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Overcoming barriers to manufacturing digitalization: Policies across EU countries

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ABSTRACT

The digital transformation of manufacturing activities is expected to bring large societal benefits in terms of productivity and sustainability. However, uptake of digital technologies is slower than desirable. As a result, governments are taking action to try to overcome some of the barriers to adoption. However, the mechanisms through which government may act are quite diverse. In this paper, we compare the national strategies across the 27 countries members of the European Union. We map each country's initiative to 14 barriers to the adoption of digital technologies in manufacturing observed in the literature. We observe that most institutional efforts focus on providing funding, developing new regulatory frameworks related to data privacy and security, and creating human capital. Some known barriers to adoption observed at the firm level, such as the lack of off-the-shelf solutions, or the need for retrofitting old equipment, are largely overlooked. We do not find any relationship between the number of initiatives proposed by each country, and the country's existing level of digitalization. We conclude by proposing several policy recommendations, as well as directions for future research.

1. Introduction

The adoption of digital technologies is usually seen as an important factor to increase firms' productivity and innovation performance (Ardito et al., 2021; Eller et al., 2020). Digitalization may also bring in environmental benefits, derived from a more efficient use of energy and materials, and enable novel sustainable business models (Broccardo et al., 2023). However, firms' face many technological, organizational, and contextual issues along their digital transformation journeys (Jones et al., 2021). Furthermore, firms may encounter resistance from their employees, who may perceive digital technologies as a threat to their jobs (Chiarini et al., 2020). These issues are known as barriers the adoption of digital technologies and, in manufacturing industries, they include the lack of appropriate infrastructure (Karadayi-Usta, 2019) and interoperability capabilities (Pedone and Mezgár, 2018), the lack of off-the-shelf solutions (Barros et al., 2017) and qualified workforce (Stentoft and Rajkumar, 2020). Manufacturing organizations have made significant efforts to decrease the impact of these barriers when going through the decision-making process and implementation stages of adopting digital technologies, most notably in recent years after the advent of Industry 4.0 (Senna et al., 2022). Yet, some technological and contextual barriers require external action in order to be mitigated (Kamble et al., 2018).

Governments may play a critical role in helping firms overcome their barriers to digitalization, and ensuring that technologies are adopted in a socially sustainable manner (Nambisan et al., 2019). In this case, public policies should go beyond the provision of R&D funding, as a result of a market failure (Schot and Steinmueller, 2018). The main reason is that the digital transformation requires the not only the deployment of technologies within the boundaries of a firm, but also the interaction with large-scale communication and information infrastructure, in a way which conforms to existing laws and regulations (Adler-Milstein, 2021; Tijan et al., 2021). As such, public intervention is desired to foster the development of technology infrastructure, and coordination among the wide variety of stakeholders involved (Audretsch et al., 2019; Bonnín Roca and O'Sullivan, 2020).

That said, existing literature on digitalization has focused on the problem mostly from the corporate side, identifying sector-specific barriers to adopt digital technologies, and based on those, propose mitigation actions (e.g. Jones et al., 2021; Kamble et al., 2018; Tortorella et al., 2022). Some studies who have analyzed the problem from the government side, by analyzing what government is actually doing, and

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how well that matches with well-known barriers to digitalization in manufacturing organizations. For instance, Bogumil-Uçan and Klenk (2021) compared digital health policies between Austria and Germany, and explained them from the lens of the forces of advocacy coalitions. Teixeira and Tavares-Lehmann (2022) wrote a review of 19 national strategies for Industry 4.0 technologies, published between 2011 and 2017. However, none of these studies have contrasted national policies against studies focusing on barriers to adopt digital technologies in manufacturing organizations.

The purpose of this paper is to analyze the alignment between digitalization strategies and known barriers to adopt digital technologies in manufacturing. In particular, we review the current National Digital Strategies from all 27 member-states of the European Union. These national strategies cover years from 2023 up to 2030, depending on the country. We use content analysis techniques (Gioia et al., 2012; Krippendorff, 2018) to compare what are the reported policy priorities, and how they connect with proposed actions and investments. We map those plans against a list of barriers towards digital technology adoption in manufacturing (Senna et al., 2022). Our analysis reveals that there are some barriers towards digitalization which have been neglected by current policy strategies, regardless of the country. We have highlighted the initiatives currently proposed by policy strategies, while also proposing a set of policy recommendations to address the neglected barriers.

2. Theoretical background: barriers to digital transformation

The emergence of digital technologies, such as artificial intelligence (Denicolai et al., 2021) and cloud computing (Lu, 2017), has brought the promise of opportunities to improve manufacturing companies' productivity (Schumacher et al., 2016), the resilience of international supply chains (Büyüközkan and Göçer, 2018), and sustainability efforts towards a circular economy (Chauhan et al., 2022). Digitalization may lead to a reduction of production costs (Ghobakhloo and Ching, 2019), decreased delivery times (Frederico et al., 2019), as well as products and services with added value that either complement or improve the company's business model (Büyüközkan and Güler, 2020).

Despite the potential benefits of digital technologies, companies face numerous organizational, technological and environmental barriers when trying to adopt them. Firms may need to incur in high levels of investments (Kamble et al., 2018), face difficulties in defining a digital strategy (Stentoft and Rajkumar, 2020), or lack a clear understanding of the benefits to the company regarding the technology choice and its business model (Stentoft et al., 2021). Firms may also suffer a lack of management support (Isensee et al., 2020), legal issues (Shelbourn et al., 2005), or difficulties in meeting industry standards (Singh and Bhanot, 2020).

From a technological perspective, digitalization results in increased complexity and technological interdependence (Denicolai et al., 2021). This interdependence forces companies to rethink their entire infrastructure, from the setup of on-site communications to the physical placement of production equipment (Wang et al., 2016; Zahra et al., 2022). To enable the integration of the increasing number of digital devices, both at shop-floor level and at the administrative level, firm's must rely either on educated and well-trained in-house IT staff, or in partnerships with R&D institutions and service providers, since this process often involves a complexity of operating systems, communications protocols and computational languages (Cirillo et al., 2021; Frey and Osborne, 2017). However, employees may exhibit a natural resistance to these changes (Frey and Osborne, 2017).

Organizations may also face barriers which are external to the organization but affect the variables regarding the adoption process (Simões et al., 2019). Technological interdependence forces firms to establish norms for data processing and exchange with other organizations (Cichosz et al., 2020). In the early stages, standard protocols and hardware architecture models may not exist (Kamble et al., 2018; Pessot et al., 2020). Regulatory frameworks may also not exist, or be inappropriate, representing a high risk for first adopters (Asquer and Krachkovskaya, 2020; Calderaro and Blumfelde, 2022). Apart from establishing legal grounds to physical asset management, organizations now need to secure their virtual assets (Christians, 2017).

Overall, barriers towards digitalization are multiple and diverse. To analyze existing digitalization policies, we need to categorize them. To do so, we resort to Senna et al.'s (2022) classification of barriers to adoption of digital technologies, based on a review of the literature, and validated empirically. They identified 14 types of barriers, related to technological, organizational, and environmental aspects.

Table 1 contains a summary of the adoption barriers we use in this study.

3. Policy context: European Union instruments to foster digitalization

To foster the adoption of digital technologies, the European Union has been promoting and updating digitalization programmes since the mid-2010s. Fig. 1 below shows the synergies and characteristics of each of the European initiatives described in this section.

The European Commission launched in 2016 the ***Digital Single Market*** **(DSM)** initiative, to promote the digital transformation of analogical processes and the design of digital services (Schmidt and Krimmer, 2022). The DSM is supported by three pillars (Szczepanski, 2015): (i) Single Market Governance Tools – to promote e-government

Table 1
Barriers to the adoption of digital technologies. Adapted from Senna et al. (2022).

#	Barrier name	Explanation
1	Investments	Financing to develop and implement digital technologies, considering unrealized return on investments and implementation risks.
2	Adaptive Organizational and Process Modifications	Organizational changes regarding strategy, cultural and hierarchical relationships. Process modifications related to internal and external integration and automation requirements.
3	Human Capital	Continuous training, need for higher education, and digital skills development.
4	Knowledge Management Systems	Adaptation of knowledge management systems to handle real-time data flow, analytics capabilities.
5	Clear Comprehension of Digitalisation Benefits	Management's understanding of the benefits brought by digital technologies.
6	Standardization Efforts	Efforts to develop industry-wide standards, and to lower certification costs.
7	Adaptive Retrofitting Implementation	Adaptation of legacy systems into digitally-capable equipment.
8	Infrastructure	Physical structures, IT and communications infrastructure required for the enabling of real-time data exchange and analysis, operations management and decision-making.
9	Security, Safety and Privacy Issues	Cybersecurity, data privacy, and safe virtual environments
10	Lack of integration and interoperability capabilities	Combination of new and existing equipment, allowing the retrieval and exchange of data
11	Regulatory Framework	Definition of rules related to infrastructure development, virtual safety, data availability.
12	Legal and Contractual Assurances	Identification, definition and establishment of legal and contractual assurances for virtual assets
13	Off-the-shelf solutions	Development of one-size-fits-all solutions which can be integrated with distinct IT systems.
14	Digital Strategy	Definition of a holistic corporate digital strategy with concrete steps to foster technology adoption.

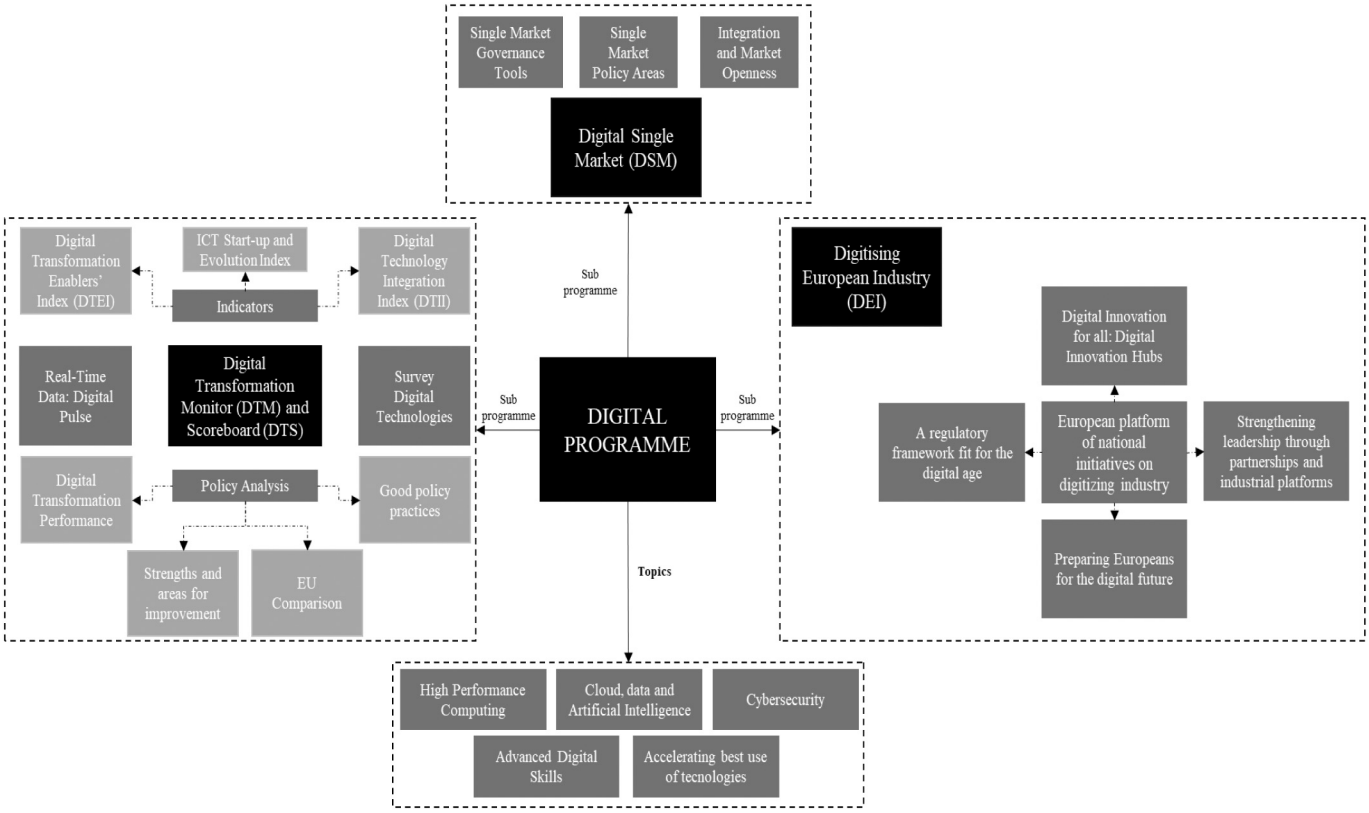

Fig. 1. DIGITAL sub programmes and topics.

solutions, provide the infrastructure for the digital citizenship initiative, and implement the "Once-Only Principle" solution for EU citizens and businesses; (ii) Single Market Policy Areas – to issue regulations and norms surrounding public procurement of goods and services in the digital age, as well as professional qualifications for government branches; (iii) Integration and Market Openness –to reduce bureaucracy for the trade of goods and services within the EU, and facilitate foreign direct investment.

The **Digitising European Industry (DEI)** initiative complements the DSM by presenting funding actions, initiatives and programmes that promote the creation of digital European communities, platforms, workforce development and regulation for the digital era (Hervas-Oliver et al., 2020). DEI consists of five pillars. The first pillar of the DEI, "*European Platform of national initiatives on digitizing industry*", targets national funding initiatives for digitalization, emphasizing the switch from manual to digital and virtual processes. The second pillar, "*Digital Innovation for all: Digital Innovation Hubs (DIHs)*", aims to establish digital communities to foster development and adoption of digital technologies across industrial sectors. The third pillar, "*A regulatory fit for the digital age*", promotes financial support, and a coordinated regulatory effort on a regional level (European Commission, 2018a). The fourth pillar, "*Strengthening leadership through partnerships and industrial platforms*", promoted large-scale public-private partnerships and digital industrial platforms to enhance EU's international competitiveness (European Commission, 2018b). Finally, the fifth pillar – "*Preparing Europeans for the digital future*" – refers to the European Commission's actions regarding workforce development and lifelong learning.

To monitor the actions and development of the DSM and the DEI, the European Commission established the **Digital Transformation Monitor (DTM) and Digital Transformation Scoreboard (DTS)** tools (Berz, 2016). DTM aims to provide concise information on national policy initiatives for digitalization of industries and companies, objectives and challenges that can be tackled by policymakers regarding the digital transformation, possible synergies between national policies of multiple EU member states, and information on the measures for the DEI initiative (Kamišalić et al., 2020). The DTS consisted of indicators, surveys, real-time data and policy analyses which allowed for benchmarking in terms of maturity levels, focus and objectives, challenges faced by the EU countries (Greco et al., 2019).

For the current Multiannual Financial Framework 2021–2027, The European Commission has launched the **Digital Europe Programme (DIGITAL)**, which intends to provide all 27 EU nations with funding opportunities to define and implement a national digital strategy for their industries, citizens and public administrations (European Commission, 2021). This European initiative aims to introduce the digital technologies and Industry 4.0 paradigms as key aspects of the European innovation policy, which promotes the successful development of high value added products and services, enabling European manufacturing industries as digital pioneers and innovators (Ciffolilli and Muscio, 2018). With an estimated budget of EUR 1.38B, DIGITAL has initiatives on five key technological areas: high performance computing; cloud, data and artificial intelligence; cybersecurity; advanced digital skills development; and accelerator for the best use of digital technologies (European Commission, 2021). DIGITAL's goals are to support the digital transformation of the EU industrial ecosystems through funding schemes, upskilling initiatives, the development of European Digital Innovation Hubs, and the twin transitions towards a green, digital and sustainable EU industry (European Commission, 2021).

4. Methods

We applied content analysis (Krippendorff, 2018) to the European National Digitalization Strategies retrieved directly from the governmental bodies for each European Union Country. Content analysis is defined as a "research technique for the objective, systematic, and quantitative description of the manifest content of a communication" (Berelson, 1952 - p.18). It is, thus, a systematic and replicable technique used for synthesizing themes, concepts and ideas out of large volumes of

textual data by converting these into categories through explicit rules of coding (Krippendorff, 2018; Stemler, 2000). Content analysis employs both qualitative and quantitative analysis of contents (Neuendorf, 2016), and that it is used to synthesize themes, concepts and ideas out of large volumes of textual data by converting them into categories through explicit rules of coding (Krippendorff, 2018; Stemler, 2000). In order to apply content analysis, researchers must be able to reduce the retrieved data into concepts that describe the observation or that allude to the research objective (Elo and Kyngäs, 2008). In our case, we employ a combination of inductive and deductive approaches to content analysis. During the inductive stage, we extract categories (known as Themes) from the raw data by understanding the common concepts. On the other hand, the deductive approach was used for our higher-level categories, which were drawn from established literature rather than from the raw data (Elo et al., 2014).

Our objective is to identify how governments are currently tackling barriers to digitalization in EU countries, to identify gaps in current strategies based on existing literature, and discuss how these policy initiatives might be improved. We included barriers or initiatives on our study following four non-exclusive criteria:

1. Barriers had to fit the definitions and scope as described in Section 2 of our study;
2. Barriers that did not fully fit the definitions and scope described in Section 2 but fulfilled a part of a given barrier were included as "sub-barrier";
3. Policies formulated as initiatives had to tackle the identified barriers;
4. Policies had to be currently implemented or have a set implementation date in one of the EU member states.

4.1. Data sources

We collected data from 31 documents covering the national digital strategy of the 27 EU countries (Table 2). Most documents were retrieved directly from the European Commission's Digital Skills and Jobs Platform – European Initiatives' section (European Commission, 2019), which is a repository for the 27 EU nation's digital strategy. Some of the documents focused solely on the governmental actions towards enhancing jobs and digital skills, so we performed additional searches to find their industrial strategy (Agence du Numérique, 2018; Czech Republic, 2018; Deloitte PT, 2016; Hungary, 2020; Italian Government, 2020; Netherlands, 2019; Republic of Croatia, 2017; Republic of Latvia, 2021; Republic of Poland, 2022; República Portuguesa, 2018). As a result, some countries were evaluated through more than one document. 18 documents were originally in English, and for the remainder we used Google Translator® to translate the original language to English (UK). Given that the time period covered by the 31 documents differed, to maintain consistency across our data sources, we focused only on policies presented until August 2022 and proposed until 2023, year when two of the strategies (Netherlands and Sweden) expired.

4.2. Data analysis

To identify barriers to digitalization and policy initiatives across our data sample, we used of (Gioia et al., 2012) coding technique. The authors propose three levels for coding documents towards achieving comparable results: first order concepts, second order themes and aggregate dimensions. First order concepts are either extracted in-vivo from the documents or are given a code in order to signify the closest-to-source level of information possible. The second order themes are thematic categories used to aggregate similar first order concepts so that all similarities between different codes are grouped, while their discrepancies are noted. Finally, if necessary, aggregate dimensions are used to group second order themes so that all similarities on a given field are highlighted while presenting the possibility for highlighting

Table 2
Documents used in our analysis.

Acronym (ISO, 1998)	Nation	Document	Publishing year	Period covered	# Pages
AT	Austria	Digital Roadmap Austria (Republic of Austria, 2016)	2016	2025	45
AT	Austria	Digitalisation Report: Now for Tomorrow – Digitalisation growth for futureproofing (Republic of Austria, 2021)	2021	2030	74
BE	Belgium	Flanders in Transition: Priorities in Science, Technology and Innovation Towards 2025 (Flemish Council for Science and Innovation, 2014)	2014	2025	67
BE	Belgium	Digital Wallonia: Digital Strategy for Wallonia (Agence du Numérique, 2018)	2018	2025	9
BU	Bulgaria	Digital Bulgaria 2025 (Republic of Bulgaria, 2019)	2019	2025	44
CY	Cyprus	Digital Cyprus 2025 (Republic of Cyprus, 2019)	2019	2025	18
CZ	Czech Republic	Innovation Strategy of the Czech Republic 2019–2030 (Czech Republic, 2018)	2018	2030	28
DE	Germany	Digital Strategy 2025 (Federal Government of Germany, 2016)	2016	2025	60
DK	Denmark	Digitalisation that lifts society: the common public access digitization strategy 2022–2025 (Government of Danish Regions, 2022)	2022	2025	36
EE	Estonia	Estonia's Digital Agenda 2030: Development agenda of the field (Republic of Estonia, 2021)	2021	2030	54
EL	Greece	Digital Transformation Bible 2020–2025 (Government of the Hellenic Republic, 2021)	2021	2025	422
ES	Spain	Digitāl Spain 2025 (Government of Spain, 2022)	2022	2025	45

(continued on next page)

Table 2 (*continued*)

Acronym (ISO, 1998)	Nation	Document	Publishing year	Period covered	# Pages
FI	Finland	Finland's digital compass (Government of Finland, 2022)	2022	2030	80
FR	France	Digital Transition Strategy 2021–2025 (AFD, 2021)	2021	2025	32
HR	Croatia	National development strategy of the Republic of Croatia until 2030 (Republic of Croatia, 2017)	2017	2030	154
HU	Hungary	National Digitalization Strategy 2021–2030 (Hungary, 2020)	2020	2030	133
IE	Ireland	Ireland's Industry 4.0 Strategy 2020–2025: Supporting the digital transformation of the manufacturing sector and its supply chain (Government of Ireland, 2019)	2019	2025	36
IT	Italy	National Recovery and Resilience Plan: Next Generation Italia (Italian Government, 2020)	2020	2026	273
LT	Lithuania	Lithuanian Industry Digitisation Roadmap 2019–2030 (Republic of Lithuania, 2019)	2019	2030	17
LU	Luxembourg	Digital Luxembourg Progress report: the evolution & the movement (Grand Duchy of Luxembourg, 2020)	2020	2025	35
LV	Latvia	Digital transformation guidelines for the year 2021–2027 (Republic of Latvia, 2021)	2021	2027	142
MT	Malta	Mîta Strategy 2021–2023 (Mita, 2021)	2021	2023	64
NL	Netherlands	Dutch Digitisation Strategy 2.0 (Netherlands, 2019)	2019	2023	52
PL	Poland	Digitization of the Chancellery of the Prime Minister (Republic of Poland, 2022)	2022	2029	19
PT	Portugal	Portugal Digital – Moving forward. Moving with a purpose: Portugal's Action Plan for Digital Transformation (República Portuguesa, 2020)	2020	2030	68
PT	Portugal	Portugal INCoDe.2030: National Digital Competences Initiative e.2030 (República Portuguesa, 2018)	2018	2030	28
PT	Portugal	Portugal i4.0 (Deloitte PT, 2016)	2016	2030	52
RO	Romania	Romania's Sustainable Development Strategy 2030 (Romanian Government, 2018)	2018	2030	111
SI	Slovenia	Slovenian Development Strategy 2030 (Republic of Slovenia, 2017)	2017	2030	72
SK	Slovakia	2030 Digital Transformation Strategy for Slovakia: Strategy for transformation of Slovakia into a successful digital country (Slovak Republic, 2018)	2018	2030	78
SW	Sweden	Smart industry – a strategy for new industrialisation for Sweden (Government Offices of Sweden, 2016)	2016	2023	40

discrepancies between very different aspects (Gioia et al., 2012). Table 3 presents an example of the coding technique applied to the barrier "Clear Comprehension of Digitalisation Benefits".

In our analysis we have considered barriers and initiatives found in the documents to be our first order concepts and second order themes, when necessary. We then connected these first and second order themes to the 14 barriers to digitalization proposed by Senna et al. (2022), which became the aggregate dimensions of our coding structure.

We used the software MAXQDA to facilitate the coding process. The final coding structure resulted in 125 codes and 3924 coded segments, with two different coders, 14 barriers, 17 sub-barriers and 94 policy initiatives. The coding of each document was revised by at least two different authors, and the final coding structure went through several iterations until there was consensus among all members of the authorship. Table 4 below displays the summary of the coding structure for each barrier, while Appendix A the full list of barriers, sub-barriers,

Table 3
Example of coding technique applied to barrier "Clear Comprehension of Digitalisation Benefits".

First-order concepts (retrieved in-vivo)	Second-order themes	Aggregate dimension
(CZ) Prepare society for trends such as IoT, AI, BigData, new types of human-machine interface, etc. (DE) To give SMEs can have access to broad knowledge of ICT solutions, we will expand and intensify our consultation services with Digitisation Guides (Digitalisierungslotsen). We will utilise all of the assistance programmes for SMEs (see Item 6: New business models for SMEs) in order to raise awareness, provide information and finance investments. (MT) Implement technological solutions to enable Government to make better use of aggregated and linked data as a resource for strategic and operational decision making. (SK) Create opportunities for the first implementations of the above technologies and promote the benefits of their use. (LV) For the full use of the opportunities of the digital economy, it is necessary to promote awareness and understanding of the use of digital opportunities by merchants, to provide consultative support to merchants for the practical use of digital opportunities, incl. to promote the use of e-commerce.	Promote awareness of IoT benefits	Clear Comprehension of Digitalisation Benefits
(LV) For the full use of the opportunities of the digital economy, it is necessary to promote awareness and understanding of the use of digital opportunities by merchants, to provide consultative support to merchants for the practical use of digital opportunities, incl. to promote the use of e-commerce	Development of Smart Devices	
(NL) Smart Industry field labs and hubs • Education and research help entrepreneurs innovate • Experimentation with digital technology • Participation in innovation projects • Assistance in finding suitable funding • 550 businesses active at 41 field labs • 5 hubs for regional cooperation (MT) Implement projects with innovative solutions based on digital technologies, both upon client request and as part of MITA's product development. (DE) Investments in digital technology must be made more attractive with tax deductions. Investments in software and digital technology make a valuable contribution to company innovativeness. In order to accommodate the fact that investment cycles are becoming shorter and shorter all the time, depreciation schedules for hardware and software and for all digital technology devices should be reduced to a maximum of three years. (BE) Smart Devices Incorporating electronics and software into products makes these products 'smart'. Such smart devices use sensors to autonomously gather, share, analyze and interpret information and then make decisions that lead to action. In this manner, smart devices become aware of themselves, their environment and their user. The development of these smart products offers real prospects for innovation and valorisation in traditionally strong sectors.		

Table 4
Summary of the coding structure.

Barriers (# coded segments)	Sub-barriers	Initiatives	Countries
Investments (337)	1	11	AT, BE, BU, CY, CZ, DE, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LV, MT, NL, PL, PT, RO, SK, SW
Adaptive Organizational and Process Modifications (32)	0	4	AT, EE, EL, ES, FR, HR, HU, IE, SK, SW
Human Capital (822)	6	21	AT, BE, BU, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, NL, PL, PT RO, SK, SI, SW
Knowledge Management Systems (40)	0	1	AT, BE, CZ, ES, FI, LT, LV, MT, NL, PL, RO, SK, SI
Clear Comprehension of Digitalisation Benefits (28)	0	2	BE, CZ, DE, IE, LT, LV, MT, NL, PL, SK
Standardization Efforts (76)	0	3	AT, CY, CZ, DE, DK, EE, EL, FI, HU, IE, LU, LV, MT, SI
Adaptive Retrofitting Implementation (2)	0	1	IE
Infrastructure (593)	5	10	AT, BE, BU, CY, CZ, DK, DE, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, MT, NL, PL, PT, RO, SI, SK, SW
Security, Safety and Privacy Issues (337)	2	2	AT, BE, BU, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IT, LU, LV, MT, NL, PL, PT, SI, SK
Integration with existing technology (47)	0	2	BE, BU, CY, CZ, DE, EE, EL, ES, HU, IE, LT, LV, MT, PL, PT, SI, SK, SW
Regulatory Framework (1156)	0	28	AT, BE, BU, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, MT, NL, PL, PT, RO, SI, SK, SW
Legal and Contractual Assurances (75)	2	2	AT, CZ, DE, DK, EE, EL, ES, FR, HU, LT, LU, LV, MT, NL, PL, RO, SK, SW
Off-the-shelf solutions (1)	0	0	BU
Digital Strategy (378)	1	7	AT, BE, BU, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, MT, NL, PL, PT, RO, SI, SK, SW

initiatives, number of coded segments, and countries pertaining to each topic.

5. Findings

Table 5 shows whether a certain national strategy covers a particular barrier to digitalization. In general, we can see high variability in the number of barriers covered per country. Some countries like Austria, Germany, Latvia or Lithuania cover most of the barriers, while countries such as Belgium, Finland, and Portugal, cover only three. The barriers covered by most countries are investments (23 countries), workforce development (22 countries) and the need for infrastructure (22 countries). Conversely, the three barriers covered by the least amount of countries are the lack of off-the-shelf solutions (1 country), retrofitting implementation strategies (2 countries), and knowledge management systems (4 countries). In the following subsections, we synthesize how the different countries propose to tackle each of the barriers to digitalization.

5.1. Investments

This barrier was mentioned by 23 out of 27 nations. However, the mechanisms envisioned by European nations to tackle this barrier are not all the same. Some nations chose to focus on the creation and development of attraction mechanisms for foreign investment and entrepreneurship development (CY, CZ, HU, HR, LV, PT, SW, SI). Others aimed on having a more robust funding initiatives schemes that encompass platform development (DE, EL, IT, NL), digital education (FR, IE, EE, LT), sustainability initiatives (EE, SW), standardization (AT, DE, EL, IE), and digital awareness (CZ, DE, FI, EE, PT, RO). Regarding the initiatives for platform development, Austria set forth a start-up enabling package that considered "*Risk capital bonus of 20% for investors to encourage investment in innovative start-ups; Increase in seed funding from AWS (Austrian Business Service) and allocation of the AWS Business Angel Fund*". Moreover, the package also considers the first stages of development by "*Funding for non-wage labour costs for the the first three employees of innovative start-ups*". Greece has a different approach and intends to establish a *Content Moderator* platform responsible for integrating open data exchange standards, provide a "*real information system, supported by a level of business logic (e.g. in the form of rules and processes)*." The platform allows companies to exchange information through a *Content Broker* in a bid to make the process more secure, easy to use, coherent and collaborative. It will also be integrated with Public Administration open data information in order to reduce the bureaucratic process (EL).

Most countries opted to include initiatives related to innovation (18 countries) and infrastructure (17 nations). Dedicated R&D funding and taxation is mentioned by 10 countries (BU, CZ, DE, EE, EL, IE, IT, LV, SK, SW). For instance, the Czech government is looking to update the legislation to provide considerable tax deductions (CZ). Likewise, the German government will introduce R&D tax breaks for firms with less than 1000 employees in the form of tax allowances which can bolster the initial stages of these companies' development (DE). Alternatively, Ireland wants to make use of existing State programmes both to provide direct RD&I grant supports through the governmental branches, and to promote the "*Future Growth Loan Scheme*", which sets a framework for enabling organizations' initial stages of development (IE).

5.2. Adaptive organizational and process modifications

Only 8 countries mentioned this barrier. To address this concern, the initiatives found in the national strategies are far and without a consensus. Some digital strategies elected to focus on initiatives for quality assurance of Information and Communication Technologies' implementation (EL, HU, SK), while others looked into providing changes to internal processes and adapting business models to accommodate for the emerging digital technologies (IE, HR, RO, SW). Two nations – Austria and Estonia – have presented digital strategies that combine these sets of initiatives with more cultural-driven actions. They have proposed work-from-home policies for organizations where non-essential workers can have more flexible hours, as well as constant educational strategies to dissipate aversion feeling for technology change – known as change acceptance initiatives (AT, EE).

5.3. Human capital

The lack of human capital was one of the most prominent barriers, with 22 countries mentioning it. The national strategies describe the need for ICT competencies, continuous training, and a digital education infrastructure targeting the Science, Technology, Engineering and Mathematics (STEM) system, especially for underrepresented groups (15 nations). Some strategies also depict the lack of working experience from tutors regarding online teaching and learning methods (AT, DE, HU, LV, RO), the lack of support for learning structuring (AT), and the lack of future job stability (SK, SW).

To address this issue, the majority of nations have focused on a group of initiatives that are similar in nature (20 nations): (i) the focus on digital inclusion and digital literacy from early school years and for the elderly; (ii) the development of digital skills through educational programmes that target multidisciplinary components and the fusion of elementary topics into digital-driven solutions; (iii) and the continuous training of the workforce through recurring training sessions on emerging technologies in partnership with digital education organizations, innovation hubs and research and development centres. Additional initiatives include, for instance, the incentive of quality-of-life improvement activities off-work and the creation of high-quality jobs with high value added (SI). Also, initiatives concerning the awareness of digital skills through promoting the benefits of training activities and constant self-improvement are of interesting note (AT, CZ, DE, EL, IE, HR, HU, LV, PT), likewise the initiatives for increasing minorities participation in the digital working space (PT). There are also initiatives to address the possibility of expanding distance learning and the renewal of the educational curriculum to better represent the ratio of students that might elect this form of education in the future (AT, DE, EL, LU, LV, PT).

With regards to firms, several countries are concerned about the retention and attraction of talents (BE, BU, CZ, DE, HR, HU, LU, PT, RO, SK, SW), as well as the incentive to demographic renewal and foreign workforce attraction (CZ, DE, DK, EE, EL, HR, LU, LV, NL, SI, SK, SW). Employability is also a prominent topic within the national strategies (14 countries), albeit usually described in a vague manner, without specifying concrete actions to decrease unemployment rates.

5.4. Knowledge management systems

An important aspect of the adoption of digital technologies is the surrounding systems that need to be integrated in order to provide a continuous flow of data and information, especially when considering real-time operations (Stentoft et al., 2021). However, only four countries address this topic, and only one initiative is mentioned, which relates to public data availability for data-driven services provided by the national governments, which are in line with their strategies to transition into e-governments and digital governments altogether – mentioned by 12 nations. Related topics mentioned in other documents include the availability of data through public access servers (AT, ES, FI, NL, PL), the use of open-source solutions with public repositories (LV, SI), public repositories for scientific publications and R&D results funded by governmental agencies (AT, CZ, PL, SK).

5.5. Clear comprehension of digitalisation benefits

Only five national strategies mention the issue (CZ, DE, IE, LV, NL).

Table 5
Summary of barriers mentioned in the European National Digital Strategies.

Barriers contemplated in the National Strategies															
	[1] Investments	[2] Adaptive Organizational and Process Modifications	[3] Human Capital	[4] Knowledge Management Systems	[5] Clear Comprehension of Digitalisation Benefits	[6] Standardization Efforts	[7] Adaptive Retrofitting Implementation	[8] Infrastructure	[9] Security, Safety and Privacy Issues	[10] Integration with existing technology	[11] Regulatory Framework	[12] Legal and Contractual Assurances	[13] Off-the-shelf solutions	[14] Digital Strategy	Total
Austria	X	X	X	X		X		X	X		X			X	9
Belgium	X							X						X	3
Bulgaria	X		X										X	X	4
Croatia	X		X						X		X				4
Cyprus	X		X			X		X	X	X	X			X	8
Czech Republic	X		X		X	X		X	X		X	X		X	9
Denmark			X			X		X	X			X		X	6
Estonia	X	X	X			X		X	X		X	X			8
Finland	X		X						X						3
France	X	X	X					X	X		X			X	7
Germany	X		X		X	X		X	X		X	X		X	9
Greece	X		X			X		X	X	X	X	X		X	9
Hungary	X	X	X					X	X	X	X	X			8
Ireland	X	X	X			X	X			X	X			X	8
Italy	X							X	X		X			X	5
Latvia	X		X	X	X		X	X	X	X	X	X		X	11
Lithuania	X		X	X	X			X		X	X	X		X	9
Luxembourg			X			X		X	X		X	X		X	7
Malta	X					X		X	X		X	X			6
Netherlands	X							X	X			X			4
Poland	X				X			X	X	X		X			6
Portugal	X		X											X	3
Romania	X		X	X				X			X	X		X	7
Slovakia	X	X	X					X	X			X		X	7
Slovenia			X			X		X	X	X				X	6
Spain		X	X					X	X			X		X	6
Sweden	X	X	X					X		X	X	X		X	8
Total	23	8	22	4	5	11	2	22	20	9	17	16	1	20	

One of the initiatives regards the expansion and intensification of consultation services with digitalisation guides in order to enhance SMEs and merchants' access to broad knowledge on ICT solutions (DE, LV). Another interesting initiative regards the creation of Smart Industry Field labs and hubs where entrepreneurs would receive education and research for digital innovation. Field labs members are able to experiment with hands-on digital solutions, participate in co-creation innovation projects, and have assistance in securing funding (NL).

5.6. Standardization efforts

Only 11 countries, less than half, mention this topic. Some focus on promoting communication process standardization efforts, much in synergy with their own communication infrastructure development (AT, CY, DE, DK, EE, FI, LU, MT, SI). Others are directing efforts towards the Industry 4.0 standards initiatives, mostly through widespread information and use of the standards already in place through the Reference Architecture Model for Industry 4.0 – RAMI 4.0 (Hernández et al., 2020; AT, CZ, DE, DK, EE, EL, IE, HU, LV). Apart from these, there are only two nations – Czech Republic and Ireland – which are enforcing initiatives to promote educational standards regarding the online and remote learning for new generations (CZ, IE).

5.7. Adaptive retrofitting implementation

The only nation that has considered efforts for the adaptive retrofitting implementation is Ireland (IE). On their document, the Irish Government looks to create and promote access to demonstrator facilities where entrepreneurs can carry out hand-on experimentation, identify and address technical challenges during the implementation stages including issues related to the integration of digital technology into legacy systems. In essence, it looks to promote a safe laboratory environment for testing and full-proofing solutions that tackle the seamless integration of multi-generation equipment, and, in-so-doing, enhance the circular factor and sustainability of the production cycle (IE).

5.8. Infrastructure

The lack of technological infrastructure is mentioned by 22 countries. This barrier was prominent in discussions surrounding telecommunications (17 countries), the promotion of smart cities (11 countries), and the transformation of a backbone transportation network (9 countries). To tackle these concerns, EU countries have drawn several initiatives. By far, the most prevalent initiative regards the development and establishment of data-related infrastructure and of public digital infrastructure – present in all 22 nations. Specifically, the initiative regards the creation of public databases for public data access that can aid in infrastructure optimization, either through the resource route (i.e. real-time energy distribution optimization, use of materials), or through the delivery/transportation route (i.e. optimization of routes, public transport information, public delivery companies information). Apart from these, there are also initiatives regarding setting up accelerators and incubators targeting infrastructure companies (AT, DE, EL, ES, IE, HU, MT, NL), development of an online platform for entrepreneurship fostering and contact sharing (ES), and the inclusion of adaptive risk management strategies regarding building and maintaining public infrastructure (NL, SK). Finally, the Netherlands also aims to create a residence scheme for essential foreign employees (i.e. non-EU countries' citizens) as part of promoting demographic renewal and managing city-wide transport that optimizes time-to-office (NL).

5.9. Security, safety and privacy issues

Issues related to the identification verification, authorization procedures and protocols, privacy and system access are mentioned by 20 countries. Specifically, two detailed concerns were pointed out: (i) lack of trust on digital solutions security (15 countries); (ii) and lack of consumer-oriented data sharing safety/security. To tackle both, governments depict initiatives targeting data security on both ways of the business-to-government link – 19 nations. On this matter, this Austrian government looks to set up the "once only" principle – all relevant data will only be submitted once to the authorities and will automatically be available for download on a range of official channels through a unique communication connection (AT). In line with this approach, the Danish government will update their policy to "*allow citizens to easily get an overview of, give and revoke consent for data to be shared and used*" (DK). Many nations are of a similar mindset, albeit not so specific, with a common objective: to promote trust in government-related information sharing, on the availability and security of data, and in the administrative safety of private identities (EE, EL, FI, FR, HU, LV).

Another initiative, from the French government, regards the development of a digital identity system in partner countries with focus on controlling the significant risks that these interconnected sharing systems may pose for individual freedoms (FR). Such initiative goes in accordance with the "*agreement between the European Commission and the USA on a EU-US privacy Shield for transatlantic data communication*", which ensures privacy and protection of trade secrets and national security, issue also considered by the German government (DE). Combined with this approach, the Belgian region of Flanders is looking to establish advanced encryption technology for intellectual property protection, due to the region's strong scientific position and solid international reputation (BE). Bulgaria is establishing the foundations to provide a "*modern framework and a stable environment*" for a national cybersecurity system. A novel approach on the topic comes from the Dutch. Their National Strategy details an implementation of five projects for citizens, business, institutions and government agencies. These projects will increase identity safety, restructure the pensioning system, provide transparent, reliable and fair supply chains for logistics, and promote easiness of credential verification for education institutions (NL).

5.10. Integration with existing technology

This barrier is mentioned by 18 countries. When it comes to sets of initiatives, the national strategies focus on two approaches: (i) scientific (RD&I) infrastructure development (BU, EE, EL, SI, SK, SW); and (ii) Collaboration initiatives with Factories of the Future (FoFs; BE, CZ, DE, EL, ES, HU, IE, LV, MT, PL, PT, SI, SK).

The development of scientific infrastructure will serve as a testing facility for integrating solutions before their implementation into the factories' shop-floors. Additionally, as pointed out by the Bulgarian national strategy, the "*construction, maintenance and access to modern research infrastructures guarantee high quality of conducted research, (…) promotion of entrepreneurship through the possibility of generating new knowledge and its transfer in the country's economy*." (BU). Moreover, the Bulgarian government points out the relevance of the electronic scientific infrastructure, which is formed by a digital laboratory where researchers and practitioners can share common solutions both in person and through remote access (BU). The Greek national strategy goes a step beyond, stating that these scientific infrastructures can also serve as repositories for testing grounds both with manufacturing data and with public administration information, in a bid to integrate not only the equipment within a shop-floor but also the information flow between the multiple levels of the organizations' value chain (EL). Complementary, the Estonian national strategies envisions the use of these digital laboratories for research on cybersecurity-related research and development, greatly enhancing the security and safety of the integration process during the implementation stage (EE).

Building on the scientific infrastructure initiatives, the national strategies also consider a set of collaboration initiatives with Factories of the Future, which are manufacturing shop-floors with enhanced digital technologies and capability of expansion for a more virtual approach to

manufacturing (IT, BE). These initiatives look to upgrade existing factories to accommodate for the requirements of a digital manufacturing environment. In line with this thought, Belgium regions are promoting investment initiatives to upgrade the manufacturing factories, claiming outcomes in the form of significant reduction of resources and energy consumption, leading to significant decrease in operational costs and enhancing the "*flexibility of the Flemish production apparatus, so that it can repost to market dynamics with twice the speed*." (BE). On a similar approach, the Czech initiative mentions the establishment of a system to uphold resource optimization and environmental protection. With a more organizational mindset, the Greek initiative considers a governance model to shape and institutionalize "(…) *interoperability between co-competent services and bodies* (…)", in a bid to promote better information exchange both within companies and between business and governmental agencies. The Portuguese government, through the PSA Mangualde Consortium, aims to develop technologies and solutions to kick-start the intelligent transformation of factories, focusing on collaborative robots, advanced tracking and tracing systems (e.g. virtual and augmented realities), autonomous guided vehicles and digital manufacturing production cells.

5.11. Regulatory framework

The lack of a regulatory framework devised to provide legal safety, intellectual property and innovation (cyber)security is mentioned by 17 countries. The actions proposed by the national strategies differ on their scope. The first topic of focus of the initiatives regards the use of digital technologies to foster circularity (BE, DE, DK, HR, RO). On this, Belgium proposed that circularity can be achieved through a set of regulations to promote design standards for key manufacturing sectors with this principle as core concern. Similarly, the Croatian government includes incentives for less carbon-intensive industries that can objectively prove their sustainability contributions through transforming their manufacturing facilities (HR).

Another regulatory framework focus refers to cooperation initiatives. These initiatives are usually described as cooperation efforts for RD&I between European members, normally fostered through European framework programmes such as the Horizon 2020 and Horizon Europe (AT, DE, ES, HR, PT), as well as other European actions such as the Electronic Components and Systems for European Leadership (ECSEL), ERA-Nets, EUREKA and Eurostars initiatives (AT, PT). Additionally, some national strategies look to establish their networks off-seas, such as the Austrian OPEN AUSTRIA initiative which seeks to establish Austrian companies in the Silicon Valley (AT) and the Estonian effort to "*promote the cross-border and global exchange of (personal) data between countries (…) and activities (…) [to] advance and ensure the global development and use of human-centric and reliable technology*." (EE, MT). Complementary, other countries looked to provide a more robust internal framework targeting strategic alliances between European universities (BU, CZ, DE, ES, FI, HR, IE, NL, PT, PL, SW). These initiatives are supported by public multi-lateral agreements of information sharing among the governments which help in fostering knowledge sharing and dissemination, especially between leaders and followers of the digital transformation (CZ, DE, IE, PT, SW). Another cooperation initiative is the "*organisation of thematic technology missions of Czech experts to countries with cooperation potential*", which can either be within the European community or internationally, and function as scouting parties for the establishment of new bi-lateral/multi-lateral agreement arrangements (CZ, IE). The Slovakian government provides a more detailed approach by looking to amend their legislation, particularly Act No. 311/2001 of the Labour Code, in such a way as to "*simplify the employment rules for entrepreneurs operating in several EU countries in the digital economy, as well as the rules of taxation and regulation compliance for a faster expansion of Slovak businesses to other EU countries*" (SK).

Another set of initiatives focus on fostering innovation. One example of a very prominent initiative repeated in 15 national strategies is the need to develop specific measures to ensure transparency and data protection in individual pricing processes following the General Data Protection Regulation (GDPR) act. This is usually combined with an initiative to modernize the Internet regulation policy, with particular focus on cybersecurity law. One example of such initiative is the Austrian proposal of enabling "*notification obligations for operators of essential services, CSIRTs, definition of international cooperation and also national and international contact points*" (AT). Another initiative that accompanies the same mindset if the French proposal to draft a regulation to identify and authenticate citizens for public access services, achievable through "*digital identity systems in partner countries, focusing on controlling the significant risks that these systems pose for individual freedoms*" (FR). Complementary, the Latvian government looks to establish a regulatory act in accordance with their Digital Technology Management Law, and which must "*include the requirement that before the creation of any ICT service, state authorities are obliged to identify its potential cybersecurity risks by performing a cybersecurity risk analysis*" (LV). The Latvian government requires "*set of measures should be such that it ensures adequate security and confidentiality of personal data*", going even further by detailing that such personal data processing should happen under a technologically neutral manner (LV). Luxembourg has implemented the "*MyGuichet.lu*" platform which corresponds to these expectations given its foundation on a regulatory act for household property laws that are valid both in the physical environment as well as in their digital and virtual forms (LU). The Portuguese set of initiatives focus not only on the intellectual property rights of products and services, but also in regulating public administration and business' proceedings regarding continuous training of their workforce with respect to adequate cybersecurity measures (PT). Additionally, the Portuguese Action Plan for Digital Transition drafts an initiative to reduce legislative and bureaucratic barriers to the free flow of data and the development of an ethical data usage guide, in accordance with the EU Regulation 2018/1907 of the European Parliament and Council, as well as the "*transposition of the European Directive 2019/1024 on open data and the re-use of public sector information*" (PT).

A last topic within the regulatory framework is the establishment of the electronic government, also known as the digital government. The initiatives on this topic refer to the creation of digital identities, such as the ID Austria (AT), as well as promoting the optimization, digitization and modernization of public administration and judiciary (AT, BU, CZ, DE, EE, EL, ES, HU, IT, PL, PT). The core concern is to provide a digital environment for citizens as a "one stop solution", where a wide array of access channels will be available, from the personal identification suite, standardization norms and procedures, citizen data regarding public services (to the extent of law, which usually exclude the criminal act and other information safeguarded by confidentiality terms), public administration records and open data repositories. Moreover, it will serve as a platform to access third party services through a safe and comfortable digital government platform.

5.12. Legal and contractual assurances

Apart from the regulatory framework, the adoption of digital technologies also requires a set of legal and contractual assurances with particular focus on virtual assets, both regarding the products and services, as well as the production processes. This barrier is mentioned by 18 countries.

The main obstacles observed within the national digital strategies are the lack of e-commerce legal assurance (DE, EL, LU, PL, SK), and the lack of digital information sharing amid peers (AT, DE, DK, EE, EL, LT, MT, NL, SK). The German national strategy focus on issues related to cross-border e-commerce legal obstacles and their effect on the availability and access of private individuals and companies to a larger assortment of goods and services at lower prices (DE). On a similar note, Luxembourg notes the recent online market development and their prominent role during crisis and local disruptions, particularly during the COVID-19

pandemic (LU). To this end, a few countries are promoting initiatives to establish legal frameworks for online markets and smart contract sharing through digital platforms (EL, LU). An example of such initiative comes from Greece, in the form of a pilot platform that is supported by Electronic Catalogues (eCatalogues), Framework Agreements and Dynamic Purchasing Systems, with intent on establishing Electronic Stores (eShops) and Electronic Markets (eMarketplaces) (EL). Another similar solution comes in the form of providing legal assurances for novel electronic payment methods such as the use of Near Field Communication contactless solutions (HU, NL, PL), which require additional guarantees in the backend portion of the transaction in order to ensure that all financial information is shared between the parties during a transaction process in a seamless, fast, and easy to use fashion.

Our data also reference difficulties regarding digital information sharing. The main obstacle on this topic regards the creation of an all-access, open data information platform that is safe, secure, and provides high levels of privacy, while also allowing the access to individuals and companies when conducting their business amid peers (DE, EE, NL, SK). Possible solutions to this issue arise from initiatives regarding the establishment of a Digital Single Market on a national level, which would function as a centralized information hub for business creation and open data availability (AT, EE, EL). Complementary to this initiative is the action to revise the current telecommunication regulations, which must "*include flexible approaches in selecting regulation instruments, creating investment incentives for broadband deployment, appropriate use of (…) over-the-top services (OTTs) [and] a minimum level of harmonisation of consumer rights* (…)" (DE, EL). Another initiative in a similar mindset is the development of legal frameworks targeting the integration of national industries to the international value chains (LT), and the strengthening of intellectual property protection laws (CZ). In a similar fashion, Malta has proposed initiatives targeting the creation of a "*comprehensive information security framework to uphold the confidentiality, integrity and availability of Government's digital assets while enhancing cybersecurity at a national level*." (MT). Luxembourg proposed the *Infrachain* initiative, which considers the use of smart contracts – virtual contracts with legal bindings that are automatically amended for each new transaction – to promote the establishment of legal framework for the digital business era.

5.13. Off-the-shelf solutions

There is only one country mentioning this problem, Bulgaria. The document states the need to have more coordinated and efficient ICT solutions for industries, particularly the "*ready-made solutions to be adapted in favor of increasing productivity*." (BU). Despite identifying the issue, the national strategy does not provide a concrete initiative to overcome this barrier.

5.14. Digital strategy

The lack of a digitalization vision among firms is mentioned by 20 countries. With such a crucial role in the adoption process, it makes sense to observe the prominence of this barrier on the European National Digital Strategies, being present in every national strategy. In a broad sense, the focus was mostly on digital strategy initiatives for fostering business innovation (12 national strategies), for providing competitive advantage and boost, and for promoting synergetic development through interorganizational cooperation (20 national strategies). This last topic is a direct counterpoint to the sub-barrier identified, which related to the collaboration initiatives between Public-Private entities (AT, BU, CZ, EL, LU, LT, LV, SK).

The lack of collaboration initiatives is seen as a cause to the poor business potential and decrease business value creation opportunities (BU). One example of such shortcoming is the "*lack [of] a system to incentivise spin-offs, start-ups, and the creation of natural cooperation between students and companies in advanced technologies, including the establishment of their own companies* (…)" (CZ). Another prominent example is the lack of metrics available to assess the synergies created between public-private entities, hence leading the policymakers to propose generic initiatives with very little impact (EL). To overcome these issues, the Greek government has proposed the development and implementation of a digital maturity assessment system for documentation of their current and future stages – the *Digitometer* – which can support companies, especially SMEs, in seeking out necessary aid from public bodies, research centres and funding initiatives for specific goals. This initiative would have the additional advantage of serving as a kick-off stage to the definition of a digital strategy, considering the maturity assessment models, when devised focusing on roadmapping establishment, often consider the management and technical aspects of the current and future technological stages (Büyüközkan and Göçer, 2018; Kiel et al., 2017).

As pointed out, the vast majority of national strategies' initiatives for digital strategy definition focus on business innovation. These can either be general, such as the Czech "*Competitive and innovative economy*" – which is a set of five different initiatives at a high level serving as guidelines for the development of more detailed public policies at a later stage (CZ), or they can be more detailed, such as the Portuguese "*Next47*" – which is an independent business unit for entrepreneurs that is responsible for the research and development of disruptive solutions, as well as for accelerating the implementation of emerging technologies on the manufacturing sector (PT). Another interesting approach to this is the proposition to introduce a sustainability mindset into the definition of the organization's digital strategy, which can be achieved through advanced manufacturing technologies and data-driven services tailored towards a positive environmental impact (AT, BE, CY, CZ, DK, EE, EL, FI, FR, HR, HU, LV, SI, SK, SW). The French "*Aim for digital sobriety*", seeks to perform constant analysis of digital projects in accordance with the Paris Agreement to select candidates for funding schemes and innovation programmes, in a bid to transform the current industry into an environmentally driven sector (FR).

6. Discussion

6.1. Strengths and limitations of national strategies

Overall, the national strategies cover the objectives of the DIGITAL Programme, presented in Section 3. In particular, we observe that there are three barriers to digitalization which receive considerably more attention in the national strategies than the rest (see Table 6): financial investments, human capital, and regulatory framework. These are consistent with a traditional view of the role of the state in innovation, where governments are responsible for tackling market failures (Dodgson et al., 2011). However, this reactive position might be quite limiting, as it is not efficient in creating new markets, solving societal challenges and fostering coordination among actors in an innovation system (Mazzucato, 2016; Schot and Steinmueller, 2018).

Surprisingly, we do not observe any relation between the number of strategies proposed by a country, and their level of digitalization measured using metrics such as the Digital Economy and Society Index (DESI) (Ghazy et al., 2022). There are some countries with a higher digitalization level, like Sweden, which mention only 23 initiatives, and others such as Austria, which mention 68, the largest in our sample. Conversely, if we look at countries with a lower digitalization level, we find cases like Slovakia, which mentions 55 initiatives, or Bulgaria, which mentions only 20 initiatives. These differences could be due to the fact that some leading countries may have a stronger private sector which rely less on state support to maintain their leadership, the ambition of some catching-up countries to use digital technologies to gain international competitiveness, or simply in differences in the expertise of the stakeholders in charge of creating the national strategies.

Table 6
Number of initiatives to overcome each barrier, per EU country.

Initiatives for each barrier in the National Strategies															
	[1] Investments	[2] Adaptive Organizational and Process Modifications	[3] Human Capital	[4] Knowledge Management Systems	[5] Clear Comprehension of Digitalisation Benefits	[6] Standardization Efforts	[7] Adaptive Retrofitting Implementation	[8] Infrastructure	[9] Security, Safety and Privacy Issues	[10] Integration with existing technology	[11] Regulatory Framework	[12] Legal and Contractual Assurances	[13] off-the-shelf solutions	[14] Digital Strategy	Total
Austria	7	3	15	1		2		7	2		24	1		6	68
Belgium	1		5		2			2	1	1	10			3	25
Bulgaria			7					1	1	1	9			1	20
Croatia	3	1	9					2			15			5	35
Cyprus	4		4			1		2	1		12			2	26
Czech Republic	8		9	1	1	2		5	2	1	15	1		5	50
Denmark			4			2		2	2		6	1		1	18
Estonia	5	2	4			2		5	2	1	10	1		1	33
Finland	2		5	1		1		3	2		10			4	28
France	4		6					5	2		6	1		4	28
Germany	8		13		2	2		3	2	1	14	2		3	50
Greece	5	1	9			2		7	2	2	14	2		4	48
Hungary	7	2	10			2		5	2	1	12	2		3	46
Ireland	6	1	6		1	3	1	2		1	5			2	28
Italy	4		3					3	2		8			2	22
Latvia	4		14	1	2	2		5	2	1	10	1		3	45
Lithuania	5		3					1			5	1		2	17
Luxembourg			12	1		2		4	2		10	2		2	35
Malta	2			1	2	2		4	2	1	12	1		1	28
Netherlands	4		7	1	2			7	2		12	2		2	39
Poland	1		4	1	2			2	2	1	9	2		2	26
Portugal	3		13					1	1		11			3	32
Romania	4	1	8	1				4			12			3	33
Slovakia	5	1	12	1	1			6	2	2	18	1		6	55
Slovenia	1		8	1		2		3	2	1	6			4	28
Spain	2		6					7	2		10			2	29
Sweden	5	1	7							1	4			5	23
Total	100	13	203	11	15	27	1	98	40	16	289	21	0	81	915

6.2. Policy implications

In terms of financial investments, national strategies frequently mention the use of collaboration and cooperation initiatives with R&D institutions, universities, and governments, as well as international scouting initiatives. Funding is also needed to create the ICT-enabling infrastructure, and some countries are considering market-based instruments, such as tax rebates, to attract corporate investment. This approach is also supported in the literature through the establishment of a supporting ecosystem for domestic digital firms (Edler and Georghiou, 2007), adoption of a regional innovation system approach (Walwyn and Cloete, 2020), and the establishment of mission-oriented consortia (Foray et al., 2012). The national strategies could be further improved by incorporating internationalization efforts towards the creation and/or wider deployment of DIHs as centralized workplaces for the development and testing of novel digital solutions (Hervas-Oliver et al., 2020). Moreover, Large-Scale Pilots (LSPs) can be used as a framework to promote stakeholder participation, develop technical solutions and identify possible setbacks, functioning as a prime example of an inter-organizational initiative (Schmidt and Krimmer, 2022).

Concerning human capital and the development of digital skills, we have observed a wide spectrum of initiatives, such as the promotion of upskilling and remote education professional programmes; the reform of formal higher-education and the establishment of doctoral degrees with a digital focus; programmes for the re-training of teachers; and remote learning platforms. In general, the digital transformation may require both a structural reshaping of educational programmes from the ground up, plus policies to attract highly-skilled workers from foreign countries, to compensate for potential labour shortages (Verma and Venkatesan, 2023). In addition, existing classifications of skills used by governments may need to be adapted to include some of the novel knowledge created in the digital transformation (Chiarello et al., 2021).

Most initiatives related to regulatory frameworks focused on ensuring data privacy, cybersecurity, and e-government. The proposed efforts could be enhanced, for instance, development of regulatory framework and legal and contractual assurances, such as a Digital Services Tax focused on human user interaction and bit-rate charges, as well as initiatives to promote the interdependence of political and economic powers considering emerging and enabling technologies (Mansell, 2021). Additional improvements are regulations for the digital marketplace and digital currencies (Alahmadi et al., 2022; Chawla and Goyal, 2022). In addition, increasing the involvement of regulation officers in public-private consortia, to help co-create rules with industry members, may also help accelerate the pace of technological change (Bonnín Roca et al., 2017).

We have also observed that there are several barriers which have been mostly overlooked by most governments. These are the need for off-the-shelf solutions, the need for adaptive retrofitting implementation solutions, and the requirement to use knowledge management systems. These barriers might be more important for those countries further away from the technological frontier, or for long-established SMEs who lack the resources to invest heavily on R&D (Müller et al., 2018; Stock and Seliger, 2016). Given differences in technical capabilities across countries, efforts at the EU level might be needed to provide industrial sectors with public technology infrastructure that single companies may not have enough incentives to develop by themselves, such as databases with publicly available data, or communication protocols (Tassey, 2004). This could be done through the DIHs already envisioned in the current DIGITAL programme, which could help with testing activities and harmonization efforts, or via government-led standardization efforts (Wiegmann et al., 2017). Additionally, the same funding could have a different section dedicated to technology providers that are going to focus on enhancing the capabilities of these ready-made solutions for specific sectors, such as modules that are more important for one sector compared to another. Another possible policy is the incubation of awarded solutions from Hackathons and other business competitions towards enhancing their large-scale adoption (Johnson and Robinson, 2014). We expect regional public-private technology centres to play a key role in the adaptation of older technologies (Oughton et al., 2002). The proposed policies are depicted in Table 7 below.

6.3. Limitations and future work

This study relies on qualitative data analysis methods, and secondary data in the form of national digital strategies from the 27 EU countries. While these are appropriate to observe trends and priorities across the EU, more insights are needed to understand the rational behind the construction of each of the strategies, and differences observed across countries.

We identify three main avenues for future work. First, we have only analyzed policies at the national level. However, we are aware that in many cases, these national policies are complemented by other strategies at the European, regional, and even city level. We have observed that in some cases, national strategies pointed to other external, secondary documents. While analyzing such myriad of documents for the

Table 7
Policy suggestions to overcome neglected barriers.

ID#	Barrier	Suggestions of policies to overcome the barrier
4	Knowledge Management Systems	• Provide incentive schemes for development and implementation of standards for knowledge management systems to decrease complexity and confusion at both the development and adoption stages.
5	Clear Comprehension of Digitalisation Benefits	• Use the smart industry field labs and hubs as networking training camps, in close partnership with industrial associations and practitioners, with knowledge sharing activities, challenge competitions and other networking fostering initiatives.
7	Adaptive Retrofitting Implementation	• Include on the definition of digital strategy a requirements' definition stage and digital maturity assessment of existing equipment, both part of the initiative to provide digitalisation funding. • Propose development of set of services targeting the adaptation of current equipment to enable digital capabilities, in partnership with RD&I centres and technology developers, such as implementation of universal communication protocol capabilities, or the development of flexible models attached to legacy systems that can be integrated into novel enterprise resource management systems. • Promote a dedicated funding scheme for supporting RD&I centres and technology providers to promote adaptative retrofitting services targeting selected key sectors (e.g. metalwork, footwear) and smaller organizations.
13	Off-the-shelf solutions	• Provide incentive to interorganizational collaborations (RD&I centres, DIHs) as promoters of off-the-shelf solutions tailored for specific sectors (e.g. automotive, cork). • Promote test funding schemes for developed solutions on multiple companies as Proof of Concepts, in order to move them to large-scale production and adoption. • Promote funding schemes for technology providers that aim to enhance the capabilities of ready-made solutions for specific sectors. • Provide incubation of awarded solutions from competitions to increase the speed of their large-scale adoption, with particular focus on SMEs and key sectors.

entire EU would be an almost impossible task, it would make sense to focus on a single country to assess the complementarities and (in)consistencies between different levels.

Second, as explained under Section 6.1, we have not observed any connection between the extension of the national strategies, in terms of number of initiatives proposed, and the level of digitalization of a country. Further empirical research is needed to understand the sources of these differences, and to evaluate the relationship between the number of initiatives, and their chances of success. It is possible that having a larger number of initiatives does not actually translate into a larger impact in the digital transformation, for instance if efforts are spread too thin, or in cases where a specialization strategy yields better results than diversification (Cai et al., 2018).

Third, in line with Teixeira and Tavares-Lehmann (2022), there is a need for evaluating what are the actual outcomes of these national strategies. In particular, it would be useful to understand whether policies were amended to adapt to unexpected changes, or new technological trends. Given that most strategies span time periods longer than four years, it would also be interesting to analyze whether political changes after an election cycle influence the implementation of digitalization policies. The uncertainty brought by political changes could be softened by developing multi-partisan agreements on industrial strategies, and securing long-term funding pools. Conducting such research would require conducting extensive longitudinal studies.

7. Conclusion

This paper analyzes the national strategies of the 27 EU countries. By performing content analysis on the national strategies, we observed similarities and a focus on initiatives that target investment, funding schemes, regulatory framework and business innovation strategy definitions. On the other hand, we found evidence of lacking initiatives for overcoming the need of retrofitting existing machinery, integrating with legacy systems, providing large-scale off-the-shelf solutions and promoting clear comprehension of the digitalization benefits. We identified a set of 94 initiatives and 17 sub-barriers, which were categorized according to the set of 14 barriers to adoption of digital technologies observed in the literature. Our findings demonstrate that all national digital strategies incorporate initiatives for each key area of the DIGITAL programme. Furthermore, many of the identified initiatives are supported by literature, increasing the validity of the proposed actions. We have provided six policy recommendations to overcome barriers not sufficiently tackled by literature, while extending the literature on the topic by identifying missing initiatives found in the national digital strategies. Our results can aid policymakers into improving the national digital strategies in an effort to consider a broader scope of industrial organizations.

CRediT authorship contribution statement

Pedro Pinho Senna: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Jaime Bonnin Roca:** Conceptualization, Methodology, Validation, Writing – review & editing, Supervision. **Ana Cristina Barros:** Methodology, Writing – review & editing, Supervision.

Data availability

Data is publicly available, manuscript contains references to all data sources

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Appendix A. Summary of the coding structure

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Investments (AT, BE, BU, CY, CZ, DE, EE, EL, FI, FR, HR, HU, IE, IT, LT, LV, MT, NL, PL, PT, RO, SK, SW)	46	Lack of RD&I Funding (BU, CZ, DE, EE, EL, IE, IT, LT, SK, SW)	19	Entrepreneurship and investment attraction (CY, CZ, HR, HU, LV, PT, SI, SW)	14
				National Funding Initiatives (AT, BE, CY, CZ, DE, HR)	9
				National Funding Programmes Platform development (AT, DE, EL, HU, IE, IT, LT, LV, NL, RO, SK, SW)	29
				Digital education funding (AT, DE, EL, ES, FR, HU, IE, IT, LT, LV, NL, PL, SK)	26
				Funding for sustainability initiatives (CZ, EE, FR, SW)	10
				Innovation funding (AT, CY, CZ, DE, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, MT, NL, RO, SK, SW)	110
				Funding for Standardization (AT, DE, EL, IE)	4
				Funding for Infrastructure (AT, CY, CZ, DE, EE, EL, FR, HR, HU, IE, IT, LT, LV, MT, NL, RO, SK)	47
				National Funding Initiatives – Awareness (CZ, EE, HU, PT, RO)	5
				National Funding Initiatives - Credit Line (CZ, DE, EE, FI, PT)	8
				RD&I targeted tax reduction initiatives (AT, CZ, DE, HU, IE, LT, SK, SW)	9
Adaptive Organizational and Process Modifications (AT, EE, ES, FR, HU, IE, SK, SW)	10	N/A		Quality assurance in ICT implementation (EL, HU, SK)	3
				Work from home (AT, ES, HU)	5

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Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
				Digitalisation of internal processes and business models (AT, EE, ES, HR, IE, RO, SW)	9
				Change acceptance (AT, EE)	5

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Human Capital (AT, BU, CY, CZ, DE, DK, EE, EL, ES, FI, HR, HU, IE, LT, LU, LV, RO, SI, SW)	54	Lack of future job stability (SK, SW)	2	Promote quality-of-life improvement activities (SI)	1
		Distance Learning - Lack of support for learning structuring (AT)	1	Promote the creation of high-quality jobs with high value added (SI)	2
		Digital Education Infrastructure - Lack of STEM system (AT, CZ, EL, HU, LU, LV, SK)	13	Demographic renewal and foreign attraction (CZ, DE, DK, EE, EL, HR, LU, LV, NL, SI, SK, SW)	19
		Lack of working experience with online teaching and learning (AT, DE, HU, LV, RO)	6	Talent attraction and acquisition initiatives (BE, BU, CZ, DE, HR, HU, LU, PT, RO, SK, SW)	19
		Lack of continuous training (CZ, DE, EL, HR, HU, LU, LV, NL, PT, RO, SI, SK, SW)	19	Awareness of digital skills (AT, CZ, DE, EL, HR, HU, IE, LV, PT)	17
		Lack of ITCE competencies (BU, CZ, DE, EL, FR, HR, HU, LV, PT, SI, SK, SW)	30	Unemployment and minorities (PT)	1
				RD&I talent (AT, CZ, EE, DE, HU, LU, PT, RO, SI, SK, SW)	21
				Digital Inclusion and Literacy (AT, BE, BU, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IT, LU, LV, NL, PL, PT, RO, SI, SK)	90
				Digital Education Funding - Grants and Scholarships (HU)	1
				Distance Learning (AT, DE, EL, LU, LV, PT)	14
				Distance Learning - Mobile Applications (AT)	1
				Distance Learning - Education curriculum platform (AT, DE, ES, LU, LV, NL, RO, SK)	16
				Distance Learning - Effect of digitalisation on distance learning (AT, LV)	2
				Distance Learning - Centralized learning Platform (AT, LV, PT)	4
				Digital Education Infrastructure (AT, BE, BU, CZ, DE, EL, ES, FI, HR, HU, IE, LU, LV, NL, PL, PT, RO, SI, SK)	57
				Digital Education Infrastructure - Digital Educational Resources (AT, BU, DE, FR, LU, LV, PT, SK)	17
				Use of digital devices (AT, HU, LV, SK)	5
				Digital Education (AT, BE, BU, CY, CZ, DE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, NL, PL, PT, RO, SI, SK, SW)	147
				Employability (AT, DE, DK, EL, FR, HR, IE, LU, LV, NL, PT, SI, SK, SW)	41
				Promote digital skills development (AT, BU, CY, CZ, DE, EE, EL, ES, FI, FR, HR, HU, IE, IT, LU, LT, LV, NL, PL, PT, RO, SI, SK, SW)	140
				Workforce training (AT, BE, BU, CY, CZ, DE, DK, EL, ES, FI, FR, HR, HU, IE, LU, LT, LV, PT, RO, SI, SK, SW)	82

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Knowledge Management Systems (AT, BE, LT, LV, RO)	11	N/A		Public data availability for data-driven services (AT, CZ, ES, FI, LU, LV, MT, NL, PL, RO, SI, SK)	29

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Clear Comprehension of Digitalisation Benefits (CZ, DE, IE, LT, LV, PL)	10	N/A		Promote awareness of IoT benefits (CZ, DE, IE, LV, MT, NL, PL, SK)	12
				Development of Smart Devices (BE, DE, LV, MT, NL, PL)	6

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments

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Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Standardization Efforts (AT, CY, CZ, DE, DK, EE, EL, IE, LU, LV, MT, SK)	22	N/A		I4.0 Standards initiatives (AT, CZ, DE, DK, EE, EL, HU, IE, LU, LV, MT, SI)	25
				Educational standards initiatives (CZ, IE)	2
				Standardized communication processes (AT, CY, DE, DK, EE, EL, FI, HU, IE, LU, LV, MT, SI)	27

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Adaptive Retrofitting Implementation (IE)	1	N/A		Integration with legacy systems (IE)	1

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Infrastructure (AT, CZ, DE, DK, EE, EL, ES, FR, HU, IT, LU, LT, LV, MT, NL, RO, SI, SK, SW)	37	Lack of supportive infrastructure - financing system (AT, LV, SI)	4	Online Platform for Entrepreneurship (ES)	2
		Lack of initiatives to promote Smart Cities (AT, BE, CZ, DE, EE, FR, HR, LU, LT, LV, RO)	17	Residence scheme for multinational employees (NL)	1
		Lack of backbone transport infrastructure network (AT, CZ, DE, EE, FR, HU, LV, RO, SK)	15	Accelerator and incubator initiatives (AT, DE, EL, ES, HU, IE, MT, NL)	14
		Lack of urban mobility infrastructure initiatives (AT, CZ, DE, EE, FR, LV, RO, SK)	16	Smart Cities initiatives (AT, CZ, DE, EE, EL, ES, FR, HU, IT, LU, LT, LV, MT, NL, RO, SI, SK)	41
		Lack of Communication and IT Infrastructure (AT, CY, DE, DK, EE, EL, ES, HU, IT, LU, LV, MT, NL, PL, RO, SI, SK)	74	Intelligent Transport Systems Development Action Plan (AT, CZ, EE, EL, ES, FR, LV, NL, RO, SK)	19
				Smart mobility services for materials (AT, CZ, EE, EL, ES, FR, HU, LV, NL, RO, SK)	26
				Adaptive risk management (NL, SK)	2
				Quantum Computing Infrastructure (AT, EL, FI, LU)	5
				Data-related infrastructure (AT, BE, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LU, LV, MT, NL, PL, RO, SI, SK)	194
				Develop Public Digital Infrastructure (AT, BE, BU, CY, CZ, DK, EE, EL, ES, FI, FR, HR, HU, IT, LU, LV, MT, NL, PL, PT, SI, SK)	126

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Security, Safety and Privacy Issues (AT, CY, CZ, DE, DK, EE, EL, ES, FR, IT, LU, LV, MT, NL, PL, SI, SK)	55	Lack of consumer-oriented data sharing capability (CY, FI, HU, MT)	4	Data security Business-to-Government (AT, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HU, IT, LU, LV, MT, NL, PL, SI, SK)	105
		Lack of trust on digital solutions security (AT, DE, DK, EE, EL, ES, FR, HU, LU, LV, MT, NL, PL, SI, SK)	37	Cybersecurity (AT, BE, BU, CZ, DE, DK, EE, EL, ES, FI, FR, HU, IT, LU, LV, MT, NL, PL, PT, SI, SK)	136

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Integration with existing technology (AT, CY, CZ, DE, DK, EE, EL, ES, FR)	11	N/A		Scientific (RD&I) Infrastructure Development (BU, EE, EL, SI, SK, SW)	12
				Collaboration initiatives with FoFs (BE, CZ, DE, EL, ES, HU, IE, LV, MT, PL, PT, SI, SK)	24

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Regulatory Framework (AT, CY, CZ, DE, EE, EL, FR, HR, HU, IE, IT, LU, LT, LV, MT, RO, SW)	51	N/A		Circular Economy benefits and initiatives (BE, DE, DK, HR, RO)	10
				Cooperation initiatives (AT, BE, BU, CZ, DE, EE, EL, ES, FI, FR, HR, HU, IE, IT, LU, LT, LV, MT, NL, PL, PT, RO, SI, SK, SW)	117
				Regulatory Framework for fair competition (AT, DE, LU, RO, SK)	6
				Regulatory framework for online markets (AT, DE, EL, LU, MT, NL, SK)	11
				Regulatory framework for transport (AT, CZ, SK)	10
				Regulation for infrastructure construction proceedings (CZ, DE, EL, HU, RO)	17
				Data regulation compliance (AT, DE, DK, EE, EL, ES, FR, HR, HU, IT, LU, LV, MT, NL, PL, PT, RO, SI, SK)	106
				Legal security regulatory framework (AT, BU, CZ, DE, DK, EE, EL, ES, FI, FR, HU, IT, LU, LV, MT, NL, PL, PT, SI, SK)	128

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Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
				Regulatory framework for public and/or private financing (CZ, DE, HR, HU, LT, RO, SK)	30
				Regulatory framework for education policy (AT, BE, CZ, ES, HR, HU, LV, RO, SK)	23
				Regulatory framework for electronic communications (AT, BE, BU, DE, EE, EL, ES, HU, LV, MT, NL, PL, SK)	35
				Regulatory framework to improve workforce (BE, CZ, ES, HR, PT, RO, SK)	15
				Establishing Regulatory Framework for Innovation Fostering (AT, BE, BU, CZ, DE, EE, EL, ES, FI, HR, HU, IE, IT, LU, LT, LV, MT, NL, PL, PT, RO, SK, SW)	79
				Collaboration entities (AT, BE, BU, CY, CZ, DE, EE, EL, ES, FR, HR, HU, IE, LU, LT, LV, MT, NL, PL, PT, RO, SI, SK, SW)	114
				Digital Research, Development and Innovation (AT, CZ, DE, EL, HU, IE, IT, LU, MT, NL, RO, SI, SK)	48
				Digital Economy (AT, BE, BU, CY, CZ, EE, FI, HR, LV, NL, RO, SK, SW)	24
				IT Benefits (AT)	2
				Public Administration System (AT, NL, PT)	4
				Digital Government (AT, BE, BU, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IT, LU, LV, MT, NL, PL, PT, RO, SI, SK)	160
				IT systems (AT, CY)	4
				E-government (AT, BE, BU, CY, CZ, DK, EE, EL, ES, FI, FR, HR, HU, IT, LV, MT, PL, PT, SK)	55
				Government effectiveness (AT, CY, SK)	5
				Guiding principles (AT, CY, EL, FI, HR, PT)	14
				Digitalisation vision (AT, CY, FI, HR)	5
				Strategic framework for digitalisation projects (AT, CY, HR)	6
				Digitalisation action plan (AT, CY, HR)	3
				IT Consolidation policy (AT, BE, BU, CY, CZ, DK, EE, EL, ES, FI, HR, IE, IT, LU, LT, MT, NL, PL, PT, SK)	55
				National digitalisation strategy (AT, CY, CZ, DE, EL, FI, MT, PT)	19

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Legal and Contractual Assurances (CZ, DE, DK, EE, EL, ES, HU, LU, LV, MT, RO, SK, SW)	16	Lack of e-commerce legal assurance (DE, EL, LU, PL, SK)	5	E-Commerce legal simplification initiatives (DE, EL, HU, LU, NL, PL, SK)	8
		Lack of Digital Information Sharing amid peers (AT, DE, DK, EE, EL, LT, MT, NL, SK)	11	Improving Business-to-Government bureaucracy (AT, CZ, DE, DK, EE, EL, ES, FR, HU, LU, LT, LV, MT, NL, PL)	35

Barrier (countries)	# segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Off-the-shelf solutions (BU)	1	N/A		N/A	

Barrier (countries)	# Segments	Sub-barriers (countries)	# segments	Initiatives (countries)	# segments
Digital Strategy (AT, BE, CY, CZ, DE, DK, EL, ES, FR, IE, IT, LT, LV, PT, RO, SI, SW)	41	Lack of Collaboration initiatives between PPPs entities (AT, BU, CZ, EL, LU, LT, LV, SK)	17	Open Science Strategy (AT, EL, SK)	5
				Boosting state-owned assets (HR)	1
				Sustainability through AMTs or Data-driven solutions (AT, BE, CY, CZ, DK, EE, EL, FI, FR, HR, HU, LV, SI, SK, SW)	34
				Research-to-Market Technology Transfer (AT, CZ, DE, FI, HR, SI, SK, SW)	22
				Strategy for competitiveness boost (AT, BE, CY, CZ, DE, EL, ES, FI, FR, HR, HU, IE, IT, LU, LT, LV, NL, PL, PT, RO, SK, SW)	111
				Business Innovation (AT, BE, BU, CZ, FI, FR, HR, PT, RO, SI, SK, SW)	30
				Interorganizational Cooperation (AT, CZ, DE, EL, ES, FR, HU, IE, IT, LT, LU, LV, MT, NL, PL, PT, RO, SI, SK, SW)	117

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techfore.2023.122822.

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