Knowledge-intensive innovation in low-tech industries

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Abstract
This article seeks to empirically explore the role of knowledge-intensive innovation in low-tech firms within changing and volatile environments. In particular it addresses the question of whether low-tech companies develop knowledge-intensive innovation strategies and practices, in what ways and how such strategies benefit firm performance. For this purpose we have conducted a multiple-case study research, building our analysis on qualitative data derived by eight cases belonging to food and drinks and wood and furniture industries. Empirical findings suggest that the relationship between the knowledge-innovation strategies and the operating environment depends on the context. The F&B cases seem to follow the industry's developments at global level, with knowledge intensive innovation based on both internal and external knowledge seeking to respond to fast technological and scientific advances, changing markets and high global competition. W&F cases seem to develop innovation based mainly on external knowledge seeking, in an effort to differentiate, catch up with globalization and confront crisis. For both sectors such strategies enable them to gain sustainable competitive advantages surpassing price competition which is rather fierce in today's globalized markets and a rather weak strategy in crisis times. The study therefore provides an empirical contribution to the emerging literature on the role of knowledge intensiveness of low-tech sectors. It also indicates that knowledge-based innovation strategies can constitute a significant strategic option for low-tech companies against the severe fiscal and economic crisis or other vulnerable and volatile environments and threats. Theoretical and practical implications are further discussed.

Keywords: knowledge-intensive innovation, low-tech industry, food and drinks industry, wood and furniture sector, economic crisis, competitive advantage

JEL classifications: O31 - Innovation and Invention: Processes and Incentives, L26 – Entrepreneurship, L66 - Food; Beverages; Cosmetics; Tobacco; Wine and Spirits, L73 - Forest Products

Introduction

Low-tech industries have been the subject of the innovation debate in the past few years although their significance for the technological and socio-economic development was long before under investigation. They have

been considered as non basic innovators, due to their "stable" mature environment where changes were slow and cost-leadership important. Yet, since the beginning of the new millennium there are no stable and stagnant business environments any more. In order to survive and prosper, low-tech companies have intensified their efforts towards both incremental and radical innovation. This is done mainly within the limits of knowledge-intensiveness thus combining existing codified knowledge with practical knowledge in competitive ways and sometimes by complementing internal R&D in their core areas.

The present paper explores in a qualitative manner the novel ways of the innovative activities developed by mature companies in two significant for the Greek economy sectors; food and drinks and wood and furniture. The two sectors while working in the same national context present major differences in the ways they confront global changes and advances in regulatory, technological and other pressures, globalization and the severe fiscal and economic crisis. Four information-rich cases of each sector prove that knowledge and use of knowledge bases are significant to the engagement of open innovation, while networking and market and technological sensing are important. Sectoral differences regard types of innovation with the food sector to present a rapid turn to radical innovation, develop extroversion and expand to high-tech sectors such as biotechnology and microbiology. On the other hand the Greek wood and furniture sector cannot follow global advances resting on isolated efforts mainly in the use of innovative raw material or quality and function improvements and process advances.

The contribution of the article to the literature is threefold. First it throws some more light on the central role of knowledge-intensive innovation in providing low-tech firms with sustainable competitive advantage within the current volatile and ambiguous environment. Second, it explores ways and strategies of innovation and the environments in which low-tech firms operate. Third, it empirically indicates that knowledge-intensive innovation has a role to play in the whole spectrum of environmental dynamism by analyzing the notion within the less dynamic environment of low-tech industries.

The remainder of the article is organized as follows: The subsequent section presents the theoretical background, delineating the role of knowledge and innovation within low-tech environments. The third section describes the research methodology and the two low-tech industries involved within the national Greek context of the new millennium. The forth section presents a discussion on the data analysis and the results obtained. The last section provides a discussion of the findings including theoretical and managerial implications, study limitations and future research directions.

Literature review

In recent years, knowledge has attracted increasing attention as a result of claims that knowledge-intensive industries are now at the core of growth, and that we are entering a new form of 'knowledge society' (Robertson and Smith, 2008; Hirsch-Kreinsen, 2010). The idea of 'knowledge economy' emerges when knowledge is assumed to be useful in producing economic benefits (Garavaglia and Grieco, 2005). Unique knowledge, be it internal or external, is the most valuable asset of a firm for achieving competitive advantage (Liebeskind, 1996), as it

provides a platform for decisions on what resources and capabilities to deploy, develop or discard as the environment changes (Ndofor and Levitas, 2004). External sources of knowledge have become more significant in the shift towards 'open innovation' systems, and more readily available, for example as information and communication technologies have improved (Grimpe and Sofka, 2009).

In innovation research, the term ''low-technology'' refers to those industrial sectors that have no or low R&D expenditures. The basis of this categorization is the R&D intensity indicator which measures the ratio of the R&D expenditure to the turnover of a company or to the output value of a sector. Sectors with an R&D intensity of more than 5% are characterized as ''high-tech'', between 3 and 0.9% as ''medium-tech'' and those below 0.9% as ''low-tech'' (OECD, 2002).

Low-tech enterprises are often regarded as somewhat old-fashioned. Although their products and production processes may be highly complex and capital intensive, in comparison to high-tech industries, their markets are generally mature, slow-growing and subject to over- capacity and high levels of price competition. Nevertheless, traditional sectors are central to economic well-being. They have been considered by researchers as significant for the technological and socio- economic development (e.g. Mendonca and Tunzelmann, 2004; Hirsch- Kreinsen et al., 2005; Smith, 2008), dominating the economies of nations all around the world. Yet, due to globalization and global and national-level crisis, low-tech firms tend to develop different kinds of competitive advantages in order to address competition within their vulnerable and mature markets. Besides the well-known and mostly-used cost-leadership, they turn to differentiation and innovation. They engage mainly in new product development and frequent changes or improvements of process technologies (Hirsch-Kreinsen 2008, Robertson and Smith 2008, Robertson et al. 2009).

Food, paper, textiles and clothing, wood and furniture, plastics and metal products are registered as low tech sectors, in contrast to biotechnology, pharmaceuticals and nanotechnology which belong to high tech sectors.

Knowledge generation in low-tech companies can be linked to the concept of "distributed knowledge base" especially for non-research-intensive enterprises (Smith, 2003, Hirsch-Kreinsen, 2008). According to Robertson and Smith (2008) a 'distributed knowledge base' is one that goes beyond internal sources to draw widely from other firms and institutions forming the basis for innovation in most industries. As levels of R&D are very low, the use of distributed knowledge is, in fact, the main source of new ideas and techniques in low-tech firms. Knowledge bases are developed, maintained and disseminated by institutions of various kinds, and they require resources (often on a large scale).

Bender (2004) assorts the sources of knowledge and expertise into five groups of actors: Suppliers of equipment, which inevitably implies mutual learning processes between supplier and client, suppliers of components and material where one can see interchange and reciprocal learning, this time between the end-producer on the one hand and the casting company and particularly the tool producer on the other, customers, particularly important for those of the firms that produce components for their customer's products (subsystems), various kinds of consultants including trades associations as well as scientific advisors

(test laboratories and research institutes) and diverse service providers whose expertise is fundamentally relevant for the core business of many of the companies in the sample. Examples are designers and other creative partners or providers of non-scientific testing facilities.

One of Hirsch-Kreinsen et al., (2003) conclusions of the PILOT research project is that "the knowledge bases of these (low-tech) industries are deep, complex and systemic. They are intensive creators and users of practical knowledge and high-grade design skills. They use engineering and scientific knowledge and are closely integrated with the science and technology infrastructure. The mere fact that they do not do much internal R&D says nothing at all about knowledge intensity or their contribution to the knowledge economy".

New knowledge in the form of products, processes and organizations leads to opportunities that can be exploited commercially and therefore end up to innovations. The low-tech industries have been the subject of the innovation debate in the past few years and its significance for the technological and socio-economic development was under investigation (e.g. Cox et al., 2002; Mendonca and Tunzelmann, 2004; Hirsch- Kreinsen et al., 2005; Smith, 2005; Tunzelmann and Acha, 2004). As recently pointed out by Tunzelmann and Acha (2004), it is hardly feasible to classify these industries according to criteria such as product similarity or a common technological basis due to the diversity of its subsectors. The centre of the debate on low-tech innovations involves attempts to include innovation processes that are not primarily based on systematic research and technological development, but on practical, experience-based and often implicit knowledge.

Although characterised as non basic innovators, low-tech sectors produce both incremental and radical innovations combining existing codified knowledge with practical knowledge in competitive ways and sometimes by complementing internal R&D in their core areas (Chesbrough, 2006 in Lichtenthaler, 2009). Accordingly, they may increasingly acquire disembodied technological knowledge in addition to their traditional inward transfer of embodied technology from high technology sectors (Robertson and Patel, 2007). Hirsch-Kreinsen et al. (2005) in their analysis show that low-tech innovativeness is based on a particular enabling configuration of cognitive, financial and material resources that a company possesses. The clothing industry showed that especially in these mature industries non-technological innovation based on sophisticated non-codified knowledge plays an important role for competitiveness and entrepreneurial success. Innovation is to a great extent the result of processes of transforming and configuring generally well known knowledge, components and technologies developed elsewhere.
During the last decade, low-tech industries are found within a rather volatile and changing environment due to globalization and trade liberalization (von Tunzelman and Acha, 2005), complex environments (Bröring *et al.*,2006), technology pressures (Kaloudis et al., 2005)as well as pressures imposed by regulatory, social and political regime changes (Morris and Dunne, 2004). The severe socio-economic crisis has further produced extremely ambiguous and hostile business environments (Colombo et *al*., 2010; Makkonen et al., 2013).

Research Design and Method

This paper uses the method of multiple exploratory case study analysis (Yin, 2003) with the individual low- tech company as the unit of analysis. As a research strategy, the distinguishing characteristic of the case study is that it attempts to examine:

(a) a contemporary phenomenon in its real-life context, especially when
(b) the boundaries between phenomenon and context are not clearly evident (Yin,2003)

Therefore, the new "face" of LT industries within the emerging volatile and vulnerable environment combined to the emergence of the knowledge-intensive open innovation concept demands more, deeper and longitudinal exploration of (a) the ways knowledge-intensive low-tech firms confront innovation as a means to competitive advantage and (b) the capabilities and other factors needed to develop such innovation and the relevant strategies.

For the purposes of this paper we followed a literal replication strategy (Yin, 2003) by choosing four information-rich cases of two low-tech sectors and namely food and wood processing industry. Cases were selected among suggested companies by sectoral experts. The major selection criterion was that innovation should refer to "open innovation" entailing a certain amount of knowledge intensity.

The data gathering took place in face-to-face, in-depth interviews with entrepreneurs and managers, using a semi-structured questionnaire which focused on information regarding innovation production since 2000. Additional sources of information were also used to complement the interview data such as plant visits, company reports, awards and company websites. The case studies were carried out in Greece during the 2010-2011 period. Our respondents generally offered very detailed responses and provided detailed timelines and histories for their firms. The typical interview lasted 2.5-3 hours, with some lasting much longer. All interviews were taped and transcribed. The founders were all involved in all key aspects of the business and consequently have first-hand knowledge of the firm's founding activities.

Table 1: Description of case data

	FC1	FC2	FC3	FC4	WC1	WC2	WC3	WC4
Foundation year /shift to KIE[1]	2003	1955/ 2000	2002	2006	2007	2004	1924/2005	1989/2000
Product family	Organic and quasi-pharmaceutical chocolate	Parboiled rice specialties,	gluten-free wheat flour, and bio-functional foods	Gluten-free Crackers snack cheese-ups	Veneer stitching, marquetry inlays	MDF laminate flooring lacquered printed	decks fences	Furniture and mattresses
% of sales in national / international markets	97 / 3	80/20	90 / 10	0 /100	90 / 10	75/25	40/60	55/45
patents	no	yes	yes	yes	yes	yes	yes	yes
Educational level of entrepreneurs	University	University	Master	PhD	TEI*	Technical School	University	University
Educated staff/Total	3/9	16/180	7/30	12/35	2/8	13/126	13/185	45/180
3-year compound annual	129%	112%	147%	128%	127%	121%	108%	109%

[1] Knowledge-Intensive Entrepreneurship

growth (CAGR)								
Sales decrease during the crisis period (2008-2011)	2009: -1.3%	2010: - 6%	2009: -9% 2010: -9%	0%	2010: -15%	2009: -5.5%	2009: -24% 2010: -6%	0%

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Both sectors are playing a significant role in Greek, European and global economy as well, while they have undergone significant changes almost since mid-nineties.

Woodworking sector had a turnover of around €2 billion in 2008, an added value of around €1 billion and an employment rate of 35.000 people in more than 15.000 companies (Eurostat, 2009). The industry faces growing competition from low-cost, emerging economies and a growing number of technical trade barriers. Greek wood companies are not considered as innovative even with the Schumpeterian concept of innovation (Karagouni et al., 2010).

Well protected and stable, the industry faced the increase of imports during the '90s. Yet, changes were rather slow till the end of the previous century; combined with the prosperity of the sector till 2007, an illusion of stability did not allow Greek W&F firms to prepare and confront the oncoming multilevel crisis. After 2008 the sector was dramatically hit by the crisis, while it had already become vulnerable due to decreasing production in absolute numbers, as well as the increasing number of mainly trendy products from Italy and Spain, cheaper products from Turkey, China and India and different approaches such as of IKEA.

Moderately paced changes at technologies, products, market development and competition combined to pressures for environmental sustainability by EU regulations, government and groups had spurred both product and process innovation such as the eco-design and the "intelligent" furniture, engaging other industries as well. Greek firms were mainly followers; advancements of existing and development of new equipment (AMT), the application of CIM and MRP, logistics, quality improvements and incremental innovations are detected within the sector. Process innovation refers more often to restructuring and modernization. Still, the sector remains not competitive. Easier transport, competitors with lower prices (economies of scale), faster deliveries (advanced logistics) and established design threat to share the Greek market pie while export numbers show major weaknesses of Greek producers. Environment is far from stable, especially when considering the Greek economic recession and its effects on furniture as durable goods and the collapse of building activity.

The food industry sector is one of the largest and most important manufacturing sectors in Europe. It is the second largest (after metal) in the manufacturing industry, with 14.5% of total manufacturing turnover. Europe's food market is made up of about 310.000 companies and 4.8 million employees. It is also the most important and most dynamic industrial sector of the Greek Economy. The sector accumulates 25% of the GNP of the industrial sector, thus taking the first place amongst all the industrial sectors. Nowadays, foodstuffs and wine make up 35% of Greek exports (Eurostat, 2009).

A research with in-depth interviews among experts enabled the delineation of the sector's profile. Despite its dynamism, the sector presents a traditional character, dominated by SMEs, dispersed in the whole country and covers all sub-sectors of food processing and fisheries. There are about 22000 companies of food and drink production, revealing a fragmented and mature industry with almost 84% to occupy 0-5 employees half of which are only primary school graduates.

The great majority of Greek food companies reserve a rather cautious attitude towards the adoption of innovations that prerequisite research for adaptation in their manufacturing procedures, as well as towards the participation in EU's RTD programmes that prerequisite co-operation with research organisations or other similar enterprises. However, this status is beginning to change and an increasing number of enterprises, especially the bigger ones, are interested in carrying out research and implement innovations.

Innovation is "pushed" by consumers either directly in very small companies or through retailers, special sector press and trade shows. Consumers demand quality, safety, health and differentiation. Issues about 'quality and manufacturing' and 'food safety' are seen by far the most important ones in terms of a strategic vision of the sector's companies, suggesting innovation challenges related to technological competition. It is also driven by legislation and needs for production improvements. The trends of innovation in the Greek F&D sector concern mainly organizational innovations, renewing processing lines and equipment, adoption of control technologies in processes and contaminants, development of new products as nutritional improvements, functional genomics and nutraceutical, development of technologies in tracking, tracing and adoption of Information Technologies for food chain management.

All experts agree that competition and legislation are the most important determinants for innovation, while high costs, bureaucracy and time consuming processes hinder it. Greek F&D companies are rather reactive than proactive. They are engaged in some innovative action to solve an important problem, confront a new competitor or react to a legislation or need that can hamper the company's further development. Environment protection, information systems, storing and distribution technologies are some of the most common innovative steps of medium and small companies in the sector.

Both industries are mature, highly fragmented and labour-intensive with many firms operating in a 'craft' production mode. The majority of the wood and furniture firms are less than 30 years old and cover mainly the domestic market, as exports are rather insignificant. Major weaknesses of both sectors regard introversion, the lack of specialized technical personnel, the lack of precise strategies, overall organization and quality control, while entrepreneurs' educational level is rather low (Likar et al., 2008). The last five years the sectoral context starts changing by becoming more knowledge-intensive. New entrepreneurs or successors have a high educational level and turn to research, innovation and knowledge management.

Discussion

Our study using rich qualitative data explores the question of whether low tech companies develop knowledge-intensive innovation strategies and practices, in what ways and how such strategies benefit firm performance. As already pointed out, low-tech industries are facing different environments and challenges, than some decades ago. In this respect creating new market segments is a crucial strategy for new entrants or for the sustainability of established firms in order to avoid constraints that the respective sector confronts as a whole (Kastelli and Caloghirou, 2012).

Cases of both sectors present knowledge-based innovation performance, which was expected, since it was the main selection criterion. Furthermore, all cases present innovation which is new to the market and are assigned to the most innovative companies in their business areas. However, regarding new-to-the-world level, F&D cases seem to be much more advanced presenting patented products, processes and technologies. On the other hand innovation of W&F sector seems to cover other functions as well, such as promotion methods and business models (WC4).

F&D cases develop innovation which targets mainly the trends of Health and Wellness and Indulgence, operating in niche markets at global level and seem capable to maintain market leadership. They combine in-house R&D to external knowledge seeking with an active engagement of science and multiple knowledge bases, transcending sectoral limits. They actually occupy research from various sciences such as chemistry, biochemistry, biotechnology, environmental and energy engineering, health and well-being science, geoponics, pharmaceutics, etc. in order to develop radical innovation. Indicatively, FC2 presented an R&D intensity of 6.8% in 2011 and 8.16% in 2010, resembling the indicators of high-tech industries. All four cases own well-developed R&D departments and devote significant amounts to R&D. They also present a densification of innovative activity over the years getting into more advanced research projects in an effort to extend or create high demand niche markets; e.g. food for cancer patients (FC3) or eco-friendly cosmetics and nutraceuticals (FC2).

W&F firms do not present break-through innovations; they seem to be more prone to differentiation strategies regarding functional parameters in order to produce sustainable competitive advantage, such as: quality (all), functionality (WC2) and exploitation of innovations elsewhere produced but adapted to local conditions (all). They rely mainly but not solely on external knowledge seeking, staying within sectoral limits thus relative science areas, suppliers and customers. They also present a milder approach to NPD intensity. They do not devote money on R&D, while only WC2 and WC4 have developed distinct NPD departments.

A strong difference between the two industries appears to regard the ways firms approach knowledge management and innovation: an enhanced combination of external and internal knowledge seeking in order to produce radical product or process novelty in the case of food companies versus internal inter-sectoral efforts of differentiation in the W&F cases.

The two industries present several similarities too. They use formal but unwritten routines to articulate, utilize and create knowledge which is usually the result of various knowledge assets combination along the

value chain. They rely on their human capital and invest on partnerships with university, technology centres, research associations, suppliers, and customers. It is quite significant that all firms have a relatively high percentage of educated staff, while entrepreneurs themselves own in their majority a Higher Education degree. We should however mention the fact that F&D owners have a stronger educational background than the W&F ones (see Table 1) and were found to have grown up in a similar entrepreneurial milieu and sometimes with already existing relations with suppliers. Although this is a mere observation of four cases and thus it cannot be generalized, it seems to be related to the sectoral dimension; the food sector is following a more dynamic path with new generations of entrepreneurs to adapt more knowledge-based and science-directed innovation strategies to advance existing family firms (e.g. FC2) or establish new ones in the same or parallel sub-sector of family's former company (FC3, FC4). Irrespectively of industry, all entrepreneurs are characterised by an innovative spirit, pro-activeness and entrepreneurial alertness and have significant prior experience in their sector.

All cases utilize –to different degrees- mixed innovation models; balancing internal projects, external partnership, venture investments and technology transfer mechanisms to identify, access, and build significant new businesses beyond their core activity. To succeed in such efforts, they invest in social and human capital and build technological and dynamic capabilities (according to Teece, 2007). They develop informal or formal routines of sensing markets and their business ecosystems, strong networking and aggressive NPD. They further seem to be very interested in achieving a harmonic R&D-marketing coordination which is vital for innovation success as Gupta et al. had already found out in 1986. Thus, they focus on brand building and marketing capabilities with a significant export orientation. It is quite significant the fact that all interviewees have underlined the importance of the development of knowledge management systems which are constantly reworked and advanced.

The case-companies have jointly used patents, trademarks, secrecy and lead time advantage as appropriation mechanisms, enjoying a temporary monopoly (Blind et al., 2006). They all have received several awards and all export. Nevertheless, once again minor differences are delineated between the two industries; while F&D cases target *ab initio* foreign markets, W&F firms start by targeting the domestic market. In all cases firm size remains a major factor in determining the level of financial resources devoted to R&D and innovation activities in general. Still, no W&F case has ever applied for any type of subsidy, contrasting F&D cases which have all used several financing mechanisms.

In order to investigate the performance of the firms studied in terms of growth and competitiveness, the compound annual growth rate, exports and employment growth were used. For the purpose of this study, we used Barringer et al. (2005) who defined as rapid-growth firms the ones with a three-year compound annual growth rate of 80% or higher, while a slow-growth firm presents a 3-year compound annual growth rate of 35% or lower. We take into consideration the three years since firm's establishment in cases of new-to-the-world companies, establishment of spin-offs in cases of corporate entrepreneurship or the firm's major shift to Knowledge-Intensive Entrepreneurship. Furthermore, we refer to percentage of losses –if any- during the crisis period (2008-2011) because balance sheets of the economic year 2012 are not available yet.

As it can be seen in Table 1, all firms are rapid growth cases, indicating relations between the use of knowledge-intensive innovation and growth rates. Furthermore, W&F companies with less radical innovation present somewhat smaller CAGR percentages than F&D ones. Additionaly, they present the bigger losses during crisis. Yet, contrasting to the overall picture of the industry with both sales and production volume having been halved, these cases seem to be capable to confront the crisis because of a wider scope of action, a capability to compete with new products or services and a knowledge and technologies exploitation capabilities. Actually food cases seem even to outperform during the period of crisis; FC4 doubled its turnover in 2012. In fact, according to interviewees' narrations, all cases have increased exports during these difficult three years with novel products in order to keep leadership in their niche markets. On the other hand, no W&F case admitted to have increased exports; still they managed to keep leadership in their markets by developing a moderate degree of innovativeness.

Conclusions

The study sets out to investigate, from the perspective of knowledge-intensive innovation strategy, how low-tech firms cope with the drastic sectoral, market, technology and global changes by adapting their behaviors, knowledge and other resource bases to produce innovation as a means to strong competitive advantage. Recent research brings the competitive environment to the forefront of the innovation literature in the framework of knowledge-intensive entrepreneurship regarding low-tech industries. Environmental dynamism is not limited within the tight definition of technological turbulence; it is also extended in many other changes, such as production shifts, instability of market demand, changes in the industry structure and environmental shocks such as a financial or other type of crisis.

This study analyzes this issue in a qualitative manner within the context of the changing business environments of two major low-tech industries and namely food and drinks and wood and furniture industry in Greece after the dawn of the new millennium. Significant changes such as globalization and trade liberalization, increasing pressures by markets and technologies as well as the changes caused by the resent severe financial crisis have created exogenous shocks in the environment of these industries' firms, turning them from perfectly stable and secure to highly vulnerable and volatile.

The study contributes to the research on dynamic capabilities in three significant ways. First, the results add empirical evidence to the just emerging stream of literature concerning knowledge intensiveness of low-tech industries enhancing our understanding of relevant strategies. In other words, the results support the view that low-tech companies turn to knowledge and develop knowledge-intensive innovation in order to develop competitive advantage. Second, the study contributes in giving a detailed analysis of ways and strategies of innovation and the environments in which firms operate. A significant finding is that different innovation strategies have different effects depending on the competitive environment and seem to be sector specific. In particular, food cases present radical innovation at global level, while, on the other hand, none of the W&F cases develop innovations that are primarily disruptive on the technology dimension. Furthermore F&D companies present an aggressive production of novelties with an increasing R&D intensity,

while W&F firms seem to occupy a milder approach of NPD with incremental innovation and improvements.

From a theoretical point of view, the implication is that the relationship between the knowledge-innovation strategies and the operating environment depends on the context. The F&B cases seem to follow the industry's developments at global level, developing innovation in order to respond to fast technological and scientific advances, changing markets and high global competition with sustainable competitive advantages. W&F cases seem to develop innovation in an effort to differentiate, catch up mainly with globalization and confront crisis.
Third, the study contributes in analyzing the turbulent and volatile environment of low-tech industries and thus challenging the prevailing views regarding their "stagnancy". These "mature" industries seem to be nowadays characterized by major changes which "*have accelerated the rhythm at which firms innovate"* (Teece, 2010)

Generally, the application of various types of innovation strategies entails quite complex and diverse actions in individual firms facing different contextual events and forming collective interpretations of them. The qualitative case analyses demonstrate in detail this phenomenon. The results expose certain longitudinal features of these strategies in terms of continuously broadening the basis for a healthy business and an evolutionary environmental fit during periods of environmental volatility. For example, food firms build strong networks with universities, research institutes and other partners and combine the knowledge resulting from such co-operations with intense in-house research to produce new processes and products. Such activities, however, maintain and strengthen environmental fitness, building in parallel their long-term orientation and successful operation in the future. On the contrary, W&F firms seem to be unable to react to the global changes being trapped in their existing value networks.

Although the study sheds light on the central role of knowledge-intensive innovation in providing low-tech firms with sustainable competitive advantages in their globally volatile business ecosystems, certain methodological issues arise. A major limitation is the quite small number of cases per sector as well as the use of only two low-tech sectors in the study which are further limited in only one country. However, the main purpose of the study was not to generalize conclusions either for particular sectors or for low-tech industries as a category, but to shed some light on the emerging literature regarding the relations among knowledge, innovation, low-tech industries and the new approach of their vulnerable environment.

Thus, further qualitative research is suggested including more cases and different low-tech sectors across different countries. Such research could also go much deeper, with true longitudinal settings to capture true effects and produce knowledge to develop quantitative measures or improve and redefine existing ones for empirical testing in subsequent quantitative studies.

Finally, the findings indicate some practical and policy-making implications. Low-tech companies can manage and exploit knowledge in order to fit changing environments and achieve high performance. However, continuous process of identifying opportunities, knowledge sources and synergies in order to produce successful innovation avoiding the threats is not an easy option. Therefore, new ways of implementing such

mechanisms should be inherent in firms' business management models. This can refer to the company's design, communication, R&D and NPD organization, networking and export orientation. The empirical analysis indicates that managers should dedicate time in questioning the environmental dynamism and find ways to do things differently. That may refer to the development of dynamic capabilities such as sensing the environment and seizing opportunities, as well as the maintenance of leadership in their niche markets. An important issue is to dare and get out of the tight sectoral limits when seeking for knowledge in order to produce innovation.

Policy-making implications emerging from the study place the emphasis on knowledge management. The findings support mainly neo-Schumpeterian growth models emphasizing the importance of temporary monopoly power and the relation of appropriability of new knowledge to lead times over rivals rather than on effective patent protection (Mayer, 1996). Recession and other environmental shocks can make such tendencies stronger. Policy makers should pay more attention and pour subsidies on restructuring industries encouraging creative destruction on the basis of knowledge creation and relevant capability development. Thus, the motivation should be the support of economically viable change through knowledge mechanisms and knowledge-based innovation in order to foster competitiveness at international level and at the long run.

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