Prioritizing innovation in Portuguese production technologies

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Abstract

English

In today's demanding global context of competition, companies have to carefully manage and prioritize their technological innovation, frequently using planning tools such as technology roadmaps. Moreover, companies many times participate in clusters to increase their research, development, and innovation capacity through collaborations with other organizations. This is the case of production technology companies in Portugal and their cluster PRODUTECH. The cluster also comprises science and technology organizations, and industrial firms from 9 manufacturing sectors.

We describe and analyse the initial steps of PRODUTECH's roadmapping process, from a preliminary sectorial survey to the cluster's on-going R&D and innovation projects. We study the priorities attributed by the different sectors to European strategic lines of innovation for production technologies, and how they are reflected in the projects. We find overall a strong level of alignment, and suggest motives that may explain some partial misalignments.

Portuguese

No exigente contexto atual de concorrência global, as empresas necessitam de gerir e priorizar cuidadosamente a sua inovação tecnológica, recorrendo frequentemente a instrumentos de planeamento como *roadmaps* tecnológicos. Juntam-se também em clusters para melhorarem a sua capacidade de investigação, desenvolvimento e inovação, através da colaboração com outras entidades. Tal acontece com os fornecedores de tecnologias de

produção em Portugal, participantes no cluster PRODUTECH, que inclui também organizações do sistema científico e tecnológico, e empresas de 9 sectores da indústria transformadora.

Neste artigo descrevemos e analisamos os passos iniciais do processo de *roadmapping* do PRODUTECH, desde um inquérito sectorial, aos projetos de I&D em curso. Estudamos as prioridades atribuídas pelos sectores às linhas estratégicas de inovação Europeias para as tecnologias de produção e a forma como estão reflectidas nos projetos. Observamos globalmente um forte alinhamento, e sugerimos motivos que podem explicar algumas falhas parciais de alinhamento.

1. Context and objectives

The rapid pace of change in science and technology, intensified competition, and globalization have substantially increased the complexity of technology innovation management (KOSTOFF; SCHALLER, 2001). Technology change has become critically important, but related decisions are also increasingly challenging, mainly due to the complex and dynamic nature of technology, market and industry development, reflected in increasing uncertainty about future conditions.

Several tools have been created and are currently broadly applied to better address such circumstances. One of them is Technology Roadmapping, which supports technological innovation management decisions in these challenging contexts. The roadmap identifies precise objectives and helps focus resources on the critical technological developments needed to meet those objectives (GARCIA; BRAY, 1997). It has been widely applied in industries such as semiconductors (e.g. WALSH 2004), large companies (e.g. PHAAL et al., 2001), or even government agencies (e.g. HOFFMAN; DAIM, 2006). There are several definitions for the roadmap process (e.g. GARCIA; BRAY, 1997, AMER; DAIM, 2010, PHAAL et al., 2011), but the main underlying rationale is to align product and technology developments with business goals and needs (LEE et al., 2011). In fact, a technology roadmap identifies alternate technology paths for meeting certain performance objectives. Usually, a single path may be selected and a plan developed. Nevertheless, in face of high uncertainty, multiple paths may be identified.

With these global motivations, PRODUTECH, the Portuguese cluster of production technologies, is developing a technology roadmap for the sector. In fact, the improvement of the technological foundations of manufacturing firms through the development and integration of advanced knowledge-based enabling technologies has been considered critical for their competitiveness (EFFRA, 2010).

This process aims at supporting the development of technologies to supply nine relevant and traditional Portuguese manufacturing sectors: footwear, textile, ceramics and glass, cork, leather, stone, metalworking, wood and furniture, and moulds, which are the main customer sectors of the production technologies industry. The cluster is a partnership between industrial companies, either technology developers or manufacturing firms, sectorial organizations, and entities from the National Scientific and Technology System (S&T). By promoting cooperation between these organizations, it aims at developing turnkey integrated solutions for customer sectors.

In this context, PRODUTECH is currently developing two structural projects. PSI – New Products and Services for the Manufacturing Industry – is targeted to the customer sectors,

and PTI – New Processes and Innovative Technologies for the Production Technologies Industry – is targeted to the technology developers. Figure 1 represents the targets and the relative positioning of the two projects. The "Production Technologies" groups represent both companies and S&T organizations, and the "User Sectors" group represents both manufacturing companies (customers) and sectorial Technology Centres.

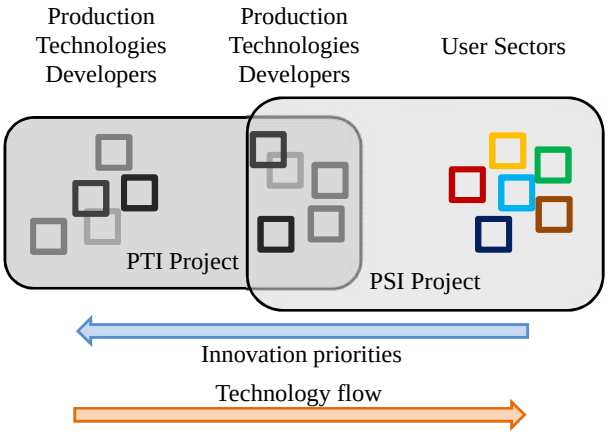

Figure 1 - Organization of PRODUTECH's projects

Prior to the creation of these two projects, PRODUTECH carried out an early stage identification of areas of alignment between the technology needs of customer sectors and technology providers, and the European and national priorities for the development of production technologies. The projects were then designed with these early inputs, mainly due to time constraints related to the deadlines to apply for national funding. After their approval, and mostly in the scope of PSI, PRODUTECH involved the customer sectors in the early roadmapping work of identifying their concrete technological needs and challenges.

In this paper, we focus on these early stages of PRODUTECH's roadmapping process as an exploratory case study of the alignment between needs and challenges, funding opportunities, and projects, in technology innovation. We start by analysing the results of the cross sectorial survey on areas and priorities for technology development, and then study the alignment of those results with the cluster's strategic lines for technology development, derived from European initiatives, as well as with the structural projects currently under development.

The remainder of the paper is structured as follows. Next, we describe the methodology applied in this study. Then, we present and discuss the results, focusing first on the outcomes of the sectorial survey, i.e., the priorities assigned to the different strategic innovation lines, and later on their alignment with the efforts allocated to PRODUTECH's structural projects. We conclude with some implications for the cluster's roadmap and R&D+I projects, as well as for the management of misalignments between stated and realized innovation priorities.

2. Methodology

To allow a bottom-up identification of areas and priorities for sectorial technology development, an initial semi-structured survey was prepared and distributed to the

Portuguese Technology Centres of each of the 9 industrial sectors. These centres are representative of their sectors, playing a key role in their innovation activities, and counting on the participation of numerous leading manufacturing companies.

The main data collected in the survey consisted of a list of potential areas of technological innovation (associated with difficulties, challenges, and trends), their importance to the sector in Portugal, as well as corresponding justifications and examples. The respondents were asked to rate the priority of each area of technological innovation on a three-point Likert-like scale ("low," "medium," and "high" priority). The priorities were mostly stated explicitly, however, in some sectors, only contextual descriptions of how important certain innovations would be, and their potential applications, were provided. In these cases, we interpreted, discussed and agreed on their priorities. In two sectors – metalworking and footwear – no explicit or implicit data on priorities were provided. As the administration of the survey allowed the centres some leeway in their replies, some did not use the format that was distributed. In these cases, the replies were later adapted to fit the original format of the survey.

The identified areas were categorized according to PRODUTECH's strategic lines of action towards technological innovation (based on MANUFUTURE [1] and EFFRA [2]): *Environment*, *Energy Efficiency* (energy savings and usage optimization), *Energy* (e.g. introduction of renewable energy sources in the production processes), *Operations Management*, *Customer-Supplier Integration*, *New Business Models*, *New Manufacturing Processes*, and *Optimization of Manufacturing Processes* (EFFRA, 2010). Along with these existing lines, two new themes were created to accommodate other topics mentioned by the sectors: *Support to Product Development*, and *Intellectual Property Protection Technologies*.

To further control impacts from the survey administration limitations described above, the survey results and subsequent classification were analysed and validated by three members of PRODUTECH's management team, with knowledge and experience relevant to technological innovation in the different manufacturing sectors.

We then performed a preliminary analysis of the priority data, looking for initial insights into the relationship between strategic horizontal innovation areas and the sectorial application of production technologies. Considering the "low", "medium", or "high" priorities of the innovation areas set by the industrial sectors, we attributed the value 3 to "high", 2 to "medium", and 1 to "low" in order to perform a quantitative assessment. In addition to their priorities, the data collected feature a variable number of innovation areas identified for each strategic line. In order to look simultaneously at these two dimensions, which reflect different aspects of the importance of a strategic line (the presence of a large number of opportunities, or their individual high priority), we used a set of complementary, classic descriptive statistics indicators: the average and the sum of priorities, as well as the number of topics identified, for each theme-sector pair, and each individual theme and sector.

Finally, in order to analyse the alignment between project development and the priorities referred by the industrial sectors, we focused on PRODUTECH's structural projects. For this purpose, we collected and analysed project data on the topics addressed, number and types of organizations involved, and budget. We then compared the priorities stated in the survey with the actual effort allocation (percentage of budget and number of participants) and participation of different organizations in the projects (S&T, sectorial, companies).

[1] MANUFUTURE is the European technology platform on future manufacturing technologies
[2] EFFRA is the European Factories of the Future Research Association

3. Results and discussion

3.1. Priorities in strategic action lines

We firstly analysed the innovation priorities stated by the different industrial sectors to rank strategic action lines, identify horizontal and niche strategic action lines, and rank the sectors according to an innovation awareness criterion.

A summary of the results is provided in tables 1, 2 and 3, for the average, sum, and count of priorities, respectively.

The rankings of the strategic innovation themes according to each of the indicators were identical, thus showing a reasonable robustness in the identification of the most relevant themes as a whole and per sector. We also performed a sensitivity analysis of the rankings with a systematic variation of the values in each cell, and each theme did not move up or down more than one position.

Table 1 - Average of Priorities

Average of Priorities	Sector									
Strategic Line	Stone	Textile	Wood&Furn.	Moulds	Ceramics	Cork	Leather	Footwear	Metalwork	Total Aver.
Optimization of Manufacturing Processes	2.4	2.5	2.5	2.3	2.0	3.0	3.0	n/av.		2.51
New Manufacturing Processes	3.0	2.4	3.0	3.0	1.8	1.9	1.5	n/av.	n/av.	2.36
Environment	2.5		3.0	3.0	2.0	2.5	2.3	n/av.	n/av.	2.19
Operations Management	3.0	2.5		2.0	3.0	2.0		n/av.	n/av.	1.79
Support to Product Development		2.5	3.0	2.0				n/av.	n/av.	1.07
Energy Efficiency	3.0		3.0		n/av.					0.86
Energy	2.0				2.0					0.57
Customer-Supplier Integration		3.0							n/av.	0.43
Intellectual Property Protection Technologies		3.0								0.43
New Business Models									n/av.	-
Average per sector	1.59	1.58	1.45	1.23	1.19	0.94	0.68	n/av.	n/av.	

Table 2 - Sum of Priorities

Sum of Priorities	Sector									
Strategic Line	Textile	Wood&Furn	Ceramics	Moulds	Cork	Stone	Leather	Footwear	Metalwork	Total
Optimization of Manufacturing Processes	27	10	14	20	6	12	3	n/av.		92
New Manufacturing Processes	31	6	9	6	15	3	6	n/av.	n/av.	76
Environment		24	4	3	5	5	7	n/av.	n/av.	48
Operations Management	5		12	2	2	3		n/av.	n/av.	24
Support to Product Development	8	6		4				n/av.	n/av.	18
Energy Efficiency		3	n/av.			3				6
Energy			2			2				4
Customer-Supplier Integration	3								n/av.	3
Intellectual Property Protection Technologies	3									3
New Business Models									n/av.	-
Sum per sector	77	49	41	35	28	28	16	n/av.	n/av.	

Table 3 - Count of Priorities

Count of Priorities	Sector									
Strategic Line	Textile	Ceramics	Wood&Furn.	Moulds	Cork	Stone	Footwear	Leather	Metalwork	Total
Optimization of Manufacturing Processes	11	7	4	9	2	5	4	1		43
New Manufacturing Processes	13	5	2	2	8	1	1	4	1	37
Environment		2	8	1	2	2	1	3	1	20
Operations Management	2	4		1	1	1	1		1	11
Support to Product Development	3		2	2			3		1	11
Energy Efficiency		1	1			1				3
Energy		1				1				2
Customer-Supplier Integration	1								1	2
Intellectual Property Protection Technologies	1									1
New Business Models									1	1
Count per sector	31	20	17	15	13	11	10	8	6	

The top four themes identified were *Optimization of Manufacturing Processes*, *New Manufacturing Processes*, *Environment*, and *Operations Management*. *Manufacturing technology* is the top priority, either through aspects related to the *optimization* of process capability, or through *new* capabilities allowing the exploitation of new materials or the improvement of product sustainability (EFFRA, 2010). Besides introducing new products, manufacturing firms can also develop innovative manufacturing technologies and each of these innovation types can be a source of competitive advantage in itself (KIRNER et al., 2009).

Environment was the following priority, with the sectors expressing a broad concern with sustainability and increasingly stricter policies and regulations, but also as a reflection of corporate social responsibility. *Operations Management* ranks fourth, with an importance that naturally somehow follows manufacturing technology, as new or higher performance processes, machines and production systems require new methods and tools for operations monitoring (EFFRA, 2010).

The low ranking of *Energy* and *Energy Efficiency* is surprising, as these are frequently considered a foundation of sustainable manufacturing, and therefore a priority in every manufacturing industry. *Customer-Supplier Integration* and *Intellectual Property Protection Technologies* are new strategic lines that emerged from the survey, but are also currently niche concerns, as they were pointed out by a reduced number of sectors.

The analysis considering the sum of priorities and the number of topics also led to nearly identical sector "innovation" rankings, pointing to the most active sectors in terms of identification of needs.

Observing the count of priorities, the top four strategic lines have priorities stated for 7 to 9 of the 9 sectors and thus may additionally have a strong potential for broader horizontal innovation efforts. The remaining strategic lines appear to be more sector-specific concerns, and potentially more suitable for niche-oriented efforts.

The substantial alignment that was found between the European Production Technologies topics for R&D+I (reflected in Portugal by PRODUTECH) and the needs identified in the sectorial survey may be explained by the bottom-up approach carried out when developing the strategic technology roadmap conducted by EFFRA. The overall method consisted in gathering contributions from relevant stakeholders, not only from production technologies developers, but also from industrial customer sectors. The main misalignments are clearly *Energy* and *Energy Efficiency*, which may be partially explained by the current notion in the different industries that these are basic areas in manufacturing and in production technologies, and therefore assumed as a pre-requisite.

3.2. Alignment with the structural projects

In a following stage, we assessed how PRODUTECH's R&D+I projects PSI and PTI reflect the priorities of the strategic lines of innovation stated by the industrial sectors.

PSI (Table 4) aims at developing new products and advanced services to be applied in the manufacturing sectors as customers of the production technologies suppliers. This project promotes the collaboration between organizations with complementary profiles, namely S&T, production technology developers, and the technology users (manufacturing companies). This is in line with the observation of MALERBA (2002), who considers innovation as an interactive process among a wide variety of actors, as firms do not innovate in isolation. Innovation has to be seen as a collective process, in which firms

interact with other firms as well as with non-firm organizations such as universities, research centres, government agencies, financial institutions and so on.

Table 4 - PSI project details

PSI Project

Project Topic	Content	Participants					
		S&T Organizations	#	Prod. Tech. Developers	#	User Companies	#
Intelligent production systems	Design and development of tools to be embedded in production systems, providing superior efficiency and autonomy	R&D+I	3	Machine tools and systems	4	Metalworking	2
		Tech. Centres	5	Control and automation	2	Wood and furniture	2
				Software	2	Textile	1
Flexible and efficient production systems	Monitoring and management of production systems' availability to minimize downtimes due to setups and tool change	R&D+I	3	Machine tools and systems	5	Metalworking	1
		Tech. Centres	2	Control and automation	1	Wood and furniture	1
				Consultancy	1		
Operations management and logistics for customized products	Design and development of tools and systems to cost efficient manufacturing of competitive customized products	R&D+I	5	Machine tools and systems	3	Metalworking	3
		Tech. Centres	5	Software	5	Wood and furniture	1
				Consultancy	1	Textile	1
						Footwear	1
Networked production systems	Integration of production systems, industrial equipment, and information systems	R&D+I	2	Machine tools and systems	2	Metalworking	2
		Tech. Centres	2	Software	2	Wood and furniture	1
						Textile	1
Energy and environmental efficiency	Development of eco-efficiency evaluation tools and systems for integrated management of renewable energy sources	R&D+I	4	Control and automation	1	Metalworking	2
		Tech. Centres	5	Software	1	Wood and furniture	1
						Textile	1

On the other hand, the technology developers also need to have access to production systems themselves. Therefore, PRODUTECH is also developing technologies for them as well as other supporting tools, in the PTI project (Table 5). In this project, however, the profiles involved are only S&T organizations and production technology developers, acting as both suppliers and customers.

As measures of the effort put into each strategic line, we used two classic innovation inputs indicators: the number of participating organizations and the budget. We categorized these indicators according to the type of organization involved.

Table 5 - PTI Project details

PTI Project

Project Topic	Content	Participants			
		S&T Organizations	#	Prod. Tech. Developers	#
Business models and support tools	Design and implemention of new business models in the production technologies industry, good practices, evaluation tools	R&D+I	2	Machine tools and systems	2
				Software	2
Advanced tools for the development of new products, systems, and services	Eco-design and eco-efficiency, engineering design, modelling and simulation, methods for development of "all-in-one" systems	R&D+I	6	Machine tools and systems	6
		Tech. Centres	3	Software	1
Systems and applications for flexible and mobile robotics	Rapid programming and control, felixble robotics, mobile robotics	R&D+I	5	Machine tools and systems	4

The projects and the strategic innovation lines are broadly aligned, with only three of the lines with lower average priorities not represented in the projects: *Support to Product Development*, *Customer-Supplier Integration*, and *Intellectual Property Protection Technologies*. Table 6 presents the relationship between the lines and the projects, dividing the effort indicators by participant profile.

Table 6 – Project participants and budget

	Strategic Line of Innovation							
	Optimization of Manufacturing Processes, New Manufacturing Processes		Operations Management		Environment, Energy Efficiency, Energy		New Business Models	
Participant profile	# participants	% budget	# participants	% budget	# participants	% budget	# participants	% budget
Prod. Tech. Developers	18	24.0%	11	9.2%	3	2.4%	4	1.0%
S&T Organizations	16	22.0%	10	6.5%	9	6.7%	2	2.0%
User Companies	6	3.0%	6	2.0%	4	3.5%	n/ap.	n/ap.
Total	40	49.0%	27	17.6%	16	12.6%	6	3.0%

The top strategic lines (*Optimization of Manufacturing Processes* and *New Manufacturing Processes*) are carefully dealt with in both projects, under four topics: intelligent production systems, flexible and efficient systems, networked systems, and advanced tools for the development of new products, systems, and services. These topics receive the largest share of the total budget (49.0%) and also feature the largest number of participants (40), reflecting the highest priority ranking for the two lines. It has been referred (TOMLINSON, 2010) that for traditional industries such as Textile or Ceramics, higher levels of supplier cooperation are significant in raising the level of innovation, and specifically that process innovation is enhanced through closer supplier collaboration. Improved performance in manufacturing processes (either new or optimized) can be measured by speed, efficiency, and quality, as indicators of process innovation output (KIRNER et al., 2009).

The second largest share, both in terms of participants (27) and in terms of budget (17.6%), is dedicated to the *Operations Management* line. The strategic lines *Environment*, *Energy Efficiency*, and *Energy* are brought together under a single topic related to energy and environmental efficiency, with an assigned budget of 12.6% and 16 participants. This allocation of effort switches the priority between *Environment* and *Operations Management*. The *New Business Models* line has a small budget of 3.0% and 6 participants. This modest level of resources is in line with its low average priority.

The only set of lines with a significant imbalance between the efforts placed on S&T Organizations and on Production Technology Developers is *Environment, Energy Efficiency, and Energy*. The low priority given by the user sectors to the *Energy Efficiency* and *Energy* lines may partially explain this imbalance.

Table 7 summarizes our analysis of the fit between the priorities stated in the survey and the efforts allocated to each innovation line in the projects. Each strategic line is matched with the corresponding project topics, and they are ordered from the highest to the lowest amount of effort allocated. In each cell, the colours reflect the priorities (red, yellow, green, and grey for only referencing a strategic line), "U" marks the presence of User Companies and "T" marks the presence of Technology Centres.

Table 7 - Alignment between innovation priorities and allocation of effort in the projects

U – User Company; T – Technology Centre

		Sector								
Strategic Line	**Project Topic**	Wood and Furn.	Stone	Textile	Moulds	Cork	Leather	Ceramics	Footwear	Metalwork
Optimization of Manufacturing Processes New Manufacturing Processes	Intelligent Production Systems Flexible and Efficient Systems Networked Production Systems Advanced Tools for the Development of New Products, Systems, and	U	T	U T	T	T	T	T	T	U T
Operations Management	Operations Management and Logistics for Customized Produtcs	U		U T		T	T		U T	U T
Environment	Energy and Environmental Efficiency	U	T	U T	T		T			U T
Energy Efficiency										
Energy										
New Business Models	Business Models and Support Tools									U
Support to Product Development	*Not addressed*									
Customer-Supplier Integration	*Not addressed*									
Intellectual Property Protection Technologies	*Not addressed*									

The top two strategic lines and their corresponding project topics have gathered the participation of every sector. They can therefore be considered truly horizontal strategic lines of innovation, and the related production technology developments can have a wide application, as there is a strong alignment between the stated needs and the participating organizations.

Operations Management presents considerable misalignments. Some sectors that did not consider this line a priority are participating in the corresponding project topics, whereas others that stated this line as a high priority have no participation. As the participating user companies and technology centres cover 6 of the 9 sectors, this can still be considered a horizontal topic, however presenting critical misalignments, which may compromise the applications of the results in the interested sectors not participating in the developments.

The topics related with *Environment*, *Energy Efficiency* and *Energy* have a reasonable alignment with the strategic lines, as the sectors that pointed out the highest priorities are participating in the corresponding developments, either through User Companies or through Technology Centres. The *Environmental* line is quite transversal. Participants again come from 6 of the 9 sectors.

New business models has the participation of a user company from the only sector that referred this strategic area in the survey. Surprisingly, none of the Technology Centres is participating in this project topic.

Some of the misalignments between stated priorities and allocated effort might be related to a lack of fit with the priorities of available funding calls. PRODUTECH's PSI and PTI projects were both funded by national programmes supported within the European Union's Seventh Framework Programme. Frequently, these funding programmes also require specific combinations and bounds (lower and upper) on the number of participants and their profiles, which constrain consortium compositions. These constraints can also arise from budget limitations, as was the case of PRODUTECH's projects.

R&D programmes assign a preferential evaluation to projects presented by allied partners, eventually competitors, in consortia (SCHIAVONE; SIMONI, 2011). In such contexts, the project promoters and coordinators need to manage carefully the composition of the consortia to make sure that the agendas and goals of the specific participants are aligned. In particular, for a cluster like PRODUTECH, avoiding the transformation of co-opetition into competition among the participating organizations is a critical concern. In addition, many members of PRODUTECH had never cooperated before, a fact that increases the complexity of project setup and management, and therefore of aligning stakeholder innovation priorities with project effort allocation.

4. Conclusions

In this paper, we have used the early stages of the technology roadmapping process of the Portuguese cluster of production technologies, PRODUTECH, as an exploratory case study of the alignment between needs and challenges, funding opportunities, and projects, in technology innovation. We analysed the results of a survey across nine relevant and traditional Portuguese manufacturing sectors, on areas and priorities for technology development, and then studied the alignment of those results with the cluster's strategic lines for technology development, derived from European initiatives, as well as with the structural projects currently under development.

The main results of the survey allowed us to identify the themes – and therefore related production technologies – which seem to be more important across sectors, and confirm a substantial alignment between the European strategic themes and the needs identified by the customer sectors. These survey results may support the development of a high-level roadmap, but they may also be, whenever possible, an important input for the planning of large projects involving many participants and with broad industrial impact. In this sense, we wanted to understand how well PRODUTECH's structural projects were aligned with the needs of the sectors, and in our analysis we found a significant alignment between both.

However, we have also identified partial misalignments between the innovation priorities stated in the survey and the effort allocation and participants in the cluster's projects. These may arise due to a variety of factors, such as the existence of more sector-specific needs, the budgets and parameters of the calls (e.g. requiring a certain composition of the consortium within each project activity, or the development of certain technological themes), the availability of resources, or even the need to achieve an alignment of agendas and goals among projects partners.

Being aware of these misalignments, the cluster may proactively seek to relax boundary conditions, for instance seeking to influence the setting of the parameters of the calls at an

early stage, or provide opportunities and incentives to improve the basic alignment of the members of the cluster. The cluster may also develop new projects, aiming at closing the identified gaps, as well as carry out other activities that build on and complement the funded projects to minimize the impact of the misalignments. Finally, the architecture of the cluster's projects can also itself be configured to maximize the potential for application of each strategic line to all the relevant sectors.

The generalizability of our conclusions is limited, due to the intrinsic features of the case study research design, and our focus on a specific cluster in a specific context. However, this opportunity to explore a rich set of cross-sectorial data is, to the best of our knowledge, rare, a fact that makes these results valuable to technology clusters with comparable organizational, activity, and funding structures, and relevant to suggest avenues for future research on an important topic that, also to the best of our knowledge, has received scarce attention in the literature. Finally, our work also points out future paths for further projects in the follow-up of the roadmapping process in PRODUTECH and in Portuguese production technologies.

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