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Reframing the High-Technology Landscape in Greece: Empirical Evidence and Policy Aspects

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ABSTRACT

Purpose:
The major purpose of the paper is to explore, identify and highlight the general and specialized (sector-specific) long-term technology trends following the evolution of technology-intensive sectors in Greece during the last years. In a similar vein, sectoral differentiations have been identified and highlighted (e.g. evolution, growth, size distribution, industrial dynamics) as an analytical dimension of innovative activity across the high-technology sectoral domain.

Design/methodology/approach:
The paper methodology consists of a systematic review of primary data collected through the Eurostat/SBS database and the SME Performance Review 2022, as one of the major tools the European Commission uses to monitor and assess countries' progress in implementing the Small Business Act (SBA). The methodological approach of the paper involves the mapping of sector-specific trends in terms of technology-intensive categories, size classes and underlying sectoral characteristics and dynamics trends.

Findings:
The exploration of detailed and long-term data within the landscape of technology-intensive sectors in Greece, provides a clearer picture for the upward and downward trends, the sector-specific differentiations and the upcoming challenges. High-tech enterprises constitute a considerably important part of the country's productive base with gradually increasing trends in all relevant categories. This is further motivated by the development of start-ups and spin-offs in several fields of higher technological specialization ('deep tech').

Research limitations/implications:
It is widely accepted that aggregated technology growth is a long-term and multi-level process within an economy. Further research regarding the actual and potential spillover effects of technology sectors across the wider economy constitutes an important area of further research. The paper provides a multi-dimensional analytical framework to identify sector-based technological and industrial underlying dynamics and understand long-term sectoral characteristics and trends within the high-tech industry evolution in Greece.

Originality/value:
The paper provides an analytical approach to explore the underlying industrial dynamic trends within the technology-intensive sectors in Greece. The exploration of detailed and long-term data within the landscape of technology-intensive sectors in Greece provides an overall view of the underlying technology-intensive sectors' dynamics, the sector-specific differentiations, the upcoming challenges and the innovation policy implications.

Keywords:
Innovation, High-technology sectors, Knowledge intensive services, Technology and innovation policy, Technology ecosystems, VC funding, Scale-up capital.

1. Introduction

Emerging technologies constitute one of the major mechanisms transforming economies in several different dimensions. In this context, high technology is connected to new science-based activities, novel technology-based processes and products, high technology new ventures (e.g. start-ups, spin-offs) as well as new technology-based emerging sectors (e.g. semiconductors, robotics, nanotechnology, biotechnology, Artificial Intelligence and machine learning).

A large part of high-technology sectors is following an upward trend during the last years in Greece. This, in turn, interacts and reinforces multiplier effects in several interlinked sectors and economic activities providing an enhanced maturity to critical aspects of the national innovation system (e.g. VC funds' investments). With the increasing recognition that explaining high-technology sectors' growth indispensably requires taking into account the

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broader time framework and the sector-specific features, the present paper aims to shed some light on the dominant long-term trends driving the emerging technology growth prospects.

Based on recently published empirical data, the paper sets out to build an analytical framework in order to explain the expansion of technology-based ecosystem in Greece. Nevertheless, it seems that some aspects are not equally developed throughout the last years. Remarkably, differentiations are observed between sectors and sub-sectors. In the long-run for instance, high-tech enterprises in the knowledge-intensive services sectors are revealing a pathway of growth consistency while the high-tech sub-category in the manufacturing sector is characterized, in several sub-sectors, by a slower (or even occasionally declining) trend.

Last but not least, the crucial role of technology and innovation policy is highlighted in congruence to the major challenges emerging next to the sustainable and robust growth of the technology-intensive industries in the country. In light of the above, a framework for the formulation of a new technology and innovation policy is needed to enhance the contribution of high-technology sectors in many complementary critical aspects (e.g. job-intensity, value added appropriation, spillovers, strategic alliances and interconnection to international value chains, technology embeddedness) related to economic transformation processes (e.g. interlinkages with economy-wide sectors).

2. Review of Literature

Technology-intensive sectors bring a transformative potential in several science-based and technology-oriented sectors. In tandem, technology-based sectors might potentially pave the way for major transformations within traditional sectors through the deployment of new processes, products, services and business models. Similarly, innovation is considered a major mechanism of economic growth and competitiveness of business firms and economies (Schumpeter, 1911; Romer, 1990). Entrepreneurship might play a decisive role for economic growth (Acs, 2006), especially when it is based on innovative ventures, high-growth firms and technological knowledge (Colombelli et al., 2013).

Meanwhile, appropriated and evidence-based government policy on entrepreneurial activity constitutes and integral part of a conducive business environment (Minniti, 2008). According to Audretsch et al. (2020), innovative start-ups can create new industries and enhance considerable economic and societal impacts. Consequently, start-ups hold a central role in technology and innovation policy agendas (through several programmes and supporting schemes) during the last years (Autio et al., 2014).

Unsurprisingly, a wide array of policy initiatives aiming to support the growth of technology-intensive sectors has been implemented worldwide. Nevertheless, differentiated features characterize different sectors and technologies; policy tools that worked at one sector might not be equally efficient to another one. Thus, the type and the extent of the policy tools vary significantly and thus, the empirical data call for specialized approaches to enrich the design of targeted and holistic innovation policies.

Government-designed schemes and measures supporting technology-based entrepreneurship include a wide range of different tools, which involves R&D subsidies, tax allowances, counselling services and training (Autio et al., 2007). The major rationale of government interventions in these fields includes the need to mitigate technology and market risk and uncertainty, to provide enriched financial resources and to accelerate scale-up growth of technology-intensive companies. Moreover, the relationship between institutions and innovation constitutes a growing field of research (Rodrik et al., 2004). As a result, institutional conditions and institutional quality are inextricably interlinked to a business environment conducive to innovation (Sharma et al., 2022).

Research results derived from empirical studies provide evidence to clearly understand innovation processes by taking into account internal and contextual factors (Becheikh et al., 2006). The present paper contributes to the existing research by focusing on the technology-intensive sectors' underlying growth trends in Greece. As an empirical study, the paper illustrates the long-term patterns across the different sectors composing the high-technology landscape. In a similar vein, sectoral differentiations have been identified and highlighted as an analytical dimension of innovative activity. Based on the empirical data, differentiated trends provide an evidence for the formulation of a favourable policy environment for technology growth and innovation both in terms of early-stage, start-up but also scale-up phases.

3. Methodology

The main purpose of the present paper is to unearth, identify and highlight the general and specialized (sector-specific) technology trends following the evolution of technology-intensive sectors in Greece during the last years. The paper involves a systematic review of primary data collected through the Eurostat/SBS database and the SME Performance Review 2022, as one of the major tools the European Commission used to monitor and assess countries' progress in implementing the Small Business Act (SBA).

The methodological approach of the paper involves the mapping of sector-specific trends in terms of technology-intensive categories and size classes along with underlying sectoral characteristics and dynamic trends. These dimensions, in turn, are analyzed in congruence to different sector-specific parameters related to the number of enterprises, employment rates and value added. In that respect, there are two main objectives: i) to identify underlying trends across sectors in common dimensions; ii) to explore differentiations between sectors; and iii) to highlight critical aspects which would contribute to foster and formulate a multi-level innovation policy for the technology-intensive sectors in the country.

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4. High-technology sectors in Greece – findings

The exploration of detailed and long-term data within the landscape of technology-intensive sectors in Greece provides an overall view for the underlying technology-intensive sectors' dynamics, the sector-specific differentiations, the upcoming challenges and the innovation policy implications.

4.1. Knowledge-intensity in manufacturing industries – number of enterprises

A critical issue related to business, sector and economy-wide growth is that of knowledge-intensity. As it is illustrated in Table 1, the number of high-technology enterprises is a relatively small part of the manufacturing sector during the period 2008-2022. In tandem, the number of high-technology enterprises is relatively stagnant. Similarly, in the sub-category *Medium-high-technology*, the number of enterprises reaches a relatively higher percentage in relation to the total number of enterprises in the manufacturing sector but it is still remaining a small part.

Table 1: Knowledge-intensity in manufacturing industries - number of enterprises

Manufacturing industries	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
High-technology	628	534	508	532	441	363	592	525
Medium-high-technology	5,932	5,751	5,500	5,314	4,375	3,665	4,926	4,649
Medium-low-technology	24,861	23,512	22,396	21,906	18,907	16,517	19,714	18,051
Low-technology	53,442	53,629	50,799	46,194	40,746	37,073	40,732	38,493
Total manufacturing	**84,863**	**83,426**	**79,203**	**73,946**	**64,469**	**57,618**	**65,964**	**61,718**

Manufacturing industries	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	-
High-technology	531	503	515	536	536	544	557	-
Medium-high-technology	4,567	4,393	4,423	4,427	4,457	4,536	4,647	-
Medium-low-technology	17,979	16,640	16,522	16,492	16,596	16,960	17,436	-
Low-technology	38,664	35,703	35,458	35,420	35,693	36,419	37,392	-
Total manufacturing	**61,741**	**57,239**	**56,918**	**56,875**	**57,282**	**58,459**	**60,032**	-

Source: SME Performance Review 2022-Eurostat/SBS database.

Similarly, the overall view of the long-term trend is illustrated in the Figure 1. As it is depicted, the major part of the manufacturing sector remains concentrated within the categories *Low technology* and *Medium-low technology*. This trend, in turn, constitutes a major feature of the Greek economy affecting its wider growth path during the last decades.

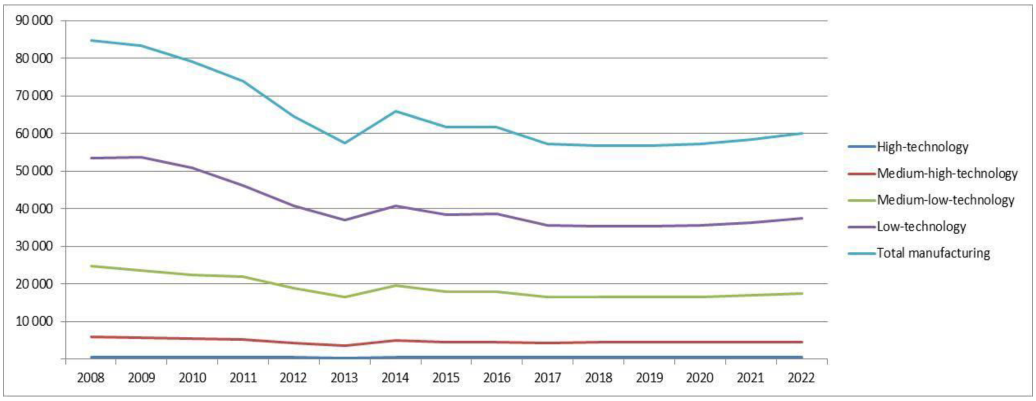

Figure 1 Knowledge-intensity in manufacturing industries - number of enterprises

Source: SME Performance Review 2022-Eurostat/SBS database.

4.2. Knowledge-intensive services – number of enterprises

The picture in the services sector is slightly different. The sub-category *High-tech*is a relatively large part –in contrast to the manufacturing industries- within the category *Knowledge-intensive services*. Moreover, the number of enterprises

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within the sub-category *High-tech* is consistently increasing, especially since 2014. Nevertheless, the major part of the enterprises in the services sector as a whole is concentrated within the category *Less knowledge-intensive services* (Table 2).

Table 2: Knowledge-intensive services - number of enterprises

	2008	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Knowledge-intensive services, of which	**139,727**	**141,833**	**137,749**	**132,553**	**128,860**	**122,337**	**186,686**	**176,627**
Market services	121,525	123,726	120,601	115,678	112,057	105,505	157,685	148,183
High-tech	13,538	13,434	12,705	12,442	12,283	12,355	24,651	24,287
Other	4,664	4,673	4,443	4,433	4,520	4,477	4,350	4,157
Less knowledge-intensive services, of which	**496,090**	**483,774**	**472,634**	**442,553**	**438,066**	**426,188**	**481,124**	**460,109**
Market services	495,736	483,413	472,280	442,199	437,714	425,794	479,885	458,939
Other services	354	361	354	354	352	394	1,239	1,170
Total services	**635,817**	**625,607**	**610,383**	**575,106**	**566,926**	**548,525**	**667,810**	**636,736**
	2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	-
Knowledge-intensive services, of which	**175,815**	**157,583**	**155,715**	**158,636**	**155,844**	**163,737**	**170,747**	
Market services	149,205	134,498	132,601	134,543	132,148	139,416	145,639	
High-tech	22,494	19,180	19,181	20,127	19,790	20,293	20,951	
Other	4,116	3,905	3,933	3,966	3,906	4,028	4,157	
Less knowledge-intensive services, of which	**462,118**	**426,513**	**419,683**	**423,039**	**411,377**	**401,955**	**419,093**	
Market services	460,958	425,396	418,565	421,925	410,226	400,828	417,968	
Other services	1,160	1,117	1,118	1,114	1,151	1,127	1,125	
Total services	**637,933**	**584,096**	**575,398**	**581,675**	**567,221**	**565,692**	**589,840**	

Source: SME Performance Review 2022-Eurostat/SBS database.

In congruence to the data presented in the Table 2, the Figure 2 illustrates the general trends and the share of *High-tech* within the *Knowledge-intensive services* during the last years. Indicatively, the comparison between two different periods (2008 and 2022) illustrates clearly an upward trend of *High-tech category* within the *Knowledge-intensive services.*

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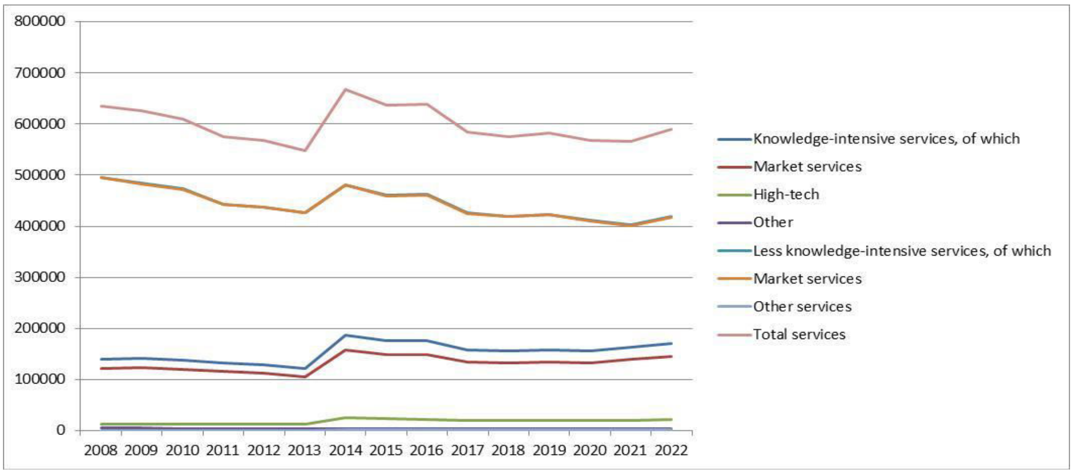

Figure 2 Knowledge-intensity in services - number of enterprises

Source: SME Performance Review 2022-Eurostat/SBS database.

4.3. Knowledge-intensity in manufacturing and services – employment

Unsurprisingly, the major part of the employment for the manufacturing sector is concentrated in *Low-technology* and *Medium-low technology* (Table 3). The aggregate level of employment in the *High-technology* sector reaches approximately 5,000 employees in the year 2021 (Manufacturing), while the total employment in the manufacturing sector is 289,207 employees for the same year.

Table 3: Knowledge-intensity in manufacturing industries – employment

Manufacturing industries	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***
High-technology	7,272	6,774	6,595	5,463	5,249	6,483	5,549	6,111
Medium-high-technology	41,688	40,616	38,327	35,069	31,177	28,624	27,112	25,386
Medium-low-technology	105,456	102,860	93,882	82,222	75,342	68,568	67,843	59,414
Low-technology	192,853	173,198	164,537	150,320	138,977	123,596	156,845	145,408
Total manufacturing	**347,269**	**323,448**	**303,341**	**273,074**	**250,745**	**227,271**	**257,349**	**236,319**
Manufacturing industries	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	-
High-technology	5,717	6,200	5,657	5,192	4,991	5,005	5,053	-
Medium-high-technology	25,397	26,701	29,362	28,729	28,783	29,602	30,592	-
Medium-low-technology	63,216	62,198	67,556	66,206	68,003	70,814	74,053	-
Low-technology	157,261	156,359	170,933	171,593	176,831	183,786	191,823	-
Total manufacturing	**251,591**	**251,458**	**273,508**	**271,720**	**278,608**	**289,207**	**301,521**	-

Source: SME Performance Review 2022-Eurostat/SBS database.

Additionally, the employment in the manufacturing sector has been dramatically decreased since 2008 (347,269) while in the same year the *High-technology* sub-category reported 7,272 employees. Following the data presented in the Table 3, the Figure 3 clearly illustrates the long-term trends in the employment dimension. The aggregate level of employment is slowly bouncing back during the last years, notwithstanding the stagnant and sluggish growth in the *High-technology* sub-category.

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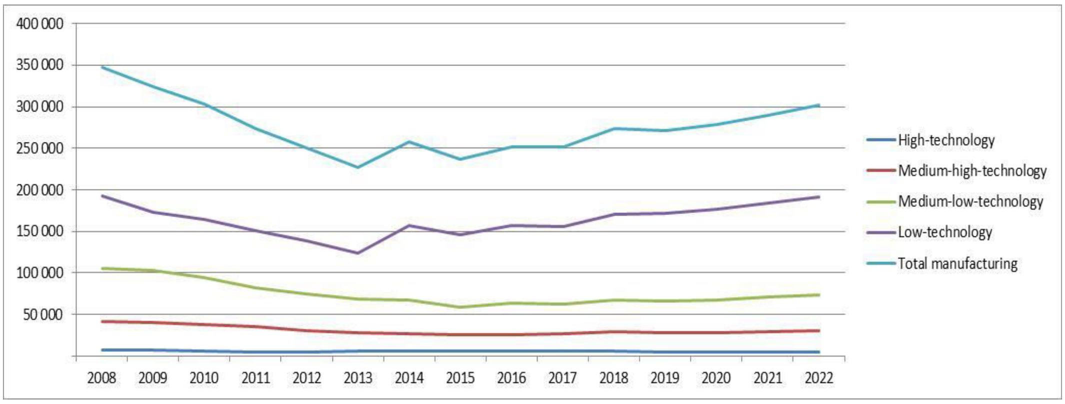

Figure 3 Knowledge-intensity in manufacturing industries – employment

Source: SME Performance Review 2022-Eurostat/SBS database.

The trends are also slightly different in the services sector. As the Table 4 illustrates, *High-tech* sub-category follows a constant and upward trend during the last years (48,235 employees in 2008 and 58,276 in 2022). Besides the upcoming trends and perspectives, the share of high-tech employment within the total employment in the services sector is relatively higher in contrast to the respective share in the manufacturing sector.

Table 4: Knowledge-intensive services – employment

	2008	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Knowledge-intensive services, of which	**305,307**	**321,471**	**300,193**	**304,745**	**275,645**	**260,547**	**332,808**	**286,072**
Market services	229,355	246,701	226,791	242,472	212,464	198,626	261,988	221,865
High-tech	48,235	48,336	46,428	38,710	41,028	41,296	56,433	51,069
Other	27,717	26,434	26,974	23,563	22,153	20,625	14,387	13,138
Less knowledge-intensive services, of which	**1,397,736**	**1,368,049**	**1,321, 274**	**1,246,218**	**1,166,878**	**1,146,709**	**1,233,766**	**1,134,658**
Market services	1,395,706	1,366,076	1,319,853	1,244,279	1,165,130	1,143,067	1,228,765	1,128,391
Other services	2,030	1,973	1,421	1,939	1,748	3,642	5,001	6,267
Total services	**1,703,043**	**1,689,520**	**1,621,467**	**1,550,963**	**1,442,523**	**1,407,256**	**1,566,574**	**1,420,730**
	2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	-
Knowledge-intensive services, of which	**319,399**	**285,368**	**302,196**	**302,776**	**292,362**	**311,074**	**330,113**	
Market services	253,172	221,587	234,655	235,956	226,761	243,311	258,215	
High-tech	53,714	51,445	54,065	54,739	53,496	55,007	58,276	
Other	12,513	12,336	13,476	12,081	12,105	12,756	13,622	
Less knowledge-intensive services, of which	**1,281,918**	**1,276,964**	**1,400,735**	**1,450,513**	**1,368,494**	**1,316,361**	**1,407,041**	
Market services	1,275,503	1,270,105	1,393,549	1,442,672	1,360,764	1,308,958	1,399,534	
Other services	6,415	6,859	7,186	7,841	7,730	7,403	7,507	
Total services	**1,601,317**	**1,562,332**	**1,702,931**	**1,753,289**	**1,660,856**	**1,627,435**	**1,737,154**	

Source: SME Performance Review 2022-Eurostat/SBS database.

Figure 4 illustrates the relatively slow but gradually upward trends in terms of employment within the *High-tech* sub-category. The aggregate employment in the services sector reaches 1.737,154 employees in 2022. Similarly,the employment level in the *Knowledge-intensive services* reaches 330,113 employees (2022).

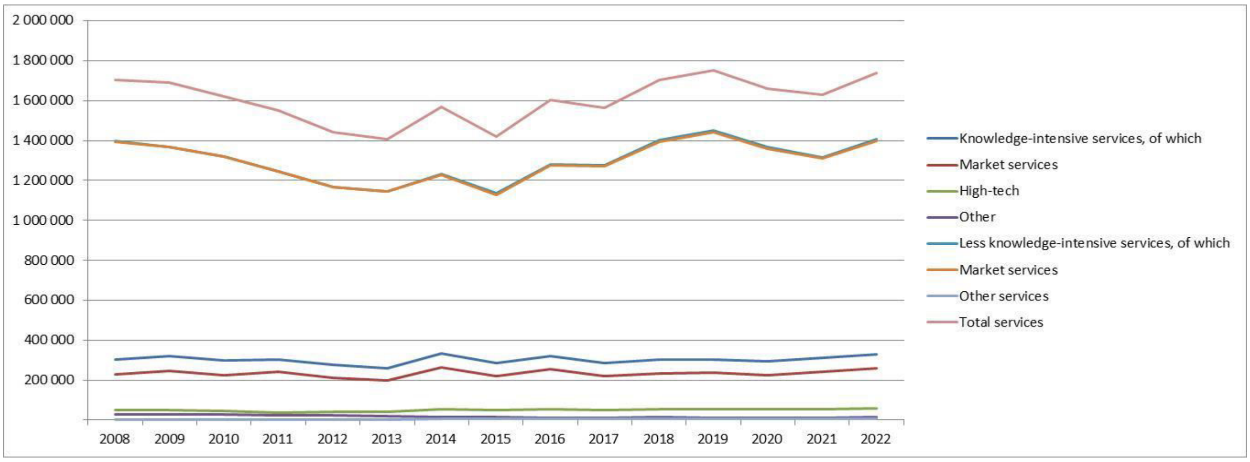

Figure 4 Knowledge-intensive services – employment

Source: SME Performance Review 2022-Eurostat/SBS database.

4.4. Value added at factor costs in manufacturing and services

Value added is a crucial parameter for the detailed understanding of relevant sectors' trends. Figure 5 illustrates the major trends in manufacturing industries under the dimension of value added (at factor costs). The exploration of the detailed data depicts some major findings. More specifically, it is evident that the different sector groups (based on knowledge-intensity) are following a similar pattern of long term decrease and gradual increase (in the last two years). However, the aggregate level of total value added produced is lower in each category.

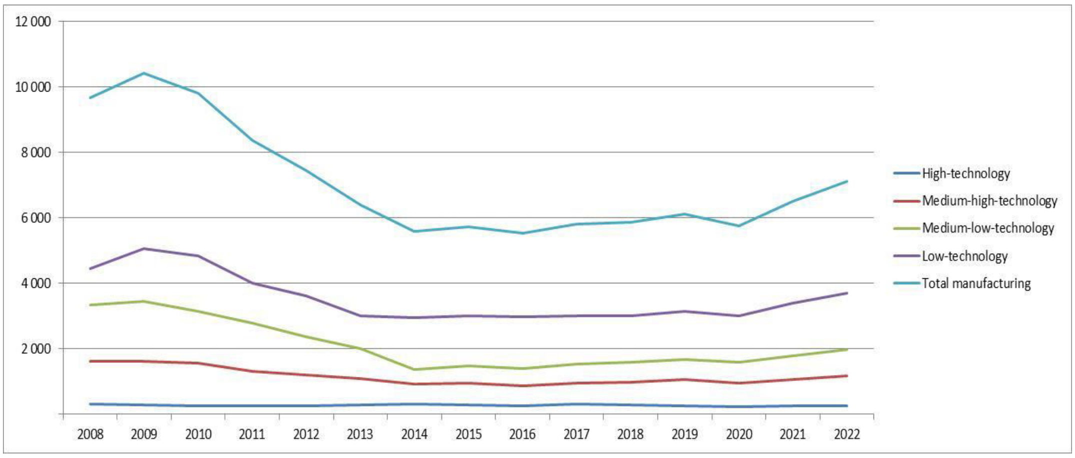

Figure 5 Knowledge-intensity in manufacturing industries – value added at factor costs

Source: SME Performance Review 2022-Eurostat/SBS database.

Figure 6 illustrates the major trends into the services sector under the perspective of value added at factor costs. More analytically, the data reveals that value added in the *Less knowledge-intensive* services such as *Market services* has been increased at a faster pace in comparison to *Knowledge-intensive services* and *High-tech* sector group of enterprises.

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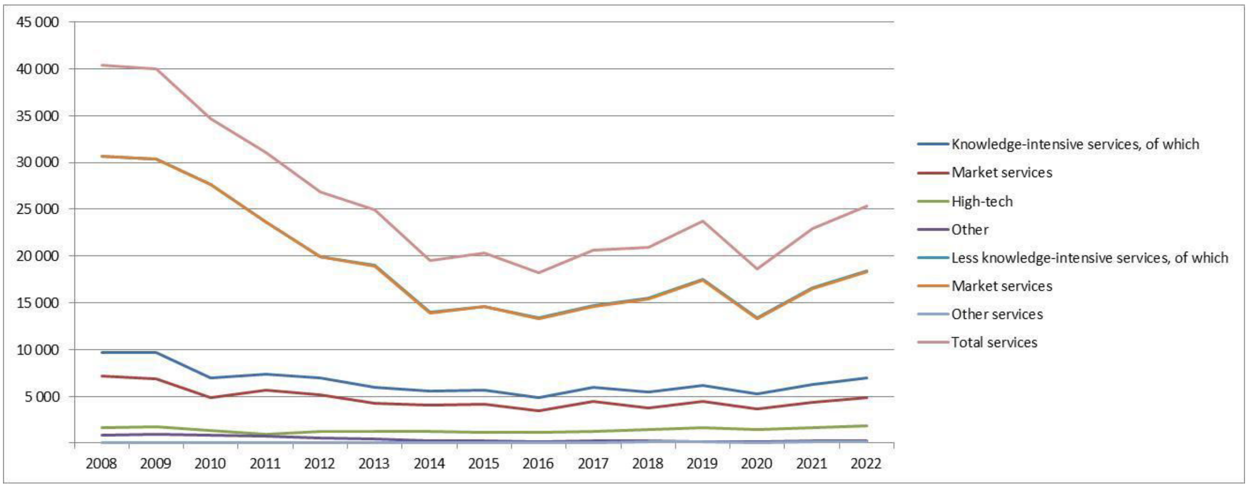

Figure 6 Knowledge-intensive services – value added at factor costs

Source: SME Performance Review 2022-Eurostat/SBS database.

4.5. High-tech manufacturing sectors (C21 and C26)

Based on NACE rev.2 classification system, the high-technology domain in the manufacturing industry is composed by two technology-intensive sectors (2-digit industries): *Basic pharmaceutical products and pharmaceutical preparations* (C21) and *Manufacture of computer, electronic and optical products* (C26). Figure 7 illustrates the general trends based on the size classes of enterprises for the sector *Basic pharmaceutical products and pharmaceutical preparations* (C21 – NACE rev.2). The major activity in the sector is diachronically concentrated in the size classes 10-49 and 50-249 employees. However, during the last years (since 2010 approximately) there is an upward trend in the size class 0-9 employees (micro companies) depicting the emergence of new start-ups and spin-off enterprises mostly specialised in technology niche markets and cutting-edge technology areas (e.g. biotechnology, medical technology, genetic engineering). Besides the number of enterprises, the major part of the employment is concentrated in medium and large companies. In the size class of enterprises with more than 250 employees for instance, the total number of employees is 6,555 (2022) and the number of employees for the size class 50-249 is 1,667 employees (2022). Conversely, within the size class 0-9 there are 160 employees while in the size class 10-49 the respective number is 540.

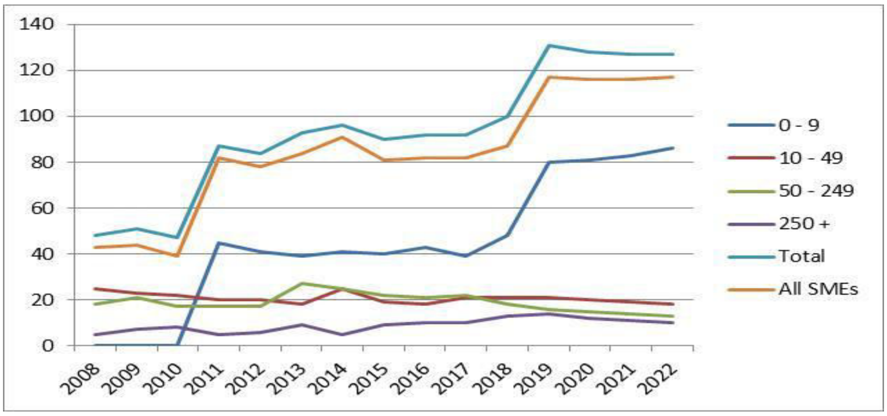

Figure 7 Manufacture of basic pharmaceutical products and pharmaceutical preparations (C21) – number of enterprises

Source: SME Performance Review 2022-Eurostat/SBS database.

Accordingly, the major part of the value added for the sector *Basic pharmaceutical products and pharmaceutical preparations* is concentrated in larger firms. The current estimation for the year 2022 reaches 585 million euros in the sub-category with more than 250 employees. The estimation for the size class 50-249 is 124 million euros while the aggregate value added for the size class 10-49 employees is 25 million euros.

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The anatomy of the sector *Manufacture of computer, electronic and optical products* (C26 – NACE rev. 2) is rather different. As the Figure 8 illustrates, the larger number of enterprises is largely concentrated into the size class 0-9 employees (399 companies in 2022 out of total 441) while the size class 10-49 employees depicts 36 enterprises (2022).

According to the employment level, the size class 50-249 depicts 1,000 employees (2022) while in the size class 0-9 employees the respective number is 913 for the same year; and 773 employees for the size class 10-49. It should be mentioned that there is a dramatic decrease of employment in the size class 0-9 employees (from 2,528 employees in 2008 to 913 in 2022).

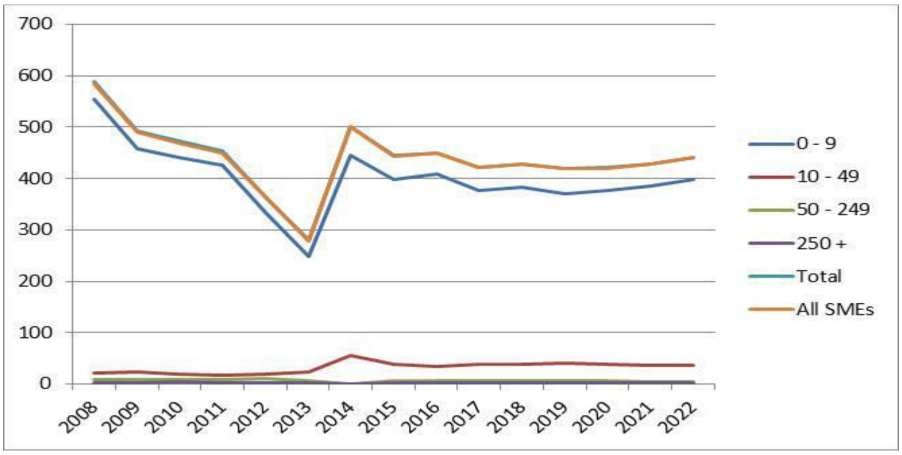

Figure 8 Manufacture of computer, electronic and optical products (C26) – number of enterprises

Source: SME Performance Review 2022-Eurostat/SBS database.

Examining the valued added (for the sector *Manufacture of computer, electronic and optical products*), the latter is distributed across the different size classes as follows: 23 million euros in the size class 0-9 employees; 48 million euros in the size class 10-49 employees; 46 million euros in the size class 50-249 employees; and 44 million euros for enterprises with more than 250 employees.

4.6. Knowledge intensive services - high-tech sectors (J61 and J62)

Regarding the sector of *Telecommunications* (J61), it is evident that a rapid surge is taking place since 2013 with reference to the number of enterprises, especially within the size class 0-9 employees (Figure 9). The size class of enterprises with 10-49 employees is following with an upward trend, since the aggregate number of enterprises (SMEs) increased from 97 (2008) to 1,418 (2022). As regards the number of employees in the sector *Telecommunications* and the size class 0-9 employees, 209 employees has been reported for the year 2008, while in 2022, the total number of employees is 3,420. Regarding the size class 10-49 employees, 664 employees have been reported in 2008 and the total number of employees is 1,859 in the year 2022. The value added increased during the same period within the size class 0-9 employees (from 6 million euros in 2008 to 70 million euros in 2022).

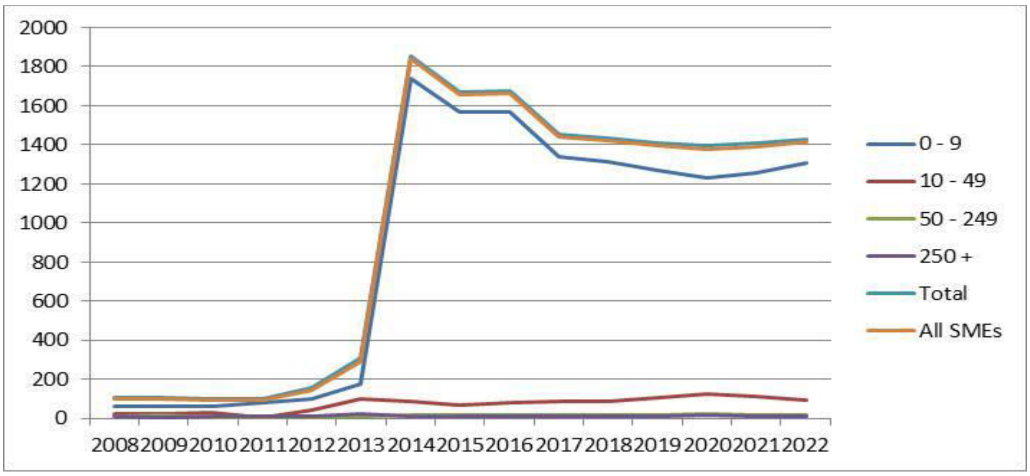

Figure 9 High-tech services: sector of Telecommunications (J61) - number of enterprises

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Source: SME Performance Review 2022-Eurostat/SBS database.

By examining the number of enterprises (Figure 10), it is also evident that within the sector of *Computer programming, consultancy and related activities (J62)*, a surge is under progress since 2013, especially within the size class 0-9 employees. The aggregate number of enterprises (SMEs) increased from 5,403 (2008) to 7,527 (2022).

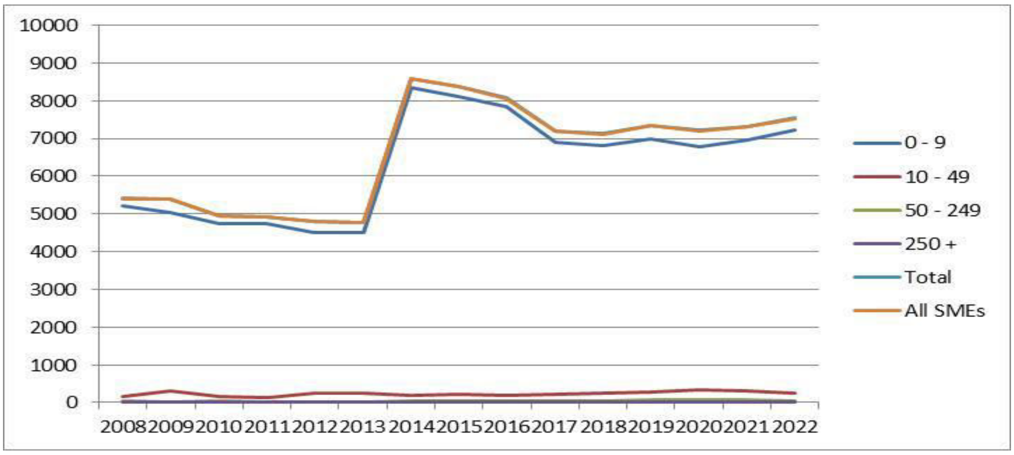

Figure 10 High-tech services: sector of Computer programming, consultancy and related activities (J62) - number of enterprises

Source: SME Performance Review 2022-Eurostat/SBS database.

As regards the number of employees in the sector *Computer programming, consultancy and related activities* and the size class 0-9 employees, 8,016 employees has been reported in the year 2008, while in 2022, the total number of employees is 11,516. Regarding the size class 10-49 employees, 3,498 employees have been reported in 2008 and the total number of employees is 5,417 in the year 2022. The value added increased during the same period in the size class 0-9 employees (from 228 million euros in 2008 to 278 million euros in 2022). Value added is also increased in the size classes 10-49 employees (from 117 million euros in 2008 to 285 million euros in 2022) and 50-249 employees (from 174 million euros in 2008 to 275 million euros in 2022) during the same period.

5. Conclusion and Recommendations

Remarkably, it should be noted that during the last years there is an increasing investment activity across several technology-intensive and start-ups in Greece. According to Foundation/EIT Digital 2021/2022 Venture Financing Report the total number of startups funded during 2021 is about 70 which is 30% more than last year, while the total investments secured by them exceed €500 million (Foundation/EIT Digital, 2022). Regarding the amounts that companies request from the funds, there is a significant increase in the area of €100,000 - €200,000 and €400,000 - €500,000.

Based on the report findings, the trend reflects a new wave of start-ups and technology-based companies. It should be noted that many of these enterprises are focusing on B2B markets while there is an intensified activity in emerging markets such as Life Sciences, Retail and AgriTech. Accordingly, based on Endeavor Greece (2022), Greek startups posted a funding record in 2021, raising more than $1 billion in a year. According to Endeavor Greece, in 2020 the Greek startups succeeded in raising 455€ millions, an amount that was 71% higher than the 266€ millions invested in the Greek ecosystem in 2019 (Endeavor Greece, 2021). However, during 2022 is expected start-ups showing a 20%-40% of slowdown due to the wider economic downturn and funding challenges.

The emergence of various schemes of Venture Capital financing during the last years across the country and the deployment of state-backed VC mechanisms (e.g. EquiFund - co-financed by the EU and national funds, as well as funding from the European Investment Fund), has created a conducive environment for technology-based companies. Especially in the early stages, the growth of technology-intensive companies is often constrained by the lack of financial resources (Alperovych et al., 2020). Subsequently, the design and deployment of venture capital programmes can contribute at the sustainable growth of technology-intensive activities.

Nevertheless, the present empirical analysis provides evidence for several complementary aspects of the evolution of high-technology sectors in Greece. Firstly, high-tech enterprises constitute a considerably important part of the country's productive base with gradually increasing trends in all relevant categories (e.g. number of enterprises, number of employees and value added). Noticeably, although there are fluctuations over time (for the period 2008-2021), with sub-periods where a downward trend is observed in sectors and categories (e.g. number of companies), during the last years a consolidation seems to be taking place. This is motivated, *inter alia*, by the development of start-ups and spin-offs in several fields of higher technological specialisation ('deep tech'), such as the wider domain of

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hardware and embedded systems, Artificial Intelligence systems, microelectronics and optical products, life sciences, biotechnology, pharmaceutical products, genetic engineering and medical technology. However, high-tech enterprises and start-ups still constitute a small part of the overall production structure (in terms of number of enterprises, number of employees and value added). Subsequently, low-tech and medium-low-tech enterprises constitute the largest part of economic activity (e.g. number of enterprises, value added), especially in the manufacturing sector.

Secondly, it is evident that there are some stark asymmetries and differentiations among sectors, such as *Basic pharmaceutical products and pharmaceutical preparations* (C21) and *Manufacture of computer, electronic and optical products* (C26) in terms of concentration, size classes' shares and overall contribution to value added and employment. Meanwhile, the data illustrate that the *High-tech* sector in services is growing at a faster pace, especially in sectors such as *Telecommunications* (J61) and *Computer programming, consultancy and related activities* (J62). In view of this, it should be noted that the growth trend in the manufacturing sector is relatively sluggish (e.g. number of enterprises) both at the level of *High-technology* and *Medium-high technology groups.* The decreasing trend of *High-technology*and *Medium-high technology groups in the manufacturing sector* is being reflected (for the period 2008-2022) at the number of enterprises, the employment and the value added dimensions. Although the high-tech domain depicts an aggregated upward trend during the last years, as it has been illustrated, some critical sectors and sub-sectors are not following suit.

Evidently, it seems that the evolution of high-tech sectors is a long, complex and multi-level process. The multiplier effects from the emergence of technology-intensive sectors involve a wide range of challenges related to scaling-up of activities, formulation and integration to wider value chains and fostering important aspects relevant to the wider technology and economic impact (e.g. value added). It is also worth noting that the critical aspects are not limited to the number of new technology-based enterprises and start-ups; the critical long-term dimensions involve value added, employment as well as technology exploitation and economic impact at local and regional level. As Marques & Morgan (2021) clearly illustrate, innovation is a crucial parameter for long-term economic growth but not always sufficient to generate development. Therefore, emphasis on local knowledge, technology embeddedness and value added appropriation within the local and regional economies constitute integral elements of revisited technology and innovation policies.

Consequently, the data retrieved illustrate that the long-term, continuous and sustainable high-tech growth environment necessitates pro-active, large scale, holistic and targeted technology and innovation policy measures. Furthermore, a wide and long-term spectrum of policy tools needs to be also combined with specialized approaches across sectors. The growth trend in one sector is not always following established patterns in different sectors. Accordingly, each sector carries differentiated features. As Pisano (2006) illustrates, what might works in one sector might not be suitable for another. As a result, one size does not fit all, when it is necessary to efficiently deal with profound uncertainty and high risks (Pisano, 2006).

Parenthetically, based on the data analyzed, it should be mentioned that the potential growth paths of technology sectors in Greece could be multiple and diversified. Three dominant pathways for the growth of technology sectors in the country could be summarized in the following complementary options: i) scale up growth in rapid developing sub-sectors; ii) niche markets growth and integration within international value chains; iii) open innovation and strategic cross-sectoral coupling.

First of all, consolidation constitutes a critical stage following the early stages of technology-based companies. While several dynamic and upward trends have been identified in different technology-intensive sub-sectors in Greece, the formulation of critical mass, the achievement of spillovers across interconnected sectors (e.g. biotechnology and pharmaceuticals; advanced software, embedded systems and semi-conductors; Artificial Intelligence and mobile applications) and the enhancement of scale-up growth of high-tech companies will further accelerate rapid expansion of technology-based sub-sectors. The need to streamline and enrich funding and investment environment through the establishment of funding tools oriented towards the whole innovation value chain (e.g. pre-seed, seed capital, VCs, scale-up capital), remains a prerequisite for strengthening the technology base while it will provide long-term growth and scale opportunities. In view of this, complementary resources and policy tools are needed. For example, business accelerators have rapidly emerged as crucial dimensions within the entrepreneurial ecosystem to support spin-offs and start-ups scaling up processes (Livieratos & Siemos, 2021).

Secondly, the long-term growth of technology-based sectors and companies has always been inextricably interlinked with the need for specialization in niche markets and the formulation of strategic positioning within international value chains. The integration of high-tech companies in wider value chains through the production of specialized technology-based intermediate products or services, which are critical to a high-end output, is usually a major strategic choice to efficiently entering new markets and to achieve sustainable technology and business growth. Aligning to innovation networks for building up innovative products or services and providing part of the final offering remains an efficient growth path for developing new technology partnerships. For example, acquisitions of start-ups by incumbents constitute a major trend within the technology-based markets. The past few years, several high-tech companies have been acquired by large international technology companies or by other VC-backed companies across the country.

Thirdly, the strategic coupling between high-tech and technology intensive-sectors with traditional production and industrial activities constitutes a crucial field of potential growth. For example, the technological adaptation of agro-food firms in the emerging digital requirements remains a potential technology application domain with

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innovation perspective. Nevertheless, the limited digitalisation of agro-food firms in Greece, especially regarding more advanced digital tools, formulates an unexploited economic landscape (Ioannidis et al., 2022). Thus, technology diffusion across critical value chains could be a promising growth path for technology-based firms.

In this context, the type of interventions should involve supply-side and demand-side measures. For example, R&D subsidies, tax cuts and allowances, innovation hubs, state-backed VCs and collaborative schemes are always major part of the technology and innovation policy agenda. Nevertheless, the mobilization of demand (e.g. R&D procurements, large-scale projects in critical complementary domains) constitutes a crucial policy tool to enhance technology development and innovation through "mission-oriented" initiatives (Mazzucato, 2021).

Building on this approach, it should be noted that policy measures needed across the value chain from technology development, pre-seed and seed stages to scale-up phases. It is worth noting also that the shortage in capital may occur in several later stages of growth (Alperovych et al., 2020). Consequently, the formulation of an integrated funding environment providing adequate access to capital not only across the early stages but also throughout the growth stages (scale-up capital), constitutes a crucial element for national innovation systems.

The design and deployment of various collaborative partnerships and open innovation approaches through different methods and channels constitute also crucial dimensions for the growth of innovative SMEs (Vanhaverbeke, 2017). A largepart of technology-based companies in Greece is getting in on the action for B2B markets. As a result, open innovation approaches (both in terms of strategic and policy design) would provide opportunities for knowledge spillovers, economies of scale, increasing returns and new innovation strategies for SMEs (Livieratos et al., 2022).

In that respect, it should be mentioned that due to their complexity and scale needed, technology-based opportunities are usually accelerated through various schemes of collaboration. The open innovation approach has provided a prompt response to business challenges while the adoption of "open innovation strategies" constitutes an important innovation management concept in several technology-intensive sectors, such as biotechnology industry (Kunz, 2022). More recently, as Chesbrough illustrated, Covid-19 has prompted a wide variety of open and collaborative initiatives (e.g. vaccines) (Chesbrough, 2020). According to Chesbrough & Bogers (2014), open innovation is defined as a distributed innovation process involving knowledge flows across organizational boundaries. In that prism, open innovation approach could provide insightful lessons for innovation policy domain in terms of designing new programmes to encourage interdisciplinary research and collaborative innovation projects as well as accelerated commercialization of science-based business opportunities.

The next field of research to be explored includes a more detailed exploration of issues related to policy design regarding special focus areas. For example, the pandemic has highlighted the promise of new technologies tackling wider social challenges related to human health. Biotechnology industry has exhibited high growth rates in terms of research achievements, scientific discoveries and science-based business activities (Angelakis & Galanakis, 2017). Similarly, climate change constitutes one of the major challenges human societies are facing and, thus, it is inextricably connected to the ability to develop new "green technologies" and renewable energy systems characterized by high technology readiness level and high level of techno-economic effectiveness while being able to address a wide range of uncertainties (Sakki et al., 2022). Consequently, based on the rapidly growing science-based business activities in Greece (e.g. start-ups, spin-offs), more research is necessaryin order to identify promising technology areas, business environment bottlenecks, sector-based specialized needs, and to discover new technology-based business and investment opportunities.

Last but not least, a holistic framework for the formulation of a new technology and innovation policy is needed to enhance the contribution of high-technology sectors in major aspects (e.g. employment and value added) and economic transformation processes (e.g. interlinkages with economy-wide sectors, such as agro-food and manufacturing). The major contribution of technology-intensive sectors into the economy is not limited at the number of enterprises and the share of employment. It is also related to the value added in economic terms but also in terms of technology accumulation, human capital, cross-sectoral spillovers and wider economic and industrial transformation. The major challenge for the technology sector involves both its sustainable growth but also the enhanced embeddedness and value added appropriation within the economic and national innovation system.

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