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Research paper

Insights from The Impact of Technology on Greek Businesses: Key Performance Indicators

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Abstract

This paper examines how digital technologies reshape Greek enterprises, with emphasis on the SME majority. We take a measurement-first approach that combines official Key Performance Indicators (KPIs) with reproducible analytics to map diffusion across sectors and identify technical mechanisms through which e-commerce, social media, cloud, data analytics, and AI affect productivity, innovation, and market reach. Using Greece's 2024 Digital Decade KPIs, we compute geometric pillar scores and distance-to-target diagnostics: Public Services 78.5%, Skills 39.6%, Infrastructure 37.0%, Business Digitalization 27.4%, yielding an overall composite of 42.1% of the EU 2030 target. The steepest shortfalls are AI (5.3%), Edge Nodes (13%), Cloud (24.1%), and ICT specialists (24%). Required catch-up rates are corre-spondingly high—AI approx. 63%/year, Edge approx.41%/year, Cloud/ICT specialists approx. 27%/year—while 5G and digital public services are near target. Post-pandemic adoption accelerated in retail and tourism, yet diffusion remains uneven due to finance constraints, skills gaps, regulatory friction, and patchy fixed gigabit infrastructure. We provide a transparent toolkit (geometric aggregation, gap decom-position, and growth-path calculations) plus an illustrative machine-learning prototype for customer analytics to demonstrate measurable ICT impacts. Policy implications are SME-centric: fast-track FTTP/VHCN and edge deployment, de-risk cloud/data/AI adop-tion via hands-on integration support and expand the ICT-skills pipeline. Aligning these levers can unlock green-digital complementarities and raise firm performance at scale.

Keywords: *digital transformation; key performance indicators (KPIs); SMEs; business digitalization; cloud computing; artificial intelligence; data analytics; ICT skills; digital infrastructure; Greece; EU Digital Decade; e-commerce; sustainability*

1. Introduction

Technological developments have become a medium for tremendous changes in the world and every aspect of our lives, including business, education, and socializing (Sakellis, 2017). Computing sciences and communications technologies progress in a manner which affects many aspects of the economy and society (Theologou & G. Michaelides, 2008). Increased use of Information and Communication Technology (ICT) in the public sector has been actively promoted by the European Union as a means of improving the way public administrations operate (Hahamis et al., 2005). The use of technologies is so bound up with the notion of globalization that it has almost become a synonym for it. Globalization has exercised a significant influence in the shaping of technologies like nuclear energy, space travel, ocean liners, aircraft, cars, phone calls, and television, which have become rapid, efficient, and accessible to virtually everyone. Digital transformation has moved from a strategic aspiration to an operating constraint for Greek enterprises. While the pandemic accelerated uptake of online channels and digital tools—especially in retail and tourism—diffusion remains uneven across sectors and firm sizes. SMEs, which make up the backbone of the Greek economy, face higher fixed costs of adoption, tighter finance, patchier connectivity, and persistent skills gaps. As a result, a small set of frontier firms captures outsized gains, while many others remain stuck at basic digitization. This paper takes a measurement-first perspective that treats digitalization as a computational production technology: networks and cloud provide capacity; data pipelines and analytics translate information into predictions; and organizational capabilities determine how much value the same tools can unlock. To ground the analysis, we assemble Greece's 2024 Digital Decade indicators and derive transparent diagnostics—pillar scores, gap decomposition, and required growth paths to 2030—alongside a network ("KPI Relationship Map") that visualizes technical dependencies across infrastructure, business capabilities, skills, and public services. Three stylized facts organize our results. First, Greece is strong where the state coordinates at scale: mobile connectivity (5G) and digital public services are near target and form a solid backbone. Second, the binding constraints sit inside firms: business digitalization lags, with low adoption of cloud, data analytics, and AI; the ICT-specialist share is also thin. Third, fixed gigabit and edge infrastructure trail mobile coverage, limiting low-latency, data-hungry applications even where demand exists. Because our indices are geometric, these weak links dominate the aggregate and cannot be offset by strengths elsewhere. For e-commerce SMEs, we illustrate how machine-learning components (probabilistic demand forecasting, inventory placement, picker routing, VRPTW delivery planning, return-propensity). For tourism, we frame digital transformation in environmental terms—energy, water, transport intensity per guest-night—so that green–digital complementarities can be tracked, not assumed.

Policy implications follow directly from the diagnostics rather than from generic checklists. Accelerating FTTP/VHCN and edge deployment raises the technical ceiling; targeted programs that de-risk cloud/data/AI adoption move firms up the capability ladder; and expanding the ICT-skills pipeline ensures these assets are productively used. Because public digital services are already mature, the state can act as a diffusion platform—identity, payments, e-invoicing, health data—lowering transaction costs for SMEs that plug in.

2. Historical Overview of Technology in Greece

Greek society and economy have long benefited from the advancement of technology. Starting from the growth of the civilization through the legacies of scientific discoveries and inventions (e.g. ancient clocks, odometer, steam turbine and the first computer), the evolution of technology has led modern Greece to a society supported by information and knowledge technology. The concept of information technology is also reflected in the Greek language: information is "pistopoiisi" (certified) and knowledge is "mathesi" (learning). The modern trajectory of technological development in Greece is best understood through the evolution of information and communication technologies (ICT) since the early 1990s. The diffusion of personal computing, the emergence of the Internet, and the gradual liberalization of the telecommunications sector marked the country's first decisive step toward the digital economy. During this period, technological adoption was driven primarily by the private sector—banks, tourism operators, and logistics firms—seeking operational efficiencies and access to international markets. Early investments in network infrastructure and enterprise software created the foundations for subsequent digital expansion. The 2000s witnessed a broad institutional shift toward digital governance and e-services. Public programs began integrating ICT into administration, education, and healthcare, setting the stage for digital interaction between citizens and the state. Businesses increasingly adopted online communication tools, enterprise resource planning systems, and e-commerce platforms. Tourism, in particular, became a laboratory for digital experimentation as hotels and travel agencies digitized reservations, pricing, and marketing through emerging online platforms. These developments demonstrated the potential of ICT to reconfigure entire value chains, linking domestic firms more closely to global markets. From the 2010s onward, Greece's digital landscape evolved from simple connectivity to intelligent systems. Mobile Internet, social media, and cloud computing reshaped communication and consumer behavior. Enterprises began experimenting with big data analytics and customer-relationship platforms, while start-ups introduced digital payment solutions, smart logistics, and remote-service delivery. Despite economic turbulence during this period, the spread of affordable mobile devices and cloud-based tools lowered the cost of digital entry for small and medium-sized enterprises, allowing them to participate in digital ecosystems that were once dominated by large corporations. In recent years, the focus has shifted toward advanced digital capabilities—artificial intelligence, the Internet of Things, blockchain, and automation—integrated into broader strategies for productivity, innovation, and sustainability. Government initiatives promoting broadband expansion, 5G networks, and digital skills have accelerated adoption across sectors, though challenges remain in the diffusion of data-intensive technologies and in bridging the persistent skills gap. These modern developments illustrate that Greece's digital transformation is not a sudden leap but a cumulative process built on decades of gradual technological embedding. By concentrating on the ICT era, the Greek experience reflects a broader pattern of digital evolution observed across Southern Europe: a late but accelerating convergence with leading EU economies. The transition from early network infrastructures to data-driven systems demonstrates the country's growing capacity to use technology as both an economic enabler and a governance instrument. This historical continuity provides the analytical foundation for assessing current digital transformation trends and for identifying the structural levers—skills, infrastructure, and innovation—that will determine Greece's digital trajectory toward 2030. At the present time, Greek businesses perceive technology as an instrument for the development of their activities. As a result, many Greek enterprises are investing in cutting-edge technology to gain a competitive advantage. Technology offers Greek enterprises new horizons. It allows the penetration of new markets and helps businesses to find new customers, suppliers and partners. It also creates new ways of operation and management, promotes more efficient usage of resources and encourages innovation in all aspects. There are several current factors concerning technology that positively influence business activity. Among these is the digitalization and transformation of the business environment through the availability and use of related technologies. This trend paves the way for new business models and the need to search for resources that do not necessarily involve physical presence. The technological advance in distribution channels also enhances the expansion of electronic commerce. Social media offer new communication channels to acquire new customers and increase brand awareness (Buhalis & Deimezi, 2003). Despite the benefits provided by technology expansion, most Greek businesses face significant difficulties that limit these developments. Additional funding is required in order to offer the necessary investment capability, investing in corporate social responsibility remains limited, and there is a lack of specialized personnel to cover the need for expertise in the handling of information and communication technology. The constant enlargement of the regulatory framework and the lack of a definitive framework in the area of data protection contribute to the discomfort of businesses, affecting their level of trust and maturity.

Technological trends continue to exert a profound influence over the business landscape in Greece, as enterprises pursue digital transformation. Demand for digital skills outpaces supply, and e-commerce is substantially reshaping select industries. Officials have sought to encourage public—private collaboration, resulting in a proliferation of investment programs. However, partly as a consequence, programs face stress and disorganization, with no integrated national strategy. Buildings recently constructed on Greek islands prominently feature photovoltaic panels and solar-thermal collectors, the market for which is expected to expand considerably in the next decade. Most tourism enterprises are also aiming to both broaden and enrich their service offerings, thereby successfully competing with larger enterprises (H. P. Hamedani et al., 2025). Because the professional vocation of tourism is considered strictly unappealing in the Greek educational system, an insufficient number of individuals possess the desirable knowledge and abilities, despite wages being higher than average distribution at a national level. Concerning agriculture, employment remains remarkably high. However, the average age of farmers tends to be very high, and some of the constraints limiting the competitiveness of the sector manifest themselves in the inability to apply advances in technology and knowledge, as well as the inability to cover fixed and variable costs adequately.

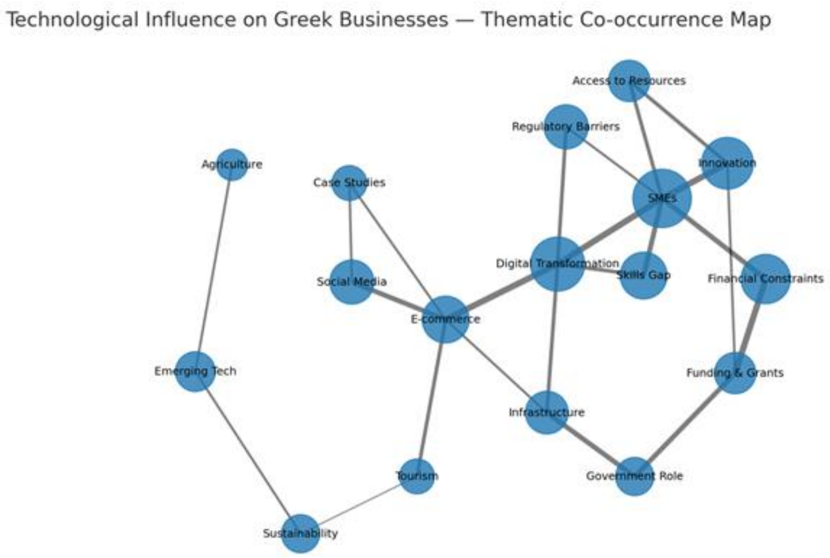

Fig. 1: Technological Influence of Greek Businesses (Authors' scheme).

Fig. 1 is about a conceptual network showing how digital transformation connects with key enablers of business performance in Greece. The central cluster links SMEs and digital transformation to skills, innovation, and regulatory or financial conditions. The left cluster (sustainability and agriculture) signals emerging opportunities, while the right cluster (e-commerce and tourism) highlights current diffusion channels. Thicker connections represent stronger thematic associations, underscoring that SME capability and finance remain the pivotal levers for technological uptake. The map displays the main themes that co-appear in the paper's discussion of technology and Greek enterprises. Proximity and linking indicate stronger co-occurrence in the narrative (conceptual association rather than causality). Three clusters are visible. First, at the center, SMEs and Digital Transformation connect tightly with Skills Gap, Innovation, Financial Constraints, Access to Resources, and Regulatory Barriers. This hub indicates that capability building and financing conditions jointly shape technology uptake among Greek firms. Second, a policy-institutional strand ties Government Role, Funding & Grants, and Infrastructure to the central hub, reflecting how public execution capacity and network readiness underpin private adoption. Third, a market-demand strand links E-commerce with Social Media, Tourism, and Case Studies, showing how customer-facing channels diffuse digital practices across services sectors. A separate left-hand cluster (Sustainability, Emerging Tech, Agriculture) highlights opportunities where green–digital complementarities can generate new niches but remain less integrated with the SME core. The structure implies three levers for impact: (i) alleviate finance and regulatory frictions around SME adoption; (ii) invest in skills and infrastructure to raise firms' absorptive capacity; and (iii) exploit market pull from e-commerce/tourism while aligning with sustainability opportunities. Strengthening links between the sustainability cluster and the SME hub (via targeted grants and sector pilots) would likely yield the largest incremental gains. Nodes represent themes coded from the manuscript; edges indicate co-occurrence within sections/paragraphs; positions follow a force-directed layout to group frequently co-mentioned items. Node size is uniform for readability; edges are illustrative of association, not statistical causation. The majority of contemporary Greek industries depend heavily on imported fuels and raw materials (see Fig. 1), which has significant adverse effects on production costs. The biotechnology area is somehow underdeveloped. Despite the existence of some valuable research development and infrastructure, the link to the industrial sector in Greece is very weak, with the considerable majority of biotechnology activities still concentrated in the public sector. Additional investments cannot be emphasized enough in this domain, which appears fundamental for the future of both the health and agrifood sectors in the country.

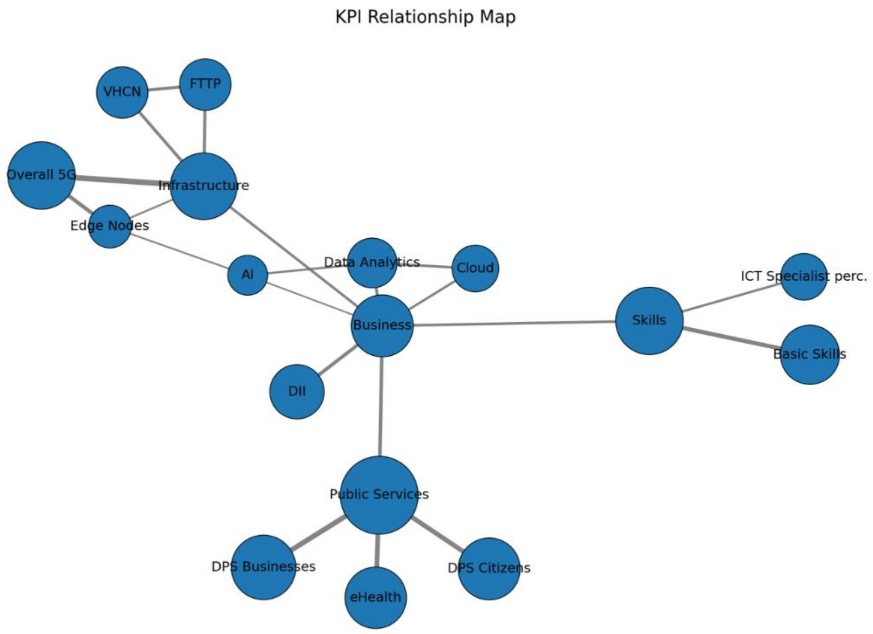

Fig. 2: KPI Relationship Map (Authors' scheme).

Fig. 2 shows KPI Relationship Map illustrating technical dependencies among Greece's Digital Decade indicators. Smaller nodes—such as AI, Edge Nodes, and Cloud—represent areas with the greatest gaps toward EU targets, while larger nodes (e.g., 5G, Public Services) show near-target achievements. The structure visualizes how infrastructure, business capabilities, and skills interact geometrically, revealing that weak links in advanced technologies constrain overall digital performance. The abbreviations used in Fig. 2 refer to core components of Greece's digital infrastructure and enterprise capabilities. Cloud denotes cloud computing, the provision of computing power, storage, and applications over the Internet that allows firms to scale resources flexibly without large capital investment. Data Analytics refers to the computational analysis of datasets to generate actionable insights for decision-making and performance optimization, while AI (artificial intelligence) encompasses algorithms and systems that replicate human cognitive functions such as learning and prediction. On the connectivity side, 5G designates the fifth generation of mobile telecommunications, providing ultra-fast data transfer and low latency essential for real-time communication. Edge Nodes are localized computing units that process data close to its source—such as sensors or devices—thereby minimizing transmission delays and supporting Internet-of-Things (IoT) applications. FTTP (Fiber-to-the-Premises) describes a broadband architecture where optical fiber extends directly to end users, enabling high-speed and reliable connections, while VHCN (Very High-Capacity Network) represents next-generation fixed networks, typically fiber-based, capable of delivering gigabit-level bandwidth required for cloud services, AI applications, and advanced digital platforms. Together, these elements illustrate how physical and digital infrastructures interconnect to support data-driven transformation across sectors.

The map visualizes Greece's Digital Decade KPIs (Key Performance Indicator is a quantifiable metric used to track progress toward a specific objective) as a network organized around four pillars—Infrastructure, Business, Skills, and Public Services. Each KPI node is connected to its pillar and to a few purposefully chosen dependencies that capture how capabilities build on one another (e.g., Cloud to Data Analytics and AI, 5G to Edge Nodes, FTTP to VHCN). Node size is proportional to progress toward the EU target (coverage, %); pillar nodes are sized by the geometric mean of their constituent KPIs. Curved, grey links aid readability and suggest complementarities rather than strict causality. Three patterns stand out. First, Public Services forms a large, cohesive cluster (with eHealth, DPS Citizens, DPS Businesses), indicating proximity to target and a strong enabling backbone for private adoption. Second, Business sits at the center of the network, bridging to Infrastructure and Skills. Within this cluster, the chain Cloud to Data Analytics to AI appears as a thin path (smaller nodes), signaling the weakest progress and the most binding constraint for firm-level digitalization. Third, the Infrastructure cluster shows two coupled pairs—FTTP–VHCN (fixed gigabit) and 5G–Edge (mobile low-latency). The relatively small Edge Nodes and modest fixed gigabit nodes explain why data-intensive and real-time applications remain limited. Interpreted operationally, the network highlights critical paths for convergence. Strengthening fixed gigabit plus edge on the left and cloud with data and AI on the right should yield the largest spillovers to the Business pillar, provided the Skills cluster (basic skills, ICT specialists) expands in parallel. Because Public Services is already strong, it can be leveraged to diffuse private adoption (e.g., interoperable identities, payments, e-invoicing, and health data flows), but it cannot fully compensate for weak business capabilities in a geometric aggregation. Notes on construction. KPI node sizes reflect their coverage values (% of EU target). Pillar sizes are geometric means of their KPIs to avoid full compensation of weak areas. Edge thickness reflects connection weights (pillar–KPI edges weighted by KPI coverage; cross-links by the mean of the connected nodes). The layout is force-directed to cluster related items and emphasize hubs and bottlenecks (Boufounou et al., 2022; Buhalis & Deimezi, 2004; E. Gkika et al., 2025; Karekla et al., 2021; Kargas et al., 2023; Laitsou et al., 2020; Lindblom & Räsänen, 2017; Lotsis et al., 2024; Marti & Puertas, 2023; Sargiotis, 2024; Tutak & Brodny, 2022).

3. Current Technological Trends in Greek Businesses

3.1. Digital transformation based on key performance indicators

Digital transformation is the development of new digital technologies to change an existing business model and provide room for additional value-producing opportunities. The resulting economic or social changes drive the transformation process and enable further market or business model innovations. Historically, digital transformation was conceptualized around the use of document management systems. Subsequently, the development of digital technologies added media, particularly photos and videos, to the transformation process (Demir, 2019). The most important digital technologies in 2011 were mobile devices, cloud computing, social media and Internet of things, and these technologies had a dramatic effect on businesses, governments and society. Arguably, the most radical form of digital transformation is the emergence and the so-called cracking of the digital economy (Challoumis, 2023, 2024). Digital transformation can also be viewed as the process of exploiting digital technologies and supporting capabilities to create a robust new digital business model (ANA-GABRIELA, 2018). After centuries of innovation and legal protectionism, the hardware and software that once required exotic materials and colleges now runs on a smartphone. Platforms like iOS or Android plug into firmware updates. Productivity plans and workflows like Trello and Evernote developed from ideas that once only existed in corporate bookshops to become multibillion-dollar businesses. Apps like Uber and Airbnb created new physical industries—transportation and hospitality—behaving entirely on virtual platforms (Griffiths et al., 2018). Digital transformation involves the application of advanced digital technologies to redesign business models and create new sources of value. It is not only a managerial process but also a technical one, relying on computational methods, software systems, and data infrastructures that enable automation, connectivity, and scalability. By embedding technology into operations, firms generate measurable improvements in efficiency, decision-making, and customer engagement. At the technical level, transformation is driven by tools such as machine learning models, natural language processing, and big data pipelines. These systems process large volumes of structured and unstructured data, identify patterns that humans cannot easily detect, and support predictive decision-making. For example, businesses use algorithms to forecast demand, optimize supply chains, and recommend products in real time. The reliability of these processes depends on the accuracy of models, the quality of data, and the efficiency of computational resources. Another central element is the integration of cloud platforms and mobile applications. Cloud infrastructures allow businesses to scale their computing power and data storage on demand, while mobile interfaces extend access to customers and employees across different locations. Security protocols, encryption methods, and distributed databases ensure that information can flow safely and efficiently across networks. These systems create a measurable impact in terms of processing speed, transaction volume, and service availability (S. S. Hamedani et al., 2025; Soto-Acosta, 2010). Digital transformation also intersects sustainability goals. Predictive maintenance tools reduce energy waste by identifying equipment faults before they escalate, while logistics optimization algorithms minimize unnecessary fuel consumption. Monitoring systems based on sensors and real-time data collection provide quantifiable indicators of resource use, emissions, and efficiency. This demonstrates that digital technologies can contribute to both economic performance and environmental outcomes. The transformation of business models through digital tools is evident in the creation of platform-based ecosystems. Matching algorithms connect service providers with users, while feedback loops and reputation systems ensure trust and transparency. These mechanisms are not abstract concepts but measurable processes that operate through code, databases, and automated workflows. In practice, this means that firms can expand their reach, adapt rapidly to market shifts, and innovate continuously through the technical infrastructure they adopt. Digital transformation goes beyond the adoption of platforms and applications. It is underpinned by scientific and computational systems that allow businesses to process data, detect patterns, and generate measurable outcomes. In the context of Greek enterprises, particularly SMEs, these processes can be operationalized through machine learning models, big data pipelines, and cloud-based infrastructures that collectively transform raw information into strategic insights.

Table 1: Greece 's Key Performance Indicators (European Commission, 2024)

Key Performance Indicators (KPIs)	Country coverage (% of EU target)	Distance from the EU target (%)
VHCN	38.4	61.6
FTTP	38.4	61.6
Overall 5G	98.1	1.9
Edge Nodes	13	87
DII	48.1	51.9
Cloud	24.1	75.9
Data Analytics	33.3	66.7
AI	5.3	94.7
Unicorns	75	25
Basic Skills	65.5	34.5
ICT Specialist perc.	24	76
DPS Citizens	75.9	24.1
DPS Businesses	86.2	13.8
eHealth	73.8	26.2

Table 1 presents Greece's performance across key digital transformation indicators, expressed as a percentage of the EU target ("Country coverage") and the corresponding distance remaining to reach that target. These KPIs reflect the four core pillars of the Digital Decade Policy Programme 2030: connectivity, business digitalization, skills, and public digital services. In the connectivity pillar, Greece shows strong progress in 5G coverage (98.1%), with only a 1.9% gap to full EU alignment. However, fixed broadband indicators such as VHCN (Very High-Capacity Networks) and FTTP (Fiber-to-the-Premises) remain at 38.4%, leaving a 61.6% gap. This indicates that while mobile infrastructure is nearly complete, fixed high-speed broadband deployment still lags behind EU leaders. Similarly, Edge Nodes, essential for real-time data processing and low-latency applications, cover only 13%, marking an 87% shortfall—one of the largest in the dataset. Under the business digitalization pillar, indicators such as Cloud (24.1%), Data Analytics (33.3%), and Artificial Intelligence (AI) adoption (5.3%) show substantial gaps of 75.9%, 66.7%, and 94.7%, respectively. These figures confirm that Greek enterprises are still in the early stages of adopting advanced digital tools, with AI diffusion being particularly limited. The Digital Intensity Index (DII)—a composite measure of business digitalization—stands at 48.1%, indicating that less than half of Greek firms reach even a basic level of digital maturity. Conversely, the Unicorns indicator (startups valued above $1 billion) achieves 75%, reflecting the growing vitality of the Greek innovation ecosystem. In the skills pillar, basic digital skills coverage reaches 65.5%, yet the share of ICT specialists remains only 24%, leaving a 76% gap relative to EU benchmarks. This imbalance suggests that Greece has built a foundation of general digital literacy but continues to face shortages in specialized, high-level digital expertise—particularly in areas like software development, AI engineering, and data management. The public digital services pillar shows the most advanced performance. Digital Public Services (DPS) for citizens and businesses are at 75.9% and 86.2%, respectively, while eHealth services stand at 73.8%. These results confirm that Greece's e-government modernization has progressed substantially, reducing administrative burdens and enabling online interactions between citizens, firms, and the state. The table reveals a dual-speed digital transformation: strong progress in connectivity and public services contrasts with significant lags in business digitalization, AI adoption, and ICT workforce development. Addressing these gaps—particularly in advanced technologies and specialized skills—will be essential for Greece to achieve full convergence with EU 2030 digital targets.

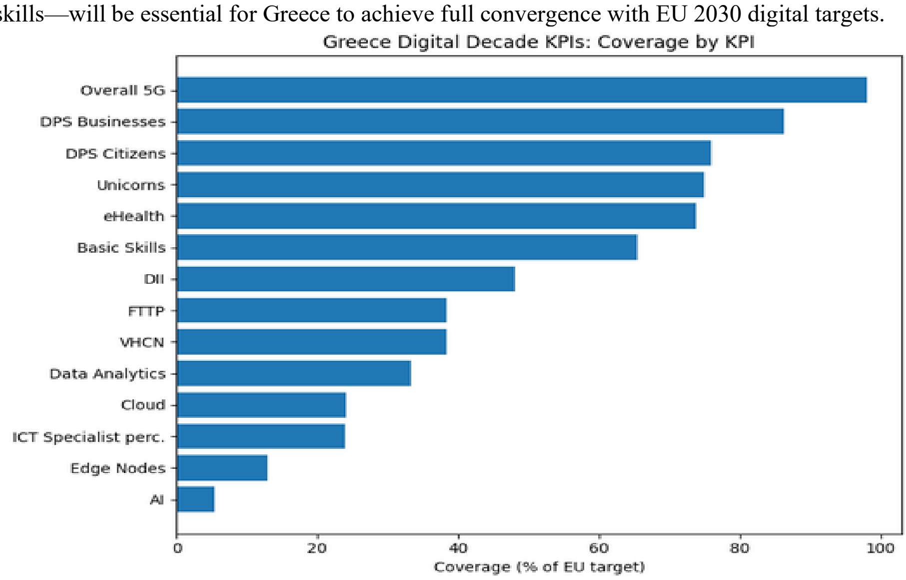

Fig. 3: Digital Impact (Authors' Scheme, See Appendix I).

Fig. 3 shows the Bar chart displaying Greece's progress toward EU 2030 digital targets. High coverage in 5G and digital public services contrasts with much lower adoption of Cloud, Data Analytics, and AI. The visual emphasizes strong state-led performance but weaker firm-level digitalization, identifying where convergence efforts should focus. The figure shows Greece's progress toward the EU 2030 Digital Decade targets, with each bar representing coverage as a percentage of the EU target. The strongest areas are overall 5G coverage, which is already near target at about 98%, and digital public services, where businesses are at roughly 86% and citizens around 76%. eHealth (≈74%) and the "unicorns" indicator (≈75%) also perform well. Together, these suggest a mature e-government backbone and strong mobile connectivity, supported by a start-up ecosystem capable of scaling firms. Mid-table indicators point to partial—but not universal—readiness. Basic digital skills sit around 66%, implying many citizens can use digital tools, yet gaps remain for inclusive participation. The Digital Intensity of SMEs (≈48%) indicates that a large share of smaller firms still lack a full set of baseline digital practices (e.g., e-invoicing, CRM/ERP use, online sales), limiting diffusion of benefits across the business fabric. The weakest results are concentrated in fixed gigabit infrastructure and advanced technology uptake by firms. Fiber-to-the-premises and VHCN are both about 38%, well below what is needed to support data-hungry services reliably. Business adoption of data analytics (≈33%), cloud (≈24%), and especially AI (≈5%) is low, and the share of ICT specialists in employment (≈24% of the target) signals a talent bottleneck. Edge nodes are also limited (≈13%), constraining low-latency applications in industry and logistics. Policy and investment priorities therefore follow directly from the pattern. Accelerating fiber and edge deployments will raise the ceiling for what firms can do, while targeted measures for SMEs—vouchers, shared cloud/data platforms, advisory and integration support—can rapidly lift cloud/data/AI adoption. Parallel efforts to expand and retain ICT talent are critical complements, ensuring that the same digital assets yield higher returns. Greece's strong performance in public digital services and 5G can act as leverage, but closing the gap to the EU target depends on pushing fixed infrastructure, firm-level advanced tech uptake, and the ICT skills pipeline in tandem.

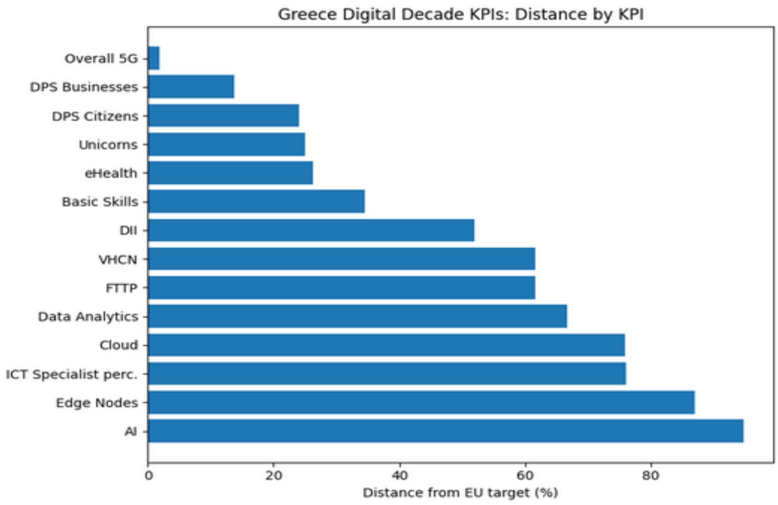

Fig. 4: Digital Impact Based on Distance (Authors' Scheme, See Appendix I).

Fig. 4 showing Greece's remaining distance to the EU 2030 targets. Long bars correspond to priority shortfalls—particularly AI, Edge Nodes, and ICT specialists—while short bars (e.g., Public Services, 5G) indicate near-complete progress. The figure highlights the binding constraints limiting Greece's overall digital index. This chart shows how far Greece remains from the EU 2030 target (100%) for each Digital Decade KPI—the longer the bar, the larger the gap to close. It's the mirror image of the coverage view: small bars mean Greece is nearly at target; long bars indicate priority shortfalls. The smallest gaps are in overall 5G (≈2% remaining) and digital public services, especially for businesses (≈14%) and citizens (≈24%). Unicorns (≈25%) and eHealth (≈26%) are also relatively close. This pattern signals strong progress in mobile connectivity and e-government that can be leveraged to accelerate private-sector digitalization. Mid-range gaps appear in basic digital skills (≈35%) and the Digital Intensity of SMEs (DII) (≈52%). These suggest that while many people can use digital tools, a large share of SMEs still lack core practices (ERP/CRM, online sales, e-invoicing), limiting uptake of more advanced technologies. The largest gaps are concentrated in AI (≈95% shortfall), edge nodes (≈87%), ICT specialists (≈76%), cloud (≈76%), data analytics (≈67%), and fixed gigabit infrastructure—FTTP/VHCN (each ≈62%). In practical terms, Greece needs a twin push: accelerate fiber/edge deployment (to raise the ceiling of what firms can technically do) and drive firm-level adoption of cloud/data/AI, supported by a pipeline and retention strategy for ICT talent. These are the binding constraints that, if addressed, would most reduce the overall distance to the EU target.

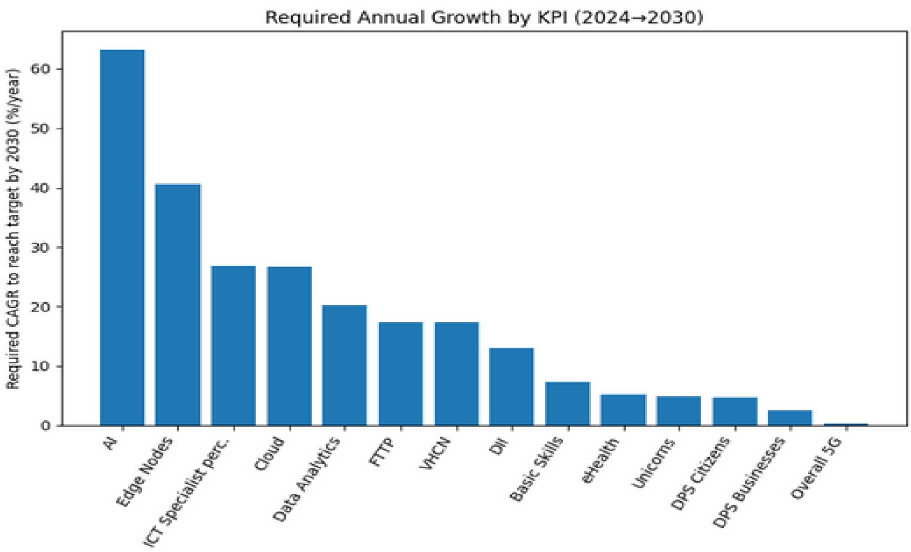

Fig. 5: Annual Growth Required by KPI (Authors' Scheme, See Appendix I).

Fig. 5 is about the projected annual growth rates each KPI must achieve for Greece to reach the EU 2030 benchmarks. The tallest bars (AI, Edge Nodes, Cloud, ICT specialists) identify high-effort, high-return domains, while near-target indicators like 5G require minimal growth. The graphic translates KPI gaps into actionable policy pacing. It shows the compound annual growth each KPI would need (from today to 2030) for Greece to hit the EU targets. The tallest bars mark the toughest lifts: AI (~63%/year) and Edge Nodes (~40%/year). Next come ICT specialists (~27%/year) and Cloud (~27%/year), followed by Data Analytics (~20%/year). On the infrastructure side, FTTP/VHCN (both ~17%/year) require sustained rollout. Mid-range needs include the SME Digital Intensity Index (~13%/year) and Basic Skills (~7%/year). At the low end, public digital services and unicorns need only single-digit growth, and overall 5G (~0.3%/year) is essentially at target already. Interpreted for policy and firm strategy, the growth burden sits on three fronts: (1) rapid adoption of advanced capabilities in firms (Cloud/Data/AI), (2) a bigger ICT-talent pipeline to make those tools productive, and (3) faster fixed and edge infrastructure build-out to enable low-latency, data-intensive applications. Because e-government and 5G are near target, marginal returns to additional effort there are lower; redoubling efforts on AI, Edge, Cloud and skills is the most direct path to shrink the overall gap. Practically, this implies targeted SME adoption programs (cloud credits, integration vouchers, hands-on advisory), skills acceleration (short, job-linked ICT up-skilling and retention incentives), and fiber/edge deployment enablers (permit streamlining, wholesale access, anchor-tenant models). If resources are constrained, prioritizing these high-CAGR areas will yield the greatest convergence towards the EU 2030 objectives.

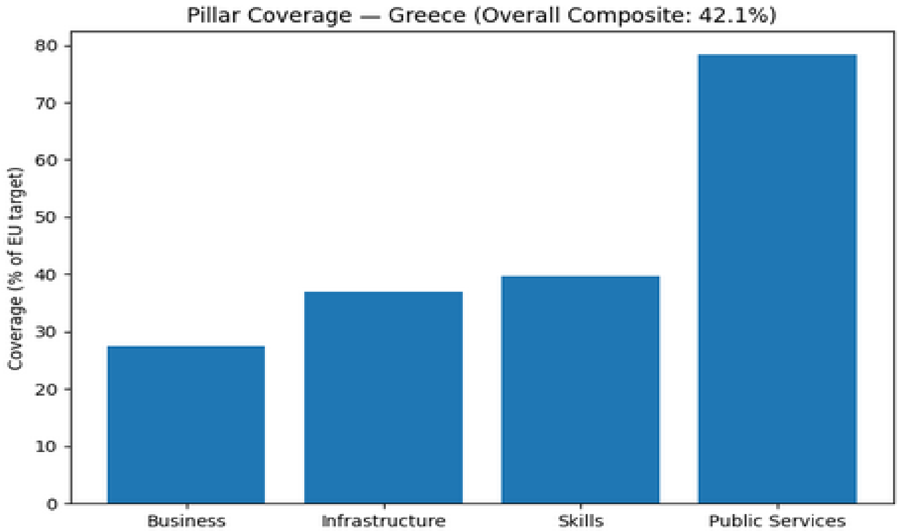

Fig. 6: Pillar Coverage of Greece (Authors' Scheme, See Appendix I).

Fig. 6 is about Greece's digital performance by pillar—Infrastructure, Business, Skills, and Public Services. Public Services form the clear strength, while Business Digitalization remains weakest at around one-quarter of the EU target. The geometric aggregation shows that no pillar can compensate for another's weakness, reinforcing the need for coordinated improvements across infrastructure, skills, and business adoption. This figure summarizes Greece's position against the EU 2030 targets by pillar. Public services are the clear strength: with coverage near 79%, e-government (citizens, businesses, eHealth) is already close to target and lifts the composite. Skills and infrastructure form a middle tier—about 40% coverage each—signaling that basic digital skills and ICT-specialist share remain insufficient and that fixed networks (FTTP/VHCN) and edge capacity still constrain what firms can do. The weakest pillar is business digitalization, at ~27%, reflecting low firm-level uptake of cloud, data analytics, and especially AI despite a decent start-up scene. Because the index is a geometric mean, strong public services cannot fully offset weak business adoption; the overall composite stays low (≈42%). Closing the gap therefore depends on a coordinated push: accelerate fiber and edge rollout to raise the technical ceiling, expand and retain ICT talent to make tools productive, and drive SME adoption of cloud/data/AI through targeted incentives and hands-on integration support. Improving these three levels together will move the business pillar first, with positive spillovers to the others.

3.2. E-commerce growth

E-commerce continues to expand expeditiously in developed countries. The share of household consumption conducted online continues to increase exponentially. As more consumers shift to online shopping, the more attractive the medium becomes for marketers and sellers. While a global e-commerce surge was evident prior to the onset of the coronavirus pandemic, the crisis accelerated this tendency, catapulting e-commerce development into an upsurge stage with major impacts on markets and businesses in the coming years (Ristevska & Temjanovski, 2019). During the COVID-19 pandemic lockdown, much of consumer spending shifted from physical stores to online retailers, particularly on those capable of supplying groceries and household staples. Subsequently, as stores opened up again, actors in physical, offline retail were vying with omnichannel and online retailers to recapture lost market share. Despite the pandemic, growing health concerns and logistical complexity have dampened retailers' enthusiasm to fully reinstate business capacity at the pre-COVID level. The rise of social media has further altered the marketing landscape. Firms now manage corporate reputations by engaging with target audiences through platforms such as Facebook, LinkedIn, Instagram, Pinterest, Twitter, and YouTube, using tools including blogs and tweets (Veneti et al., 2019). Small-to-medium enterprises (SMEs) deploy these platforms to establish and grow social networks and strengthen customer relationships. LinkedIn lends professional credibility and requires minimal upkeep. Facebook offers a blend of personal and professional interaction. Twitter occupies a more informal space conducive to open conversation (Joan Morley, 2012). Conventional marketing and networking are becoming obsolete as digital tools supplant them. Business models have shifted from one-way communication to a multi-directional system where consumers actively provide feedback on products and services, disseminating information widely. Complete message control has become impossible in a world dominated by social media, and the ownership of communication has transitioned from businesses to consumers (Angelakis et al., 2015; Asonitou et al., 2019; Bellas et al., 2007; Cohen et al., 2012; Galani et al., 2010; Georgios & Georgios, 2019; Gravas et al., 2011; He, 2019; Makarov, 2020; Shi, 2024; Singh & Kumar, 2024; Tsaliki & Tsoulfidis, 1994; Tsianaka & Dimitra, 2023; Tsiklauri-Shengelia, 2024; Vasiliou, 1996; Voulgaris et al., 2002; Yan, 2003; Zhou, 2023). Dialogue among consumers represents the most crucial form of communication, and companies should leverage credible advocates, such as employees and consumers, fostering transparency. Today consumers often possess more knowledge about a business than its owners, as they independently evaluate company reputation, culture, and services. People with shared interests bond and seek information from each other rather than external experts; for instance, in 2005, 56% of U.S. respondents expressed greater trust in persons with similar interests, up from 22% in 2003.

4. Impact of Technology on Small and Medium Enterprises (SMEs)

Small and medium enterprises (SMEs) constitute the dominant form of business activity in Greece and invariably are the greatest source of employment, economic growth, and prosperity in the country. SMEs have relatively limited resources; a depreciation of capital stock or losses can severely hinder their growth, impose hardship on creditors, and threaten the survival of the business. The rapid development of information and communication technologies has resulted in greater levels of scientific knowledge and managerial expertise being available to the business community leading to emerging technological choices in both the business activities and the operation of SMEs, creating opportunities and innovative capabilities for greater entrepreneurship (T. Ocra, 2013). Access to new technology enables SMEs to employ improved production methods, access new markets, and develop organizational structures, fostering innovation. Enhanced capabilities enable them to contribute to economic development and undergo significant structural change. SMEs that recognize opportunities and utilize information and communication technologies undertake entrepreneurial activity on a larger scale compared with those that do not (Soto-Acosta et al., 2016).

4.1. Access to resources

Technology, particularly digital technologies, enables small and medium enterprises to gain access to knowledge, resources, and skills on a flexible and interactive basis. The Internet constitutes a vast source of information that can assist organizations throughout their business life cycle. Whether firms are in the start-up phase, in a growth phase, or in a mature phase, the Internet is an important tool that can be utilized for several purposes, such as locating and purchasing supplies, finding capital, obtaining information about local markets or companies, searching for specific specialized knowledge, and selling goods and services worldwide Technology can offer businesses the means to develop new products or services, enter new markets, and improve business efficiency and effectiveness. Utilizing technology can also provide businesses with a competitive advantage. In the case of Greek Small-Medium Enterprises (SMEs), it can enhance innovation and economic growth within their business domains.

4.2. Innovation and competitiveness

Technological innovation provides a basis for increased competitiveness and has been recognized as an important factor for the growth of countries and firms (Gerguri & Ramadani, 2010). In a globalized business environment, innovation leads to competitive advantage, improved performance, and the long-term survival of enterprises. In order to intervene actively in the changing environment, firms continuously search for sources of opportunities; the key to exploitation lies in establishing new organizational forms, tools, and management programs. Innovation has become a prerequisite for firms and individuals for developing sustainable competitive advantages and responding efficiently to environmental changes such as high volatility and uncertainty. Particularly for small and medium-sized enterprises (SMEs), innovation constitutes an essential competitive weapon since it enables them not only to respond to environmental changes but also to reduce the resource disadvantages they face (Gerguri & Ramadani, 2010). Innovation facilitates access to knowledge and resources that are external to the firm, provides technological and marketing opportunities, and fulfills the business owners' aspiration for growth and expansion. Hence, technological innovation can stimulate SMEs' performance directly or indirectly by providing access to external resources and capabilities. In the context of a lasting economic crisis, the effect of such a shock on the R&D behavior of Greek manufacturing firms is heterogeneous in terms of firm size (Giotopoulos et al., 2022). Large enterprises appear to recover quickly and even increase their expenditures in R&D following the onset of the crisis, whereas small and micro firms newly incorporate R&D activities during the pre-crisis period and only very few of them continue investing in R&D during the recession. The shrinking of the set of innovating firms takes place exclusively among small and micro firms, while medium and large-sized firms maintain their pre-crisis levels. This finding highlights a reallocation of resources away from R&D among smaller firms during turbulent times, whereas larger firms sustain or even intensify their innovation efforts.

Governmental amplification of the availability of funds to support SMEs can mitigate the constraints small companies face in undertaking innovation activities during difficult economic periods. Measures such as tax reductions on R&D expenses, over-depreciation rates on R&D equipment, increases in public R&D funding, and expedited regulation for attracting researchers to contract-based research or university collaborations can offer additional incentives for overcoming R&D crunch conditions. A policy mix of this nature would enable smaller firms to survive long-lasting crises and secure growth prospects afterward. Nonetheless, the development of a digital transformation strategy can help organizations create new business models and long-term economic value (e.g., competitive advantage, productivity, income, efficiency, and placement of the firm in the supply chain). Today, the digital transformation of SMEs has already become a fundamental part of business growth. The integration of digital technologies and data analytics in the e-commerce process reinforces the traction of online businesses by providing enhanced insights into customers' behavior. The use of data analytics also enables a customer-oriented approach through the automation of the shopping process and the development of intelligence regarding customer preferences and shopping habits.

5. Challenges Faced by Greek Businesses in Adopting Technology

Greece exhibits indicators of rising standards of living, urbanization, education, and labor force skills that position it well to adopt new technologies (Hahamis et al., 2005). The nation's approach to technological development emphasizes the imposition of international standards, the creation of new products across diverse sectors, and a growth strategy rooted in strong inter-firm cooperation. Existing literature portrays technology as a critical factor in fostering sustainable competitiveness and an instrument for the successful achievement of innovative policy objectives, economic growth, and industrial regeneration. "Technology denotes knowledge or know-how and comprises the ways in which existing resources can be converted into products and services of higher value," rather than merely physical artefacts. In the context of Greece, the development of technology is expected to bring significant benefits to small and medium enterprises (SMEs) by diminishing the adverse impact of capital shortages on access to resources for innovation. The broad diffusion of information technologies is set to reshape competitive patterns within the Greek business system by expanding the range of technological opportunities open to all enterprises and thereby diminishing the advantages of larger firms. The commercial benefits of technology remain limited by financial obstacles. In many instances, the ability to purchase relevant equipment is the principal regulating factor. For companies with a formalized structure, the lack or inadequacy of a carefully elaborated plan for the aim and operation of any new technological investment is a central barrier to penetration. The adoption of technology also postulates an equal or superior qualification and skills profile from the company's staff, the lack of which continues to be a limiting factor to the penetration of technology in Greece. The lack of a sufficiently flexible and comprehensible legislative infrastructure is viewed as a threat to technological assimilation, as is the absence of essential complementary assets that enable the diffusion and exploitation of technological innovation presently on offer through government services and regulation.

5.1. Financial constraints

Greek businesses continue to face major financial challenges, despite the ongoing potential benefits afforded by technological advances. Costs involved in introducing digital technologies remain a significant barrier for companies, especially for small and medium-sized enterprises (SMEs) (Asimakopoulos et al., 2006). This severely limits many firms' capacity to integrate these new technologies into business operations; bureaucratic obstacles further inhibit their ability to avail themselves of the support funds offered by the government and the European Union. The wider economic climate has also forced banks to impose much more rigid requirements on loan applicants, raising the cost and difficulty of accessing capital. What figures are available indicate that only a small number of businesses currently take out loans to finance investments in innovations, including technology. A further limitation stems from the poor quality of the existing labor force – a problem exacerbated by economic uncertainty and the resultant rise in "brain drain" (Alexandrova et al., 2024; Chaudhary, 2024; Giovanis et al., 2017; Gries & Naudé, 2020; Nikolaos, 2016; Pazarskis et al., 2021; Robinson & Venieris, 2009; Shahidi et al., 2024; Solos & Leonard, 2022; Trabelsi, 2024; Tzovas, 2007; Wan et al., 2025; Wang et al., 2021; Yuan et al., 2024). Given this shortage of properly qualified personnel, businesses are forced to train employees themselves, rather than recruit pre-prepared individuals. Moreover, even when suitable personnel are on hand, their numbers tend to be insufficient for meeting larger-scale technological development and usage objectives. In combination, these factors clearly hamper efforts to modernize the Greek economy (Challoumis, 2021, 2025a). However, the recent economic downturn has nevertheless demonstrated how technology can provide small companies with easier access to the appropriate resources, thereby enhancing the overall innovative output of the country. In the context of the other major trends outlined in 'Current Technological Trends in Greek Businesses,' it therefore becomes all the more important to promote the utilization of digital advances across all sectors of the business landscape.

5.2. Skill gaps in the workforce

Many Greek businesses cite a lack of adequately skilled employees as a principal obstacle to technology adoption (Schwalje, 2011). Globally, demand for skilled labor continues to rise, but tight labor markets leave many otherwise strong labor pools lacking key skills. Employers require higher soft skills and specialized technical knowledge in employees, resulting in sizeable skills gaps. A 2009 survey across 22 Latin American and Caribbean countries found that 85 percent of businesses served by the private sector believed their workforce lacked sufficient skills. Similar gaps are apparent in the northern, southern, and western nations of these regions. These gaps increase concerns about the ability of emerging economies and developing countries to attract investment, improve productivity, and compete in international markets. They also highlight the challenge of building a workforce that is both higher skilled and more flexible in order to adopt new organizational practices. The evolution of Greece's digital economy reveals that the most critical skills gap has shifted from basic digital literacy toward advanced information and communication technology competencies. The primary deficiencies now concern expertise in data analytics, cloud computing, and artificial intelligence—areas that form the foundation of high-value digital transformation. While a growing share of the population possesses basic digital skills, enterprises continue to face acute shortages in these more specialized domains. This imbalance constrains the capacity of firms to leverage emerging technologies effectively and limits their potential for innovation, productivity growth, and international competitiveness. Small and medium-sized enterprises, which constitute the majority of Greek businesses, exhibit particularly uneven digital maturity. Many operate with basic digital tools, such as online communication and simple administrative systems, but lack integrated infrastructures capable of supporting advanced data-driven processes. Surveys of domestic firms show that digital adoption frequently remains confined to individual applications or isolated functions, rather than being embedded in strategic management or production workflows. The result is a fragmented form of digitalization that delivers operational efficiencies but fails to generate sustained structural transformation. The human capital dimension remains a decisive factor in this process. The outflow of highly educated professionals during the previous decade continues to influence the national supply of ICT specialists, though recent trends suggest partial recovery through return migration and domestic upskilling. Nonetheless, the demand for data scientists, software engineers, and system architects far exceeds the available labor pool, creating persistent bottlenecks. The educational system, while improving its alignment with digital economy needs, has yet to produce sufficient graduates with the practical and interdisciplinary expertise required by modern firms. Expanding short, job-linked training programs and integrating digital modules into non-technical degrees could alleviate this mismatch over time. Equally important is the distribution of skills across regions. Metropolitan centers such as Athens and Thessaloniki attract the majority of digital talent, while peripheral and island regions often lack the capacity to absorb or retain qualified professionals. This uneven geography of skills contributes to digital asymmetries across the national economy. A balanced regional approach—combining local incubators, telework hubs, and targeted incentives—would help diffuse technical know-how more evenly and prevent the concentration of innovation capacity in a few urban nodes.

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At the enterprise level, the integration of artificial intelligence, cloud computing, and data analytics constitutes the most challenging frontier of Greece's digital transformation. Despite significant progress in connectivity and digital public services, the diffusion of these advanced technologies within firms remains limited. Most businesses still operate with legacy systems that hinder interoperability, while cloud adoption and data management infrastructures are at an early stage. The result is a technological divide between a small number of frontier firms—capable of deploying sophisticated digital tools—and the vast majority of enterprises that continue to rely on conventional, fragmented solutions. The structural weakness of the AI–cloud–data stack reflects both technological and organizational constraints. On the technological side, insufficient fixed gigabit coverage and edge computing capacity restrict the feasibility of real-time applications. On the organizational side, the absence of integrated digital strategies within SMEs leads to cautious and piecemeal experimentation rather than systematic transformation. Many firms perceive the adoption of AI and data analytics as high risk or costly due to uncertainty about returns, compliance issues, and lack of specialized staff. Consequently, technological investment is often postponed or confined to surface-level digital tools such as social media management or basic e-commerce. A comprehensive transition to cloud and AI systems requires not only infrastructure and funding but also a cultural shift toward data-driven decision-making. Firms that embed analytics into their core operations—supply-chain forecasting, pricing optimization, and customer engagement—demonstrate significantly greater adaptability and resilience. Encouraging this shift involves rethinking management practices, promoting interoperability standards, and supporting the creation of shared data spaces where businesses can securely collaborate. By lowering entry barriers and standardizing digital platforms, the national economy can accelerate the diffusion of advanced technologies even among resource-constrained SMEs. Emerging national initiatives illustrate a growing awareness of this imperative. Strategic programs focusing on artificial intelligence, high-performance computing, and digital innovation hubs aim to bridge the gap between research and application. These initiatives provide opportunities for cross-sectoral experimentation in areas such as smart manufacturing, precision agriculture, and sustainable tourism. When aligned with industrial policy and human-capital development, such actions can transform isolated technological projects into cohesive ecosystems that foster innovation across value chains. Bridging the digital divide requires a policy mix that simultaneously addresses infrastructure, skills, and firm-level capabilities. Investment in broadband and edge networks must proceed in parallel with targeted support for business adoption of cloud and data solutions. Financial instruments—such as digital integration vouchers, advisory programs, and innovation grants—can de-risk initial investments for SMEs and encourage scalable experimentation. Equally, labor-market policies should prioritize specialized ICT training, certification schemes, and retention incentives for skilled professionals, ensuring that digital capital is not only installed but effectively used. Sector-specific initiatives offer an especially promising route. Manufacturing, agri-food, logistics, and health services each present unique opportunities for AI and data applications. Establishing testbeds within these sectors enables firms to pilot digital tools in realistic settings, demonstrating tangible efficiency gains and reducing uncertainty. Coordinated governance among ministries and regional authorities would further enhance the coherence of such programs, ensuring that funding streams and regulatory frameworks move in the same direction (I. Gkika et al., 2025; Sargiotis, 2025a). The effectiveness of Greece's digital transformation will depend on its capacity to integrate advanced technologies not as isolated add-ons but as systemic enablers of productivity and sustainability. By coupling infrastructure modernization with a strategic emphasis on human capital and sectoral innovation, Greece can convert its current digital lag into an opportunity for accelerated convergence with European peers. The transformation is as much institutional and cultural as it is technological—requiring persistent commitment, coordination, and the diffusion of digital confidence across all layers of the economy.

5.3. Regulatory barriers

A variety of factors have limited the resources available for digital transformation, including restricted access to finance, lack of worker skills, and regulatory barriers. Skill deficiencies have been recognized as a challenge. Alongside broader infrastructure development, regulatory barriers present additional obstacles to adoption of new technologies. Funding for the digital infrastructure and development is a challenge for local authorities in Greece, especially following reforms involving decentralization of power and financial autonomy. Consequently, a well-defined national framework to identify funding and resources is essential to support development. Establishing a dedicated unit responsible for implementation, coordination, and monitoring of digital initiatives is recommended. Institutional and organizational changes, accompanied by education and training on new technologies, are imperative. Local government business process re-engineering should precede full digital adoption. Developing broadband infrastructure and increasing Internet penetration is crucial for bridging the digital divide, benefiting not only the public sector and businesses but also citizens. In response, Greece is participating in the European Initiative eEurope 2005, which has outlined points for a broadband strategy; the effectiveness of outcomes remains to be seen. Enhancing interactivity in citizen transactions, building trust, and integrating services into portals are necessary measures to promote democratic outreach and responsiveness. Further research, including comparative studies of EU countries' progress and assessments of Greece's local and central integration, could help target resources effectively (Hahamis et al., 2005).

6. Case Studies of Successful Technological Integration

Since the beginning of the 21st century, the gradual expansion of information and communication technologies has brought about several economic and social transformations (Hahamis et al., 2005). Both nationally and internationally, Greek businesses have taken steps to adapt to the new environment by adopting technological tools to serve their goals. The wide diffusion of the internet and new online technologies, such as social networks, have altered ways of communication and interaction, revolutionizing several business sectors in particular, including commerce (Vlachos, 2013). Small and medium-sized businesses (SMBs) in particular regard some technologies as formative elements of future business developments. Today, many Greek businesses prepare extensive development programs, including a range of technologies closely related to the internet. The adoption of Internet business and e-commerce solutions allows companies of all sizes to immediately adopt new e-business practices and quickly respond to the challenges and opportunities of the global Internet environment. Research has revealed several advantages connected to the use of new technologies in the business field. Businesses encounter fewer administrative needs, improving the quality and accuracy of decision-supporting information. They also establish better cooperation with their partners and develop competitive and strategic advantages in comparison to those maintaining traditional business procedures . Through an empirical approach, interview data highlight the commercial significance of traditional e-commerce technologies as well as several alternative solutions, such as digital marketing strategies, which help Greek businesses overcome the major challenges linked to the adoption of new technologies.

6.1. Case study 1: e-commerce success

Internet-use statistics indicate that at the end of 2018, more than 56% of the United States population were purchasing products from online stores. Similarly, 75% of the United Kingdom population went shopping via the Internet in 2016. Developing countries and emerging-market economies also promote e-commerce activities. It is expected that the current trend in e-commerce will continue to grow in the following years for both developed and emerging-market economies. Most Western European online stores appear to be selling electronics and apparel products (Ristevska & Temjanovski, 2019). Other products explicitly designed for online sales include customized premeditated packages of products with related usage such as sport equipment, cooking articles and related paraphernalia, and play and hobby material. Furthermore, special attention is given to those products where retailers are able to sell their products at a relatively low price compared with local, physical deposit stores. The aforementioned products generally correspond to the needs of traveling customers while, at the same time, they serve general customers needing to replace some devices or articles with new ones. Travel and tourism agencies also hold an important part of online purchasing share. Payments for such activities may include air tickets, accommodation costs, and car hire, among others (Vlachos, 2013). Other typical products and activities with a considerable share of online business are books, and products related to artistic and hobby activities. Typical examples of the last category, apart from those already mentioned, might be the purchase of cards, paper material for the preparation of crafts, small furnishings, and musical instruments. Almost all types of consumable items normally found at supermarkets are now also partly sold and distributed through online stores, including grocery, clothes, and electronic items.

6.2. Case study 2: digital marketing strategies

The internet is a swift and effective medium for conducting business, empowering organizations to extend their market reach and target specific audience segments. Digital marketing integrates seamlessly with the traditional marketing mix—comprising place, price, product, and promotion—facilitating the implementation of coherent strategies (Puleng Modise, 2014). Although technology has transformed interactions between marketers and consumers on a global scale, marketing fundamentally concerns human relationships rather than technological tools. The pervasive adoption of digital platforms shapes consumer behavior by enabling continuous engagement through email, instant messaging, and social media channels. Consequently, consumers are better informed and able to promptly access and filter pertinent information. A considerable proportion of prospective customers depend on internet-based technologies each day to research products and services prior to purchase.

7. Role of Government in Promoting Technology Adoption

Government programs encourage the adoption of technological innovations and knowledge absorption in business. The European Commission has been the principal source for funding projects that build the technological capabilities of firms. Industrial policy has played a fundamental role in the introduction of technology into the Greek economy. Grants given by the government, particularly in connection with the EU (no specific Greek program currently exists) provide an incentive to firms to embark on a process of technology adoption and upgrading. Technology often determines the design of products that are to be produced or the systems of organization that can be made available. Government policy has supported the expansion of telecommunications infrastructure (Hahamis et al., 2005). Strategic objectives are, first, the strengthening of the role of the State as a promoter and controller of electronic communications and broadcasting, and, second, the liberalization and modernization of the Greek telecommunications market so that the Greek economy can play a leading part in the development of the European and global economy (Challoumis, 2025b; Challoumis & Eriotis, 2024). Online services are also provided by local authorities and the central Government. More general services that may be complementary to the core e-Government services—such as services for electronic business (search for partners, services, or online applications)—are not yet developed. The telematic program which allows the processing of public tenders electronically has been in operation since 1997.

7.1. Funding and grants

Funding plays an important role in facilitating the adoption of new technologies by Greek businesses. The Government of Greece has established specific funds to support companies in their growth, particularly those that are innovative and find it difficult to secure financing from traditional banks. These funds provide financial assistance to businesses with innovative proposals, such as a broad range of services for sculptors or the production and commercialization of incense for churches, that demonstrate the ability to expand domestically and internationally. The Greek bank system offers a wide range of credit products to mitigate financial difficulties and support the economy. Grants are awarded not only for the purchase of pioneering technology but also for training and employing new human resources who can achieve the business objectives. In the post-COVID-19 period, funding has also become available to support business workers who have been affected. Although the bureaucracy in Greece remains a challenge, precautionary methods can help ensure compliance as taxes continually evolve (Ahorsu et al., 2022; Boufounou et al., 2022; Challoumis & Eriotis, 2025; IMF, 2021; Loayza & Pennings, 2020; Syukur, 2020; "The Impact of the Protective Measures on Healthcare Workers During Covid-19 Pandemic in Tertiary University Hospital," 2021). Companies also consider working with the Ministries of Culture, Tourism, Environment, and Food.

7.2. Infrastructure development

The technological infrastructure forms the fundamental backbone for Greece's economic development. Establishing a secure yet flexible technological base is a prerequisite for the implementation of innovative services, infrastructural adaptability, and economics of scale according to the unprecedented potential that technology opens for ancient cities. ICT infrastructure is situated at the crossroads of policies, economy and technology. The provision of broadband infrastructure is a complex problem that combines technology and economics and the permanent question of a public monopoly versus free market. High-tech services may change the balance between cities; thus their distribution should be considered in the strategic planning of urban development and evolution (Bucci, 2012; Bundin et al., 2022; Collaborative et al., 2021; Khan & Liu, 2019; Sobrino García, 2022; Yakovliev, 2019).

8. The Future of Technology in Greek Businesses

As in other countries, a significant number of Greek small and medium enterprises (SMEs) are currently experiencing the process of digital transformation and migrating their business to the Internet by developing e-shops. The development follows the most commonly used technological tools (e-commerce and social media marketing), determining the prospects and the functional and organizational features of the new generation of Greek entrepreneurial activities. In the early 2000s most Greek enterprises responded favorably to the diffusion of information and communication technologies (ICT) by adopting commercial packages (accounting, payroll, office automation) and purchasing machines and equipment designed to produce and utilize information. Unfortunately, the adoption of more complex complementary ICT by economic and social agents (enterprise resource planning, customer relationship management, e-procurement) encountered many problems. The adoption of innovative organizational practices is limited compared to other countries, seemingly strengthening the index of the absorptive capacity of heterogeneous production structures (Dhareshwar, 2018). The introduction **(section 3: Current trends of technology in businesses based on e-commerce and social-media marketing)** of new technologies has created new opportunities to sell goods and services and to communicate with existing and potential customers. Many projects start with activities in social media and continue through the establishment of an e-shop, ad hoc online ordering mechanisms, and the selection of a range of online advertising services. The opportunities arise through the increased regional concentration of the sectors where the projects originate and the growth in originality connected with the attempt to limit competition and form differentiated business models.

Starting from the 1990s, an important public and/or private push to SME innovation spread throughout the country. A predominant view considered innovation and technology as synonymous notions, with the mere acquisition of technological equipment assumed to move the firm immediately on the path of innovation. Opportunities were related to patterns of technology transfer. The moderate success observed in many sectors encouraged private and public actors to shift towards incremental purchases of new equipment, improvements to existing applications, and small-scale integration actions. However, these actions delivered limited externalities to the entire regional system, indicating a probable sub-optimization of the innovation process. The Greek experience of emerging digital marketing tools shows that advertising is the primary motive for engaging with social media, followed by customer loyalty, competitor analysis, increased sales and inquiry generation. Despite a general lack of coherence, a number of structural relations emerge through a multivariate analysis of business and technological factors. Raising an existing knowledge barrier, increasing the degree of innovation and uniqueness of the business offerings, and augmenting the intensity of budgetary, technological and communication resources devoted to digital tools have all enabled a group of businesses to take full advantage of the new technological opportunities in the sector.

8.1. Emerging technologies

Emerging technologies provide new opportunities for Greek businesses to expand and innovate. Amid budgetary constraints, many establishments are investing strategically in digital systems to remain competitive. The foremost driver of growth and employment is the Information and Communication Technology (ICT) sector. The national strategy for information society development emphasizes robust frameworks, including the insertion of ICT in education, citizen empowerment through digital literacy, and the use of technology for economic enhancement that will accelerate development in traditionally weaker sectors (Hahamis et al., 2005). The ongoing digital evolution shapes the intellectual and operational landscape of Greek businesses across all sectors and sizes, influencing marketing, sales, operations, production, and service provision. Continuous adaptation is essential to remain competitive, particularly in the dynamic tourism sector, where innovation and technology serve as critical success factors for companies needing organizational, functional, or operational transformation. Beyond retail and tourism, other sectors present distinct digitalization challenges and opportunities. For instance, manufacturing can leverage the Internet of Things (IoT) and predictive analytics to optimize production lines, monitor equipment performance, and reduce downtime through predictive maintenance systems. Likewise, agriculture can benefit from precision farming powered by sensor networks, satellite imagery, and AI-driven crop monitoring that improve water and fertilizer efficiency while reducing environmental impact. These sectoral applications illustrate how data analytics and IoT create measurable efficiency gains, aligning with Greece's dual objectives of digital and green transformation. Including such cross-sector digital pathways widens the relevance of the national digital strategy beyond services, embedding smart manufacturing and agri-tech as pillars of sustainable competitiveness. Digital transformation in Greece extends far beyond retail and tourism. Other key sectors—manufacturing, agriculture, logistics, energy, and healthcare—face distinct technological barriers and opportunities that can decisively influence national productivity and sustainability outcomes. Addressing these domains widens the country's digital base and ensures that innovation reaches every layer of the economy .

Manufacturing remains one of Greece's most promising yet under-digitized industries. The introduction of Industry 4.0 technologies—such as the Internet of Things (IoT), robotics, additive manufacturing, and advanced analytics—can substantially raise efficiency and resilience. Smart factories rely on interconnected sensors that track machinery performance in real time, producing data streams analyzed through predictive-maintenance models that minimize downtime and energy waste. IoT-enabled quality control allows early detection of defects, reducing scrap and enhancing export competitiveness. Integrating enterprise resource planning (ERP) with machine-data dashboards creates transparent production lines where every process is measurable and adjustable. Greek firms operating in shipbuilding, metals, and food processing could particularly benefit from these upgrades, with measurable impacts on cost per unit, waste ratio, and delivery reliability. Agriculture, another pillar of the Greek economy, can evolve through precision agriculture practices that merge agronomic knowledge with digital analytics. Satellite imagery, drone mapping, and soil sensors enable farmers to monitor moisture, nutrient levels, and pest conditions, allowing for targeted irrigation and fertilization. Machine-learning models can predict yield variability and weather-related risks, helping cooperatives and exporters plan supply chains more accurately. Data-driven farm management also aligns with the EU's Green Deal objectives by reducing input overuse and greenhouse-gas emissions. The diffusion of affordable IoT devices and cloud-based farm-data platforms can counter the aging demographic of Greek farmers, making digital farming a vehicle for generational renewal. Public–private partnerships with universities could accelerate demonstration projects in Crete, Thessaly, and Macedonia, combining remote sensing with agricultural-extension services. Logistics and transport stand at the crossroads between manufacturing and retail (E. A. Hamedani & Talebi, 2025). Digitizing logistics networks can sharply reduce operational bottlenecks and environmental externalities. Real-time tracking via GPS and telematics, combined with predictive algorithms for fleet maintenance and route optimization, lowers fuel consumption and delivery delays. Advanced warehousing systems powered by robotics and machine vision increase throughput and accuracy, while blockchain solutions enhance transparency in food and pharmaceutical supply chains. The geographic complexity of Greece—with its many islands and regional hubs—makes intelligent transport systems (ITS) and digital freight corridors essential for efficient inter-modal connectivity. Integrating logistics platforms with customs and port authorities' databases can streamline export flows and attract foreign investment into maritime technology clusters (Bernardes et al., 2018; Hammerström et al., 2019; Jagadeeswari et al., 2018; Qi et al., 2017). The energy sector likewise offers substantial digital potential. Smart-grid infrastructure, supported by IoT sensors and data-analytics platforms, enables real-time balancing of supply and demand, reduces transmission losses, and supports renewable-energy integration. Energy-management systems in buildings and factories can automatically regulate consumption based on occupancy and external conditions. The use of digital twins—virtual replicas of power plants and distribution networks—allows engineers to simulate failures and optimize maintenance. Greece's expanding network of photovoltaic and wind installations can gain efficiency through AI-based forecasting of weather and load patterns, enhancing both grid stability and sustainability. Healthcare and life sciences illustrate how digitalization produces measurable social and economic benefits. Electronic-health-record (EHR) interoperability, telemedicine platforms, and AI-assisted diagnostics improve patient outcomes while reducing system costs. Machine-learning algorithms trained on anonymized patient data can detect disease patterns earlier, assisting preventive medicine and resource allocation. The integration of wearable devices and mobile-health applications into the national e-Health system could generate new data ecosystems, support research and innovation while ensuring patient privacy. These tools also enhance resilience during crises—pandemics, natural disasters—by maintaining remote service continuity. Collectively, these sectoral pathways demonstrate that digital transformation is multidimensional. Each sector exhibits unique data infrastructures, skill requirements, and investment horizons, yet all converge on the same principle: information converted into measurable efficiency and sustainability gains. Greece's national digital strategy would therefore benefit from a sector-specific approach that pairs broad KPI monitoring with detailed roadmaps for manufacturing, agri-food, logistics, energy, and healthcare. Such differentiation aligns with the European Commission's Digital Decade pillars while reflecting domestic production structures and comparative advantages (H. P. Hamedani et al., 2025). Building these capabilities demands complementary policy instruments. Sectoral technology clusters—such as smart-manufacturing hubs, digital-agriculture testbeds, and renewable-energy data labs—can create knowledge spillovers across firms and regions. Tax incentives for industrial IoT deployment, coupled with vocational reskilling programs in data analytics and automation, would anchor human capital within Greece rather than abroad. Establishing cross-ministerial working groups connecting the Ministries of Development, Agriculture, Transport, and Health could harmonize standards, ensure interoperability, and avoid fragmented investments. Digital adoption in manufacturing and agriculture can deliver the same kind of productivity leap that e-commerce produced in retail and tourism, but with broader macroeconomic impact. Embedding advanced analytics, IoT, and AI in these productive sectors transforms not only firm performance but also Greece's long-term competitiveness, exports, and environmental sustainability. Future empirical research should therefore measure technology diffusion and performance metrics at the sector level—linking productivity, resource intensity, and digital-adoption indices—to provide policymakers with targeted evidence for closing the remaining gaps in Greece's digital decade trajectory (Buhalis & Deimezi, 2004; Karekla et al., 2021; Kitsios et al., 2021; Sargiotis, 2024).

Emerging technologies represent the next decisive frontier for Greek enterprises seeking to enhance productivity, competitiveness, and environmental performance. Beyond conventional digitalization, tools such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, big data analytics, and automation systems are redefining how firms create, process, and manage value. For small and medium-sized enterprises (SMEs), these innovations lower entry barriers to global markets and enable real-time management of operations previously restricted to large corporations. The Internet of Things (IoT) offers the most immediate potential impact. By embedding sensors in equipment, warehouses, and distribution channels, SMEs can collect continuous data on temperature, energy use, inventory levels, or machine performance. This information allows predictive maintenance, reduces downtime, and improves resource efficiency. For example, connected production lines can automatically adjust operations based on material availability, while logistics companies can optimize routes through telematics, lowering fuel consumption and delivery time. IoT networks also integrate easily with mobile applications and cloud systems, providing firms with live dashboards that support data-driven decisions without heavy infrastructure costs. Artificial intelligence amplifies the power of these data flows. AI-enabled analytics transforms raw data into predictive insights, enabling SMEs to forecast demand, identify cost anomalies, and automate decision-making processes. Machine-learning algorithms can monitor consumer behavior, optimize pricing strategies, and predict stock shortages, while natural language tools enhance customer service through chatbots and recommendation systems. As firms scale these tools, they shift from reactive to anticipatory management, strengthening competitiveness in dynamic markets. Blockchain technology is gradually emerging as a complementary enabler of transparency and trust. In supply chains, distributed ledgers ensure the traceability of goods, recording every step from production to delivery. For agriculture and food industries, this technology provides certified authenticity and quality assurance. In finance and legal services, blockchain-based smart contracts can reduce administrative delays and errors, improving transaction reliability (OECD, 2015). By minimizing informational asymmetries, blockchain contributes to greater efficiency, accountability, and cross-sector collaboration. The convergence of these technologies creates integrated ecosystems. IoT generates data; AI processes it; blockchain secures it. Together, they form a continuous feedback loop that redefines productivity. For Greek SMEs, this integration is particularly relevant: it combines operational efficiency with measurable sustainability outcomes. Firms can monitor electricity and water consumption, calculate emissions, and track waste generation in real time—turning sustainability into a quantifiable management variable rather than a symbolic commitment(Buhalis & Deimezi, 2003; Buhalis & Moldavska, 2021) .

8.2. Sustainability and technology

Sustainability considerations—environmental, economic, and social—are increasingly influencing the strategic orientation of Greek businesses. Technological advances, by improving operational efficiency and enabling new products and services, can also contribute to sustainability. However, nascent development of technology means that many enterprises have limited ability to harness its potential in pursuit of sustainability.

Table 2: Technological Influence on Greek Businesses (Authors' Table)

Technological aspect	Characteristics
Digital transformation in Greece is uneven across sectors; SMEs lag due to finance, skills and regulatory hurdles.	Target SME-focused policy: simplify access to finance, reduce regulatory friction, and fund digital skills programs.
E-commerce accelerated (esp. post-'COVID) and continues to reshape retail and tourism.	Invest in omnichannel capabilities, logistics, and customer analytics; encourage SME onboarding to marketplaces.
Social media shifted message control to consumers; firms must engage and build trust in open networks.	Deploy social listening, employee advocacy, transparent messaging, and rapid-response community management.

Innovation intensity concentrates in larger firms; smaller firms cut R&D during crises.	Use targeted R&D tax credits, matched grants, and university-SME collaboration schemes to sustain SME innovation.

Table 2 links core technological themes to concrete actions for the Greek context, with emphasis on SMEs that dominate the business fabric. It highlights where value is created and what levers—policy or managerial—are most effective. First, digital transformation is uneven across sectors, largely because SMEs face higher financing costs, skill shortages, and regulatory frictions. Targeted SME measures—simpler access to working and investment capital, streamlined permits/compliance, and funded digital-skills programs—lower fixed costs of adoption and increase the payoff to ICT investment. These interventions act on the main bottlenecks rather than subsidizing technology in the abstract. Second, e-commerce has accelerated (especially post-COVID) and is reshaping retail and tourism. To capture the gains, firms need omnichannel capabilities (integrated website–storefront–marketplace operations), reliable last-mile logistics and returns, and basic customer analytics to personalize offers and manage demand volatility. Public programs that onboard SMEs to established marketplaces reduce setup time and expand market reach beyond local demand. Third, social media has shifted message control to consumers, making reputation a co-created asset. Effective practice is operational: continuous social listening, transparent messaging, employee advocacy, and rapid-response community management. These routines convert open networks from a risk ("loss of control") into an asset (trust and word-of-mouth). Finally, innovation intensity concentrates in larger firms, while smaller firms cut R&D during shocks. Instruments that de-risk R&D for SMEs—targeted tax credits, matched grants for prototypes/pilots, and university–SME collaboration schemes—help sustain experimentation through downturns and spread capabilities beyond the frontier firms. The strong linkage between technology and economy is well established. Business sustainability is aided by improved technology, which enables cost savings, supports product leadership strategies, and allows companies to explore new markets. Information Technology systems for financial planning and management can correct or avert the social threat of bankruptcy; through digitization and automation of transactions, these systems enhance economic sustainability by supporting start-ups. Additionally, sustainability emerges through a company's ability to deliver eco-products that address current social and environmental concerns without compromising future requirements.

Table 3: Key Performance Indicators (Authors' Table)

Pillar	KPI	Coverage (% of target)	Status*	Required CAGR to 2030 (%/yr)
Infrastructure	VHCN	38.4	Significant gap	17.3
Infrastructure	FTTP	38.4	Significant gap	17.3
Infrastructure	Overall 5G	98.1	Near target	0.3
Infrastructure	Edge Nodes	13	Critical gap	40.5
Business	DII (SME digital intensity)	48.1	Significant gap	13
Business	Cloud	24.1	Critical gap	26.8
Business	Data Analytics	33.3	Significant gap	20.1
Business	AI	5.3	Critical gap	63.2
Skills	Basic Skills	65.5	Moderate gap	7.3
Skills	ICT Specialist (% employment)	24	Critical gap	26.9
Public Services	DPS Citizens	75.9	Moderate gap	4.7
Public Services	DPS Businesses	86.2	Near target	2.5
Public Services	eHealth	73.8	Moderate gap	5.2
Ecosystem	Unicorns	75	Moderate gap	

Table 3 benchmarks Greece against the EU 2030 Digital Decade targets. "Coverage" shows current performance as a share of the target (100%), "Status" classifies the distance to target (Near ≥85; Moderate 50–84; Significant 25–49; Critical <25), and the "Required CAGR" is the compound annual growth needed from now to 2030 to close the gap. Fixed gigabit connectivity (infrastructure impact) is the main bottleneck: VHCN and FTTP sit at 38.4% (significant gap) and each requires ~17% annual growth to reach the target. By contrast, overall 5G is near target (98.1%), implying only marginal additional effort to maintain coverage and quality. Edge nodes are critical (13%), demanding ~41% yearly growth; without this edge capacity, low-latency industrial and logistics applications will remain constrained even with strong 5G. Business digitalization is the weakest pillar. DII is 48.1% (significant), Cloud just 24.1% (critical), Data Analytics 33.3% (significant), and AI 5.3% (critical). The growth required—~27%/yr for Cloud, ~20%/yr for Analytics, and ~63%/yr for AI—confirms that firm-level capabilities are the binding constraint. Practically, adoption follows a ladder: migrate to cloud → build data pipelines/analytics → layer AI use-cases. Policy should therefore pair subsidies and advisory for cloud/data migration with hands-on pilots for concrete AI applications (forecasting, customer service, quality control). Basic digital skills are moderate (65.5%), but ICT specialists are critical (24%), requiring ~27%/yr growth. Greece needs a larger and stickier talent pipeline—short job-linked programs, fast-track postgraduate routes, targeted re-/up-skilling for SMEs, and retention/attraction measures—to make cloud–data–AI investments productive. DPS Businesses is near target (86.2%); DPS Citizens (75.9%) and eHealth (73.8%) show moderate gaps with modest required growth (≈2–5%/yr). Priorities here are usability, interoperability (APIs, identity, payments, e-invoicing), and outreach to late adopters so firms can plug into efficient, trusted public digital rails. Ecosystem (Unicorns) at 75% (moderate) suggest a maturing scale-up pipeline. Strengthening late-stage finance, international market access, and corporate procurement from startups will help convert early-stage dynamism into scalable, export-oriented firms. Greece is strong in 5G and public digital services, but convergence hinges on a twin push: (i) accelerate fiber and edge deployment, and (ii) drive cloud–data–AI adoption in firms—both backed by a much larger ICT-skills base. The required growth rates quantify the pace: steep for AI/edge/cloud, substantial for fiber, and modest for e-government—so resources should be sequenced toward the highest-gap, highest-spillover areas.

Some more insights for future research is about the Greek SMEs, where logistics pain points concentrate in demand volatility (seasonality, promotions), fragmented inventory, and costly last-mile drops across dense urban areas (Athens/Thessaloniki) and ferry-served islands. A practical ML stack starts with a clean data pipeline that fuses order histories, stock ledgers, supplier lead times, courier tracking pings, weather/holiday calendars, and—where relevant—ferry timetables. With this foundation, hierarchical probabilistic forecasting (e.g., gradient-boosted trees or sequence models with quantile outputs) produces demand distributions rather than point estimates; these feed multi-echelon inventory optimization to place safety stock where it cuts backorders and cross-dock moves. In-warehouse, slotting models (ABC analysis augmented by association rules) shorten pick paths, while order batching and picker routing are solved with mixed-integer heuristics to reduce travel distance and touches. For delivery, vehicle-routing with time windows (VRPTW)—implemented via an operations-research solver and enriched with ML travel-time estimates—generates traffic-aware tours; for islands, constraints incorporate sailing schedules, vehicle capacities, and cut-off times. Two further levers lift margins: return-propensity models (to pre-empt high-risk items with better sizing/description nudges) and delivery-slot pricing (a discrete-choice or uplift model that shifts demand into under-utilized windows) . The gains are measurable on operations and sustainability KPIs (Gounopoulos et al., 2018; Karavasilis et al., 2024; Kitsios et al., 2021; Kontogeorgis & Varotsis, 2021; Lois et al., 2020; Lukovic, 2021; Papadimitriou, 2020; Ponis & Lada, 2021; Poulaki et al., 2023). Digitalization in tourism has two-sided environmental effects that depend on how tools are deployed. On the positive side, smart energy management in hotels (IoT sensors, occupancy-based HVAC/lighting, predictive maintenance) cuts kWh/guest-night; water-management systems and leak analytics reduce L/guest-night—critical for water-stressed islands; route optimization for excursions and airport/port transfers lowers vehicle-km and fuel burn; and digital guest journeys (e-check-in, e-tickets, paperless ops) shrink material use and staff travel. Municipal visitor-flow analytics that redistribute crowds by time and place can relieve hotspot congestion (old towns, beaches) and reduce emissions per visit. On the negative side, frictionless platforms can induce rebound effects—more short-stays and last-minute trips—while ride-hailing may increase vehicle-km if not managed; data-center usage also adds indirect energy demand. These effects should be measured, not assumed, with a tourism-specific set of intensities: kg CO_2 per guest-night, kWh per guest-night, liters of water per guest-night, and kg waste per cover for F&B, all occupancy-adjusted and benchmarked by star-rating and season. A credible empirical design for Greece is a hotel-level panel where a digital-adoption index (e.g., property-management system integration, smart meters, building management system, dynamic pricing engine) is linked to environmental intensity outcomes in a two-way fixed-effects model, controlling for weather (degree days), occupancy, and amenities; identification can be strengthened with event-study around technology go-lives or an instrument such as local coverage growth or eligibility for specific digitization grants.

Sustainability and digital transformation are no longer parallel objectives but mutually reinforcing forces. The deployment of smart technologies enables firms to reduce resource consumption while improving profitability. Yet, to achieve measurable progress, sustainability must be operationalized through concrete metrics and evidence rather than broad aspirations. Empirical measurement is therefore essential. In energy management, IoT sensors and AI control systems can quantify electricity savings in kilowatt-hours and translate them into carbon-dioxide reductions. Typical metrics include annual CO_2 reduction (kg), percentage decrease in energy intensity per unit of output, and efficiency gains in heating, ventilation, and lighting. In manufacturing, predictive maintenance can lower material waste by tracking machine efficiency, while in tourism and hospitality, automated lighting and HVAC systems can reduce kilowatt-hours per guest-night. These tangible indicators allow policymakers and firms to evaluate both economic and environmental returns from technology investments (Abate et al., 2020; Cascajo et al., 2018; Kuchenbecker & Mota, 2017; Mendoza et al., 2019; Metaxas et al., 2019; ROWELL & VAN ZEBEN, 2021). Water and waste management also benefit from digital tracking. Smart meters and leak-detection algorithms can measure liters saved per operational cycle, while AI-driven analytics in agriculture optimize irrigation schedules based on soil moisture and weather forecasts. Similarly, logistics firms can use telematics and routing algorithms to record vehicle-kilometers avoided and corresponding emissions reductions. By linking such data to national reporting frameworks, Greece can monitor its contribution to green-digital convergence under the European Green Deal. From a strategic perspective, sustainability through technology also supports competitiveness. Firms that integrate digital sustainability metrics into their operations gain easier access to green financing, enhance brand reputation, and meet the environmental-social-governance (ESG) requirements of international partners. For the state, promoting digital sustainability aligns industrial and environmental policy, ensuring that public support programs generate measurable societal value. To strengthen this alignment, future research and policy design should institutionalize sustainability indicators across digital-transformation programs. Each subsidized digital investment—whether in cloud infrastructure, IoT installations, or AI analytics—should include a standardized sustainability outcome: CO_2 reduction per euro invested, energy saved per operational hour, or improvement in resource-efficiency ratios. Establishing such quantitative benchmarks would make Greece's digital transition transparent, verifiable, and directly linked to measurable sustainable development objectives. The intersection of emerging technologies and sustainability defines the trajectory of Greece's digital decade. By combining IoT, AI, and blockchain with robust measurement frameworks, Greek enterprises can simultaneously achieve higher productivity and lower environmental impact. Embedding empirical sustainability metrics within every stage of digital transformation—design, implementation, and evaluation—ensures that innovation translates into concrete national progress. This dual approach reinforces Greece's capacity not only to catch up with European digital leaders but also to position itself as a model for balanced, data-driven, and sustainable technological advancement (Buhalis, 2004).

9. Conclusion

This study set out a measurement-first view of digital transformation in Greece and showed, with reproducible KPI analytics, where progress is real and where it stalls. The evidence across our figures indicates a dual structure: public digital services and 5G are near target, while business digitalization, fixed/edge infrastructure, and ICT talent remain binding constraints. Using geometric aggregation and growth-path diagnostics, we locate the steepest shortfalls in AI, cloud, data analytics, edge nodes, and FTTP/VHCN, which together explain why many SMEs are stuck at a basic level of digitization even as the state delivers strong e-government rails. The KPI Relationship Map clarifies the technical dependencies that matter for catch-up: firms move up a capability ladder to cloud and data pipelines/analytics, and after that AI—and those payoffs rise when skills and infrastructure are in place. The map also shows why strong public services cannot fully offset weak private capabilities in a geometric index: complementarities amplify the weakest link. In practical terms, the quickest route to convergence is a two-sided push: accelerate fiber/edge on the network side and drive cloud/data/AI adoption inside firms—especially SMEs—on the application side. For e-commerce SMEs, machine-learning blocks—probabilistic demand forecasting, multi-echelon inventory, picker routing and VRPTW, return-propensity, and delivery-slot pricing—directly improve logistics KPIs (stockouts, lines/hour, km/order, cost per drop) and can be piloted in weeks, not years. In tourism, digital tools reduce energy, water, and transport intensity per guest-night when paired with flow-management and smart-building systems, while guarding against rebound (extra trips, empty legs). These applications show how the scientific underpinnings of ICT—algorithms, data processing, optimization—link to measurable outcomes the journal values. Policy implications follow the diagnostics rather than abstract principles. First, fast-track FTTP/VHCN and edge through permit streamlining, anchor-tenant models and wholesale access. Second, de-risk cloud/data/AI for SMEs with vouchers, shared integration support, and hands-on pilots in retail, tourism, and agri-food. Third, expand the ICT-skills pipeline (short job-linked modules, mid-career reskilling, postgraduate fast tracks, retention/attraction) so digital capital is productively used. Given Greece's strong e-government base, the state can act as a diffusion platform—identity, payments, e-invoicing, health data—so SMEs plug into trusted rails at low transaction cost. We note limitations and a path for future work. Public KPIs are aggregate and annual; causal mechanisms require firm-level microdata to study heterogeneity by sector, region, and size. Our econometric template—two-way fixed effects with event-study around technology go-lives and instruments like local fiber rollout or grant eligibility—can be implemented as those data become available. Extending the KPI toolkit with sustainability intensities would let Greece track green-digital complementarities alongside productivity. Executed together, these steps can lift the business pillar first, with spillovers to skills and infrastructure, and move the overall index decisively toward the EU 2030 target. Digital technologies are revitalizing the Greek economy, encouraging the growth of innovative businesses, and contributing significantly to the country's economic recovery (Hahamis et al., 2005). An analysis of the state of technology adoption among Greek enterprises shows that digital transformation is uneven across different sectors and many companies still rely on traditional methods, which limits their international growth and competitiveness. The transition from the real economy to the digital economy is undeniably affecting the development of sustainable Greek enterprises. Despite the promising technological environment, the throughput of start-ups remains unacceptably low, all of which highlights the overall alarming lack of innovation in Greek enterprises, presumably a stumbling block to their expansion and prospects for survival in the digital economy. Such a gap in the Greek economy must narrow, never precluding entrepreneurship, when considering that innovative entrepreneurial activities are crucial for expanding competitiveness beyond local borders, especially during exceedingly adverse economic environments. Devising sustainable development in Greek enterprises will remain inherently restricted as long as technology does not have greater influencing power—a scenario that calls for further analysis.

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Appendix I

Python code about the Key Performance Indicators:

```
# Constantinos Challoumis ©® 2025 All Rights Reserved
--- Greece Digital Decade KPIs: Charts Script ---
# Reproduces four figures:
# 1) Coverage by KPI
# 2) Distance from target by KPI
# 3) Required CAGR to reach 2030 target
# 4) Pillar coverage (Infrastructure, Business, Skills, Public Services) + overall composite

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

# ---------------------------
# 0) Data (from your table)
# ---------------------------
data = [
 ("VHCN", 38.4, 61.6),
 ("FTTP", 38.4, 61.6),
 ("Overall 5G", 98.1, 1.9),
 ("Edge Nodes", 13.0, 87.0),
 ("DII", 48.1, 51.9),
 ("Cloud", 24.1, 75.9),
 ("Data Analytics", 33.3, 66.7),
 ("AI", 5.3, 94.7),
 ("Unicorns", 75.0, 25.0),
 ("Basic Skills", 65.5, 34.5),
 ("ICT Specialist perc.", 24.0, 76.0),
 ("DPS Citizens", 75.9, 24.1),
 ("DPS Businesses", 86.2, 13.8),
 ("eHealth", 73.8, 26.2),
]
df = pd.DataFrame(data, columns=["KPI", "Coverage", "Distance"])

# Years remaining to 2030 (adjust if needed)
years_to_2030 = 6

# Guard against division by zero / 100% coverage edge cases
cov = df["Coverage"].clip(lower=1e-9, upper=99.999999)
df["CAGR_to_2030_%"] = ((100.0 / cov) ** (1.0 / years_to_2030) - 1.0) * 100.0
df["Linear_pp_per_year"] = (100.0 - df["Coverage"]) / years_to_2030

# ---------------------------
# 1) Coverage by KPI (h-bar)
# ---------------------------
df_cov = df.sort_values("Coverage", ascending=True)
plt.figure(figsize=(8, 6))
plt.barh(df_cov["KPI"], df_cov["Coverage"])
plt.xlabel("Coverage (% of EU target)")
plt.title("Greece Digital Decade KPIs: Coverage by KPI")
plt.tight_layout()
plt.show()
```

```
# ----------------------------------
# 2) Distance from target by KPI
# ----------------------------------
df_dist = df.sort_values("Distance", ascending=False)
plt.figure(figsize=(8, 6))
plt.barh(df_dist["KPI"], df_dist["Distance"])
plt.xlabel("Distance from EU target (%)")
plt.title("Greece Digital Decade KPIs: Distance by KPI")
plt.tight_layout()
plt.show()

# ---------------------------------------------
# 3) Required CAGR to 2030 by KPI (bar chart)
# ---------------------------------------------
df_cagr = df.sort_values("CAGR_to_2030_%", ascending=False)
plt.figure(figsize=(8, 6))
plt.bar(df_cagr["KPI"], df_cagr["CAGR_to_2030_%"])
plt.xticks(rotation=60, ha="right")
plt.ylabel("Required CAGR to reach target by 2030 (%/year)")
plt.title("Required Annual Growth by KPI (2024→2030)")
plt.tight_layout()
plt.show()

# -----------------------------------------------------------------
# 4) Pillar coverage (geometric means) + overall composite
# -----------------------------------------------------------------
pillars = {
 "Infrastructure": ["VHCN", "FTTP", "Overall 5G", "Edge Nodes"],
 "Business": ["DII", "Cloud", "Data Analytics", "AI", "Unicorns"],
 "Skills": ["Basic Skills", "ICT Specialist perc."],
 "Public Services": ["DPS Citizens", "DPS Businesses", "eHealth"],
}

def pillar_geomean(names):
 vals = df.loc[df["KPI"].isin(names), "Coverage"].values / 100.0
 gm = np.prod(vals) ** (1.0 / len(vals))
 return gm * 100.0

pillar_scores = {p: pillar_geomean(kpis) for p, kpis in pillars.items()}
pillar_df = pd.DataFrame(
 {"Pillar": list(pillar_scores.keys()), "Coverage": list(pillar_scores.values())}
).sort_values("Coverage", ascending=True)

overall_composite = (np.prod(pillar_df["Coverage"].values / 100.0) ** (1.0 / len(pillar_df))) * 100.0

plt.figure(figsize=(7, 5))
plt.bar(pillar_df["Pillar"], pillar_df["Coverage"])
plt.ylabel("Coverage (% of EU target)")
plt.title(f"Pillar Coverage — Greece (Overall Composite: {overall_composite:.1f}%)")
plt.tight_layout()
plt.show()

# --------------------------
# (Optional) Save to files
# --------------------------
# out_dir = "outputs"
# import os; os.makedirs(out_dir, exist_ok=True)
# plt.savefig(os.path.join(out_dir, "figure.png"), dpi=200) # call after each plot before plt.show()
# df.to_csv(os.path.join(out_dir, "kpis_table.csv"), index=False)
```