Chapter 23
Strategic Challenges of the Portuguese Molds Industry:
A Sectoral Innovation Perspective

António Carrizo Moreira
University of Aveiro, Portugal

Miguel A. M. M. Ferreira
Department of Economics, Management, Industrial Engineering, and Tourism, Portugal

ABSTRACT

In a competitive environment shaped by continuous change, the understanding of the different forces that support or hinder the development of an industry, enables more informed, and assertive decision making. As such, following a sectoral system of innovation perspective that takes into account the temporal evolution of its most important events, the main objective of this chapter is to define a set of strategic lines for the sustainable development of the Portuguese molds industry. The study supports set of strategic priorities so that the Portuguese molds industry can embrace both an international favorable position and an entrepreneurial outward looking governance perspective. This chapter proposes that the future outlook will support the diversification to and the penetration of new sectoral markets, associated with a strong international product engineering and development cluster capable of supplying integrated solutions to several international markets.

INTRODUCTION

The business environment is very dynamic, uncertain, and highly competitive with firms trying to outperform each other in order to achieve a stable market position. Technological advances are 'forcing' firms to be innovative, and to search for new ways to compete in a global technology-oriented, smart world (Gerguri et al., 2013; Lo, 2015).

Innovation systems can be defined as a group of innovation facilitators, which include private firms and public research institutions that, by interacting with each other, can promote the creation and facili-

DOI: 10.4018/978-1-5225-1978-2.ch023

tate the diffusion or application of a series of technological innovations (Malerba, 2002; Gambardella & McGahan, 2010).

In general, a system of innovation is composed of entities (organizations and institutions) and the relationships among them. Organizations are formal structures that are consciously created and have an explicit purpose. Institutions are sets of common habits, norms, routines, established practices, rules or laws – known as the rules of the game – that regulate the relations and interactions between individuals, groups and organizations (Freeman, 1987; Malerba, 2002; Moreira, Carneiro, & Celada, 2008). Clearly, a system of innovation is composed of localized knowledge spillovers and a strong foothold of human capital, key ingredients of smart cities and smart regions.

Innovation and innovation systems are becoming increasingly important for policymakers to achieve their economic, and social goals. The "Europe 2020" strategy, a key European Union (EU) program for the current decade, aims to promote a smart, sustainable and inclusive economy. According to the European Commission (2011), innovation has to be placed in the center of the strategy, as it provides the best ways to successfully address key social challenges.

The concept of sectoral systems of innovation (SSI) was developed by Malerba (2002), who claims that a SSI is a set of new and established products developed for a special purpose by a set of agents that carry out activities for the creation, production, and sale of these products. Malerba (2002) describes an SSI through three dimensions that are responsible for generating innovation and new technologies: knowledge and technological expertise, players and chains, and institutions. Although these three dimensions are the main pillars of the concept of sectoral systems of innovation as a result of the interaction of various functional logics, complexity, and dynamism (Malerba, 2002), they are rarely associated to smart cities.

Edquist (1997) has introduced the concept of innovation systems based on the following features:

- The innovation, intrinsically connected to learning, and knowledge;
- A holistic and interdisciplinary perspective, involving institutional, organizational, social and political determinants;
- A path-dependent historical perspective;
- An emphasis on the interdependence and non-linearity of the innovation process;
- The main role given to institutions.

Following this systemic approach, the links between businesses and other organizations are portrayed as the result of the technological interdependence of their knowledge (Chang & Chen, 2004; Moreira, Carneiro, & Tavares, 2007).

The research question behind this work is: What is the future of the molds industry in Portugal? In order to address this main question, it is imperative to frame the analysis taking both an evolutionary and a systemic perspective. As such, this chapter seeks to answer the following questions:

- How is characterized the Portuguese molds industry?
- How has it evolved over the last/recent few years?
- How important is the Portuguese molds industry in the context of the national economy?
- How is the Portuguese molds industry positioned *vis-à-vis* the world molds industry?
- What are the main critical factors that will influence the future of the Portuguese molds industry?

- What are the main future strategic lines so that the Portuguese molds industry remains sustainable in the coming years under the perspective of a smart region?

This chapter has been prepared based on the sustainable development of the Portuguese molds industry (PMI), taking into account the temporal evolution of its most important events. We followed a sectoral system of innovation perspective in order to define its future, and its most relevant factors, taking into account two basic ingredients of the smart city concepts: human capital, and business-led urban/regional development.

A set of strategic priorities will be defined to position the molds industry in an international favorable position, and an entrepreneurial outward looking governance perspective, instead of a dirigiste one, based on Heidenreich's (2004) regional innovation dilemmas.

This chapter consists of five sections. Section 1 presents the introduction, the main objectives pursued by this chapter.

In section 2 the literature review is presented based on the exploration of the concept of Sectoral Systems of Innovation. Within this section the concept of smart cities is going to be addressed. Section 3 characterizes the PMI, in which it is presented the current general situation of the PMI, particularly in what pertains to the value chain, its social and economic development over the past few years, and its international position. This section also presents the molds industry taking into account the sectoral innovation perspective, giving an integrated view of the main factors that will influence the future of the industry.

The strategic axes that will support a sustainable global position for the molds industry are defined in section 4. Finally, in Section 5 are mentioned the conclusions of the chapter, clarifying the contributions and limitations of the study, as well as the suggestions for future research.

BACKGROUND

Marshall (1920) points out three of the main reasons why companies are located within a given geographical area: firstly, the fact that concentrating in a particular space allows for the development of a specialized workforce, highly geared towards the industry's specific needs; secondly, companies experience economies of scale through the development and use of the same technologies, or particular types of established infrastructures; and finally, the companies' geographical proximity devises a chain of information and ideas. The knowledge relating to technology, product, and markets is indeed more easily shared and more effectively transformed into valuable innovation amongst geographically close players.

According to Porter (1998), clusters are geographic concentrations of interconnected businesses and institutions that operate within the same industry scope, and are important for the development of competitiveness by creating synergies with other entities, namely specialized resource suppliers such as components, machinery and services, infrastructures and raw-materials.

Some of the most known clusters in the world are located in the US, such as Hollywood, in the district of Los Angeles (California), film capital of the world, and Silicon Valley, also in California, as the geographic region where several companies focused in scientific and technological innovation have been settling since the 1950s, highly focused on the production of electronic and IT components (Porter, 1998; Saxenian, 1995).

Morosini (2004) defines industrial cluster as a set of socio-economic entities characterized by a social community of people and a population of economic agents in close proximity in a given geographical region. Within the cluster, the economic agents work alongside with the social community by sharing and nurturing organizational, technological and production knowledge, with the purpose of generating products and services of greater added value for its market. Therefore, the synergy between economic agents and the social community of people plays an important underlying role to the economic strength of the clusters, not awarded solely to the companies themselves (Pyke, Becattini, & Sengenberger, 1990).

The above mentioned economic agents include government or nongovernment institutions, such as universities, research centers, industrial associations and technology institutes, which are responsible for the promotion of a mutual economic cooperation, as well as the sharing of technological knowledge among the several members of an industrial cluster (Schmitz, 2000).

Considering all the activities performed by the various members of a cluster, there are several established connections between them, comprising a set of common grounds: clients; suppliers and service providers; infrastructures such as transportation or communication; the same range of specialized human resources with skillsets for the industry; education and training facilities for employees; technical expertise from universities or research/technology centers; and same venture capital markets. The number and the economic value of these established relations might determine the strength of an industrial cluster (Feser & Bergman, 2000).

Porter (1998) states that the existence of clusters affects company competitiveness in what concerns three main aspects: firstly, it positively contributes to the productivity increase of the region's companies; secondly, it outlines constant innovation processes; and, lastly, it stimulates the formation of new businesses, which expands and strengthens the cluster itself.

Vieira and Romero (2008) defined a list of cluster characteristics:

1. The existence of multiple small and medium-sized companies in a given geographic space, with the same type of flexible production system;
2. A strong trust-based cooperative interconnection among companies;
3. Complementarity-based relations between local companies and institutions, and companies and institutions outside the region;
4. Specialization of one or more, but not all, stages of the manufacturing process of a particular product or product family (typically the product is the distinguishing factor among other clusters);
5. Presence of leading companies, which plan and expand the industry's international dimension;
6. Frequent human resource mobility within the cluster, which allows for the dissemination of knowledge, thus contributing for a continuous collective learning process.

Although the concept of smart cities is not new, there have been several concepts/definitions associated to it, among which one can refer the following ones:

- A forward-looking city in terms of people, governance, economy, environment and quality of living (Giffinger et al., 2007);
- An IT-based, well-equiped city, interconnected, and integrated. Within this concept technical instrumentation, computing platforms, and communications technologies play a central role (Harrison et al., 2010);

The concept of "smartness" has revolved around the availability of the ICT infrastructure since the beginning of the digital era. However, the role of human capital, education, and urban development have recently emerged (Berry & Glaeser, 2005; Glaeser & Berry, 2006) relating educated labor force, urban growth, and innovative entrepreneurs. Fu (2007) related human capital to localized knowledge spillovers. Caragliu, Del Bo, & Nijkamp (2011) put forward the following main characteristics of a smart city:

- The utilization of a networked infrastructure to improve economic, social, cultural, and urban development.
- The emphasis on business-led urban development.
- The social inclusion of residents in public services.
- The emphasis in relational capital and human development.
- The social and environmental sustainability of smart cities.

Sectoral Systems of Innovation

Innovation is a non-linear evolutionary process, which results from the continuous interaction of several actors, both internal and external to the company (Freel, 2003; Malerba, 2002; Hekkert et al., 2007). According to Lundvall (2007), innovation goes through a process of new combinations, whether they are new products, processes, raw materials, forms of organization and/or new clients. It includes the generation of new ideas, encompassing the development process and its applications, and consequently the analysis and dissemination of the newly obtained knowledge.

Innovation and technological change are greatly affected by the industry in which they are included (Malerba, 2004). The rapid increase in technological opportunities implies quick technological changes, in which innovation plays an important role regarding growth, affecting companies', regions', and countries' competitiveness (Tushman & Rosenkopf, 1992; Malerba, 2002).

The concept of Innovation Systems (IS) was born in the late 1980s, and it integrated the analytical perspective of important institutions, such as OECD and UNCTAD (Lundvall, Johnson, Andersen, & Dalum, 2002). The innovation system describes the interactions among actors, i.e. the various institutions, organizations, and companies that work without an interdependent relation, including cooperative dynamics such as competitive relations, without any of them controlling the system, but simply working together in a deliberate, unplanned fashion to reach a common purpose (Bergek et al. 2008).

Beije (1998) defines IS as a group of private firms, public research institutes, and several innovation facilitators who, by interacting, promote the creation, diffusion and/or application of one or multiple technological innovations. In a sense it is part of a smart city perspective as it aims to improve economic and regional development based on relational capital and human development.

Silvestre (2007) mentions the rise of innovation as a means for technological change, keeping in mind that the idea of IS is related to system design, based on plurality and complexity interconnectedness. In this way, the IS can be subdivided and limited according to different perspectives: geographical, originating the National Innovation Systems (NIS) and the Regional Innovation Systems (RIS); and economically, where Sectoral Innovation Systems (SSI) come from. Clearly, one can consider that these approaches may fall under the perspective of smart region.

Breschi and Malerba (1997) firstly introduce the concept of SSI, which was described as a system of firms that are active in the development and production of consumer goods, and in the creation and application of sectoral technologies. They also added that intra-sectoral relations might arise in two

ways: through interactive, cooperative processes in regards to technological evolution or through market competitive processes of innovative activities.

Afterwards, Malerba (2002) argued that the SSIs are surrounded by (a) the perspective of change dynamics and industrial metamorphosis, (b) independence and complementarity between sectoral limits, and (c) the acknowledgement of innovation as a method for acquiring knowledge. Therefore, Malerba (2002) asserts that in a SSI comprises the involvement of individuals, businesses, non-business organizations, and industrial associations, each of them holding unique skills. Knowledge is easily spread through interaction among the above-mentioned actors.

The reformulated concept of sectoral innovation system outlined by Malerba (2003) comprises the following three basic elements: knowledge and technology mastery, which determine the system's limitations; the actors and the intra-sectoral networks, which are usually rather heterogeneous and include individuals, businesses, public organizations, and even clients; and lastly, national institutions that have an active role in creating and defining the system agents' actions and interactions, steering their behavior in a particular direction.

It is important to mention that sectoral systems are subject to changes, which may be caused by either industry's technology and learning system or by the patterns of innovation. Therefore, a basic change, in terms of knowledge, may result in an important intra-sectoral consolidation or, differently, generate great changes in the industrial process, which may demand that the firms acquire new competences. The shifts of structures of consumer demand may be another source of change, which may allow for the entry of new competitors, risking the survival of the incumbents. Generally, these dynamics are essentially co-evolutionary in nature, demanding changes in technology, knowledge, actors, and institutions (Schrempf, Kaplan, & Schroeder, 2013).

As in the smart city concept, the importance of innovation systems stems from the interaction among actors. Heidenreich (2004) argues that the trust-based patterns of cooperation, the local experience-based, context-bound knowledge and the path dependent accumulation of competencies are crucial for the region to prosper. Heidenreich (2004) has also found that the governance structure of an innovation system may, to some degree, limit the innovation process of the region.

THE PORTUGUESE MOLDS INDUSTRY

Belonging to a cluster is very important for SMEs to survive and to remain competitive, whether it is in regional, international or even global terms (Morosini, 2004). An example of this is the Portuguese Molds Industry (PMI), which includes companies with very distinct characteristics that can be grouped according to its position in the supply (or value) chain.

According to Vieira & Romero (2005), there are, firstly, mold producers, whose commercial, engineering, and project skills are fairly limited. In a second group one can find product engineering/project specialized firms, with or without production capacity, that are responsible for the development of innovative solutions for their customers. Generally speaking, they are the ones responsible for penetrating the most demanding markets. Commercial companies belong to the third category, also known as brokers, which have neither product engineering nor production abilities, outsourcing those skills from companies that do not have commercial capabilities in terms of final customers.

The Portuguese molds industry is part of a cluster that is concentrated in two specific regions: Marinha Grande, and Oliveira de Azeméis. Whereas in Oliveira de Azeméis the concentration consists of larger

companies, in Marinha Grande there are mostly small businesses, and micro-enterprises (CEFAMOL, 2012).

Considering the particular case of the Portuguese molds industry, its geographic concentration has favored the transmission of ideas and acquired knowledge, allowing for technological innovations to quickly spread from one company to another.

This ability to communicate among companies is also underpinned by the recurring worker mobility, which has a positive effect in terms of knowledge transmission, on one hand, but might not has been perceived positively by certain managers, on the other hand, that fear the loss of specific know-how that gives companies competitive advantage, which results, in mistrust among the actors (Neto, 2014).

The main competitive advantage of the PMI is linked to the strong inter-firm relationships that have been developed over the past 60 years in the industry, which is, usually, independent from the partner company's position in the industry's supply or product chain (Vieira & Romero, 2008).

The PMI has features common to many other clusters, such as (Vieira & Romero, 2008): the presence of a wide range of SMEs, which are endowed with a high level of expertise and flexibility; strong competitive and cooperative behavior among firms; frequent subcontracting and specialization in certain stages of the process, in which there are companies that subcontract the whole productive process; leading companies, which possess a strong innovative outward-oriented behavior, that are the main drivers of the industry's development.

The are some important attributes, which are not very common when compared to other clusters: the low usage of local resources, namely in what concerns machinery, equipment and any related technology, which are imported, mostly from Germany; the cooperative relationships among competing firms supported by strong personal relations based on trust; and the location of their foreign clients (Neto, 2014). The leading companies normally keep close relationships with their clients, mainly from abroad, which constitute important sources of knowledge and that have significantly contributed towards the evolution of the industry as a whole (Vieira & Romero, 2008).

Based on the Strategy Plan for the Portuguese Molds Industry, drafted by SPI (2008), companies' activities of the PMI may be split into four main areas: mold concept and design, prototyping, mold manufacturing, and injection of parts and components. According to SPI (2008), these differentiated areas of the value chain correspond to different specialization areas.

Mold concept and design are executed using CAD and CAM technologies, which allow the creation of virtual three-dimensional models, and the development of the corresponding equipment/machinery programs, which are then applied to the CNC equipment in order to manufacture the pieces for each of the molds. One of the great advantages of these technologies places in the preview of any engineering irregularities in the product, which previously meant that fixing them was costly and would increase the delivery times.

Prototyping is a technique, previous to the final mold, that accounts for the production of the physical 3D models in different materials (polymers, ceramics, metal, wood, etc.), from their corresponding models. Laser stereo lithography, high speed machinery (three to five axes), laser sintering and 3D printing are some examples of cutting edge technology currently used in prototyping.

Mold manufacturing consists of the rough grinding and finishing, typically of alloy steel, based in numerical command programs designed by CAD/CAM software. Currently, the most used machinery processes for the manufacturing of molds are called CNC milling and CNC turning. Some of the complimentary products and services, such as coating, have been adding value to the molds, which reflects on the increase of its lifespan due to the increase of its resistance to wearing, corrosion and oxidation.

The part and component injection, an activity that mold companies have been progressively incorporating into their value chain, basically resides in the pressurized filling of a mold's cavity with a molten polymer. Inside the mold, the molten material quickly cools down until it reaches enough rigidity to allow for its removal, ensuring the desired geometry.

Generally speaking, and in what concerns the field of competences of the PMI, SPI (2008) has divided PMI's companies into two types of different positioning, which are very much related to their dimension: the typical small mold enterprises are positioned, in terms of the industry's value chain, only in the fields of conception, mold project and manufacture; whereas larger enterprises are present in all activities of the value chain, possessing a strong knowledge/mastery of all of the production process, providing support services regarding concept development, and product and project development, as well as the production of the final product, often in collaboration with entities that belong to the National Scientific and Technological System (Moreira & Carvalho, 2015).

In addition, several of these entities cooperate with marketing companies, which may induce a narrow view in what regards to the final client and a lower level of involvement in the creation of the final product. However, it is important to note the importance marketing companies have in the enhancement of the PMI's international competitiveness, given its higher commercial capacity, which has been beneficial to many SMEs, given that the molds industry has significantly grown in Asia.

In turn, larger enterprises hold their own commercial forces that are responsible for the development of their businesses, still showing capabilities in terms of offering differentiated products, such as injection machines or CAD/CAM software tools for mold projects. Some of these differentiated companies take a different path, focusing in the concept and production of molds in the low end competitive niches.

These companies respond more quickly to constant market changes, by focusing on their services' diversity and extension, as well as on a faster technological development, which gives them a greater added value, thus ensuring that they are more protected from the price-based competition.

The Portuguese molds industry has been growing throughout the years, and consolidating its international market image, driven by both external demand and the set of production competences and capabilities. Currently, the PMI has about 450 SMEs devoted to the design, development, and manufacture of molds and special tools, employing about 8,000 workers (CEFAMOL, 2015).

According to ISTMA, Portugal is currently among the main mold manufacturers in the world, namely in the field of the plastic injection molds, where it ranks eighth, globally, and fourth, in Europe, presently exporting more than 85% of their total production (CEFAMOL, 2015).

As reported by CEFAMOL (2015), in 2014, exports exceeded €560 million (see Figure 1), with production around €660 million. Exports are sent to 89 countries, with focus on the main markets: Spain, Germany, France, Czech Republic, United Kingdom, Poland, United States, and Sweden.

Figure 1 analyzes the evolution of sales to foreign markets for the past 23 years, demonstrating the industry's strong export-oriented vocation. However, it is possible to identify two distinct periods: the first, from 1990 to 2001, where one witness a relatively constant growth (with a single exception in 1993, in which there was a slight decrease), and the following period up to the present day, described by peaks, although presenting the same growth trend.

The trade balance and the export intensity (exports/production) of the PMI are presented in Table 1, where one concludes that there is a clear export orientation. The trade balance increased from 293.2 million Euros in 2004 to 405.15 million Euros in 2013 (CEFAMOL, 2015). Also the export intensity of the PMI is never lower than 77% of the total production. The export intensity has been increasing based on the plastic specialization of the molds industry.

Figure 1. Evolution of exports (in 10^6€) since 1990
Source: Own preparation from data from CEFAMOL (2015).

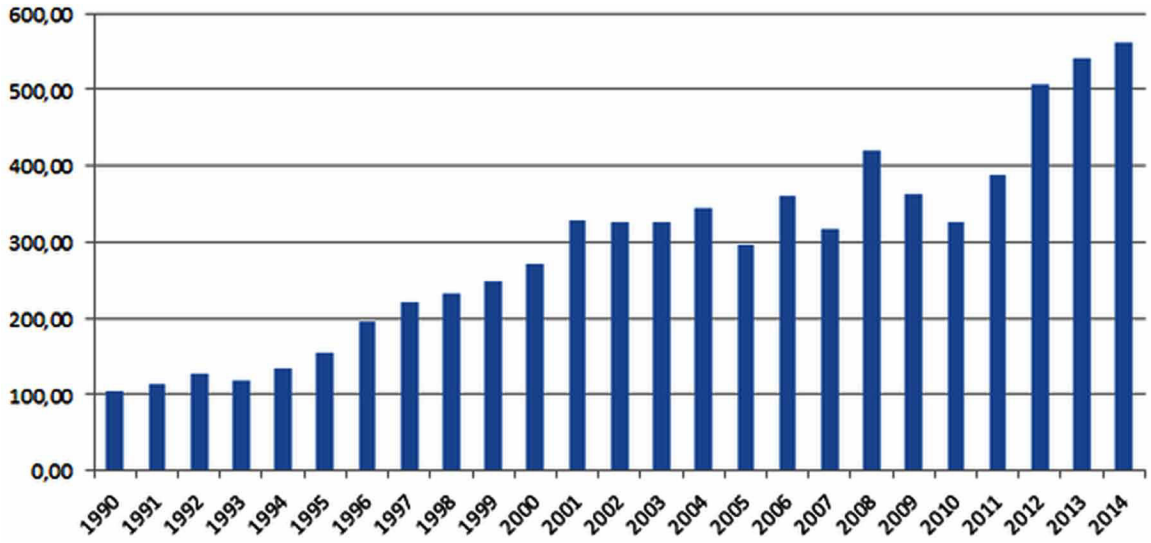


Table 1. Trade balance (in 10^6€) and export intensity between 2000 and 2013

Year	Production	Exports	Imports	Trade Balance	Export Intensity (%)
2000	299.3	270.4	39.5	230.9	90%
2001	368.9	328.5	52.8	275.7	89%
2002	359.2	326.6	63.2	263.4	91%
2003	358.6	326.0	57.2	268.8	91%
2004	366.7	345.1	51.9	293.2	94%
2005	350.6	297.5	43.9	253.6	85%
2006	434.9	361.1	54.8	306.3	83%
2007	381.6	317.6	51.1	266.5	83%
2008	465.0	420.0	73.1	346.9	90%
2009	407.1	363.0	68.0	295.0	89%
2010	417.3	325.6	77.1	248.5	78%
2011	494.9	378.8	84.7	294.1	77%
2012	536.6	512.1	102.1	410.0	95%
2013	581.3	540.7	135.5	405.2	93%

Source: Own preparation from data from INE, AICEP and CEFAMOL (2015).

As shown in Table 2, there is a clear preponderance of the European market, which represents, in average, nearly 78% of total exports. The American market has decreased its importance in recent years as a result of the offshoring strategies of American firms to East-Asian markets, based on cheaper hand-

Table 2. Exports (in 10^6€) by client market

	2009	2010	2011	2012	2013
Total	**363.0**	**325.6**	**388.1**	**507.0**	**540.7**
Spain	79.8	54.4	70.5	100.5	135.7
Germany	95.2	93.3	91.4	104.9	109.4
France	59.3	43.1	68.9	88.3	82.2
Poland	7.1	9.1	12.3	18.6	26.3
US	10.3	11.6	10.1	10.9	20.1
Czech Republic	9.0	13.8	7.0	22.7	18.7
Mexico	6.3	11.8	9.5	9.5	15.0
United Kingdom	8.0	11.4	10.0	17.0	14.1
Russia	3.3	5.4	5.4	8.9	12.0
Belgium	8.6	5.8	7.8	7.3	11.0
Netherlands	5.2	5.6	5.3	7.0	8.0
Switzerland	5.7	8.0	7.3	8.8	7.7
South Africa	0.6	1.2	3.1	1.3	6.6
Venezuela	0.5	0.3	2.4	5.8	5.3
Morocco	1.8	1.7	3.8	2.5	5.3
Others	62.3	49.1	73.2	92.9	63.3

Source: Data based on information from Instituto Nacional de Estatística and CEFAMOL (2015).

Table 3. Evolution of main clients' industries between 1984 and 2012

	1984	1991	1994	2001	2008	2010	2012
Health technologies	-	-	-	-	1%	-	-
Toys	28%	8%	8%	2%	-	-	-
Household equipment	9%	34%	32%	7%	6%	5%	3%
Automotive industry	1%	14%	20%	27%	72%	72%	78%
Packaging industry	13%	7%	9%	18%	5%	12%	8%
Electronics and Telecommunications	21%	9%	9%	12%	3%	2%	2%
Domestic appliances	14%	-	-	7%	5%	-	-
Electric material	-	13%	10%	6%	-	2%	-
Furniture industry	-	-	-	-	-	1%	-
Construction materials	-	-	-	-	-	1%	-
Aeronautics	-	-	-	-	-	-	1%
Outros	14%	15%	12%	21%	8%	5%	8%

Source: CEFAMOL (2012).

Table 4. Number of firms vs. firm size between 2005 and 2012

	2005	2007	2008	2009	2010	2011	2012	Var % 05/12
< 10	325	317	307	305	252	247	239	-26%
[10; 49]	174	164	189	170	168	170	179	3%
[50 a 499]	37	34	36	32	29	32	35	-5%
> 500	0	0	0	0	0	0	0	-
Total	**536**	**515**	**532**	**507**	**449**	**449**	**453**	**-15%**

Source: CEFAMOL (2015).

Table 5. Number of firms vs. number of employees in the PMI between 2005 and 2012

	2005	2007	2008	2009	2010	2011	2012	Var % 05/12
Number of firms	536	515	532	507	449	449	453	-15%
Number of employees	8,369	7,987	8,240	7,640	7,311	7,688	7,964	-5%
Number of employee/firm	15.61	15.51	15.49	15.07	16.28	17.12	17.58	12.6%

Source: CEFAMOL (2015).

labor in those countries as well as a result of the strong depreciation of the American dollar. One can also conclude that Spain emerges as the main market in 2013.

Regarding client industries, one realizes the importance of the automotive industry, which in 2012 represented 78% of the whole market (Table 3). If one can argue that the automotive industry is very important for the PMI, it is difficult to ignore that this strong dependence might create a strategic fragility. The main reason behind the strong decrease of some clients of the PMI (toys, household equipment, packaging, domestic appliances, and electronics) that they are no longer competitive in the Western industrial world. However, those industries are thriving in East Asia, namely in China, where firms are willing to purchase locally molds, based on its cheap hand labor industrial system (Neto, 2014).

The last few years have reported a diversification effort towards gaining market share in new fields and niches with greater added value, such as the aeronautical and medical devices industries. However, such effort is still in its early stages in what concerns significant turnover.

In regards to the social and economic dimension of the PMI, tThe relevant information made available by CEFAMOL refers to the period between 2005 and 2012. Data released from CEFAMOL are based on data from the Ministry of Employment and Social Solidarity, with a clear focus on Economic Activity Code CAE 25734 (*Production of Metallic Molds*). The number of firms is shown in Table 4.

The greatest decrease occurred among micro-enterprises (fewer than 10 employees), while the number of small enterprises (10-49 employees) despite the ups and downs, shows a slight variation between 2005 and 2012 (CEFAMOL, 2012).

The evolution of the total number firms and employees in the PMI is found in Table 5, which follows a downward perspective. However, the average number of employees by company has been increasing, which is related with the increase of the installed capacity in the last few years (CEFAMOL, 2015).

Table 6. Evolution of the ALP of the PMI

Year	Sales Volume	Employees	ALP of PMI	ALP of the Transforming Industry	PAT – NACE 25
2000	299,300,000 €	6,711	44,598.42 €	23,142.61 €	18,239.31 €
2001	368,900,000 €	-	44,057.28 €	24,192.69 €	18,469.84 €
2002	359,200,000 €	-	43,516.13 €	25,244.55 €	19,440.79 €
2003	358,600,000 €	-	42,974.99 €	26,191.50 €	19,315.36 €
2004	366,700,000 €	-	42,433,84 €	27,500.14 €	21,146.93 €
2005	350,600,000 €	8,369	41,892.70 €	28,498.17 €	21,853.26 €
2006	434,900,000 €	-	44,835.17 €	29,728.00 €	23,323.31 €
2007	381,600,000 €	7,987	47,777.64 €	31,539.32 €	24,913.94 €
2008	465,000,000 €	8,240	56,432.04 €	32,257.11 €	26,392.60 €
2009	407,100,000 €	7,640	53,285.34 €	33,097.13 €	23,842.67 €
2010	417,300,000 €	7,311	57,078.38 €	34,088.01 €	25,616.48 €
2011	494,900,000 €	7,688	64,373.05 €	34,066.85 €	24,925.10 €
2012	536,600,000 €	7,964	67,378.20 €	34,384.70 €	25,334.72 €

Source: Own preparation. Data from CEFAMOL (2015).

Table 6 shows the PMI's Apparent Labor Productivity (ALP). In order to analyze the Portuguese molds industry ALP its comparison is shown with the industrial production (NACE code 25) and with the Metallic molds production industry (NACE code 25734). As some data were unavailable regarding the number of employees, ALP between 2000 and 2005, and 2005 and 2007 were linearly estimated as a linear function of available data.

In order to establish a comparison with the ALP values for the general manufacturing industry, and of CAE 25, the following data were collected from INE (National Statistics Institute) and PORDATA – Contemporary Portuguese Database (2015), gathered in Table 6.

The competitiveness of the PMI becomes clear, in terms of Apparent Labor Productivity, whether pertaining to the manufacturing industry as a whole, or as the NACE 25 group in which it is included. This is mainly due to the highly technological and automated nature of the industry.

Silva (2009) demonstrates a positive evolution of the employee qualifications in the PMI, with an increase in the number of workers with a secondary school and college degrees, resulting from the growing need for the ability to deal with constant technological evolution.

In 2012, about 40.5% of the number of employees in the molds industry had a secondary school or college education, compared to the 26.1% of the observed average within the manufacturing industry in general. By analyzing the qualifications of the human resources, 2012 accounted for a total of 61% classified as skilled workers within the PMI, a much higher value than the 45.6% average obtained from the general manufacturing industry in Portugal (CEFAMOL, 2012).

Table 7 presents the market shares of the molds industry in relation to the world mold exports, in which the main mold exporters of 2013 were: China (21.0% of the total); South Korea (10,0%); Japan (9.6%); Italy (8.0%), Germany (7.9%); USA (5.6%); and Canada (5.1%) (CEFAMOL, 2015).

Table 7. Position and market share of Portugal regarding mold's world exports

	2007	2008	2009	2010	2011	2012	2013
Position	12	10	8	11	10	8	8
Market share (%)	2.87	3.28	3.54	3.10	3.11	3.69	3.91

Source: CEFAMOL (2015).

Table 8. Production of main clients analyzed between 2007 and 2012 (values in Euros)

	2007	2008	2009	2010	2011	2012
Spain	207,716,493	192,486,430	143,253,294	124,148,000	134,728,000	145,549,000
France	578,996,380	696,239,731	600,846,256	519,746,000	529,965,000	480,375,000
Germany	1,897,429,180	2,061,137,137	1,812,152,345	1,714,906,000	1,969,763,000	2,005,065,000
EUA	3,975,912,409	3,635,502,176	2,924,680,000	3,544,512,000	3,483,140,000	-
UK	168,268,697	153,152,157	150,829,000	163,557,000	176,602,000	195,437,000
Czech Rep.	101,544,695	113,627,114	103,961,000	122,962,000	158,336,000	167,279,000

Source: Own preparation. Data from CEFAMOL (2015).

Table 9. Exports of main clients analyzed between 2007 and 2012 (values in Euros)

	2007	2008	2009	2010	2011	2012
Spain	60,362,611	79,358,150	73,023,740	53,347,000	66,283,000	77,171,000
France	242,603,170	239,199,682	207,514,000	171,271,000	197,212,000	278,658,000
Germany	700,940,742	706,258,888	671,469,280	710,723,000	757,437,000	838,473,000
EUA	461,196,924	438,720,653	654,543,000	638,045,000	620,953,000	749,423,000
UK	57,921,046	39,701,555	30,827,265	40,340,000	43,867,000	39,957,000
Czech Rep.	126,549,211	143,356,274	120,721,270	126,166,000	142,234,000	159,285,000

Source: Own preparation. Data from CEFAMOL (2015).

In order to analyze the positioning of the PMI in some of their client markets, the analysis crosses information from ISTMA in regards to the determination of apparent consumption within the various markets. Thus, this analysis focuses only on the molds for the plastic industry, defined by the disaggregated codes NC 848071 and NC 848079 (CEFAMOL, 2015).

The three main markets are represented (Spain, France and Germany) comprising about 60% of the Portuguese plastic mold exports, as well as two other markets that are considered as "traditional" (USA and UK), although increasingly marginal, and lastly, the emerging market of the Czech Republic.

Firstly, Table 8 exposes the internal product value of the several mold industries. Secondly, in Table 9, shows the mold exports value, and Table 10 presents the imports value for the same period of time.

During this stage it appears that contrary to what happened in 2011, in which the main PMI markets grew significantly (despite the lower expression in the French market), in 2012 the "engine" of the European economy, Germany, stagnated and France dropped a significant 15,5 percentage points. Only

Table 10. Import of main clients analyzed between 2007 and 2012 (values in Euros)

	2007	2008	2009	2010	2011	2012
Spain	122,418,627	150,091,403	126,691,787	103,641,000	141,800,000	160,814,000
France	231,712,197	261,508,940	192,296,000	202,354,000	231,437,000	275,268,000
Germany	418,865,234	470,136,554	449,194,938	487,008,000	596,090,000	651,059,000
EUA	881,791,608	777,818,408	804,853,000	905,672,000	998,906,000	1,346,051,000
UK	84,650,874	80,835,043	67,271,041	80,631,000	98,272,000	147,737,000
Czech Rep.	117,490,092	141,595,433	146,392,229	131,764,000	134,185,000	179,927,000

Source: Own preparation. Data from CEFAMOL (2015).

Table 11. Portuguese exports for main clients between 2007 and 2012 (values in Euros)

	2007	2008	2009	2010	2011	2012
Spain	38,595,980	62,207,870	62,725,608	36,493,632	41,998,252	64,575,701
France	51,196,961	66,494,422	47,003,151	35,235,060	54,531,750	69,834,958
Germany	45,664,898	62,056,616	64,842,492	62,218,775	58,264,768	79,563,931
EUA	19,510,783	10,992,468	10,900,181	13,009,743	11,462,304	10,687,509
UK	9,968,768	10,093,197	6,415,760	10,587,267	8,247,954	13,663,054
Czech Rep.	1,365,772	7,136,499	7,593,508	12,747,240	5,338,558	19,777,632

Source: Own preparation. Data from CEFAMOL (2015).

Table 12. Market share for main clients between 2007 and 2012

	2007	2008	2009	2010	2011	2012
Spain	14.31%	23.63%	31.85%	20.92%	19.98%	28.18%
France	9.01%	9.25%	8.03%	6.40%	9.67%	14.64%
Germany	2.83%	3.40%	4.08%	4.17%	3.22%	4.38%
EU	0.44%	0.28%	0.35%	0.34%	0.30%	ND
UK	5.11%	5.20%	3.43%	5.19%	3.57%	4.51%
Czech Rep.	14.8%	6.38%	5.86%	9.92%	3.55%	10.52%

Source: Own preparation. Data from CEFAMOL (2015).

Spain and other secondary markets grew. Taking into consideration the annual average growth in each market during this time period, Germany, the UK and the Czech Republic stand out positively, whereas France and the US stand out negatively.

Tables 11 and 12 present the exports and market shares for the main client markets of the PMI. The weight of the German mold market is unavoidable.

With the exception of Spain, where the PMI has a significant share, in the rest of the analyzed markets there is still a favorable margin for the growth. It is interesting to note the growth the market share has had in the German market since 2007. In fact, 2012 saw a strengthening of all the exposed market shares, without taking into account the American market.

Neto (2014) reports some of the most important events from the last few years: the UK molds industry has completely vanished in the past few years; in Spain and France, only the stamping tools industry survived; Italy currently survives almost exclusively at the expense of their vast domestic market, mainly supported by the two major existing automotive centers in the country (Neto, 2014).

The mold industries in the US and Canada have suffered quite a lot in the past few years, but managed their way through based on (Neto, 2014): a great investment on technological development, which significantly increased productivity, in the attempt to overcome the high costs of hand labor; the huge size of US domestic market; and the American industry policy authorities considered that the mold and tool industry was strategically relevant to the country's economy, favoring domestic production.

This strategy is very characteristic of Japan, where the domestic mold production has always been favored, where despite cost advantages from producing in China, the molds are still manufactured exclusively in Japan, which puts the Japanese molds industry in a comfortable position (Neto, 2014).

Germany and Switzerland, highly renowned international mold producers, have clearly suffered with the de-industrialization process of Europe (Neto, 2014).

Neto (2014) considers that rigor and dimensional precision have always lacked in the Portuguese molds industry in comparison to the reputable Germans or Swiss, whereas the Portuguese mold makers are known for having a very influential creative and artistic talent. This reality is also justified by the fact that the industrial equipment used in Portugal is to this day, very little focused on dimensional precision.

As it was previously mentioned, the PMI has benefitted from the disappearance of several European mold companies, mainly in Spain and France, but also a few in Germany and Switzerland.

On account of geographical reasons, the main competitors of the Portuguese mold producers are their European counterpart manufacturers.

STRATEGIC AXES

In order to generate a sustainable development of the PMI and tune it with the concept of smart region, several strategic priorities were defined. For each axis, specific strategic objectives were defined, as well as plans of actions set out to reach those strategic objectives.

The definition of the proposed actions for each axis took into account various industry stakeholders, encompassing companies, suppliers, technological and R&D centers, educational institutions, training organizations, and business and industry associations.

Axis 1: Development of Structural Conditions

The definition of structural conditions is important for the implementation of all the remaining strategic axes in order to foster sustainable development of the PMI. Thus, some of the challenges that embody the domestic industry capacity to meet their threats and take advantage of their opportunities cover the qualification of human resources. This is understood as a basic condition for the sustained growth of the PMI in its economic and social aspects.

The incentives for improving technical skills have an interventionist perspective so that the industry can cope with the inadequate domestic supply, which greatly affects it. Thus, partnerships with universities, technological centers, and other institutions are necessary so that firms involved in those partnerships

reinforce their skills and innovation capacity in scientific and technological areas through the creation of R&D projects.

The development of IT is of high importance as it promotes greater virtual mobility and streamlines communications and the digital economy. Likewise, the development of an entrepreneurial culture and innovation, shared by all players is crucial.

A restructuring of financial support to companies is important for the PMI. As such, it is important to take into account the growing importance of intangible capital in the companies' growth and the seed capital risk to support innovation-based activities. The creation of a joint funding model taking into account not only the costs but also the results of technical and scientific projects may be conducive to innovation.

Axis 1 has the following strategic objectives:

- To disseminate essential base-of-the-pyramid conditions for the sustainable development of the PMI;
- To develop human resources skills;
- To generate competitive capacity from the consolidation of the business fabric of the industry;
- To stimulate the companies' innovation and R&D technological levels.

As action plans for Axis 1 it is suggested:

- To stimulate the training of human resources, with special focus on specialized technological skills areas;
- To integrate new staff with higher technical training across companies;
- To strengthen the skills and innovation capacity in scientific and technological areas;
- To encourage R&D partnership-based programs with different research and knowledge-based institutions;
- To stimulate the use of latest IT;
- To develop investments models tuned to innovation processes;
- To promote an entrepreneurship and innovation culture.

Axis 2: Convergence between Public Policies and Businesses Strategies

Public policy plays a central role in designing conditions for the development of the national economy. As such, there should be clear incentives for investment, given the relationship between investment and growth through support mechanisms for attracting domestic and foreign investment, firms' technological upgrading, and job creation, among others.

The promotion to support the implementation of partnerships, mergers and acquisitions, and entrepreneurship, will be crucial for the development of business-led regional development. Therefore, the provision of financial support mechanisms should be at the center of the economic policies that enable the creation of more adequate and stable relationships among firms.

Support for internationalization and export is essential to the PMI, given its small domestic market, which must be clearly underpinned on quality and innovation. Incentives to investment, the provision of mechanisms to support investment plans abroad, and tools to simplify and liaising with partners, customers, and suppliers should be the basis of this process.

With regard to the science and technology policy, it is necessary to define support mechanisms for the design of a technology infrastructure that allows the organization of the PMI activities and services, according to (a) the sectoral development strategies, and (b) the R&D support activities, promoting the cooperation among firms and specialized agencies, as in this case, CENTIMFE.

Other socio-economic development factors should be targeted, promoting job creation, investment in advanced technologies, and the generation of distinctive competencies, such as engineering and product development, R&D, nanotechnologies, among others.

Axis 2 has the following strategic objectives:

- To develop integrated policies in order to enable the future of the PMI;
- To strengthen the competitiveness of the PMI on a global scale;
- To develop public policies at different levels so that business strategies generate competitive advantages for the PMI.

As action plans for Axis 2 is suggested:

- To support the woo back of foreign investment;
- To support the firms' technological modernization;
- The development of business and technology partnerships;
- The provision of financial support mechanisms;
- The promotion of the internationalization of companies, with a clear focus on quality and innovation;
- The implementation of training policies and qualification of human resources;
- The creation of employment policies;
- To encourage the cooperation between companies and R&D organizations;

Axis 3: Development and Dissemination of New Technologies

The foundation of sustainable growth of the molds industry is based on technological development, innovation, and dissemination of new technologies.

The importance of some technologies – nanotechnology, surface technology and coatings, eco and bio-materials, structural composites, eco-design, eco-efficient manufacturing processes, co-engineering, in-mold technologies, micromachining, micro injection molding, among others, identified as part of the Engineering & Tooling Technology Roadmap for the period 2014-2020, defined by CENTIMFE as a strategic tool to support the molds industry –, will determine future development paths (Baptista, 2015). This roadmap is aligned with the PMI strategy, identifying new global technological trends, national scientific and technological skills, and some of the new technological and scientific developments of the tooling industry. Moreover, nano technologies are expected to have major economic development in the near future (Moreira & Vale, 2016).

The PMI within a SSI character will involve individuals, firms, technological knowledge centers, and industry associations, each of them holding unique skills. Thus, the knowledge held by each actor spreads out easily through interactions among the various actors; the value that results from these specific skills is not limited to the agent that has it, but involves the whole sectoral system of innovation, with a major impact for the sustainability of a smart region.

Axis 3 has the following strategic objectives:

- To focus on innovation, development and dissemination of new technologies;
- To promote practices in companies with a view to innovation;
- To disseminate the development and implementation of new technologies within the PMI;

For Axis 3 the following action plans are suggested:

- The development and dissemination of emerging technologies;
- The monitoring of the world's major technological trends;
- To participate in and to organize international conferences that contribute to the exploration and technological surveillance;
- To set future R&I investment trends;
- To promote production process related innovation in order to improve product quality, productivity, and the incorporation of emerging technologies;
- To promote technological knowledge sharing events and activities encompassing various players: businesses, individuals, technological knowledge centers, and industry associations;
- To establish interfirm arrangements for the implementation of joint projects;
- To develop intra and intersectoral collaborative networks, in order to generate and capture new business opportunities;

Axis 4: Specialization of the Value Chain

Taking into account the characterization and international positioning of the molds industry, there are several open routes for its development based on possible synergies among the various types of businesses. As such, and given the technological expertise of the mold makers, it can be as important to strengthen the competitiveness of firms within the industry as to diversify the range of activities, aiming at renewing its industrial cycle. SPI (2008) pointed out three areas of expertise that, even today, can become of added value for many of firms of the PMI:

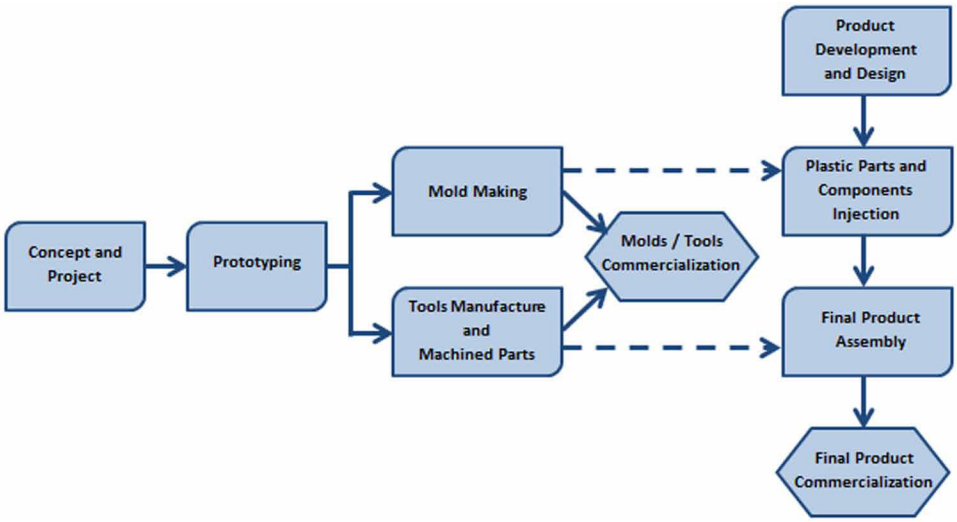
1. The specialization in plastic and composite materials highly complex molds;
2. The specialization in high precision special tools and machined parts;
3. The specialization in plastic products and components, based on composite materials.

Compiling the three types of expertise, the proposed industry value chain is synthesized in Figure 2.

We first emphasize the specialization in highly complex molds for plastics and composite materials. On one hand, highly accurate micro-molds are not within the reach of any company. On the other hand, large molds require not only major investments, but also expensive machinery and facilities, which are natural barriers for new competitors.

This first expertise involves firms to focus on the design, project, and manufacturing of molds, through the prototyping stage up to the marketing and commercialization of these molds for the plastic injection industry. At this stage, some of the important strategies for achieving global competitiveness include (SPI, 2008): increasing productivity; increasing the effectiveness of the project, supply based on an integrated service, outsourcing to low-cost countries the mold production base, leaving the final

Figure 2. Proposed industry value chain for PMI
Source: Own preparation.



machining and maintenance for local production; and the presence and action in adding value market areas and differentiating oriented businesses.

The second stream emerges with the specialization in high-precision special tools and machined parts, an area little explored by the many firms of the PMI. The goal is to achieve opportunities in areas of design, project, manufacturing and marketing of high-precision tools and machined parts, and using advanced prototyping techniques during its production process.

This can be seen as an alternative development to well-known molds for plastic, which can be particularly important in the event of an economic slowdown, but involves large efforts in terms of productivity, R&D, investments in technology and/or specific equipment, and the marketing of these tools or machined parts. This will be easier to develop with time, rather than reacting to sudden economics crisis.

Finally, the third specialization proposed, in plastic products and components based on composite materials, focuses on upstream activities in the supply chain of the molds industry, namely directing its efforts to the design of the product with the customer, and to the production of plastic and composite materials products. As the focus is on the production of molds and tools or machined parts, internal sub-activities can be outsourced to third parties.

This specialization requires some improvements in what pertains to productivity, as well as a commercial increased effort to develop product marketing capabilities, and plastic and composite materials based components.

The consolidation of the three areas originates this strategic axis defined as specialization of the value chain in order to increase the competitiveness of the industry through added value competencies in product engineering, design, and development of molds, special tools, and machined parts.

High complexity molds for plastics and composite materials, and high precision special tools and machined parts are considered core areas of the industry, while the third expertise that incorporates the production of plastic components and products based on composite materials, complements the two

abovementioned specializations. As such, as part of a smart region based on a strong relational capital with other industries, axis 4 has the following strategic objectives:

- To foster the competitiveness of firms;
- To increase the capacity of design and development of high complex molds;
- To increase the capacity of design and development of special tools and high precision machined parts;
- To develop new markets for special tools and high precision machined parts;
- To widen the value chain by complementing the production of plastic products with the manufacturing of plastic part and components.

For Axis 4 the following action plans are suggested:

- To augment productivity, and project and production efficiency;
- To develop integrated solutions that enhance the supply of particular molds;
- To foster outsourcing activities from lower-cost countries;
- To focus client-based relationships on end machinations and maintenance;
- To invest in the design, production and marketing of high precision tools and machined parts, market segment little explored in the domestic industry;
- The integration of production of plastic components, extending the value chain;
- To focus on small and medium series production for more specialized customers;
- To develop new technological and commercial skills to new plastic products and special tools.

Axis 5: Engineering and Product Development Cluster

This fifth axis complements previous ones by broadening the service supplied. In the case of the Portuguese molds industry, several companies already have an ongoing diversification strategy, through the engineering and manufacturing of innovative products, which according to Neto (2014) is one of the most promising of the Portuguese economy.

This differentiation process has led to an engineering and prototyping sector that has attracted investments and generated new knowledge and technologies (Neto, 2014). To complement this, integrating companies are needed, i.e., companies that acquire in the domestic market some of the components and systems and to integrate them into finished products for export.

The development of the engineering and product development cluster may be the way forward for the Portuguese mold companies to provide an integrated service – involving the development, design, prototyping, and manufacturing of innovative products – that can be unique and of added value for the industry (Neto, 2014).

Axis 5 has the following strategic objectives:

- To invest in a diversification strategy;
- To focus on innovative product engineering and production;
- To contribute to the industrialization of the country;
- To attract investment from integrating companies;
- To develop the product engineering and development cluster.

For Axis 5 the following action plans are suggested:

- To focus on the diversification of firms through product engineering and manufacturing of innovative products;
- To properly exploit the hand-intensive and highly specialized technologies present in the PMI;
- To foster an engineering and prototyping sector;
- To support the supply integrated service of development, design, prototyping and manufacturing of innovative products;
- To invest in the promotion and advertising of products and services, and in a brand image for this new cluster.

Axis 6: Penetration into New Sectoral Markets

For the molds industry it is important to diversify and penetrate in new sectoral and geographical markets, in order to reduce the current risk as a result of its high dependence on the automotive industry.

According to SPI (2008), the automotive, electronics, aeronautics, health devices, and energy and environment industries are the main targets. Several opportunities are expected around the technological revolution already underway in the auto industry, both in terms of new powertrains (hybrid cars, and the 100% electric vehicles) or the application of new composite materials, such as the increasing incorporation of electronic components in the vehicles. All of them are very important to the PMI.

The miniaturization trend in the electronics industry might create opportunities in terms of development of molds and high-precision small-sized machined parts, for which companies must develop specific skills.

Although highly regulated, the aeronautics industry is very important for the deployment of innovation, such as new propulsion systems and new materials. Likewise, the health equipment industry is expected to have a high growth rate in terms of (a) the development and production of innovative medical devices, (b) the use of high precision machining parts, (c) the development of molds for plastic devices or molds based on new composites.

There is a clear paradigm shift related with energy and environmental issues as energy production and environmental waste treatment deposited in large plants is expected to change to a more dispersed model, which may be extended to consumers themselves, which will create a wide range of opportunities in this area in the coming years.

As a result of succeeding in entering in new target industries, it is expected that new geographical markets are gained as a consequence of the development of new technological capabilities such as China, which is one of the leading world importers, the US, for its regained importance in the molds industry, Europe, for its industrial prevalence in the automotive and aeronautic industries, and Russia and India, for their potential economic growth.

The development of these markets, most of which present themselves as interesting niches for the PMI, should be prospected as a key part of an integrated process covering the design, development, and production of innovative products, framed within an industrial, technological, and financial cooperation involving strategic partnerships with engineering and design companies.

Axis 6 has the following strategic objectives:

- The diversification and penetration into new sectoral markets;

- To reduce the dependence of the automotive industry;
- To expand to new geographic markets;
- To foster the sustainable growth of the PMI.

The following action plans are suggested for Axis 6:

- To strengthen the positioning in the automotive industry, which is growing steadily;
- To gain competences on micromachining as means for penetrating in the electronics market;
- To invest in new technologies and materials in order to enter demanding markets as the health, aeronautics, and energy industries;
- To promote intrassectoral relationships and synergies to absorb tacit knowledge from various industrial sectors;
- To develop sales channels and promote strategic partnerships with engineering and design companies.

CONCLUSION

Over the past few years, the PMI has benefited from the disappearance of several molds companies in Europe, particularly in Spain and France, but also some in Germany and Switzerland, which, are among the main competitors of the Portuguese molds producers.

The PMI can be seen as a source of contributions to different areas such as R& D, new technologies innovation and development, as well as for the innovative nature of the processes and products with strong investment in new technologies and technological equipment. Therefore, the technological development is a key factor to this industry, which competes on a global scale.

The importance of the automotive industry for the molds industry could be in the first instance, a decisive factor, jeopardizing its future.

Economically, the PMI is affected by a number of trends occurring worldwide that decisively influence the activity of the firms. One can highlight the following ones: offshoring of production to Asia; price fluctuations of raw materials (steel and oil) and energy; evolution of exchange rates; the economic growth of the European Union, China, India, Russia and some Eastern European countries; the Portugal 2020 investment framework; and demand for energy efficient solutions, in terms of production operations and market solutions.

From an economic and geographical point of view, the advantage of the PMI involves the bipolar geographical concentration between Marinha Grande and Oliveira de Azeméis, becoming a facilitating factor in terms of communication and cross-company cooperation, and the dissemination of knowledge and technology among players.

Giving particular emphasis to the lack of qualified human resources for this industry, there have been various efforts from various entities – especially CEFAMOL, CENFIM, and NERLEI – involving the creation and promotion of courses and training projects in close partnership with (higher, professional and secondary) education and training institutions, especially the Instituto Politécnico de Leiria and the University of Minho. The emphasis on human capital is of key importance in order to develop a true smart region.

In what regards to technological factors, it is considered that they leverage the creation of sustainable competitive advantages and economic long-term growth of the PMI as a whole. As a consequence, investing in technological factors must be kept so that a new networked infrastructure improves the social, economic, and geographical development of the PMI, tuned with the needs of a smart region.

Nowadays, the PMI should invest in identifying the key global technology trends in the development of scientific and technological skills for the industry, as well as new developments of advanced production technologies such as nanotechnology; surface and coating technology; new functional materials; simulation methods and tools; advanced automation and manufacturing cells; additive manufacturing; micro-machining; in-mold technologies; micro-molding; and micro-assembly. This will support the development of the relational capital among firms, and the sustainability of this smart region.

This will support the development of the relational capital among firms, and the sustainability of this smart region.

The monitoring the technological evolution provides essential information for the decision process of acquiring new technologies and equipment, which in turn enhance the firms' and the PMI competitive position.

The involvement of firms in innovative projects for new industries will result in the absorption of new knowledge to the PMI, assuming the commitment to training as a strength, which is expected to attract human resources. The introduction of new technologies will result in the increase of flexibility, productivity, and capacity planning. The industrial fabric will be reinforced or even extended, creating new job opportunities, supporting a business-led geographical development.

Six strategic axes are proposed to reach a sustainable development of the PMI. Within each axis specific objectives and action plans are set:

1. **Development of Structural Conditions:** Axis 1 aims to disseminate essential basic conditions for sustainable development of the PMI, to motivate the qualification of human resources, to generate competitive capacity from the consolidation of the business and production base of the industry and to stimulate the firms' innovation and R&D technological levels.
2. **Convergence between Public Policies and Businesses Strategies:** Axis 2 emerges to develop integrated public policies initiatives to strengthen the competitiveness of molds industry on a global scale.
3. **Development and Dissemination of New Technologies:** Axis 3 seeks to invest on innovation, and diffusion of new technologies, in order to promote innovation practices among businesses, with special focus on cutting-edge technologies in the area the tooling.
4. **Specialization of the Value Chain:** Axis 4 seeks increased competitiveness by increasing the capacity of design and development of both highly complex molds, and high precision special tools and machined parts, or by integrating the production of plastic components and products based on composite materials.
5. **Engineering and Product Development Cluster:** Axis 5 seeks the deployment of a diversification strategy, a focus on product engineering and manufacturing of innovative products that attract the investment integrating companies, able to transform the skills of existing companies in the PMI.
6. **Penetration in New Sectoral Markets:** Finally, endowed with a more compelling character for the sustainable development of the PMI, Axis 6 seeks to materialize diversification and penetration of new sectoral and geographic markets, in order to reduce the risk arising from the current dependence on the automotive industry. As can be seen, the interrelatedness of the technological infrastructure, the human development generated by public policy support, and the relational capital

developed among stakeholders are designed to generate a sustainable smart industry involved in a smart economy.

In conclusion, the strategy of the PMI should go through a broadening and deepening of international relationships, aiming to increase the involvement of the development, production, and marketing of demanding end products in various sectoral international markets.

A sectoral innovation dynamics is bound to emerge after defining the six above-mentioned strategic axes. However, it is the promotion of inter organizational networking activities that can underpin the development of a dynamic Product Development and Engineering cluster with competitive advantages to penetrate in different sectoral and geographical markets. For this to occur, new product development capabilities, new R&D capabilities need to be mobilized and fostered involving higher education institutions and technology centers so that knowledge can be disseminated (Carvalho & Moreira, 2015; Moreira et al., 2008).

As Heidenreich (2004) defends, an entrepreneurial sectorial innovation system is necessary not only have a solid bed of knowledge-based SMSs, but also creative entrepreneurs and innovative work force so that the PMI can create a strong foothold in knowledge intensive sectors- moreover, Heindenreich (2004) also claims that it is mandatory to abandon the stability of institutional order of Dirigiste innovations systems and to embrace smarter regions.

REFERENCES

Baptista, A. (2015). Roadmap tecnológico 2014–2020 para o engineering & tooling. *Revista O Molde, 105*, 42–44.

Beije, P. (1998). *Technological change in the modern economy: Basic topics and new developments*. Cheltenham, UK: Edward Elgar.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmarki, S., & Rickne, A. (2008). Analysing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, *37*(3), 407–429. doi:10.1016/j.respol.2007.12.003

Berry, C., & Glaeser, E. (2005). The divergence of human capital levels across cities. *Papers in Regional Science*, *84*(3), 407–444. doi:10.1111/j.1435-5957.2005.00047.x

Breschi, S., & Malerba, F. (1997). Sectoral innovation systems: Technological regimes, Schumpeterian dynamics, and spatial boundaries. In C. Edquist (Ed.), *Systems of innovation - technologies, institutions and organizations* (pp. 130–156). London: Pinter.

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology*, *18*(2), 65–82. doi:10.1080/10630732.2011.601117

Carvalho, A. C., & Moreira, A. C. (2015). Open innovation profile in small and medium-sized firms. The perspective of technology centres and business associations. *International Journal Innovation Learning*, *18*(1), 4–22. doi:10.1504/IJIL.2015.070242

CEFAMOL. (2012). *Posicionamento competitivo da indústria portuguesa de moldes - Edição 2012*. Marinha Grande, Portugal: CEFAMOL.

CEFAMOL. (2015). *Posicionamento competitivo da indústria portuguesa de moldes - Edição 2015*. Marinha Grande, Portugal: CEFAMOL.

Chang, Y.-C., & Chen, M.-H. (2004). Comparing approaches to systems of innovation: The knowledge perspective. *Technology in Society*, *26*(1), 17–37. doi:10.1016/j.techsoc.2003.10.002

Edquist, C. (1997). *Systems of innovation: Technologies, institutions and organizations*. London: Pinter Publishers.

Feser, E. J., & Bergman, E. M. (2000). National industry cluster templates: A framework for applied regional cluster analysis. *Regional Studies*, *34*(1), 1–19. doi:10.1080/00343400050005844

Freel, M. (2003). Sectoral patterns of small firm innovation, networking and proximity. *Research Policy*, *32*(5), 751–770. doi:10.1016/S0048-7333(02)00084-7

Freeman, C. (1987). *Technology policy and economic performance: Lessons from Japan*. London: Frances Pinter.

Fu, S. (2007). Smart cafe´ Cities: Testing human capital externalities in the Boston metropolitan area. *Journal of Urban Economics*, *61*(1), 87–111. doi:10.1016/j.jue.2006.06.002

Gambardella, A., & McGahan, A. (2010). Business-model innovation: General purpose technologies and their implications for industry structure. *Long Range Planning*, *43*(2), 262–271. doi:10.1016/j.lrp.2009.07.009

Gerguri, S., Rexhepi, G., & Ramadani, V. (2013). Innovation strategies and competitive advantages. *Modern Economics: Problems, Trends. Prospects*, *8*(1), 10–26.

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanović, N., & Meijers, E. (2007). *Smart Cities: Ranking of European Medium-Sized Cities*. Vienna, Austria: Centre of Regional Science (SRF), Vienna University of Technology. Available from http://www.smartcities.eu/download/smart_cities_final_report.pdf

Glaeser, E., & Berry, C. (2006). *Why are smart places getting smarter? Taubman Center Policy Brief 2006-2*. Cambridge, MA: John F. Kennedy School of Government.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., & Williams, P. (2010). Foundations for smarter cities. *IBM Journal of Research and Development*, *54*(4), 1–16. doi:10.1147/JRD.2010.2048257

Heidenreich, M. (2004). The dilemmas of regional innovation systems. In P. Cooke, M. Heidenreich, & H. J. Braczyk (Eds.), *Regional innovation systems* (pp. 363–389). London: Routledge.

Hekkert, M., Suurs, R., Negro, S., Kuhlmann, S., & Smits, R. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, *74*(4), 413–432. doi:10.1016/j.techfore.2006.03.002

INE & PORDATA. (2015). *Produtividade aparente do trabalho: Total e por ramo de atividade*. Retrieved July 12, 2015, from http://www.pordata.pt/Portugal/Produtividade+aparente+do+trabalho+total+e+por+ramo+de+actividade-2303

Lo, J. Y.-C. (2015). Selling science: Resource mobilization strategies in the emerging field of nanotechnology. *Research Policy*, *44*(8), 1513–1526. doi:10.1016/j.respol.2015.05.005

Lundvall, B. (2007). National innovation systems: Analytical concept and development tool. *Industry and Innovation*, *14*(1), 95–119. doi:10.1080/13662710601130863

Lundvall, B., Johnson, B., Andersen, E., & Dalum, B. (2002). National systems of production, innovation and competence building. *Research Policy*, *31*(2), 213–231. doi:10.1016/S0048-7333(01)00137-8

Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy*, *31*(2), 247–264. doi:10.1016/S0048-7333(01)00139-1

Malerba, F. (2003). Sectoral systems and innovation and technology policy. *Revista Brasileira de Inovação*, *2*(2), 329–375.

Marshall, A. (1920). *Principles of economics*. London: Macmillan and Co, Ltd.

Moreira, A. C., Carneiro, L., & Celada, C. (2008). Defining the regional innovation strategy for the year 2015: The case of the ITCE clusters in the North of Portugal. *International Journal of Innovation and Regional Development*, *1*(1), 66–89. doi:10.1504/IJIRD.2008.016860

Moreira, A. C., Carneiro, L., & Tavares, M. (2007). Critical technologies for the North of Portugal in 2015: The case of ITCE sectors – information technologies, communications and electronics. *International Journal of Foresight and Innovation Policy*, *3*(2), 187–206. doi:10.1504/IJFIP.2007.011624

Moreira, A. C., & Vale, A. A. (2016). Sectoral systems of innovation and nanotechnology. Challenges ahead. In M. Peris-Ortiz, J. Ferreira, L. Farinha, & N. Fernandes (Eds.), *Multiple helix ecosystems for sustainable competitiveness* (pp. 147–168). Springer International Publishing. doi:10.1007/978-3-319-29677-7_10

Morosini, P. (2004). Industrial clusters, knowledge integration and performance. *World Development*, *32*(2), 305–326. doi:10.1016/j.worlddev.2002.12.001

Neto, H. (2014). *Um olhar sobre a indústria de moldes*. Lisbon, Portugal: Gradiva.

Porter, M. E. (1998). Clusters and the new economics of competition. *Harvard Business Review*, *76*(6), 77–90. PMID:10187248

Pyke, F., Becattini, G., & Sengenberger, W. (Eds.). (1990). *Industrial districts and inter-firm co-operation in Italy*. Geneva: International Institute for Labor Studies.

Saxenian, A. (1995). Regional advantage: Culture and competition in Silicon Valley and route 128. *Harvard Journal of Law & Technology*, *8*(2), 521–528.

Schmitz, H. (2000). Does local co-operation matter? Evidence from industrial clusters in South Asia and Latin America. *Oxford Development Studies*, *28*(3), 323–336. doi:10.1080/713688314

Schrempf, B., Kaplan, D., & Schroeder, D. (2013). *National, Regional, and Sectoral Systems of Innovation – An overview*. Retrieved March 22, 2015, from http://www.progressproject.eu/wp-content/uploads/2013/12/Progress_D2.2_final.pdf

Silva, A. C. (2009). Lei n.º 85/2009. *Diário Da República*, *166*(1), 5635.

Silvestre, B. S. (2007). Modelos de análise de aglomerados industriais: Implicações no estudo do aglomerado de petróleo e gás do norte fluminense. *Revista Gestão Industrial*, *3*(2), 119–130.

SPI. (2008). *Plano estratégico para o sector de moldes em Portugal*. Porto, Portugal: SPI.

Tushman, M., & Rosenkopf, L. (1992). Organizational determinants of technological change: Toward a sociology of technological evolution. *Research in Organizational Behavior*, *14*, 311–347.

Vieira, F., & Romero, F. (2005). Uma tipologia de análise da inovação no sector dos moldes em Portugal. *Comportamento Organizacional e Gestão*, *11*(1), 85–94.

Vieira, F., & Romero, F. (2008). Networks and industrial clusters. In G. Putnik & M. Cruz-Cunha (Eds.), *Encyclopedia of networked and virtual organizations* (pp. 1058–1065). Hershey, PA: IGI Global. doi:10.4018/978-1-59904-885-7.ch138

KEY TERMS AND DEFINITIONS

Apparent Consumption: The production plus imports minus exports, sometimes also adjusted for changes in inventories. The intention here is not to distinguish different uses for a good within the country, but only to infer the total that is used there for any purpose.

Apparent Labor Productivity: Value added per person employed.

Innovation System: The flow of knowledge, technology and information among people, businesses and institutions that is key to the innovative process. It involves the interaction of a complex set of relationships among universities, firms and research institutions so that innovation and economic development may thrive.

Regional Economic Development: The set of sustained, concerted actions taken by policy makers to promote the economic well-being and the standard of living of certain communities or regions. These actions may involve investing in infrastructure, social well-being, human capital, business development, among other initiatives.

Regional Innovation System: The set of relationships of the innovation system that is rooted inside the borders of a region.

Smart City: The concept of smart city is related to the integration of information and communication technology, human and relational capital, and business-led urban development. The vision behind this concept is the generation of urban development. In this chapter we include the system of innovation as an integral part of the business-led urban development.

Strategy: A method or a high level plan to achieve a desired future. Normally it is associated to the achievement of a goal or a solution to a problem under limited resources and under conditions of uncertainty. It involves setting goals, determining actions to achieve the goals, and the mobilization of resources to execute the actions.