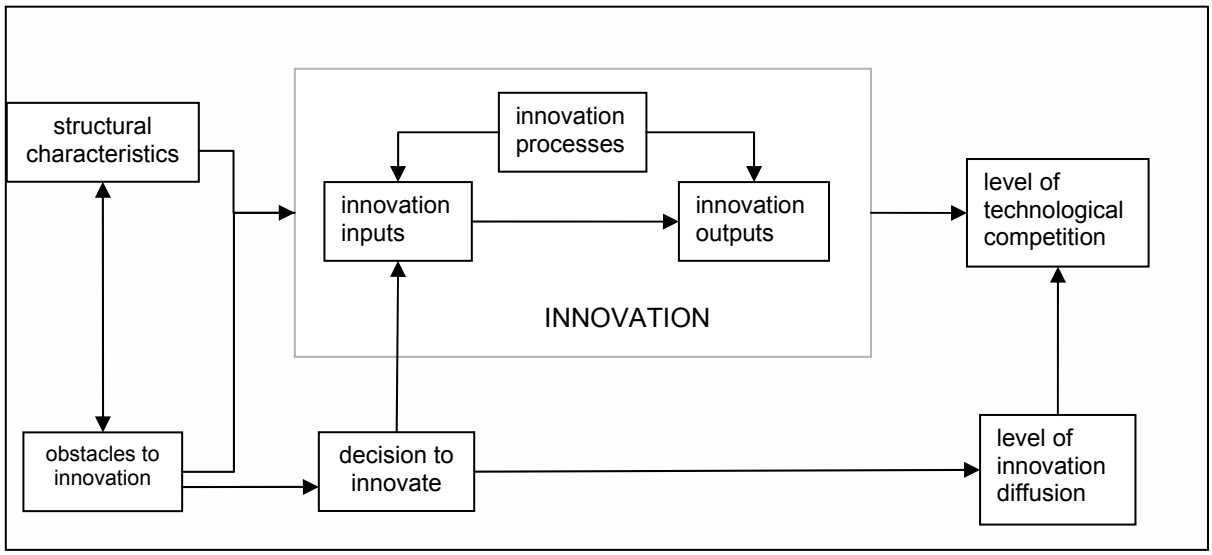
4.2. Conceptual framework, Data and Methodology

Innovation has been traditionally regarded as a linear process, where firms invest in research and development (R&D) in order to generate knowledge to create new products, which are patented and introduced in the market.

This perspective is being largely abandoned, based on the recognition that many innovations do not originate on investments in R&D or are not aimed at the creation of new products. Also, many innovations are not patented, especially in the service industries (Evangelista & Sirilli, 1995). Furthermore, innovation effort is not always effective in terms of creation of innovation output (Klomp, 2001). The formulation of innovation policies thus requires a greater insight on the firms' innovation behaviour, by distinguishing between innovation inputs and outputs and by looking into the innovation process itself, that is, the way the innovation activities are organized in order to generate innovation output. It is nowadays accepted that the innovation process is a complex phenomenon, featuring many linkages from inputs to outputs and from the R&D department to other departments in the firm (Kline & Rosenberg, 1986).

The conceptual framework used in this study (Figure 1) considers the firms' innovation strategies (the set of innovation inputs, innovation processes and innovation outputs) together with the firms' decision to innovate and the sectoral determinants of both.

Figure 1. Framework of analysis



The objective of the firms that innovate is to use innovation inputs (R&D expenditure and others) and create innovation outputs (new products or new processes). The use of inputs is characterized by a set of processes (such as funding, cooperation or organizational changes). The generation of innovation outputs is also accompanied by a series of related processes (such as the protection of innovation). The innovative firms' strategies depend on the perceived obstacles to innovation and also on the structural characteristics of the sector. Both are possibly inter-related. The level of innovation diffusion in a given industry is defined by the percentage of firms that innovate. The level of technological competition in the industry is characterized, using cluster analysis, by The level of innovation diffusion and the type of innovation strategies of the innovative firms

The CIS is a survey on firms' innovative behaviour which is carried out throughout the whole European Union using a harmonized questionnaire. It is suitable for the analysis of our research question since it provides information on both the firms' decision to innovate and the behaviour of the innovative firms. For both innovators and non-innovators, information is also available on the perceived obstacles to innovation.

This survey distinguishes between innovation input and innovation output. On the input side, it acknowledges the existence of other innovation activities besides expenditure in R&D, such as the acquisition of machinery and equipment, external knowledge acquisition and expenditures in training, marketing and design. On the output side, innovation is assessed not only by the number of patents applied or hold by the firm but also from the introduction of processes and products new to the firm. A further advantage of the CIS data is the inclusion of information about the innovation processes, such as financing methods, cooperation arrangements, structural and management changes, sources of knowledge and ways of protection of innovation (where besides patents, a variety of strategic methods of protection are considered, such as time lead, secrecy and complexity of design).

The choice of variables to include in the study is based on the conceptual framework described in the last section. Information on the total sectoral innovation expenditure is not considered, since the analysis is not focused on innovation intensity but either on the firms' decision to innovate and type of innovation strategy. Also, information on the economic effects of innovation is not included, since it is not a dimension that is under direct control of the firm.

A series of indicators were calculated from the information available on the CIS III dataset:

a) Variables on the innovation inputs: expenditure in intramural R&D as a share of the total sectoral innovation expenditure (Exp. R&D / total innovation exp.) and expenditure in acquisition of machinery and equipment (Exp. machinery / total innovation exp.) as a share of the total sectoral innovation expenditure.

b) Variables on the innovation processes with impact on innovation inputs: percentage of firms in the industry receiving public funding from the European Union; percentage of firms that have been cooperating in innovation projects; percentage of firms indicating as very important sources of knowledge sources from within the firm, sources from customers, sources from universities and sources from competitors; percentage of firms that have implemented new corporate strategies, advanced management techniques, changed organizational structures and changes in the products' aesthetic appearance.

c) Variables on innovation outputs: percentage of firms in the industry that have introduced into the market a new or improved product, sectoral turnover due to new or improved products as a share of total sectoral turnover, percentage of firms that have introduced a new or improved process.

d) Variables on the innovation processes with impact on innovation outputs: turnover covered by patent application as a proportion of total sectoral turnover, percentage of firms in the industry reporting protection of innovations through complexity of design and through long-time advantage.

The selected indicators on innovation inputs, innovation processes and innovation outputs are first synthesized by factor analysis. The factors are interpreted as dimensions of the firms' decisions to innovate and innovation behaviour and are used in a cluster analysis to identify different, homogeneous and mutually-exclusive sectoral patterns of innovation diffusion and technological competition. These clusters are then interpreted and characterized in terms of the principal components and the original variables.

In a second stage, the consistency of the innovation patterns found is tested against other CIS data not used in the clustering procedure: variables related to the sectoral structural characteristics and perceived obstacles to innovation. A factor analysis is performed on these new set of variables, in order to disentangle the associations that may exist between some of the indicators. The factors obtained are identified as different dimensions of each industry's innovation environment and then used to characterize the clusters of innovation patterns. Finally, the sectors are once more clustered, according to the factors related to the innovation environments and the resulting cluster membership is compared with the one obtained for the clustering of innovation patterns (the definition of the variables used and the detailed results on factor and cluster analysis can be found in the International Review of Applied Economics' paper).

4.3. Patterns of innovation diffusion and technological competition

Using multivariate statistical analysis, the industries were classified in 4 clusters (Table 1) based on both inter-cluster and intra-cluster heterogeneity. Cluster 1 contains a series of mostly low-tech extractive and manufacturing industries and six service industries, including some standardised transport services. This group can be labelled **non-competitive process innovation**, since the high proportion of process innovators is not associated with clear strategies to gain and secure innovation advantage (as measured by use of internal R&D and sources of knowledge from customers, universities and competitors) or to protect the benefits from innovation (either with formal or strategic methods).

Table 1. Innovation patterns

Cluster Characterization	Cluster Membership: Sectors
Cluster 1:non competitive process innovation	Other mining, Food and beverages, Textiles, Pulp and paper, Publishing and printing, Non-metallic minerals, Basic metals, Machinery and equipment, Electricity and gas supply, Recycling, Wholesale,

	Land transport, Water transport, Transport-related and travel, Finance-related, Other business activities
Cluster 2: non-competitive widespread innovation	Air transport, Post and Telecommunications, Financial intermediation, Insurance
Cluster 3: output-competitive innovation	Chemicals, Fabricated metals, Electrical machinery, Motor vehicles, Furniture, Computer-related activities.
Cluster 4: input competitive innovation	Wearing apparel, Leather and footwear, Wood and Cork, Radio/TV and telecommunication equipment, Medical and precision instruments, Other transport equipment

Cluster 2 contains four sectors from the service industries. The innovation pattern in the sectors in this cluster can be labelled **as non-competitive widespread innovation**: innovation is a part of the business strategies of a large proportion of firms, although there is not intense competition to be ahead of other firms and explore the benefits of innovation, since the commercial importance of innovation is relatively small. The lack of competition is confirmed by the low importance attached to advanced process innovation, and in particular, to patent innovations. Cluster 3 includes five manufacturing industries and one service industries (Computer-Related Activities). The characteristics of this cluster are related to an **output-competitive innovation**: a relatively high number of firms develop new products that are important in terms of the sectoral turnover. Innovation is aimed at securing a market share in the innovative products market, that is, in the innovation outputs market. Cluster 4 contains six manufacturing industries. Innovation in this cluster is concentrated on a relatively few number of firms and can be labelled as **input-competitive innovation**: a small proportion of firms rely on their technological position to secure the benefits of innovation (sales of new products). This technological position is determined by the quality of innovation inputs used, that is, the stock of knowledge and the innovation potential possessed by the firm, which lead to the creation of technology barriers for the decision to innovate of other firms.

Overall, the patterns of technological competition in Portuguese industries are defined by the coexistence of high level of innovation opportunities and a tendency to secure the benefits of innovation. In economic terms, this is equivalent to a strong demand for innovation and a tendency of the suppliers of innovation (the firms that innovate) to secure their market share in innovation sales or their share on available public funding. High levels of technological competition appear both in industries with relatively high level of innovation diffusion (Cluster 3) and in sectors where innovation activities are concentrated in a small set of firms (Cluster 4). In first case, the firms develop innovation strategies oriented to the output, mainly using external resources and in the second case competition is based on the input side of the innovation, through the use of internal resources.

Lower levels of technological competition occur when the demand for innovation is relatively low and the suppliers do not show a strong tendency to protect the benefits of the innovation. This can occur when the innovation is widespread diffused within the sector (Cluster 2) or when the dominant type of innovation is process innovation, which is not directly linked to commercial results (Cluster 1).

Also, high levels of technological intensity seem to imply high levels of technological competition. With the exception of Machinery and Equipment, all the sectors classified as high-tech in the OECD taxonomy (OECD, 1997) belong to clusters classified here as competitive in terms of technological strategies. In opposition, low levels of technological competition occur in most of the service industries. The only

exception is the sector of Computer-related Activities, a fact which may be explained by the relatively high level of market competition in this industry.

4.4. Innovation diffusion, technological competition and innovation environment

According to the technological regime/technological trajectory literature, the sectoral patterns of innovation diffusion and technological competition are determined by characteristics specific to the sector- what we can call the "sectoral innovation environment". In this section we verify whether the clusters of innovation patterns are both distinct and internally homogeneous when considering those determinants. We also investigate whether the individual sectors within each of the clusters are associated with substantially different innovation environments. We assume that the innovation environment can be assessed by the perceived obstacles to innovation and the industries' structural characteristics.

Based on multivariate statistical methods, we found that: (i) patterns of innovation diffusion and technological competition seem to be associated with different innovation environments. In particular, the level of vitality and the perceived market, organization and information problems are the factors that most differentiate the clusters found. The importance of risks and financial obstacles do not seem to differ substantially across the four clusters; (ii) the clusters classified as patterns of high technologic competition (Cluster 3 and Cluster 4) are more internally homogeneous than the clusters classified as patterns of low technological competition (Cluster 1 and 2).

4.5. Concluding remarks

There are four distinctive innovation patterns of innovation diffusion and technological competition in Portuguese manufacturing and service industries. Patterns of high technological competition are characterized by a strong demand for innovation and a tendency of the innovative firms to gain and secure technological/innovation advantage in order to secure their market share in innovation sales.

Given the inter-industry heterogeneity in innovative patterns, selective technological policies directed at the industries following each pattern should identify what should be stimulated in those industries in order to maximize the benefits of innovation for society as a whole.

The cluster classified as output-competitive (cluster 3) shows an output-oriented innovation, with numerous product innovators. There are also many opportunities for the commercialization of innovation output. According to some authors (e.g. Edquist *et al.,* 2002) these are the innovation characteristics that most contribute to employment generation. These sectors should then receive particular attention and be the target of increased public resources. This could also increase the level of technological competition among firms in these sectors, since they tend to have relatively low levels of investment, which reduce the firms' ability to engage in innovation.

In the cluster classified as input-competitive innovation (Cluster 4), the number of product innovators is small but there is a high degree of technological competition. Innovation in these sectors is mainly disembodied. This type of innovation generates knowledge that might be also useful in other sectors of the economy. For this reason, technological policies in these sectors should aim at increasing the level of innovation diffusion, which seems to be limited by market, organization and information obstacles.

The clusters classified as non-competitive (Cluster 1 and Cluster 2) face a relatively low demand for innovative output and are characterized by a small degree of technological competition. However, firms in both clusters have a relatively high ability to innovate, as judged by the level of sectoral investment and the relative unimportance of market, organizational and information problems. Suitable technological policies for Cluster 2 would have a market-pull dimension, aiming at increasing the demand for innovative products,

which would lead to an increase in the firms' innovative effort. In cluster 1, where only process innovation is widespread diffused, market-pull policies would probably be less relevant than technology-push policies, aiming at improving the firms' innovation activities, especially in disembodied form.

The conclusions and policy implications of this study should consider, however, that the introduction of selective technological policies must be based on information on a wide range of factors apart from the levels of innovation diffusion and technological competition. In particular, information is required on the interdependences between industries and the role of positive externalities, in order to identify the sectors where innovation generates more social benefit. Also, it is crucial to complement the analysis of the inter-sectoral heterogeneity in innovation diffusion and technological competition with the study of intra-sectoral heterogeneity in the firms' innovation behaviour.

References

Arvanitis, S., Hollenstein, H. (2001) Innovative activity and firm characteristics. A cluster analysis of Swiss manufacturing using firm-level data, in: *Innovative Networks: Co-operation in National Innovation Systems.* pp. 48–76 (OECD, Paris).

Audretsch, D B. (1997) Technological regimes, industrial demography and the evolution of industrial structures, *Industrial and Corporate Change,* 6, pp. 49-82.

Castellacci, F. (2004) How innovation differs across sectors in Europe? Evidence from the CIS-SIEPI database, Working Paper, Nº 04/04, Centre for Technology, Innovation and Culture, University of Oslo.

Cefis, E., Orsenigo, L. (2001) The persistence of innovative activities: a cross countries and cross-sectors comparative analysis, *Research Policy*, 30, pp. 1139-1158.

Cohen, W.M., Nelson, R. R., Walsh, J P. (2002) Links and impacts: the influence of public research on industrial R&D, *Management Science,* 48, pp. 1-23.

Coombs, R., Miles, I. (2000) Innovation, measurement and services: the new problematique, in S. J. Metcalfe, I. Miles (Eds.) *Innovation Systems in the Service Sectors. Measurement and Case Study Analysis*. pp. 85–104 (Kluwer Academic Publishers, Boston, Dordrecht, London).

Dosi, G. (1982) Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change, *Research Policy* 11, pp. 147-162.

Edquist, C., Hommen, L., McKelvey, M. (2002) *Innovations and Employment: Product versus Process Innovation* (Cheltenham, UK: Edward Elgar).

Evangelista, R., Sirilli, G. (1995) Measuring innovation in services, *Research Evaluation,* 5, pp. 207–215.

Evangelista, R. (1999) *Knowledge and Investment. The Sources of Innovation in Industry* (Cheltenham, UK: Edward Elgar).

Evangelista, R. (2000) Sectoral patterns of technological change in services, *Economics of Innovation and New Technologies*, 9, pp. 183-221.

Gallouj, F. (1999) Les trajectoires de l'innovation dans les services: vers un enrichissement des taxonomies évolutionnistes, in : Série Économie et Gestion des Services (EGS) *Économies et Sociétés.* Vol.1, pp. 143–169.

Hollenstein, H. (2003) Innovation modes in the Swiss service sectors: a cluster analysis based on firm-level data, *Research Policy,* 32, pp. 845-863.

Kaiser, H F. (1958) The Varimax criterion for analytical rotation in factor analysis, *Psychometrika,* 23, pp. 187-200.

Kleinknecht, A., Mohnen, P. (2002) *Innovation and firm performance: Econometric explorations of survey data* (Palgrave, Basingstoke).

Kleinknecht, A. and Oostendorp, R. M.(2002) R&D and export performance: taking account of simultaneity, in: Kleinknecht and Mohnen (Eds) *Innovation and firm performance*. pp. 310 – 320 (London : Palgrave).

Klevorick, A., Levin, R., Nelson, R., Winter, S.G (1995) On the sources and significance of interindustry differences in technological opportunities, *Research Policy,* 24, pp.185-205.

Kline, S J., Rosenberg, N. (1986) An overview of innovation, in: R. Landau, N. Rosenberg (Eds) *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (National Academy Press, Washington).

Klomp, L. (2001) Measuring output from R&D activities in innovation surveys, paper presented at the *ISI 53 Conference*, Statistics Netherlands.

Leiponen, A., Drejer, I. (2005) Technological regimes and strategy: intraindustry heterogeneity in the organization of innovation activities, paper presented to the *DRUID Tenth Anniversary Summer Conference 2005 on Dynamics of Industry and Innovation: Organizations, Networks and Systems*.

Malerba, F. (2002) Sectoral systems of innovation and production, *Research Policy*, 31, pp. 247-264.

Malerba, F., Orsenigo, L. (2000) Knowledge, innovative activities and industrial evolution, *Industrial and Corporate Change,* 9, pp. 289-314.

Martins, Fraga O. Maria, Anciães, P. (2008), Patterns of innovation diffusion and technological competition in Portuguese manufacturing and service industries", *International Review of Applied Economics*, forthcoming.
Nascia, L., Perani, G. (2002) Diversity of innovation in Europe, *International Review of Applied Economics*, 16, pp. 277-293.
Nelson, R., Winter, S. (1977) In search of a useful theory of innovation, *Research Policy,* 6, pp. 36-76.
Nelson, R., Winter, S. (1982) *An Evolutionary Theory of Economic Change* (The Belknap Press of Harvard University Press, Cambridge, USA).
OECD (1996) *Innovation, Patents and Technological Strategies* (OECD, Paris).
OECD (1997) Revision of the high-technology sector and product classification, *STI Working Paper Series* Nº 1997/2*,* OECD, Paris.
Pavitt, K. (1984) Sectoral patterns of technical change: towards a taxonomy and a theory, *Research Policy,* 13, pp. 343-373.
Pavitt, K., Robson, M., Townsend, J. (1989) Technological accumulation, diversification and organisation of technological activities in UK companies, 1945–1983, *Management Science,* 35, pp. 81–99.
Peters, L., Swinnen, G., Tiri, M. (2004) Patterns of innovation in the Flemish business sector- a multivariate analysis of CIS-3 firm-level data, *IWT-Studies* Nº47, IWT Observatory, Brussels.
Pianta, M. (2000) The employment impact of product and process innovations, in: M. Vivarelli and M. Pianta (Eds.) *The employment impact of innovation: evidence and policy* (Routledge, London).
Porter, M E. (1980) *Competitive Strategy* (New York: Free Press, New York).
Sellenthin, M., Hommen, L. (2002) How innovative is Swedish industry? A factor and cluster analysis of CIS II, *International Review of Applied Economics*, 16, pp. 319-331.
Veugelers, R., Cassiman, B. (1999) Make and buy in innovation strategies: evidence from Belgian manufacturing firms, *Research Policy,* 28, pp. 63-80.
Winter, S G. (1984) Schumpeterian competition in alternative technological regimes, *Journal of Economic Behavior and Organization,* 5, pp. 287-320.