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Innovation Modes and Firm's Performance: Evidence from Portugal

Sérgio Nunes[1]; Raul Lopes[2]; José G. Dias[3]

Abstract

It has been shown that firms tend to develop different modes of innovation triggered by the relationship between different types of knowledge and learning processes underpinning it. This paper aims at identifying different modes of business innovation; second, relating them to firms' innovative and economic performance; and, analyzing the relationship between the different innovation modes and the economic impact of the crisis on the firms' performance. These hypotheses are tested by regression and latent class models for the Portuguese population of firms using a sample of 397 firms, stratified by level of technological intensity, firm's size and region. Results show three firms' heterogeneous modes of innovation in terms of its relationship to the economic and innovative performance and with significant differences in terms of resilience to the economic crisis. These findings lead to a reflection on innovation, competitiveness and regional policy.

Key-words: *economic performance, latent class model, logistic regression, innovation modes, innovation process, governance mechanisms, economic crisis, firm´s resilience, innovation policy*

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Introduction

Distinct strands of literature and international organizations have shown that firms do not develop their innovation activities in the same way, identifying different behaviors of firms, both in their innovation processes and economic performance. Identified different modes of innovation, cannot fail to consider several implications for public policy and also for innovation strategies. The recognition of other modes of innovation, not science and technology driven, has the major importance in terms of its policy implications. In fact, the abandonment of monolithic policies for promoting innovation (R&D), the appreciation of different strategies in terms of competitiveness policy and the incorporation of the territorial dimension in the different public policies, are currently the main challenges for the political and economic leaders of Europe in general and each territorial agent in particular.

Taking Portugal as a case study, this paper has three main objectives: first, we will try to identify different modes of business innovation. Second, we will relate them to the innovative and economic performance of Portuguese firms. Finally, we will try to investigate the relationship between the different modes of innovation and the impact of the economic crises. The paper is organized in four sections. In the first section we present the theoretical and conceptual framework that supports the possibility of identifying different modes of business innovation. The second section presents the main methodological options of empirical analysis. We show the latent class model used and the process of building the database, the variables employed and the selection and estimation of the model. Then we present the main results and a proposal for the definition of different modes of innovation. In section 3 we will relates the different modes of innovation identified with the innovative and economic performance of firms. The innovation performance is measured by one-dimensional variables (product and process innovation) and multidimensional ones. Economic performance is measured by the variable "level of growth in turnover". In order to test this relationship, four econometric models are estimated using the logistic regression. We estimate another econometric model to test the relationship between the modes of innovation and the current economic crises. Finally we present the main conclusions and it´s political implication.

1. Innovation modes: building a conceptual framework from organizational knowledge to territorial networking

Different methodological approaches have been applied in the identification of distinct modes of innovation (see, for example, Gokhberg, Kuznetsova and Roud, 2012; Parrilli and Elola, 2011; Parrilli, González and Peña, 2012; Corrocher, Cusmano and Morrison, 2011; Marlon and Lambert, 2009; Žížalová, 2009; Jensen *et al*., 2007; Lundvall, 2007; Tödtling, Lehner and Kaufmann, 2006; Lorenz and Lundvall, 2006; Tödtling, Lehner and Trippl, 2004).

Knowledge and learning have been in the centre of every conceptual framework developed by the different approaches. Both the learning process and the knowledge associated with him it can take several forms. The articulation between forms of knowledge and learning can define distinct modes of innovation used by firms. Jensen *et al.* (2007) proposes two different ways of learning and innovation: the mode based on the production and use of scientific and technological knowledge encoded – Science, Technology and Innovation (STI) and the mode based on learning from experience and supported by interactive learning process – Doing, Using and Interacting (DUI). This is, conceptually, our starting point. We consider differentiating factors and dimensions introduced by Jensen *et al.* (2007) as well as additional factors believed to be relevant in differentiating modes of innovation.

Lundvall (2007) and Jensen *et al*. (2007) highlight the role of knowledge in the innovation process, recognizing the importance of collective learning processes in the knowledge production. The knowledge produced and accumulated in this way – by collective learning processes – cannot be confused with scientific knowledge from the traditional system, assigned mostly to large firms and scientific research system in particular. Innovation occurs in all sectors, whether more or less technology and knowledge-intensive, and the knowledge relevant for innovation derives not only from traditional scientific system, but also from the collective learning processes associated with various contexts and interaction (formal and informal) of their various agents (Nunes, 2012; Nunes and Lopes, 2012b). Like Hudson stresses (1999: 62) "*The emphasis now is therefore upon recognizing that innovation is an interactive process that involves the synthesis of different types of knowledge rather than privileging the formal scientific knowledge of the R&D laboratory over other forms of knowledge*" and

"*creating dense horizontal flows of knowledge and information within, and vertical flows of knowledge and information between, the various functional divisions of the company, while opening the ears of those involved within the company to voices from outside its boundaries" (op. cit: ibid).*

Jensen *et al.* (2007) argue that there is a tension between these two modes of learning and innovation: the mode based on the production and use of scientific and technological knowledge encoded and the experience-based interactive learning mode. This tension has led to a bias on the part of politicians and researchers in order to privilege the mode based on science, understanding innovation mostly linked to formal processes of R&D, particularly in science-based industries and high technology. Jensen *et al.* (2007: 104) introduced a 2 x 2 typology of innovation models (Table 1). Research on innovation has given special attention to the cells 1 and 4 and agents of policy have concentrated their efforts in cell 4.

Table 1 – Dimensions of the innovation modes

	Low-tech sectors	***High-tech sectors***
DUI Mode	**1**	2
STI Mode	3	**4**

Source: Jensen *et al.* (2007: 104)

This author shows that both modes of innovation are practiced with different intensities for different types of firms, as well as the most innovative firms are those who practice combinations of the two modes of innovation. The interactions among the technological innovations in hardware and software, and between human resources, organizational change and networking, on other hand, are both crucial to the process of innovation and the rate at which innovations are transformed into economic performance. The results performed by the authors support that "*It is the firm that combine a strong version of the STI-mode with a strong version of the DUI-mode that excels in product innovation* (Jensen *et al.*, 2007: 685). These results confirm the argument that innovation and collective learning processe cut across the entire economy (both in terms of high and low technology) and innovation capacity of firms is heavily dependent on combinations of these two "pure" modes and not just in the traditional way, supported by science and codified into patents.

Taking as starting point this seminal works, in this paper we add four conceptual relevant dimensions of the innovation process: the context of knowledge (different external contexts, from local to global), different mechanisms of interaction and modes of learning associated with the governance of the dynamics of the innovation process, the radicalness of the innovation process (incremental to radical innovation) and the predominance of the activities of firm´s innovation process (knowledge production, knowledge transformation and Product Placement in the Market). When a process of innovation is supported mainly by dynamic of cooperation, the territory, the various networks of knowledge and the interaction mechanisms (especially the mechanisms of informal nature) play a key role in the effectiveness of the innovation process (see Fuller-Love, 2009; Nunes, 2012; Nunes and Lopes, 2012a and Nunes and Lopes, 2012b) and should be taken into account as differentiated dimensions of the innovation modes. Additionally, the innovation modes should not be independent from the type of innovation that firms introduced into the economy and the activities that fuel their innovation process.

In summary, Table 2 attempts to identify the main factors and dimensions that in our synthesis contribute to define different modes of innovation.

Tabela 2 – Conceptual dimensions of innovation modes

	STI Mode	**DUI Mode**
Knowledge type	Analytical, codified and explicit, science-base: *know-why*	Tacit and contextual: *Know-how* e *know-who*
Learning type	Made mostly from formal processes of R&D	Informal interaction processes: learning based on experience, *by doing, by using, by interacting*;
Innovation type	Radical	Incremental
Innovation activities	Knowledge production Knowledge transformation	Knowledge transformation Product placement in the market
Knowledge context	Global and generalizable	Restricted and territorial
Governance strategy of knowledge management and promotion of the innovation process	Sharing internally, in the organization, of knowledge from a broad base of general and coded knowledge Innovation activities mainly developed in-house – *in-house model* – or in a closed business network	Networks of knowledge sharing between various departments of the organization and external actors, building structures and networks of relationships that enhance learning specific ways: project teams, problem-solving groups, job rotation, proximity to the customers Innovation activities mainly developed in cooperation – *networking model*

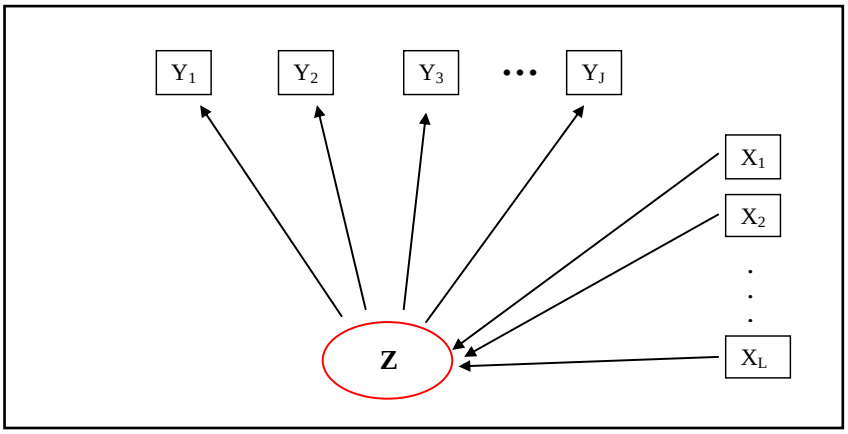
Source: Authors' own elaboration based on Lundvall (2007), Jensen *et al.* (2007), Asheim and Gertler (2005), Nunes (2012), Nunes and Lopes (2012a) and Nunes and Lopes (2012b)

2. Main methodological options used in the analysis

2.1. Methodology for analysis: a Latent Class Model

As a way to identify different modes or ways to develop innovation activities, from certain behaviors developed by firms, we used a latent class model, the methodology also used in Jensen *et al.* (2007). In simple terms, the latent class analysis can be seen as a factorial analysis technique of categorical variables on which the latent variables or factors are discrete. The different modes of innovation are impossible to identify, being necessary to seek to understand them from a set of characteristics and behaviors of different firms, but these identifiable. The following figure helps to illustrate the main idea behind this type of model. The latent variable Z is discrete with S categories or groups, i.e., Z=1, 2, …, S, that cannot be observed directly, but can be identified from its manifestations: $Y=Y_1$, Y_2, …,Y_J, being J the number of manifest variables. Moreover, L concomitant variables are used in clusters profiling: $X=X_1$, X_2, … X_L.

Figure 1 – Latent Class Model



From Figure 1, we can make the following interpretation:

- The conditional probability : probability of the observation belong to the cluster Z = S, since the firm has the characteristic X, which represents a model of the type probit/logit;
- The conditional probability : probability of observing the behavior of Y, given that the firm is in cluster Z = s.

For a more detailed discussion of this statistical model we suggested the reading of McCutcheon (1987) or Clogg (1981).

2.2. The construction of the database

The database used in this article resulted from the following methodological procedures. The population was obtained from COFACE[4] and consists of 981 firms that satisfy the following criteria: in 2008 had a turnover of more than € 1 million and simultaneously an increase in turnover of at least 5% between 2007 and 2008. It was intended to thereby identify the more dynamic group of firms from the point of view of their economic performance. You can differentiate the universe by the following variables:

- Levels of technological intensity and knowledge services: High Technology (HT), Medium-High Technology (MHT), Medium-Low Technology (LMT) and Low Technology (LT). We also considered firms in the sector of Knowledge Services (SC). These are variables that aim to capture the sectoral structure of analysis. This typology was chosen because it is the most commonly used in the literature and in the own documents of international reference entities, such as the OECD and the European Union;
- Firm Size – classified into Micro (0-9), SME (10-250) and Large Firms (> 250), through the number of employees (2008). This variable is intended to capture the dimension of organizational structure;
- Regional dimension – NUT III (Grande Lisboa e Península de Setúbal, Pinhal Litoral e Grande Porto). This variable is intended to capture the regional dimension.

As it is not financially possible to carry out an investigation to the entire population, was later designed a representative sample of the universe, obtained by stratification and proportional affixation, which was respectively surveyed - via telephone - during late 2010 and early 2011. Sample comprises 397 firms, stratified by the level of technological intensity, firm size and region.

[4] COFACE SERVIÇOS PORTUGAL, S.A. See www.coface.pt

2.3.The variables used, the definition and estimation of our model

Methodologically the latent class model was applied to the database which mentioned in the previous section, having been selected as inputs – the manifest variables – the 12 variables and categories listed in Table 3.

Table 3 – Manifest variables and categories

Variables	*Categories*	*Dimension of the innovation process*
1. Multidisciplinary groups	*Likert* (1 - Irrelevant; 5 - Fundamental)	*Organizational Learning*
2. Quality circles/groups	*Likert* (1 - Irrelevant; 5 - Fundamental)	
3. Collective proposals	*Likert* (1 - Irrelevant; 5 - Fundamental)	
4. Integrated functions	*Likert* (1 - Irrelevant; 5 - Fundamental)	
5. Groups more indistinct	*Likert* (1 - Irrelevant; 5 - Fundamental)	
6. External cooperation	*Likert* (1 - Irrelevant; 5 - Fundamental)	
7. R&D department	*Likert* (1 - Irrelevant; 5 - Fundamental)	
8. External financing	*Likert* (1 - Irrelevant; 5 - Fundamental)	
9. Innovation new to the market	*Likert* (1 - Irrelevant; 5 - Fundamental)	*Radicalness of innovation*
10. Predominance of innovation activities	Knowledge production Knowledge transformation Product Placement in the Market	*Innovation activities*
11. Knowledge context	Territorial Global	*Territorial configuration*
12. Learning and interaction mechanisms	Formal Informal	*Learning mechanisms and interaction dynamics*

Source: Authors´ own elaboration

Jensen *et al.* (2007: 687) used to assess the different ways to innovate variables (binary), essentially allocated to the internal context of business (organizational learning related with DUI-innovation mode) except for the consideration of cooperation with external customers and investigators (variables related with STI-innovation mode). In our model, we considered additionally variables associated with the radicalness of innovation practiced, the different type of activities associated with knowledge engaged in the materialization of the innovation process, the contexts and the mechanisms used for interaction and learning. It was attempted thus contemplating the various components of characterization of different innovation modes that we detailed in Table 2. Based on 12 variables manifest we tried define clusters that correspond to groups of firms with different modes of innovation. It was also taken as concomitant variables (or

characterization) the level of technology intensity, the NUT III regions and firm size (please see table A1 on Appendix). Table 4 presents a conceptual proposal of the relationship between the variables considered and the two "pure" innovation modes considered.

Table 4 – Variables and a conceptual proposal for two "pure" innovation modes

	DUI Mode	STI Mode
Organizational Learning	++	+
Radicalness		
Incremental	++	
Radical		++
Predominance of Innovation Activities		
Knowledge production	+	++
Knowledge transformation	++	++
Product placement in the market	++	+
Knowledge Context		
Territorial	++	++
Global	+	++
Learning and Interaction Mechanisms		
Formal	+	++
Informal	++	+

Source: Authors´ own elaboration

The model was estimated – using the software Latent Gold 4.5 – for different starting values to minimize the effect of local optima. Models from one to four latent classes were estimated. Model selection selects the best number of latent classes needed to retrieve population heterogeneity and the interpretation that the researcher can perform in case of doubt. Table 5 presents information criteria: BIC – Bayesian Information Criterion (Schwartz, 1978) and AIC – Akaike Information Criterion (Akaike, 1974). Minimum values of BIC and AIC identify the best model.

Table 5 – Information criteria

Models	*Clusters*	*Log-likelihood*	*BIC*	*AIC*	*Parameters*
Model 1	*1-Cluster*	-5643,7	11514,8	11363,4	38
Model 2	***2-Cluster***	-5468,5	**11445,6**	11106,9	85
Model 3	***3-Cluster***	-5414,6	11619,1	**11093,2**	132
Model 4	*4-Cluster*	-5370,4	11812,0	11098,9	179

Considering the information criteria shown in Table 5, the choice of number of clusters is not clear. According to the BIC criterion would be taken to choose the model 2, while according to the AIC criterion would choose the model 3, i.e., the pattern does not point in the same direction. The literature has been defending that the BIC criterion is very restrictive as to the choice of the number of clusters, while the AIC criterion is considered less conservative (see, e.g., McLachlan and Peel, 2000). In this case, the choice depends on the interpretation that the researcher makes of the clusters. The choice fell on the model 3 – 3 clusters – since, compared to Model 2, yield an additional cluster, which individualizes a group of firms whose characteristics are relevant to the ongoing discussion, as we shall see later.

Table A2 in Appendix, shows in detail the results of the estimates of the latent class model considering the three clusters mentioned. The results allow identifying the conditional probability of a firm practicing a particular behavior, knowing that belongs to a particular cluster. The second row of all tables refers to the size of each cluster. Cluster 1 contains 67% of firms, 20% the second and the third 13%, respectively. The column of *p-value* shows that all manifest variables are considered statistically significant, and can affirm that help explain the differences found. In general terms, it can be argued that since there are other variables in the model, this variable adds significant explanatory power. The last column refers to the ratio of sample. Crossing the information (*profile* information from the outputs) constant in the previous tables, with additional information that can be obtained through the Latent Gold 4.5 (*probmeans* and graphical representations of both); it is possible to characterize and identify a label for each latent class, representing distinct modes of innovation. The labeling and profiling of latent classes is pursued in next section.

3. Different modes of innovation: a proposal

Based on the analysis of the previous tables, we propose three general modes of innovation, associated with each of the clusters identified by the three-latent class model.

Table 6 – Modes of Innovation – Main Features

	Cluster 1	*Cluster 2*	*Cluster 3*
MANIFEST VARIABLES	***Low Learning DUI***	***Moderate DUI/STI***	***Moderate DUI***
Organizational Learning	++	+	+
R&D Department	+	+	+
External Cooperation		++	
External Financing	+	+	+
Incremental to Radical innovation	+	+	++
Market-Transformation-Production	**M**	**M-P-T**	**M-T**
Knowledge Context	**G**	**T**	**G**
Learning and interaction mechanisms	**I**	**I**	**F-I**
CONCOMITANT VARIABLES			
Level of technological intensity	***Low Learning DUI***	***Moderate DUI/STI***	***Moderate DUI***
Low technology	++	+	+
Medium-low technology	++	++	++
Medium-high technology	+	++	++
High technology	+	+	+
Knowledge services	+	++	+
Nuts III regions (not significant)			
Grande Lisboa e Península de Setúbal	++	++	+
Grande Porto	+	++	+
Pinhal Litoral	+	+	+
Firm size			
Micro		++	
SME	++	++	++
Large	+		+

Source: Authors´ own elaboration

Then are summarized the characteristics of each of these three innovation modes.

Mode 1 – *Low Learning DUI* mode of innovation

This cluster gathers about 67% of the sample firms. In terms of characterization variables, this is a group that hosts essentially SMEs located in Lisboa metropolitan area. As the results presented later show, this cluster is characterized by firms with a low innovative intensity, and its innovation process is basically experimental-incremental type, i.e. in the line of the DUI mode. By presenting similarity with the corresponding group defined by Jensen *et al*. (2007), we designate this group by "*Low Learning DUI*" innovation mode.

Indeed, one of the main innovative features of the mode of these firms includes the following:

- these are firms that use low technology (LT) or medium-low technology (MLT), whose innovation activity is restricted overwhelmingly to "Product Placement in the Market";
- Consequently, in terms of radicalness of innovation, are firms that promote mainly incremental innovations (product and process improvement). To this purpose they value more strongly the global knowledge than territorial one. Such would justify that do not confer great relevance to external cooperation, because, apart from market exchanges, the mechanisms of interaction are mostly informal and confined to the firm organizational context;
- Given the nature of the mode of innovation practiced by these firms, about 60% of them do not confer great importance to the existence of a department of R&D. In contrast, they especially value the process of organizational learning, either the intensity of use of multidisciplinary teams, quality circles, the collective proposals made employees, or integrated functions.

This cluster presents some less expected results. In particular the fact that mainly use global knowledge, and often have some degree of radicalness in innovation practiced, but, in contrast, does not value external cooperation and rely particularly on informal interaction. This apparent contradiction can be explained by the following facts. Firstly, these are firms whose innovation is materialized primarily in placing the product on the market, which may lead to overestimation of global knowledge and the degree of radicalness of innovation (self-assessment of knowledge and technology embodied in the product that sell). Secondly, the process of interactive learning these firms occurs mainly within the firm, which by their small size will practice mainly informal modes of relationship. Finally, these firms benefit from a favorable market for its dynamism and the density of flows of information and knowledge it provides, such as the Lisbon Metropolitan Area. This framework of territorial market could cause the firms to benefit from informal interaction processes without properly valuing the corresponding interactions with their surrounding context, even by the informal nature of such relationships.

Mode 2 – *Moderate DUI/STI* mode of innovation

In this cluster are grouped around 20% of the sample firms. These are firms that we designate by Moderate Innovators, combining practices inherent with DUI mode and procedures specific to STI mode. As Jensen *et al. (*2007) also concluded, in our test the cluster that combines two modes of innovation is what reveals greater performance, as discussed in detail in the next section. In terms of characterization variables, this is a group consisting predominantly of SMEs located in metropolitan context (either in Lisbon or Porto). A alongside with the SMEs is important to highlight the relevance of micro firms in the composition of this cluster, the rest being the only one where the probability of finding this firms size is remarkably higher than in the other clusters. In general in this group they are firms with a level of technological intensity relatively superior to those identified in the previous mode of innovation, emerging here predominantly industrial firms of medium technological intensity (MLT and MHT), or firms that operate in the field of knowledge services (SC).

As regards the innovation mode of these firms noteworthy:

- The fact that, like the previous cluster, devote themselves primarily to incremental innovation, not confer particular attention to the existence of internal departments of R&D and favoring the informal mechanisms of interaction and learning.
- Differently from the previous mode of innovation, firms now tend to combine practices of "placing the product on market", with practice of transformation and even knowledge production, indicating a higher innovative performance.
- Another aspect clearly distinguishing the previous cluster is that this innovation mode firms valuing predominantly the territorial knowledge, absorbed through external cooperation seen this relations as "very important". Thus, the informal mechanisms of interaction now occur in the articulation of the firm with its surrounding territory, rather than inside the firms as in the previous mode of innovation.
- In terms of organizational learning, firms in this cluster value with less intensity the organizational learning, and this mainly associated with the "functional integration" within the firm.

Also in this case the presence of STI mode characteristics (such as the importance attributed to the "transformation" and even "production" of knowledge), appears to be in contradiction with the emphasis given to regional informal mechanisms of interaction, rather efforts in R&D. However, if we consider that these firms are often micro-businesses and the knowledge that they mobilize for innovation allows no more than incremental innovations, it will be understand better the importance of the territorial locational context (the two metropolitan areas) and its learning mechanisms by networking. In any case, remember, this cluster combines two modes of innovation, but with a clear predominance of an experimental type of DUI.

Thus, we designate this cluster by "*Moderate DUI/STI*" innovation mode.

Mode 3 – *Moderate DUI* mode of innovation

In cluster 3 are grouped around 13% of the sample firms. It is the smallest cluster presenting intermediate characteristics to the two previous clusters. Like cluster 1 is constituted essentially by SMEs (and some large firms). We are in the presence of industrial firms that predominantly use mid-range technology such as cluster 2. Sharing with cluster 2 still a type of innovative activity where the "placing the product on market" combines the "transformation" of knowledge (but not the "production of knowledge" that sometimes reveals itself in cluster 2). Finally, as the cluster 1, mobilizes global knowledge rather than local, but neither appreciates the mechanisms of interaction and learning outside the firm (as in cluster 2), or as intensely as the first cluster the internal mechanisms. We should register that in this cluster the most interactions are governed by formal mechanisms, despite the importance of informal mechanisms also assume in this cluster. The fact that the firms in this group did not particularly appreciate the behaviors of organizational learning or external cooperation, could mean that the innovation activity of these firms is essentially a mercantile interaction process, which is consistent with the nature of the activity of innovation (market-transformation) and justify the importance that the formal mechanisms assume this innovation mode.

Thus, we designate this cluster by "*Moderate DUI*" innovation mode.

In summary, the analysis allowed us to identify three groups of firms, with three different ways of innovation. Whilst none of the identified clusters falls in intense modes of innovation, they typify behaviors of business innovations, and with significant differences between them. Among these we highlight, on the one hand, the emphasis given to intra-organizational learning processes, and, on the other hand, the appreciation of networking relationships (formal and informal) with actors outside the firm, especially those located in the same territorial context (in which case it will not be strange that we are analyzing firms predominantly located in metropolitan environment, particularly rich in information flows and knowledge). The low level of technological complexity associated with the activity of firms in the study, explain the reduced importance that all clusters attribute to the existence of a department of R&D. On the other hand, this means that firms can engage in innovation processes without external financing constitutes a critical process, which explains the low importance attributed to this factor by most firms of various clusters.

4. Innovation Modes, Firm´s Performance and the Economic Crisis

This section aims at analyzing what is the relationship that can be established between the different innovation modes identified and the economic and innovative performance of the firms. Additionally, we will make an attempt to analyze the relationship between different modes of innovation and the impact of the international economic crisis felt by firms. Figure 2 shows the analysis developed and Table A3 presents all variables used in estimations[5] (please see Appendix).

Innovation Modes and Innovative Performance

As a way to test the relationship between the innovation modes and innovation performance of firms were estimated three econometric models. The first model seeks to test this relationship taking product innovation as the dependent variable.

We estimate Model 1 and Model 2 measuring innovative performance with two variables: number of product innovations and process innovations that firms have introduced in the market in the last five years. We introduce these two output innovation

[5] All econometric work in this section was performed with Stata 10.1.

variables as dependent variables. As an independent variable we take the innovation modes, defined in the last section.

Model 1 and Model 2 was estimated using logistic regression, according to the nature of the dependent variable. We compute separately product and process innovations against the innovation modes. We integrate all the estimation results in Table A4 (please see Appendix). The estimates of both models allow note that as firms goes from the innovation mode "Moderate DUI" to "Moderate DUI/STI" mode, the probability of introducing product innovations increase, in marginal terms, in 30% and in 45% in innovation process, respectively. In summary, we can say that in terms of product and innovation process, the "Moderate DUI/"STI" innovation mode allows firms to achieve an innovation performance more intense.

As we know, the innovative performance is a multidimensional phenomenon, and if possible we should try to measure this performance more broadly. In Model 3 we use an aggregate measure of innovative performance, trying to incorporate some of that diversity. Based on business survey data, we construct a new variable – "Aggregate Innovation Performance". We take four types of innovation outputs: product, process, organizational and patent introduction. We asked firms which type of innovation they had introduced in markets in the last five years. Now we are dealing with an ordinal variable that ranges from "zero types of innovation" – if the firm didn´t introduce any type of innovation – to "four types of innovation" – if firms simultaneously introduced all types of innovation. We take this variable as the dependent variable and the innovation modes as independent variable. The Model 3 was estimated by using ordered logistic regression, according to the nature of the dependent variable. The results can be seen in table A4 in Appendix.

Based on these results, it can be said that as firms goes from the innovation mode "Moderate DUI" to "Moderate DUI/STI" mode, the probability in marginal terms of registering more intense levels innovation performance increase (the marginal effect is 3% for the third level, 6.6% for the fourth level and 15.7% for the last one). As in previous models, the results seem to suggest that the mode "Low Learning DUI" allows firms to an innovation performance slightly lower than the reference mode, although this outcome would not statistically significant. We can then say that analyzing the

innovation performance through either one-dimensional either multidimensional variable, the "Moderate DUI/STI" innovation mode always has better results.

Innovation Modes and Economic Performance

Model 4 attempts to capture the economic performance of firms through the growth of firm's turnover (sales volume) between 2007 and 2008, classifying firms into 6 levels. As independent variable we use our innovation modes.

Model 4 was estimated by using ordered logistic regression, according to the nature of the dependent variable. The results are shown in Table A4 (please see Appendix). As in previous models, the results seem to suggest that the mode "Moderate DUI/STI" allows firms to increase the probability of belonging to the upper classes of the growth in turnover, compared with lower levels. In summary, we can say that the "Moderate DUI/STI" innovation mode also allows firms to increase their probability of registering for classes of higher economic performance compared with smaller classes.

We also estimated the previous models for each of the control variables described previously. The main estimation results (taking only the statistically significant results) listed in table A5 (please see Appendix). The results show that in general the "Moderate DUI/STI" innovation mode performed better than the other modes of innovation.

Innovation Modes and the impact of economic crisis on firms

Among other insights, Nunes and Lopes (2013: 14) found empirical evidence that most firms (65%) in our sample (the some we used on this paper) recognize that the economic crisis has had a negative impact on their innovation process. Second, the firms use multiple channels and interaction mechanisms as a means to obtain external knowledge, and these knowledge networks revealed an important way to manage the impact of the crisis in the firms. Finally, firms with smaller impact of the economic crisis are the most dynamic ones (in terms of economic and innovative performance), particularly those innovation process is supported by a strong networking interaction; as a corollary of the networking relevance, the territorial context have a strong role to reduce the impact of the crisis in the firms' innovation process. Given these results, we must analyze whether there is a difference in the impact of economic crisis on firms

depending on the mode of innovation practiced. That is precisely the objective of this section.

The Model 5 tries to help us on this task and takes as the dependent variable the "Impact of Crisis in Innovation". This is an ordinal variable that can assume three values: "1" if the firm indicated that the crisis has had an impact with "*low relevance*" in their innovation process, "3" if the firm indicated that the impact of the crisis was "*very important*" and "5" if the answer was "*fundamental*". The dependent variable is the same as we use in the previous models. Model 5 was estimated by using ordered logistic regression, according to the nature of the dependent variable. The results are shown in Table A4 (please see Appendix).

The results allow us to suggest that if a firm belongs to the "Moderate DUI/STI" innovation mode the probability of the firms feel the impact of the economic crisis become lower. More precisely, in terms of marginal effects, if a firm belongs to the "Moderate DUI/STI" innovation mode – comparing to the reference mode – the probability of the firm answer that the impact of the crisis is “Indifferent” increases 16% and, simultaneously, the probability of the firm answer that the impact of the crisis is “Fundamental” decreases about 10%. In other words, practicing the "Moderate DUI/STI" innovation mode enables firms to a greater degree of resilience to the impacts of the economic crisis.

5. Conclusions and policy recommendations

The analytical work we have done allows us to draw two orders of conclusions. On the one hand about the innovation strategy adopted by firms, on the other hand when the implications of these different strategies on the performance of firms. Of a different order and conclusions arising lessons to be learned in terms of orientation for the innovation and competitiveness policy. Regarding the first aspect, the results make clear that firms do not innovate all the same. The three modes of innovation that we found in the sample of firms in this study are a good illustration, because as demonstrated three modes have very different characteristics. In this particular matter to emphasize that it is neither firm size nor the technology standard used what individualizes the mode to innovate. Firms innovate in different ways depending on their behavioral strategies,

which are transversal to the technology and size of the features. Our results show that in certain circumstances even micro-enterprises can be more innovative than other firms.

Regarding the relationship between the innovation modes and firms performance, the results obtained are unambiguous: the more complex modes of innovation (ie, not limited to bringing products to market but to transform and even to produce knowledge) and that value the networking with agents outside the firm, especially territorial, reveal a superior performance on three levels. These firms show more intense innovation indicators, show better economic results, and also show an increased resilience to the current economic crisis

In fact, the modes of innovation identified in the sample of Portuguese firms we studied showed that, in all these three analytical dimensions, the mode of innovation that we call *Moderate DUI/STI* (cluster 2) provides better results than any of the others. Similarly, *Low Learning DUI innovation mode* systematically shows the worst results in all analytical dimensions.

This means that the firms with a lower negative impact of the economic crisis are the most dynamic ones (in terms of economic and innovative performance), particularly those innovation process is supported by a strong networking interaction. As a corollary of the networking relevance, the territorial context has a strong role to reduce the impact of the crisis in the firms' innovation process.

The results we achieved confirm the essential conclusions of Jensen *et al.* (2007) with reference to empirical withdrew to Denmark: more than the "pure" modes of innovation, the firms more successful adopting innovation strategies that blend typical elements of the mode innovation driven by science & technology (STI) with practices of learning by doing, by using and interacting belonging to the DUI innovation mode.

This convergence of results seems to us with major importance, because it is associated with so specific factors:

- The fact that as far as we could determine this is the first work that replicates, in a different context, the methodology of latent class analysis used by Jensen *et al.* (2007), thus allowing direct comparison of results;
- The fact that our sample is very different from analyzed by Jensen *et al.* (2007). Reflecting the difference in context between the reality of Denmark and

Portugal, 67% of our sample (cluster 1) reveals a weak innovation capacity (only 31%, less than half, in the case of Denmark); in our study did not reveal any pure mode of innovation STI (30% in case of Jensen *et al.* (2007)). Incidentally none of the modes that we have identified is associated with firms using "high-tech", and it is only marginally active in "medium-high technology" or "knowledge services". Our sample shows average levels of technological intensity, or even "low-tech", as with the mode of innovation with poor results (low learning DUI cluster). Despite these differences, the relative mode "Moderate DUI Mode" (13%) and the group "Moderate DUI/STI" mode (20%) is not significantly different from the corresponding modes found in Denmark by Jensen *et al.* (2007) (18% and 13%, respectively);

- The marked convergence is further strengthened by the fact that in our assay we did not limited to replicate the methodology of Jensen *et al*. (2007), but we have added other conceptual and analytical dimensions, both in terms of defining the modes of innovation and in terms of performance analysis of the innovation modes defined, and the results remain consistent with those obtained by authors who took by reference.

It is our belief that our conceptual contribution, incorporating components consistent with the genesis of the innovation process presented in the international literature, will help consolidate a broader theoretical framework, and therefore with greater explanatory power, of the definition of the different innovation modes, with the political consequences resulting therefrom for each country, region and firm. In this case, they are the competitiveness policy, the innovation policy that supports the competitiveness and the regional policy that gives territorial coherence and relevance to those policies. In particular, to the Portuguese case, we believe that our results lead us to the need to consider the four following challenges in the political arena.

First, without fail to consider the relevance of technological upgrading, the central concern of traditional policies of innovation, it is urgent grant priority attention to the factors supporting the innovation capacity of firms operating in business segments of medium and low technology. In particular matter stimulates the innovative potential of micro-enterprises and SMEs.

Secondly, without prejudice to give centrality to the dynamics that result in the production of knowledge, or even the "simple" transformation support knowledge innovation, it acknowledge the economic importance of incremental innovation, particularly when it comes to modes associated innovative features that combine DUI with STI features.

Thirdly, the results shown here, reinforced by the ones obtained in Nunes and Lopes (2012a and 2012b) indicate that the territorialisation of innovation and competitiveness policies can represent a major contribution to the effectiveness of public policies in this area. Recurrently the results show that in the dynamics of the innovation the territory is a key factor. Indeed, the innovation modes based in territorial networking reveal themselves as more robust ways to promote innovation and, by extension, with better economic performance. Consequently, the promotion of dynamic specialization based on regional clusters, combined with an active public intervention in fostering networks of territorial governance of innovation should be central objectives of regional development policy. This particular should not underestimate the role of informal mechanisms of interaction and social networks of territorial genesis.

Finally, the relationship, not yet established in the literature, between the innovation modes and the firm's (and by extension the territorial context) resilience to the economic crises should contribute for the reflection about the policy action to facing nowadays problems.

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Appendix

Table A1 – Concomitants variables and categories

Variables	*Categories*
Level of technological intensity	Low technology
	Medium-low technology
	Medium-high technology
	High technology
	Knowledge services
Nuts III regions	Grande Lisboa e Península de Setúbal
	Grande Porto
	Pinhal Litoral
Firm size	Micro
	SME
	Large

Source: Authors´ own elaboration

Tabela A2 – Model 3 estimation: three latent classes

	Cluster1	*Cluster2*	*Cluster3*		*Total*
Cluster Size	***0,6712***	***0,2005***	***0,1282***	***p-value***	***1,000***
Variables					
Multidisciplinary groups				*0,0160*	
Irrelevant	0,0871	0,0003	0,0349		0,0630
Low Important	0,1071	0,2256	0,1667		0,1385
Indiferent	0,3225	0,6107	0,4593		0,3980
Very Important	0,3447	0,1629	0,2398		0,2947
Fundamental	0,1386	0,0005	0,0993		0,1058
Quality circles/groups				*0,0001*	
Irrelevant	0,1066	0,1789	0,0263		0,1108
Low Important	0,0617	0,2148	0,244		0,1159
Indiferent	0,0981	0,2084	0,0836		0,1184
Very Important	0,5991	0,2545	0,5729		0,5265
Fundamental	0,1345	0,1435	0,0731		0,1285
Collective proposals				*0,0000*	
Irrelevant	0,1051	0,0429	0,1488		0,0982
Low Important	0,1131	0,4234	0,0018		0,1612
Indiferent	0,2394	0,2395	0,1796		0,2317
Very Important	0,3993	0,1674	0,4776		0,3627
Fundamental	0,1431	0,1268	0,1922		0,1461
Integrated functions				*0,0005*	
Irrelevant	0,0376	0,0129	0,0189		0,0302
Low Important	0,0001	0,0269	0,2718		0,0403
Indiferent	0,2990	0,2543	0,6694		0,3375
Very Important	0,3847	0,6802	0,0054		0,3955
Fundamental	0,2786	0,0257	0,0345		0,1965
Groups more indistinct				*0,0130*	
Irrelevant	0,1085	0,0886	0,0007		0,0907
Low Important	0,1427	0,4251	0,0017		0,1814
Indiferent	0,5270	0,4701	0,7496		0,5441
Very Important	0,2034	0,0025	0,2479		0,1688
Fundamental	0,0184	0,0137	0,0001		0,0151

Source: Authors´ own elaboration

Table A2 – Model 3 estimation: three latent classes (cont.)

	Cluster1	*Cluster2*	*Cluster3*		*Total*
Cluster Size	***0,6712***	***0,2005***	***0,1282***	***pvalue***	***1,000***
Variables					
External cooperation				*0,0000*	
Irrelevant	0,1879	0,0338	0,0443		0,1385
Low Important	0,1057	0,1838	0,1608		0,1285
Indiferent	0,4211	0,0952	0,6534		0,3854
Very Important	0,2852	0,6872	0,1415		0,3476
R&D Department				*0,0000*	
Irrelevant	0,1448	0,1541	0,1011		0,1411
Low Important	0,0374	0,5834	0,1473		0,1612
Indiferent	0,4217	0,0231	0,2918		0,3249
Very Important	0,1816	0,0008	0,1881		0,1461
Fundamental	0,2145	0,2386	0,2716		0,2267
External Financing				*0,0000*	
Irrelevant	0,2900	0,0568	0,1225		0,2217
Low Important	0,3546	0,4498	0,1899		0,3526
Indiferent	0,1537	0,3671	0,6047		0,2544
Very Important	0,2017	0,1262	0,0829		0,1713
Innovation new to the market				*0,0150*	
Irrelevant	0,0037	0,0000	0,0000		0,0025
Low Important	0,0344	0,0585	0,0818		0,0453
Indiferent	0,4641	0,6510	0,3234		0,4836
Very Important	0,3432	0,1675	0,5939		0,3401
Fundamental	0,1545	0,1229	0,0009		0,1285
Predominance of Innovation Activities				*0,0001*	
Knowledge production	0,1264	0,2983	0,1678		0,1662
Knowledge transformation	0,1184	0,2441	0,2747		0,1637
Product Placement in the Market	0,7552	0,4576	0,5576		0,6700
Knowledge context				*0,0000*	
Territorial	0,1801	0,6882	0,2775		0,2947
Global	0,8199	0,3118	0,7225		0,7053
Learning and interaction mechanisms				*0,0420*	
Formal	0,3226	0,3467	0,5585		0,3577
Informal	0,6774	0,6533	0,4415		0,6423

Source: Authors´ own elaboration

Table A2 – Model 3 estimation: three latent classes (cont.)

	Cluster1	*Cluster2*	*Cluster3*		*Total*
Cluster Size	***0,6712***	***0,2005***	***0,1282***	***pvalue***	***1,000***
Caracterization variables					
Level of technological intensity				*0,0180*	
Low technology	0,3251	0,1361	0,1081		0,2594
Medium-low technology	0,2431	0,3385	0,4185		0,2846
Medium-high technology	0,1507	0,1822	0,3020		0,1763
High technology	0,0836	0,0635	0,0720		0,0781
Knowledge services	0,1976	0,2796	0,0994		0,2015
Nuts III regions				*0,1800*	
Grande Lisboa e Península de Setúbal	0,6050	0,5565	0,4406		0,5743
Grande Porto	0,2280	0,2643	0,3780		0,2544
Pinhal Litoral	0,167	0,1792	0,1814		0,1713
Firm size				*0,0065*	
Micro	0,0002	0,3383	0,0199		0,0705
SME	0,8486	0,6041	0,8406		0,7985
Large	0,1513	0,0577	0,1396		0,1310

Source: Authors´ own elaboration

Table A3 – description of the variables used in the models

MODELS	**VARIABLES**	
	DEPENDENT	**INDEPENDENT**
Model 1	**Innovation Product** 0 – No 1 – Yes	**INNOVATION MODES** 1. Low Learning DUI 2. Moderate DUI/STI 3. Moderate DUI
Model 2	**Innovation Process** 0 – No 1 – Yes	
Model 3	**Aggregated Innovation Measure** 1. Zero type of innovation 2. One type of innovation 3. Two types of innovation 4. Three types of innovation 5. Four types of innovation	
Model 4	**Growth of Turnover 07-08 (%)** 1. 05-10 2. 11-15 3. 16-20 4. 21-30 5. 30-50 6. > 50	
Model 5	**Impact of Economic Crisis** 0. No 1. Yes	

Source: Authors´ own elaboration

Table A4 – Innotion modes, firm performance and economic crisis: estimation results

	Firm´s Performance				**Economic Crisis**
	Innovation			**Economic**	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Innovation Modes	**Product**	**Process**	**Aggregated**	**Turnover**	**Impact**
Moderate DUI – reference mode					
Moderate DUI/STI	**6.588*** **	**6.424*** **	**4.668*** **	**2.828*** **	**0.496*** **
	(0.00189)	**(4.2e-06)**	**(3.98e-07)**	**(0.000615)**	**(0.00103)**
Low Learning DUI	0.921	0.732	0.980	0.957	0.760
	(0.815)	(0.330)	(0.940)	(0.854)	(0.331)
Constant	2.846***	0.613*			
	(0.00119)	(0.0933)			
Observations	397	397	397	397	397

Source: Authors´ own elaboration *Robust pvalue in parentheses *** p<0.01, ** p<0.05, * p<0.*1

Table A4 – Model 5: Marginal Effects (cont.)

ICI	*Coefficients* *Odds Ratio*	*Impact of Crisis in Innovation (marginal effects)*		
		1 – low relevance	3 – very important	5 – fundamental
Moderate DUI – reference mode				
Moderate DUI/STI	**0.496*** ** **(0.00103)**	**0,16*** **	**-0,06*** **	**-10,2*** **
Low Learning DUI	0.760 (0.331)			

Font: Authors' own elaboration *Robust pvalue in parentheses, *** p<0.01, ** p<0.05, * p<0.*1

Table A5 – Innovation modes and firm performance: estimation results with control variables

	Innovation Modes – Moderate DUI (reference)	
Firm´s Performance	**Low Learning DUI**	**Moderate DUI/STI**
Product Innovation	• In MLT is better than the reference mode	• SME; MLT
Process Innovation	• In Oporto region is worst than the reference mode	• SME; All regions; MLT and MHT
Aggregated Innovation	• In KS is worst than the reference mode	• SME; Lisbon and Oporto; MLT and MHT
Economic	• In LT is worst than the reference mode • In MHT is better than the reference mode	• Lisboa and Leiria; LT, MLT and MHT

Source: Authors´ own elaboration