RISE SME

# D1.1
# Industrial ecosystems and existing risk-driven supply chain models
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| Abstract | This document presents the findings of tasks 1.1 and 1.2 of the RISE-SME project, which focus on establishing the theoretical foundations and definitions of ecosystems relevant to the project. It introduces key concepts for managing disruptions in supply chains, with a focus on small and medium enterprises (SMEs) operating in complex and dynamic environments. Using a social-ecological approach to resilience, the study systematically identifies context and intervention variables that influence ecosystem resilience. The document examines four ecosystems—Textile, Agri-food, Digital, and Mobility—detailing their characteristics and resilience factors. A theoretical model linking context and intervention variables is proposed for each ecosystem. |

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**RISE-SME:** Resilient Industry Supply Chain Enhancement for SMEs

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# Executive summary


**Project Overview:**
The RISE-SME project is focused on strengthening European ecosystems by developing a quantitative model to help SMEs detect and anticipate supply chain disruptions. This initiative promotes the adoption of advanced technologies and fosters new alliances, aiming to create more flexible, agile, and resilient supply chains across four key ecosystems: agri-food, digital, mobility-transport-automotive, and textile. The project aims to:

- Develop a comprehensive understanding of current and future risks within the targeted supply chains.
- Characterize industrial ecosystems, map potential disruptions, and propose new models to enhance supply chain readiness and responsiveness, particularly for SMEs.
- Promote the adoption of advanced technologies and sustainable practices to improve supply chain resilience.

**Work Package 1 (WP1)**
WP1 serves as the foundation for the project by analyzing the risks and resilience factors within the four ecosystems. It focuses on:

- Task 1.1: Gathering and analyzing data to understand ecosystem characteristics and dependencies, and establishing networks to address common challenges.
- Task 1.2: Reviewing existing supply chain models with a focus on resilience, using systematic literature reviews and an abductive approach to assess their applicability across different ecosystems. The role of digital technologies in current models is also preliminarily analyzed.

**Ecosystem-Specific Insights:**

- Textile Ecosystem: Challenges include limited remote production capabilities and significant financial risks. Strategies for resilience include market diversification, digital technology adoption, and sustainable practices to reduce external dependencies and waste. The sector faces pressure to innovate in sustainability, emphasizing the reduction of carbon footprints, enhancing product transparency, and implementing recycling systems.
- Agri-Food Ecosystem: Key challenges involve vulnerability to climate change, political crises, and the need for sustainable agricultural practices. Innovation throughout the value chain is essential, driven by the demand for sustainable food and environmental impact reduction. Digital transformation through precision agriculture, IoT, and big data, is crucial for improving efficiency and sustainability.
- Digital Ecosystem: Resilience is bolstered by AI, IoT, and big data, which enhance efficiency and flexibility. Challenges include the need for advanced digital skills, and existing vulnerability to cyberattacks. Collaboration between companies, governments, and research institutions is critical for developing innovative solutions.
- Mobility Ecosystem: Resilience depends on reducing carbon emissions, adapting to environmental regulations, and integrating technologies like autonomous vehicles. Digitalization and advanced supply chain management are essential for improving ecosystem efficiency and flexibility.

**Outcomes:**

The project's initial phase produced a general Supply Chain Fit model and specific models tailored to each ecosystem. These models are designed to improve supply chain performance in terms of readiness, responsiveness, recovery, and adaptability to disruptive events. They will be used in WP2 to define methodologies for quantifying disruption impacts and technology scouting.

**Conclusion:**

RISE-SME is setting the stage for more resilient supply chains in Europe by addressing key challenges in critical industrial ecosystems. Through detailed analysis and innovative modeling, the project aims to equip SMEs with the tools needed to navigate and thrive in a dynamic global market.

## Table of Contents

## List of Tables

## List of Figures

| List of Abbreviations and Acronyms | |
|---|---|
| AI | Artificial Intelligence |
| CASE | Connected, Autonomous, Shared and Electric |
| DGTES | Digital Ecosystem |
| EIA | European Irrigation Association |
| EPAC | Electrically Pedal Assisted Cycles |
| EU | European Union |
| GMO | Genetically Modified Organisms |
| IoT | Internet of Things |
| M&A | Mergers and Acquisitions |
| OEM | Original Equipment Manufacturers |
| R&D | Research & Development |
| SC | Supply Chain |
| SLR | Systematic Literature Review |
| SME | Small and Medium-sized Enterprises |
| US | United States of America |
| WP | Work Package |

# 1 Introduction

The RISE-SME project aims to support European ecosystems by developing a quantitative model to help SMEs in detecting and anticipating supply chain disruptions. This model will facilitate the adoption of advanced technologies and the formation of new alliances, promoting flexible, agile, and resilient supply chains. RISE-SME will focus on the agri-food, digital, mobility-transport-automotive[1], and textile ecosystems, engaging sectorial clusters and Digital Innovation Hubs to ensure broad impact and support.

The first work package (WP1) establishes a foundational understanding of current and future risks and disruptions in the supply chains of selected industrial ecosystems. By studying supply chain resilience and risk management concepts, WP1 analyses critical dependencies and weaknesses, particularly concerning advanced technologies, with a focus on the impact on SMEs. The objectives include characterizing industrial ecosystems, mapping disruptions and risks, identifying existing supply chain models, proposing general models, and analysing the drivers and challenges in managing and measuring supply chain readiness and responsiveness to disruptions.

Task 1.1 collects and analyses information to understand the characteristics and dependencies of the industrial ecosystems, ensuring a comprehensive view of the risks and disruptions affecting SMEs. This task establishes networks within ecosystems, addressing common disruptions and serving as a foundation for subsequent tasks. Task 1.2 identifies and critically reviews existing supply chain models that address disruptions, focusing on resilience. Using a systematic literature review and an abductive research approach, this task maps the relationships between resilience practices and their impact on readiness, responsiveness, and recovery. It compares the findings from Task 1.1 with the characteristics of each model to assess their current and potential use in different industrial ecosystems. The literature on supply chain risks, trade-offs, and synergies between resilience and sustainability practices is also explored. Additionally, a preliminary analysis of the role of digital technologies in current supply chain models is conducted, advancing the understanding of supply chain resilience concepts and informing the development of new models.

On this initial stage, an extensive identification of risks within the targeted European ecosystems was carried out, further expanded with quantification of prominent ecosystem characteristics and disruptive events' possibilities, as well as with the experiences from organizations of the multiple industries. To start, a mapping of characteristics of supply chains (SC) for each ecosystem was carried out, as well as the associated risks and critical dependencies of supply chains with a specific focus on SMEs. Through the identification of relevant scientific literature for each ecosystem in known databases, interviews with industrial ecosystems' clusters, and secondary data obtained from grey literature, a primary characterization of each of the four European industrial ecosystems under consideration was accomplished. Afterwards, statistical information concerning the indicators for each industrial ecosystem was retrieved and analysed, with intent to

[1] From this point on, this document will consider the expression 'mobility' as corresponding to 'Mobility-Transport-Automotive', as presented in the Grant Agreement.

understand the major risks and critical dependencies, as well as weaknesses, of the different industrial ecosystems.

Following this initial approach, a rigorous systematic literature review (SLR) was carried out within well-established databases to retrieve supply chain models used both generally, as well as implemented on each industrial ecosystem. A secondary data source, comprised of grey literature concerning consultancy, governmental and business-related reports, was used as a complementary approach to the SLR. The objective of this second stage was to ensure that identified supply chain models pertained companies from the European industrial ecosystems and, concurrently, had the aim of establishing supply chain practices that would have direct effect on the organization's resilience towards highly disruptive events. Intervention variables (i.e. resilience capabilities, SC strategies, SC design), as well as contextual variables for each industrial ecosystem were also identified during this second stage of the task.

Through and abductive approach, a general Supply Chain Fit model, as well as specific supply chain fit models for each industrial ecosystem, were developed. Conceptually, the intervention variables would serve as moderators on the risks and critical factors, considering each industrial ecosystem characteristics, regarding the supply chain performance in terms of its readiness, responsiveness, recovery and adaptability or transformation capabilities to withstand disruptive events. This set of SC Fit models is the main conceptual outcome of this first deliverable (D1.1) "Industrial ecosystems and existing risk-driven supply chain models".

## 1.1 Purpose and scope

This first deliverable (D1.1) "Industrial ecosystems and existing risk-driven supply chain models" is set to describe the characterization of targeted industrial ecosystems, their associated disruptions and risks, as well as the identified risk-driven supply chain models and disruption-driven supply chain models. It is a conceptual deliverable, considered as the cornerstone for the project in terms of the conceptualization of supply chain models and the identification of European industrial ecosystems risks, critical factors and characteristics. Its final result is a conceptual Supply Chain Fit model that incorporates intervention variables (resilience capabilities, SC strategies and SC design) to understand the relationship between the European industrial ecosystems and the SC requirements in order to increase their readiness, responsiveness, recovery and adaptability or transformation capabilities towards disruptive events.

## 1.2 Methodology

This deliverable presents the results of two tasks that, although strongly related, were executed sequentially and with different methodologies. This section is divided into two parts, one for T1.1 and the other for T1.2.

### 1.2.1 Methodology for T1.1

Task 1.1. is related to the characterisation of the ecosystems and their associated disruptions and risks, and has the objective to collect and analyse information to provide a deep understanding of the characteristics of the identified industrial ecosystems, focusing on the critical dependencies that affect all the supply chains and, specifically, the SMEs in the respective ecosystem.

This will help to understand the characteristics and difficulties faced by the multiple actors within each of the four selected industrial ecosystems.

To accomplish this task, the partners agreed to use secondary data gathered from scientific and grey literature in order to capture the distinctive aspects of each industrial ecosystem as well as the risks and disruptions associated with their activities.

The task will serve as the foundation for the remaining tasks of WP1 and all tasks of WP2, since it provides a thorough analysis of the characteristics, actors, common disruptions and risk assessment for the selected industrial ecosystems. The results are the foundation for the selection of the sub-sector of each ecosystem.

The following actions have been implemented:

- Action 1 – Identify relevant scientific literature for each ecosystem using databases such as Scopus and Web of Science; and grey literature (e.g., European Commission, Eurostat)
- Action 2 – Meeting with the partner clusters to identify relevant documents to define the main ecosystem actors and critical factors
- Action 3 – Characterise each ecosystem with statistical information
- Action 4 – Analyse and categorise the critical dependencies and weaknesses of the industrial ecosystems

### 1.2.2 Methodology for T1.2

Task 1.2 methodology was performed in four main steps, as shown in figure 1.

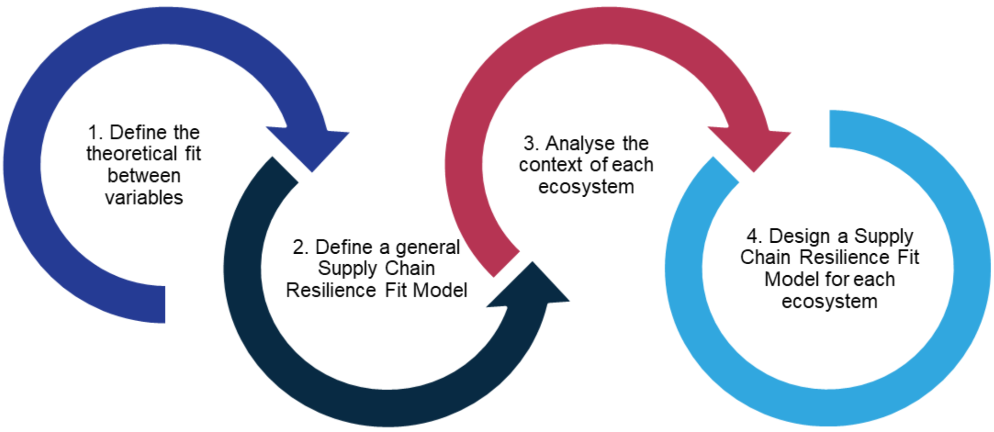


***Figure 1:*** *Task 1.2 Methodology*

The first step consists in defining the theoretical fit between context and intervention variables. This step began with a systematic literature review (SLR) with two complementary objectives: (a) identification of current models for managing risks and disruptions in supply chains; (b) identification of the main disruptions and risks associated with the four ecosystems that make up the scope of the project.
The SLR method [93] was used to ensure that the review is transparent, auditable and replicable. A systematic literature review consists of the identification, selection, analysis and synthesis of existing research on a particular topic and its presentation in a clear manner in order to meet what is known and not known about the topic – as depicted in Figure 2.

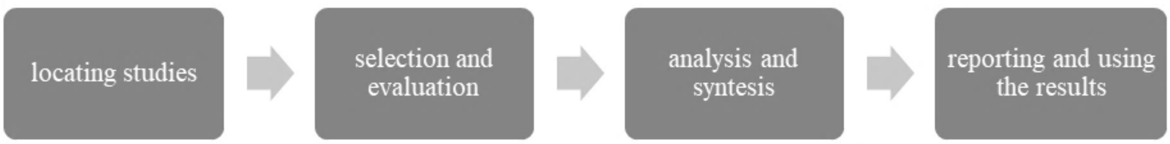


***Figure 2:*** *Systematic Literature Review process (based on [93]).*

Following recent studies, Scopus was defined as the database for the search, whereas the search queries were based on all possible combinations of the different groups of keywords. Only journals (articles and reviews) were searched, limited to the areas of "Business Economics", "Engineering", "Operations Research Management Science", "Social Sciences" and "Decision Sciences". Considering the recent changes when it comes to SC resilience-related topics, only studies published in the last five years were included. The first search, carried out in March 2024, returned a total of 636 items. The following search query was used:

*TITLE-ABS ( "supply chain*" OR "value chain*" ) AND TITLE-ABS ( "disruption*" ) AND TITLE-ABS ( "model*" OR "framework*" OR "strategy*" OR "foresight" ) AND TITLE-ABS ( "resourc*" OR "Waste" OR "business model*" OR "Global" OR "complex" OR "mobility" OR "raw material*" OR "Skill" OR "maturity" OR "readiness" ) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND ( LIMIT-TO ( SRCTYPE , "j" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( SUBJAREA , "BUSI" ) OR LIMIT-TO ( SUBJAREA , "ENGI" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )*

From the initial list of publications, two approaches were adopted. First, the 20 most cited publications that met the inclusion requirements were explored in detail by researchers with the aim of identifying the most influential models in the current literature. Recent publications from the main newspapers in the area were also analysed. To reduce interpretation and procedural bias, three researchers classified the level of fit between variables separately and meetings were held to discuss the results and reach consensus. As a result, the main intervention variables applied in the literature when it comes to manage SC resilience were identified.
As the second step, the main intervention variables of SC resilience were used to define a general Supply Chain Resilience Fit Model, which was later adjusted to each ecosystem context (as represented in section 2.4).

The third step corresponds to the analysis of the context of each ecosystem based on the defined variables. It was performed through a search carried out within the publications of the SLR, identifying those that specifically addressed the ecosystems under study. The search queries used, and their respective item numbers are presented below.

Textile:
TITLE-ABS ( "supply chain*" OR "value chain*" ) AND TITLE-ABS ( "disruption*" ) AND TITLE-ABS ( "model*" OR "framework*" OR "strategy*" OR "foresight" ) AND TITLE-ABS ( "resourc*" OR "Waste" OR "business model*" OR "Global" OR "complex" OR "mobility" OR "raw material*" OR "Skill" OR "maturity" OR "readiness" ) AND TITLE-ABS ( "textile" OR "fashion" ) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND ( LIMIT-TO ( SRCTYPE , "j" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( SUBJAREA , "BUSI" ) OR LIMIT-TO ( SUBJAREA , "ENGI" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )
Number of papers: 14

Agri-food:
TITLE-ABS ( "supply chain*" OR "value chain*" ) AND TITLE-ABS ( "disruption*" ) AND TITLE-ABS ( "model*" OR "framework*" OR "strategy*" OR "foresight" ) AND TITLE-ABS ( "resourc*" OR "Waste" OR "business model*" OR "Global" OR "complex" OR "mobility" OR "raw material*" OR "Skill" OR "maturity" OR "readiness" ) AND TITLE-ABS ( "agriculture" OR "farming" OR "food" OR "beverage" ) AND NOT TITLE-ABS ( "forestry" OR "logging" OR "equastrian" OR "industrial equipment" OR "machinery" OR "chemicals" OR "hunting" OR "trapping" OR "cooking" ) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND ( LIMIT-TO ( SRCTYPE , "j" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( SUBJAREA , "BUSI" ) OR LIMIT-TO ( SUBJAREA , "ENGI" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" )
Number of papers: 70

Mobility:
( TITLE-ABS-KEY ( "supply chain*" OR "value chain*" ) AND ( "disruption*" OR "resilience" ) AND ( "model*" OR "framework*" OR "strategy*" OR "foresight" ) AND ( "resourc*" OR "Waste" OR "business model*" OR "Global" OR "complex" OR "mobility" OR "raw material*" OR "Skill" OR "maturity" OR "readiness" ) AND ( "automotive" OR "rail" OR "waterborne" ) ) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND ( LIMIT-TO ( SRCTYPE , "j" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( SUBJAREA , "BUSI" ) OR LIMIT-TO ( SUBJAREA , "ENGI" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )
Number of papers: 23

Digital:
( TITLE-ABS-KEY ( "supply chain*" OR "value chain*" ) AND ( "disruption*" OR "resilience" ) AND ( "model*" OR "framework*" OR "strategy*" OR "foresight" ) AND ( "resourc*" OR "Waste" OR "business model*" OR "Global" OR "complex" OR "mobility" OR "raw material*" OR "Skill" OR "maturity" OR "readiness" ) AND ( ICT OR Telecommunication OR Software OR Web OR Consumer Electronics) ) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND ( LIMIT-TO (

*SRCTYPE , "j" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( SUBJAREA , "BUSI" ) OR LIMIT-TO ( SUBJAREA , "ENGI" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )*
*Number of papers*: *4*

This detailed approach of the SLR focused on the ecosystems allowed to identify the main context variables used in the literature when it comes to manage SC resilience, as well as the context variables that characterise the ecosystems.
Finally, the analysis of the relationship between variables within the ecosystems contexts was performed. The definition of the theoretical fit – Supply Chain Resilience Fit Model - was performed based on the results of the literature review (as represented in Chapter 3).

# 2 Theoretical background and supply chain resilience models

This section presents the main concepts that guided the design of the developed theoretical model and the variables that compose it. The theoretical model is presented and explained at the end of the section to facilitate the understanding of the following sections.

## 2.1 Supply Chain Resilience

Resilience, a term originally introduced as a system's capacity to adapt to change [107], has evolved across disciplines. Various authors have since described resilience as a system's ability to recover and revert to its original state. In the context of the RISE-SME project, resilience is understood as the ability "to persist, adapt, or transform in the face of change" [105]. This contemporary interpretation diverges from traditional views of SC resilience, emphasizing that resilience does not necessarily mean reverting to the original state but also involves finding innovative ways to address change and meet market demands through adaptation or transformation [102].

The COVID-19 pandemic has highlighted the relevance of SC resilience, leading companies and policymakers to rethink how relationships between different actors in SCs are managed. Furthermore, successive crises (such as the pandemic itself, and the wars in Ukraine and Palestine, just to name a few) have led to disruptions in SCs, demonstrating, on the one hand, their importance and impact on business and society in general and, on the other hand, highlighting the fragilities inherent in the current predominant model. Recent events have also shown that an isolated view of companies and their closest relationships does not adequately respond to the complexity and dynamism of current, often global, SCs. Authors [105] argue that new resilience-related narratives must be introduced in the "new normal" post-pandemic, incorporating reflections on the climate and biodiversity crisis. This perspective suggests that achieving SC resilience requires firms to continually learn and adapt resources using dynamic capabilities in unstable environments [96, 100, 102].

Thus, a social-ecological system perspective has recently emerged within SCM literature [105, 108, 102] understanding SCs not as static but as dynamic systems, and highlighting transformation as a paramount aspect of resilience. In this new vision, transformation refers to a new state companies can achieve through growth and renewal [102] where learning represents a crucial aspect. The intention to return to the stability that existed before the rupture is replaced by the identification of opportunities and the search for innovation. Hence, following this new perspective, the three stages usually defined as part of the SC resilience process (readiness, response, and recovery), can be adapted to prepare, respond, and transform [102].

Finally, business continuity is a common essential element of resilient and sustainable SCs [97]. However, although recent studies have recognized that sustainability and resilience should be considered part of the same efforts in the context of a transformative perspective [102], research combining both constructs is still incipient. Therefore, sustainability is seen as a fundamental aspect to be considered in the development of resilient SCs and will be considered an important element in this document and in the RISE-SME project.

## 2.2 Supply chain fit

Considering the complexity of the environments where SCs operate and the dynamics of current markets, the alignment between the aspects that characterize the environment where companies operate, and the strategies adopted is fundamental to the ability to "survive" in the face of different challenges. This gives rise to the concept of strategic fit, or just fit – a concept intrinsically related to the field of strategic management and a fundamental element for the construction of theories in the most diverse areas [104, 99, 98]. The concept of fit is considered a "pillar" of this study as it helps to understand how the adaptation of different actions to be taken by SC actors are aligned with different characteristics of the ecosystems. Fit is understood to be the adjustment of one or more variables – activities, strategies, capabilities, business areas or organisations – relative to the others, such that the combination leads to improved results [94, 103, 106]. The objective is the search for the best results by tweaking the variables under analysis [99].
We apply the "Fit as matching" perspective, which highlights that "fit is a theoretically defined match between two related variables" [103]. The fit between context variables and intervention variables was analysed and used to develop the concepts and models presented in this deliverable.

## 2.3 Model variables

Following the concept of strategic fit, the variables that are part of the model were defined into two sets: the context variables and the intervention variables (Figure 3). We consider that context variables are inherent characteristics of ecosystems and/or society, and their change depends on a wide range of factors that, often, go beyond the action of ecosystem stakeholders. In this way, the intervention variables are those that can be changed so that the effects of the context variables on performance are changed in a positive way. Thus, the model reflects the concept of fit as moderation, where context variables are the predictor, performance is the criterion (or dependent) variable, and intervention variables are the moderator, as shown in Figure 3.

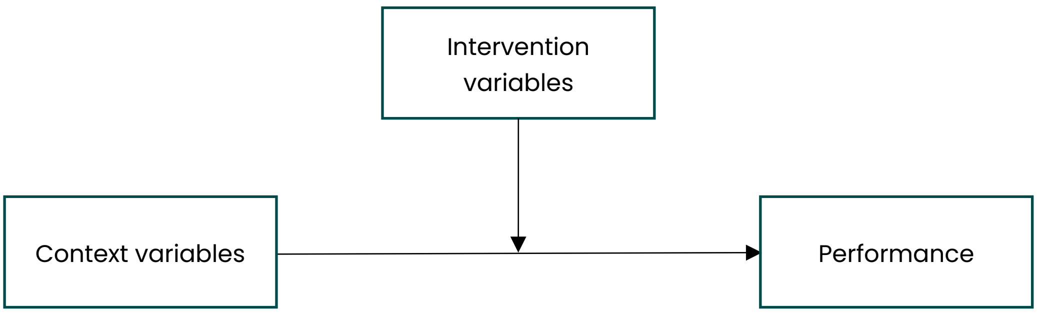


***Figure 3:** Relationship between variables*

### 2.3.1 Context variables

In ecosystem analysis, context variables include resilience indicators and critical factors, identified through literature review and documental analysis. Resilience indicators enable ecosystems to withstand disturbances, while critical factors influence overall. Understanding their interaction aids in predicting changes and enhancing ecosystem resilience.

#### 2.3.1.1 Indicators of Ecosystems Resilience

Three sets of variables were used as characteristics of the ecosystems that impact their resilience: Ability to Produce and Supply, Exposure to Indirect Demand Shocks and Financial Constraints (Table 1) [109].

***Table 1:*** *Overview of resilience indicators*

| Macro Indicators | Ecosystems characteristics | Description |
|---|---|---|
| **Ability to produce and supply** | Essential industry classification | Industry designated as an essential industry, exempt from confinement measures [110]. |
| | Ability to reorganise production remotely | Task-based measures of potential teleworking [111] |
| | Ability to supply products remotely | Share of employment in occupations involving face-to-face contacts with customers [111] |
| | Potential for supply chain disruption | Hirschman-Rasmussen index of of the relative importance of backwards supply chain linkages [112] |
| **Exposure to indirect demand shocks** | Exposure to domestic demand fluctuations | Cyclicality of demand [112] |
| | Exposure to foreign demand fluctuations | Share of value added embodied in exports [112] |
| **Financial constraints** | Short term liquidity risk | Cash conversion cycle [109] |
| | Longer term borrowing constraints | Share of tangible assets in total assets [109] |

Source: [109]

The "Ability to Produce and Supply" dimension evaluates industries' resilience through four characteristics: essential industry classification, which identifies critical sectors exempt from confinement, even during severe crises; the ability to reorganise production remotely, indicating potential for telework; the ability to supply products remotely, assessing jobs needing face-to-face contact and their adaptability; and the potential for supply chain disruption, using the Hirschman-Rasmussen index to measure the importance of supply

chain linkages. These factors collectively determine how well an industry can maintain operations during crises.
The "Exposure to Indirect Demand Shocks" dimension assesses the vulnerability of industries to demand variations through two main characteristics. Exposure to domestic demand fluctuations examines the cyclicality of internal demand, reflecting how sensitive companies are to economic changes within the country, indicating their reliance on the domestic market. Exposure to foreign demand fluctuations measures the share of value added in exports, highlighting the dependence of industries on external markets. The volatility in international demand can significantly impact sectors with high export exposure, demonstrating the need for strategies to mitigate these impacts.
The "Financial Constraints" dimension assesses the financial risks faced by industries through two main variables. Short-term liquidity risk examines the cash conversion cycle, indicating how quickly a company can convert assets into cash to meet immediate needs. Long-term borrowing constraints analyse the share of tangible assets in the total assets, reflecting the companies' ability to secure long-term financing. These variables are crucial for understanding financial stability and the ability of companies to sustain operations during economic crises.

### 2.3.1.2 Critical factors

This deliverable defines critical factors as variables that significantly impact the functioning and resilience of ecosystems. These factors are essential for understanding how ecosystems respond to different influences and changes, and their identification is crucial for developing effective strategies for ecosystem management and protection.
Based on the systematic literature review described in Section 1.2, the main critical factors in each analysed ecosystem were identified. This process involved a thorough analysis of the various sources and studies reviewed, allowing the identification of patterns that influence the ecosystems. Subsequently, these factors were organized and grouped into 10 critical macro factors, each representing a set of interrelated variables that significantly influence the studied ecosystems.
These macro factors provide a comprehensive and integrated view of the essential elements that must be considered for the analysis and development of effective strategies within these contexts. Table 2 describes the identified critical factors.

***Table 2:*** *Overview of critical factors*

| # | Macro Factors | Description |
|---|---|---|
| 1 | Health and pandemic disruptions | Pandemics and epidemics, including COVID-19, causing supply shortages, capacity bottlenecks, and production stoppages. |
| 2 | Environmental crises and natural disasters | Natural disasters such as earthquakes, extreme weather events, and other environmental impacts affecting the supply chain. |
| 3 | Political conflicts and crises | Port conflicts, political crises, trade sanctions, and political instability affecting the availability of materials and logistics. |

| # | Macro Factors | Description |
|---|---|---|
| 4 | Technological disruptions and low digital maturity | Technological failures, cyberattacks, and problems with navigation and power systems causing supply chain interruptions. |
| 5 | Challenges in sustaining existing business model | Difficulties in maintaining the existing business model due to market changes, supply chain disruptions, or shifts in consumer expectations. |
| 6 | Supplier and customer concentration (overdependencies) | Excessive dependence on a few suppliers or customers, which increases risk in case of failures or changes in the relationship. Resource Efficiency. |
| 7 | Global and complex supply chains (decentralization of supply and demand) | Globalized supply chains involve multiple suppliers and partners located in different parts of the world, making it challenging to adopt practices that increase visibility and collaboration. |
| 8 | Skills gaps | Delays resulting from limitations in production capacity and technical capabilities. |
| 9 | Waste | Waste of resources along the supply chain, resulting in inefficiencies that can negatively impact operational costs and environmental sustainability. This includes inefficient production processes and overproduction. |
| 10 | Infrastructure and Logistics Disruptions | Physical disruptions to infrastructure and logistics, transportation crises, labour shortages, and dependence on imports that affect the efficiency and continuity of supply chains. |

## 2.3.2 Intervention variables

The systematic literature review reinforced that the resilience of SCs is a highly complex aspect and depends on a large number of factors. Adopting a social-ecological perspective of resilience, we recognize that SC actors impact, and are impacted by, factors that go far beyond their isolated actions and their closest relationships. From the SLR it was possible to identify the intervention factors (i.e., those that can be changed by SC actors) most commonly related to improving the resilience of SCs: resilience capabilities, SC design and SC strategies. In this section, each of these three intervention variables is explained.

### 2.3.2.1 Resilience capabilities

It is commonly agreed that the resilience process encompasses three stages: readiness, response, and recovery. Following a social-ecological perspective on resilience in SCs, we adopted the three steps [102]: prepare, respond and transform.
The first stage refers to preparation, when companies are identifying opportunities and challenges related to their operations with regards to the resilience of SCs [102]. This phase, which encompasses pro-active actions, involves identifying and developing practices and

capabilities that allow companies to prepare for crises that may occur and involves preparing the SC to reduce its exposure to disruptive events, which includes the ability to identify and mitigate or avoid risks before damage occurs [97].

By adapting different models [97, 102], we identify six capabilities that can be developed during the preparation stage: adaptability and flexibility, visibility, efficiency, redundancy, market strength and financial strength. Adaptability and flexibility refer to the ability to adjust according to a given situation. In SC resilience, flexibility may involve changing production patterns (e.g., quantity, scheduling, inputs), sourcing or distribution routines (e.g., new suppliers, substitute components, new routes, and transport modes), developing customization capacity, and creating a multi-skilled workforce. Visibility denotes the ability to connect systems and procedures, as well as the capacity to access and provide the required timely information to and from relevant partners for better decision-making, encompassing collaboration and information sharing. Enhancing efficiency involves reducing waste, increasing workforce productivity and effectiveness, and ensuring adequate quality control, which collectively contribute to robustness. Redundancy involves having reserve capacity (in production and distribution), stock (of raw materials, components, or products), and backup utilities available for use if necessary (as a contingency plan). Strengthening a company's market position (e.g., satisfaction, brand image, differentiation, customer relationships) and financial position (e.g., diversification, funding availability, profit consistency, and insurance) are also ways to boost resilience. Table 1 provides examples of actions corresponding to each resilience capability.

Response is considered a more reactive set of actions, related to how quickly and efficiently a company acts during urgent situations [91, 101]. Moreover, as a consequence of the preparation phase, companies must now make decisions about taking advantage of opportunities. These decisions will have a direct impact on the company's positioning in relation to resilience and can be decisive in the transformation process.

In the last phase, companies apply the lessons learned throughout the process and implement the actions necessary for the new reality. Instead of just returning to the initial stage, at this stage companies transform, not only according to needs (in an adaptation process) but also to identified opportunities. Although it is not a homogeneous process – as persisting and adapting are also forms of resilience - it is understood that the current context requires greater commitment from companies to sustainability issues and, in this sense, the perspective of transformation gains even more relevance.

### 2.3.2.2 Supply chain design

In simplified terms, a supply chain is made up of different actors, commonly called nodes, linked by the movement of information and materials. To understand a supply chain, you need to know all the nodes and the connections between them, from the starting point to the ending point. This network of nodes and connections, from a company's perspective, can be understood as SC design. In this study, we approach SC design from the perspective of three fundamental aspects: density, complexity and criticality. The way SCs are designed, according to these three aspects, has great influence on their resilience [91, 92].

Although SC design can be considered, in part, an inherent characteristic of the activity sectors and, therefore, could be considered a context variable, in this study we assume that actors in SCs normally have the capacity to select their suppliers and make decisions related to their market. Therefore, we consider SC design as an intervention variable.

SC density describes the geographic dispersion of nodes within an SC [92]; a higher density indicates that nodes are closer together. Thus, a supply chain is said to be dense when its nodes are closely grouped, as seen by a lower average distance between nodes. Conversely, a less dense supply chain results from dispersed nodes. Furthermore, certain areas within a supply chain can be described by supply chain density. A territory is heavily populated when its entities are close to one another. On the other hand, an area is less dense when there is greater geographical separation between things. A supply chain with multiple densely populated locations, for instance, has a higher overall density than one with fewer densely populated places. To sum up, the degree of disruption that might occur is mostly determined by SC density, which is determined by the distance between nodes in the network. Potential supply chain problems can be managed and mitigated with the use of an understanding of and measurement of this density [92].

SC complexity also significantly influences the severity of supply chain disruptions [92]. SC complexity encompasses the total number of nodes and the total number of forward, backward, and within-tier flows. Forward flows represent the movement of materials from an upstream node to a downstream node, while backward flows involve the reverse movement from downstream to upstream nodes, such as in returns. Within-tier flows indicate material transfers between nodes within the same tier. A supply chain with more nodes and flows is inherently more complex than a less complex one.

SC criticality is the last SC design variable considered in this study. In a SC, each node is important because it adds value. However, some nodes are more important than others based on what they do and how much value they add. For example: a supplier providing a key part is more critical than one supplying a less important part; a company that combines many parts into a big component is more critical than one combining fewer parts; and a distribution centre that sends materials to many places is more critical than one that sends to only a few places. Thus, the number of critical nodes within a SC determines how critical the SC is.

### 2.3.2.3 Supply chain strategies

The model proposed by Marshall Fisher [113] in his significant and influential paper published in the Harvard Business Review led many authors to adopt two types of SC strategies: lean - equivalent to Fisher's Efficient strategy, and agile - equivalent to Fisher's Market-responsive strategy (114, 115, 116, 117). According to Christopher [114], there are three critical dimensions that determine which approach - agile or lean - makes the most sense for a company: variety, variability (or predictability), and volume.

Agility is needed in less predictable environments where demand is volatile and the requirement for variety is high. Conversely, lean works best in high volume, low variety, and predictable environments. Table 3 present the main characteristics of Lean and Agile strategies.

***Table 3:*** *Main characteristics of Lean and Agile SC strategies*

| SC Strategy | Lean | Agile |
|---|---|---|
| Objective | Focuses on cost reduction and incremental improvements for existing products.<br>Focuses on elimination of waste and non-value-added activities across the supply chain | Tracks and understands customer requirements by interacting closely with market. Aims to produce in any volume (and not just the optimal capacity utilization volume) and deliver simultaneously to a wide variety of markets. Provide customized products as short lead times (i.e. focuses on responsiveness) |
| Inventory strategy | Generates high inventory turnover and minimizes inventory through the supply chain | Deploys significant stocks of parts to tide over unpredictable market requirements |
| Lead time focus | Shortens lead-time only so long as doing so does not increase delivery or inventory costs | Reduces lead times to customer specifications and requirements |
| Manufacturing focus | Maintains high average capacity utilization rate | Deploys excess/buffer capacity to ensure that raw material/components are available to manufacture the product according to market requirements |
| Product design strategy | Reduces the cost of production | Produces to modular designs, by using a limited number of basic components and processes that can be assembled into different products |

Source: Adapted from [117]

Additionally, authors have increasingly adopted a combined lean and agile, or leagile strategy. Leagile is understood as the combination of the two strategies and can operate, for example, cost-effectively in upstream activities of the supply chain and responsively to volatility in the market downstream [95].

## 2.4 Supply Chain Resilience Fit Model

The analysis of the relationship between context variables and intervention variables, following the strategic fit perspective, gave rise to the "Supply Chain Resilience Fit Model" (represented in Figure 4), the theoretical model that guides the in-depth study of Industrial Ecosystems.

The first relationships, represented in the figure by continuous arrows, reflect the assumption that the context in which a company or SC is inserted impacts its performance (in this case, resilience performance). As presented in the previous sections, two context variables were defined, the SC resilience indicators and the critical factors. This assumption is broadly recognized in the literature.

The dotted arrows represent the impact of intervention variables on the relationship between context variables and performance. In other words, the model suggests that the intervention variables – resilience capabilities, SC design, and SC strategies – moderate the relationship between context variables and performance. To the moderation perspective of fit, the impact that a predictor variable (context) has on a criterion variable (performance) is dependent on the level of a third variable, known as moderator (intervention). This perspective is used when the theory specifies that the impact of the predictor varies across the different levels of the moderator, which can be viewed categorically (e.g., types of environment, stages of product life cycle, organizational types) or characteristically (e.g., degree of business-relatedness, degree of competitive intensity). The type of moderation affects the direction or the strength of the impact on the dependent variable (e.g., performance) [103].

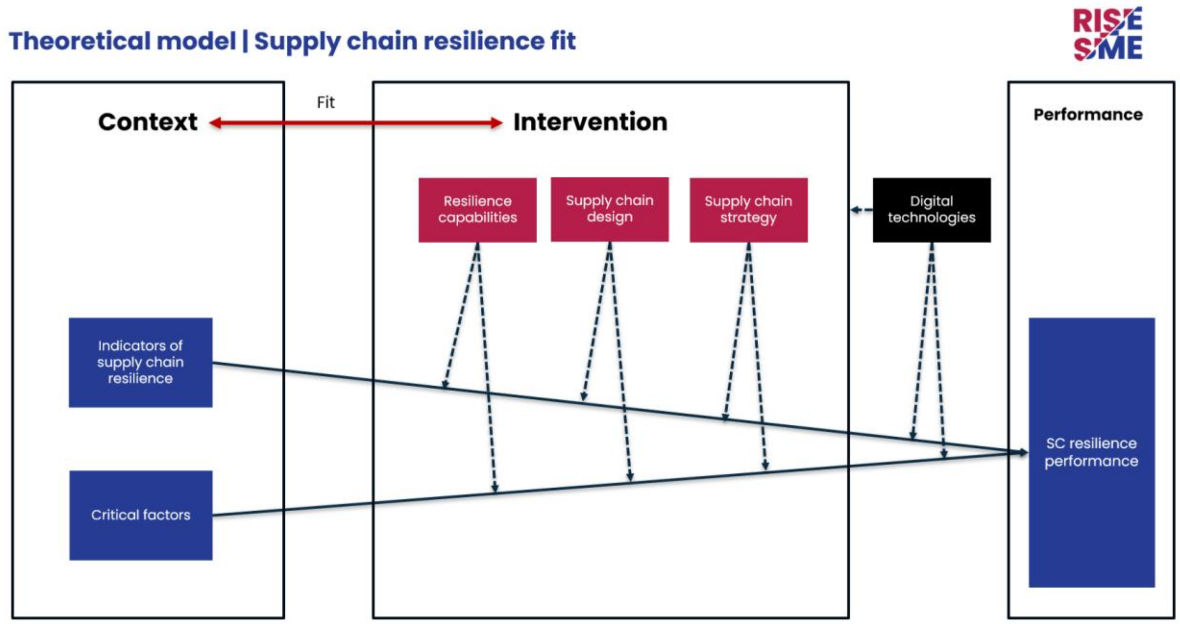


***Figure 4:*** *Supply chain resilience fit Model*

Afterwards, we analyse the theoretical fit between the variables. The objective is to understand how the adoption of different practices related to the three intervention variables may or may not influence the relationship between context variables and performance. The identified relationships (demonstrated by the arrows in Figure 4 above) are presented in detail in the tables 4, 5 and 6. Each filled cell in the tables corresponds to a proposition. Based on the literature review, the researchers identified the most significant relationship between variables. We emphasize that this step of the analysis was carried out by three researchers involved in the project separately and meetings were held to reach consensus.

Table 4 presents the relationship between the indicators of ecosystems resilience and resilience capabilities. The analysis was based on the following generic proposition:

*Generic proposition 1: The "resilience capability A" has a positive impact on the relationship between "the indicator of ecosystem resilience X" and resilience performance.*

***Table 4:** Relationship between Indicator of Ecosystem Resilience and Resilience Capabilities*

| Indicators of ecosystems resilience | Prepare | Respond | Transform |
|---|---|---|---|
| Level of Economic Essentiality | X (Market strength) | | X |
| Ability to reorganise production remotely | X (Adaptability and Visibility) | | X |
| Ability to supply products remotely | X (Adaptability and Visibility) | | X |
| Potential for supply chain disruption | X (Adaptability and Efficiency) | X | X |
| Exposure to domestic demand fluctuations | X (Adaptability) | X | X |
| Exposure to foreign demand fluctuations | X (Adaptability) | X | X |
| Short term liquidity risk | X (Financial strength) | | |
| Longer term borrowing constraints | X (Financial strength) | | |

Table 5 presents the relationship between the indicators of ecosystems resilience and SC design. The analysis is guided by the following generic proposition:

*Generic proposition 2: The higher the level of "SC design characteristic A", the greater (or lesser) the impact of the "Indicator of Ecosystems Resilience X" on performance.*

***Table 5:** Relationship between Indicator of Ecosystem Resilience and supply chain design*

| Indicators of ecosystems resilience | Density | Complexity | Criticality |
|---|---|---|---|
| Level of Economic Essentiality | | | |
| Ability to reorganise production remotely | + | - | - |
| Ability to supply products remotely | + | - | - |

| | | | |
|---|---|---|---|
| Potential for supply chain disruption | - | + | + |
| Exposure to domestic demand fluctuations | - | + | + |
| Exposure to foreign demand fluctuations | + | - | + |
| Short term liquidity risk | | | |
| Longer term borrowing constraints | | | |

Note: Plus (+) or minus (-) symbols are used in the table to indicate the direction of impact.

Table 6 presents the relationship between the indicators of ecosystems resilience and SC strategies. The analysis is guided by the following general proposition:

*Generic proposition 3: The adoption of the "SC strategy A" has a positive impact on the relationship between the "indicator of ecosystem resilience X" and performance.*

***Table 6:*** *Relationship between Indicator of Ecosystem Resilience and supply chain strategy*

| Indicators of ecosystems resilience | Agile | Lean | Leagile |
|---|---|---|---|
| Level of Economic Essentiality | | | |
| Ability to reorganise production remotely | | X | X |
| Ability to supply products remotely | X | | X |
| Potential for supply chain disruption | X | | X |
| Exposure to domestic demand fluctuations | X | | X |
| Exposure to foreign demand fluctuations | X | | X |
| Short term liquidity risk | | X | X |
| Longer term borrowing constraints | X | | |

Finally, the systematic literature review that gave rise to the variables identified for the model also demonstrated the growing relevance of digital technologies, not only as potential moderators of the relationship between context and performance, but also as drivers of the intervention variables themselves. Therefore, although it is not the objective of the tasks that make up this deliverable, we considered it important to highlight the role of technologies in the model, which will be further explored in the following tasks of the RISE-SME project.

# 3 Industrial ecosystems

This chapter presents the four ecosystems that are part of the scope of the RISE-SME project: textile, agri-food, digital and mobility. The main characteristics of the industries that comprise them are described, as well as an assessment of the aspects that impact their resilience. Finally, an analysis of the relationships between context variables and possible interventions to be carried out by ecosystem stakeholders is presented, culminating in a relationship model for each ecosystem.

## 3.1 Textile ecosystem

This session presents an overview of the Textile ecosystem, including overall sector characteristics, its impact on the economy and society and the main types of actors. Regarding textile resilience characteristics, indicators of resilience and critical factors that could influence the ecosystem will also be presented.

### 3.1.1 Overview

The **textile ecosystem** is very complex due to a large number of SMEs, global competition, a strong link between large brands and suppliers and environmental problems. Looking at the sectors and sub-sectors defined in the NACE classification, the textile ecosystem includes the transformation of natural (e.g. cotton, flax, wool), man-made and artificial (synthetic polyester and viscose) fibres into yarns and fabrics, production of yarns, home textiles, industrial filters, technical textiles, carpets and clothing. The ecosystem also includes the production of footwear and leather, the manufacturing of intermediate goods and fashion goods, as well as the distribution of these products to the markets operated by wholesalers, agents, and retailers. The fashion industry is the main market for textile products. Table 7 proposes a classification of the sectors and subsectors (I, II, III, IV, V and VI) of the textile ecosystem based on NACE codes

***Table 7:*** *Sectors and sub-sectors of the textile ecosystem from Csil report.*[2]

| Sectors | Subsectors |
|---|---|
| **I - Intermediate products for textiles** | **Man-made fibres**<br>C206 - Manufacture of man-made fibres<br>**Yarns**<br>C131 - Preparation and spinning of textile fibres<br>**Fabrics**<br>C132 - Weaving of textiles<br>C133 - Finishing of textiles<br>C1391 - Manufacture of knitted and crocheted fabrics |
| **II - Intermediate products for leather and fur goods** | **Tanned and dressed leather and fur** |

[2] Csil report - Data on the EU textile ecosystem and its competitiveness, 2021. Data on the EU textile ecosystem and its competitiveness - Publications Office of the EU (europa.eu)

| Sectors | Subsectors |
|---|---|
| | C1511 - Tanning and dressing of leather; dressing and dyeing of fur |
| **III - Textiles** | **Home textiles**<br>C1392 - Manufacture of made-up textile articles, except apparel<br>C1393 - Manufacture of carpets and rugs<br>**Technical & industrial textiles**<br>C1394 - Manufacture of cordage, rope, twine and netting<br>C1395 - Manufacture of non-wovens and articles made from non-wovens, except apparel<br>C1396 - Manufacture of other technical and industrial textiles<br>C1399 - Manufacture of other textiles n.e.c. |
| **IV - Clothing** | **Textile wearing apparel and accessories**<br>C1412 - Manufacture of workwear<br>C1413 - Manufacture of other outerwear<br>C1414 - Manufacture of underwear<br>C1419 - Manufacture of other wearing apparel and accessories<br>C1431 - Manufacture of knitted and crocheted hosiery<br>C1439 - Manufacture of other knitted and crocheted apparel |
| **V - Fashion leather and fur finished products and footwear** | **Leather clothes and accessories**<br>C1411 - Manufacture of leather clothes<br>C1512 - Manufacture of luggage, handbags and the like, saddlery and harness<br>**Articles of fur**<br>C1420 - Manufacture of articles of fur<br>**Footwear**<br>C1520 - Manufacture of footwear |
| **VI - Distribution of fashion products** | **Wholesale & agents of fashion products**<br>G46.1.6 - Agents involved in the sale of textiles, clothing, fur, footwear and leather goods<br>G46.4.2 - Wholesale of clothing and footwear<br>**Retail of fashion products**<br>G47.7.1 - Retail sale of clothing in specialised stores<br>G47.7.2 - Retail sale of footwear and leather goods in specialised stores |

In Figure 5, the contributions of all the sectors in terms of net turnover and value added are represented.

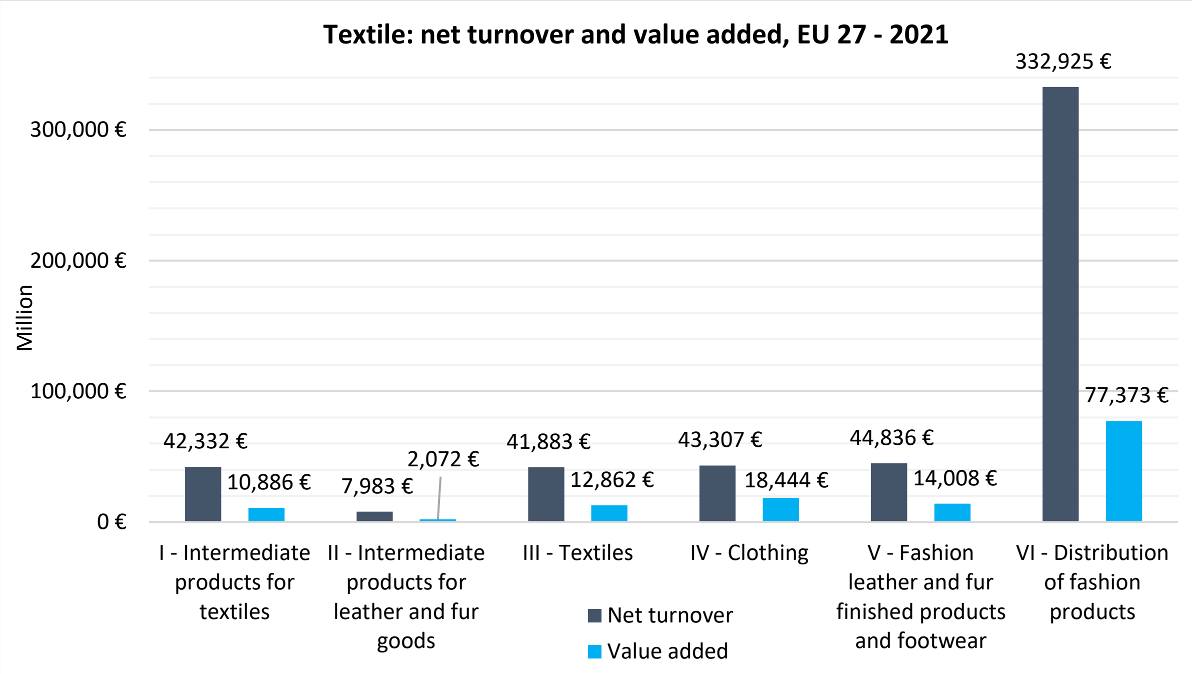


***Figure 5:** Textile subsectors net turnover, all subsectors. Source: Eurostat [Statistics | Eurostat (europa.eu)][3].*

It is evident that the *Distribution of Fashion Products (VI)* sector predominates in both dimensions. Despite being the most economically significant, this sector represents the diversity of the textile ecosystem, as its activities are directly connected companies of different sectors. It is in fact, the most *horizontal* among them all. The activities within it involve retail, wholesale sales and sales agents, which are also present in other industrial sectors. The nature of this activities themselves explains the reasons behind such economic magnitudes.

By excluding the *Distribution of fashion products* sector from the analysis, is it possible to better appreciate the data concerning the other subsectors. Regarding net turnover, there is an equitable distribution among sectors *I, III, IV*, and *V*, while in terms of value added, the *clothing* sector *(V)* stands out slightly above the others. Therefore, considering net turnover and value added together, the sectors *intermediate products for textiles (I), textiles (III), clothing (IV)*, and *fashion leather and fur finished products and footwear (V)* can be seen as the most indicative for the ecosystem.

#### 3.1.1.1 Facts and figures

SMEs are at the core of the ecosystem, representing 99.5% of the companies and more, companies with less than 50 employees account for more than 90% of the workforce and produce almost 60% of the value added. On the one hand, the high share of SMEs in the ecosystem can be considered a vulnerability since these companies are generally more exposed to risks, especially those that come from external factors such as the critical

[3] Data for subsectors C131, C132, C133 and C206 are from 2022.

disruptions that have characterized current business environment. Women represent more than 70% of all employees in the sector.

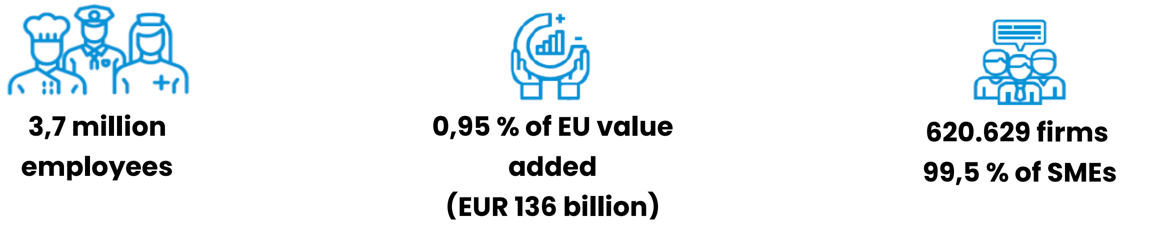


***Figure 6:*** Textile ecosystem. *Source: European Commission - Annual Single Market Report 2021.*

Figures 7 shows the distribution of the textile ecosystem among EU countries with the most significant ecosystem contributions in terms of total net turnover, number of companies and employees (the last represented by the size of the circle). As it can be seen, Italy has an outstanding relevance in these three indicators while Germany, France, and Spain follow, with Germany distinguishing itself slightly due to its higher net turnover (although presenting a third of the number of companies compared to Italy) and larger workforce. Meanwhile, Poland, the Netherlands, Belgium, and Sweden collectively comprise the rest of the ecosystem, exhibiting similar net turnover figures but varying in terms of company count and employees.

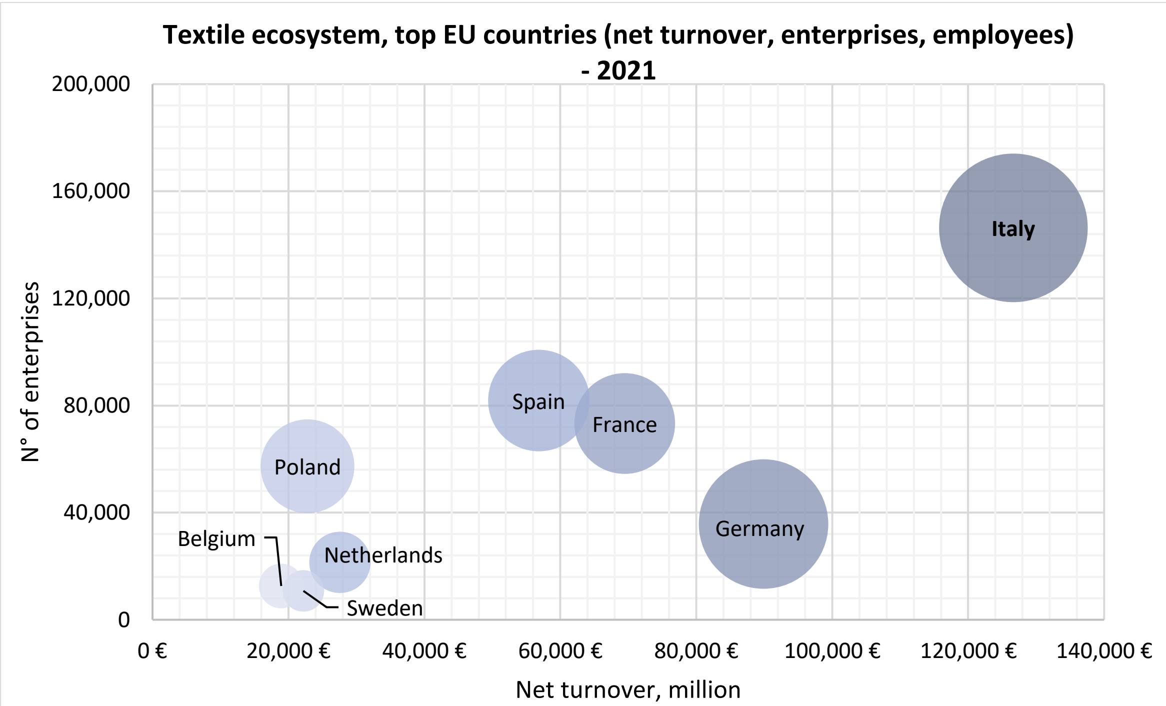


***Figure 7:*** *Distribution of total net turnover, enterprises, and employees among EU countries. Source: Eurostat (the bubble dimension represents the number of employees)[4].* Statistics | Eurostat (europa.eu);

When ranking the countries along these three dimensions (Table 8) the leadership position of Italy is once again clear, with Germany following closely in terms of net turnover and

[4] Data for subsectors C131, C132, C133 and C206 are from 2022.

employees. France and Spain also right behind. Based on the data, it can be affirmed that Italy, Germany, Spain, and France are the countries that best represent the ecosystem in terms of net turnover, number of enterprises, and employees.

***Table 8:*** *most representative countries in terms of net turnover, number of enterprises and employees Source: data from Eurostat, 2021.* Statistics | Eurostat (europa.eu).

| **Net turnover** | Million | **Enterprises** | | **Employees** | |
|---|---|---|---|---|---|
| Italy | 126.655 € | Italy | 146.326 | Italy | 756.999 |
| Germany | 89.897 € | Spain | 81.855 | Germany | 574.598 |
| France | 69.470 € | France | 73.272 | Spain | 353.486 |
| Spain | 16.265 € | Poland | 57.325 | France | 347.854 |
| Netherlands | 27.571 € | Germany | 35.743 | Poland | 301.232 |

Considering the economic relevance of the textile ecosystem for a specific country, table 9 presents the ratio between the net turnover of the ecosystem and the GDP of the countries. Italy and Portugal are the countries where the textile industry is most significant for GDP, with a percentage value nearly double the European average. Spain follows, but not with the same percentage value as the first two countries. For France and Germany, although the textile sector is economically significant, the percentage of GDP attributed to it is lower than the European average, since it is not as pivotal sector as in other European countries.

***Table 9*:** Textile ecosystem's relevance to each country's gross domestic product. *Source: data from Eurostat. Statistics | Eurostat (europa.eu) and Statistics | Eurostat (europa.eu).*

| ***Country*** | ***GDP %*** | ***Country*** | ***GDP %*** | ***Country*** | ***GDP %*** |
|---|---|---|---|---|---|
| 1 - Italy | 6,95% | 4 - Sweden | 4,11 % | **10 - EU27** | **3,51%** |
| 2 - Portugal | 6,46% | 5 - Poland | 3,96% | 20 - France | 2,78 % |
| 3 - Spain | 4,65% | 8 - Belgium | 3,73% | 24 - Germany | 2,49 % |

Regarding the textile ecosystem innovation capability, it is important to emphasize that this sector is facing urgent challenges and requiring innovations, including reducing its carbon footprint, increasing product traceability and transparency, thus reducing the waste of primary resources in production and distribution, and trying to implement a recycling system across the industry (European Commission, 2024; Niinimäki et al., 2020). In this context of rapid change and adaptability, the number of new patents is an indication of the competitiveness of the industry (Figure 6).

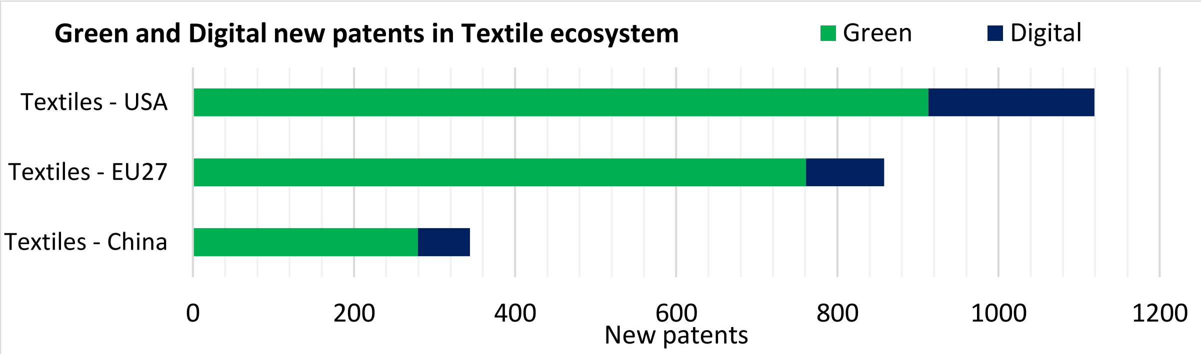


***Figure 8:*** *number of new green and digital patents per market. Source: dataset elaborated from [Textiles | European Monitor of Industrial Ecosystems (europa.eu).](#)*

Figure 8 shows a comparison between EU, USA and China markets when it comes to new patents. The patents are divided into *green* and *digital*[5], demonstrating a big effort of USA and EU in economic and research terms to provide new ideas and solutions to make the textile industry more environmentally sustainable.

### 3.1.1.2 Main actors and geographical distribution

This section aims to provide an overview of the composition of the textile ecosystem by identifying its main actors and analysing their geographical distribution. Some of the most important actors of the textile ecosystem belong to the categories identified below:

- **Raw materials suppliers:** e.g. fibre producers, mainly in countries outside EU.
- **First and lower levels of manufacturers:** they take care of intermediaries' production phase, like yarn manufacturers and trim manufacturers.
- **Distributors and retailers:** increasingly represented by large fashion companies that sell worldwide.
- **Consumers:** can be private individuals, reselling companies, or other manufacturing companies.
- **Other actors involved in circular economy** - such as disposal, reuse, and recycling companies.
- **Logistic operators**: vital for the industry, but they usually operate in several ecosystems, so it is difficult to understand how much of a logistics company operates in textile.

This ecosystem needs to be supported by other actors actively contributing to create value:

- **Policymakers** – local, national, and European levels.
- **Research centres and confederations in Europe** -Relevant knowledge and technology actors across Europe, responsible for the creation of innovative solutions for the ecosystem. Table A2 in the annex shows some of the most important ones.
- **Technology providers**: incubation centres for high-tech startups emerging from universities and research centres, which can be useful and profitable for industries.

[5] Green and Digital patents are related to the technologies showed in Figure 17 and 26 of Monitoring the twin transition of industrial ecosystems - TEXTILES.

Considering the different actors and categories, figure 9 presents an example of an attempt of a textile ecosystem's categories map. In this example, the Clothing and the Textile industries in Europe are considered the focal points, interacting with other actors that are located worldwide. The figure provides information about the representativeness of countries and regions upstream (suppliers) and the main actors downstream (clients). The map is not intended to be a representation of the entire ecosystem. A similar representation can be done for other sectors such as footwear or industrial textiles (intended to automotive or construction sectors, among others).

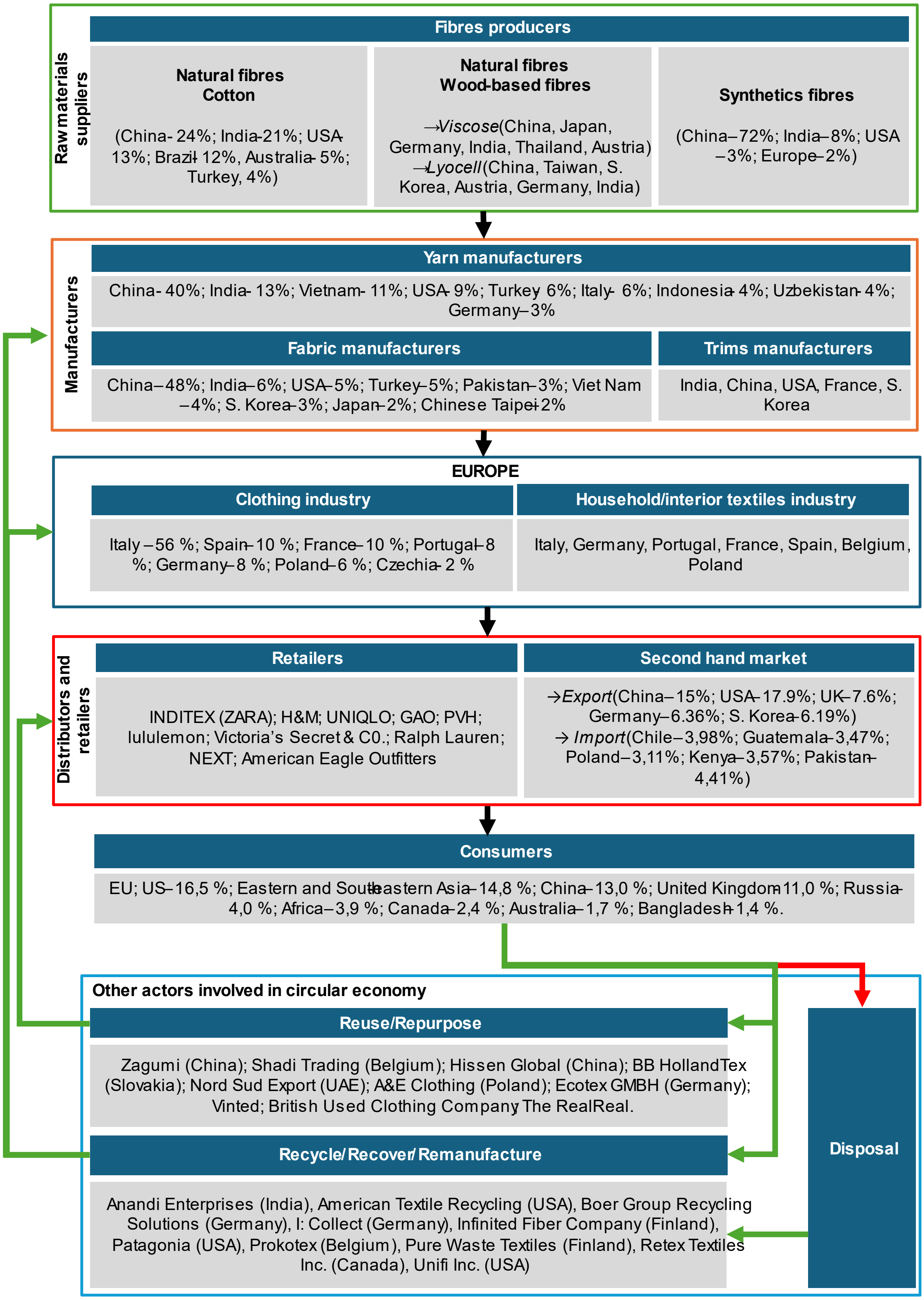


***Figure 9:*** Example of supply chain map for Clothing and Household textile industry. Source: [9-23]

### 3.1.2 Indicators of Ecosystems Resilience

The resilience of industrial ecosystems is critical for ensuring the sustainability and adaptability of value chains in the face of disruptions. In the textile industry, which spans from raw material production to finished garments, the indicators of ecosystem resilience behaviour are presented in Table 10.

***Table 10:*** *Overview of Textile Indicators (0 means less resilient, 10 means more resilient)*

| Macro Indicators | Ecosystems characteristics | Level |
|---|---|---|
| Ability to Produce and Supply | Essential industry classification | **1** |
| | Ability to reorganise production remotely | **1** |
| | Ability to supply products remotely | **10** |
| | Potential for supply chain disruption | **1** |
| Exposure to Indirect Demand Shocks | Exposure to domestic demand fluctuations | **10** |
| | Exposure to foreign demand fluctuations | **2** |
| Financial Constraints | Short term liquidity risk | **1** |
| | Longer term borrowing constraints | **1** |

Note: 0 means less resilient, 10 means more resilient

Looking into the macro resilience indicators - Ability to Produce and Supply, Exposure to Indirect Demand Shocks, and Financial Constraints – some examples of possible disruptions and actions for the textile ecosystem, as follows:

- Regarding the company's Ability to Produce and Supply, textile manufacturers might implement remote work for design and administrative staff while ensuring safe working conditions in factories. Additionally, firms may reduce the production of physical retail spaces and focus on enhancing e-commerce capabilities to meet consumer demand without requiring physical proximity.
- About the Exposure to Indirect Demand Shocks, a decline in household consumption due to economic downturns can reduce demand for luxury textiles, prompting firms to shift focus towards producing more affordable clothing. Additionally, fluctuations in export demand due to geopolitical tensions may necessitate diversifying markets to stabilize revenue streams.
- Finally, Financial Constraints might emerge when textile firms may require immediate liquidity to purchase raw materials or pay workers during supply chain delays. In addition, the likelihood of financial constraints in the longer run due to borrowing constraints, affecting future investment and growth. This could include challenges in securing credit to invest in sustainable technologies or expand production capabilities, impacting the speed of recovery as economic activity resumes.

By addressing these indicators with specific strategies tailored to the textile value chain, the industry can enhance its resilience, ensuring long-term sustainability and competitiveness in an ever-evolving global market.

### 3.1.3 Critical factors

The critical factors identified in the textile ecosystem are: health and pandemic disruptions; environmental crises and natural disasters; political conflicts and crises; technological disruptions and low digital maturity; challenges in sustaining existing business model; supplier and customer concentration (overdependencies); global and complex supply chains (decentralization of supply and demand); skills gaps; waste; and infrastructure and logistics disruptions. One of the key critical issues for EU textiles is the reliance on a global supply chain, which makes the whole system vulnerable, but it is not the only issue, as anticipated before. The ecosystem is facing big challenges to be able to remain competitive in the global market, but also to persist, adapt or transform in the face of the increasingly common disruptive events. Table 11 presents some of the main critical factors.

***Table 11:*** Textile critical factors

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| Health and pandemic disruptions | • Possible closure of frontiers and lockdowns can impact this ecosystem given its highly interconnected supply chain and significant employment and GDP contributions | 10 |
| Environmental crises and natural disasters | • The global economic crisis, currency devaluation, and concerns about natural disasters impact the development of the supply chain. | 15 |
| Political conflicts and crises | • The impact of regional conflicts further complicates global | 15 |
| Technological disruptions and low digital maturity | • Limited capacity of an organization to effectively adopt and integrate digital technologies, limiting its competitiveness and ability to innovate in the current market.<br>• Digitalization drives the systematic redesign of products, business models, and value chains. | 3 |
| Challenges in sustaining existing business model | • Difficulties in maintaining the existing business model due to market changes or shifts in consumer expectations.<br>• New digital technologies are an opportunity to move from selling products only to selling products and services as a whole. | 1, 2, 3, 25 |

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| Supplier and customer concentration (overdependencies) | • European textile ecosystem relies mostly on importation from foreign countries for what concerns raw materials, intermediate and final products. | 2, 5, 8, 24 |
| Global and complex supply chains (decentralization of supply and demand) | • Textile supply chains are global and complex, making difficult their map and the adoption of practice to increase visibility, and collaboration (companies usually do not have sufficient information on their supply chains).<br>• Suppliers are spread across the world with impact on the distribution process, and with clear implications on the environmental footprint and robustness of supply chains. | 1, 2, 4, 22 |
| Skills gaps | • Many suppliers are located in developing countries, where it is difficult to provide skills to workers due to poor labour policies.<br>• There is a lack of workers who are trained in both digital and green skills, which are in high demand to manage the future transition of the industry.<br>• Shortage of workers with advanced digital skills. | 1 |
| Waste | • Textile waste is usually incinerated or transported to landfills or developing countries without any regulation or tracking of the disposal phase.<br>• It is estimated that 1/3 of the garments produced each year are unsold or returned after purchase, and then directly incinerated.<br>• Difficulties in recycling fibres because of the blended composition. | 1,2,5,7,24 |
| Infrastructure and Logistics Disruptions | • High energy and water demand in each stage of the supply chain.<br>• High amount of scrap and waste generation during textile production processes.<br>• The current global supply chain relies on fast transport, which is very energy intensive, and disruptions in the energy supply sector can severely affect the global textile system. | 1, 2, 5, 6 |

Regarding the critical factors presented in table 11, some aspects may be emphasized such as:

- The **mismatching between skills demand and supply** is an issue for the textile ecosystem, particularly digital skills. Green skills, although still in low demand, represents a future demand change in textile sustainability [1].

- Nowadays most of the **EU textile waste is not collected** and directly sent to foreign countries (usually economically disadvantaged and without stringent environmental laws) to be incinerated. In 2022, EU generated 7.5M tons of waste in textile, being 33% collected and reused/recycled. The main problem is that Europe is missing a common framework to coordinate production, the "design to recycle", and disposal to be ready to recycle and close the loop [26].
- Regarding the technological perspective, **transparency** and **traceability** of products is still a challenge. Companies typically share data only with first-tier suppliers/customers, while communication and collaboration with the second (and lower) tier of the supply chain is generally very low or even non-existent [1].
- **Dependency from foreign countries** is another important critical factor/challenge in textile industry. Europe has a high dependency for the supply of materials and components to some countries, with emphasis on China (43.1% of total imports). In addition, imports exceed exports, revealing a trade imbalance in the ecosystem [24].

### 3.1.4 Textile Supply Chain Resilience Fit Model

Figure 10 represents presents the final model for the textile ecosystem. The context variables presented are those identified as most relevant to the ecosystem. Indicators of ecosystem resilience with a score lower than 5 points were inserted, as well as all critical factors identified as potentially impacting the ecosystem. In turn, the intervention variables presented are those that best respond to the context variables relevant to the ecosystem. Moreover, the textile ecosystem's intervention factors were associated with the following critical factors: Health and pandemic disruptions, Environmental crises and natural disasters, Political conflicts and crises, Technological disruptions and low digital maturity, Challenges in sustaining existing business model, Supplier and customer concentration (over dependencies), Global and complex supply chains (decentralisation of supply and demand), Skills gaps, Waste and Infrastructure and Logistics Disruptions.

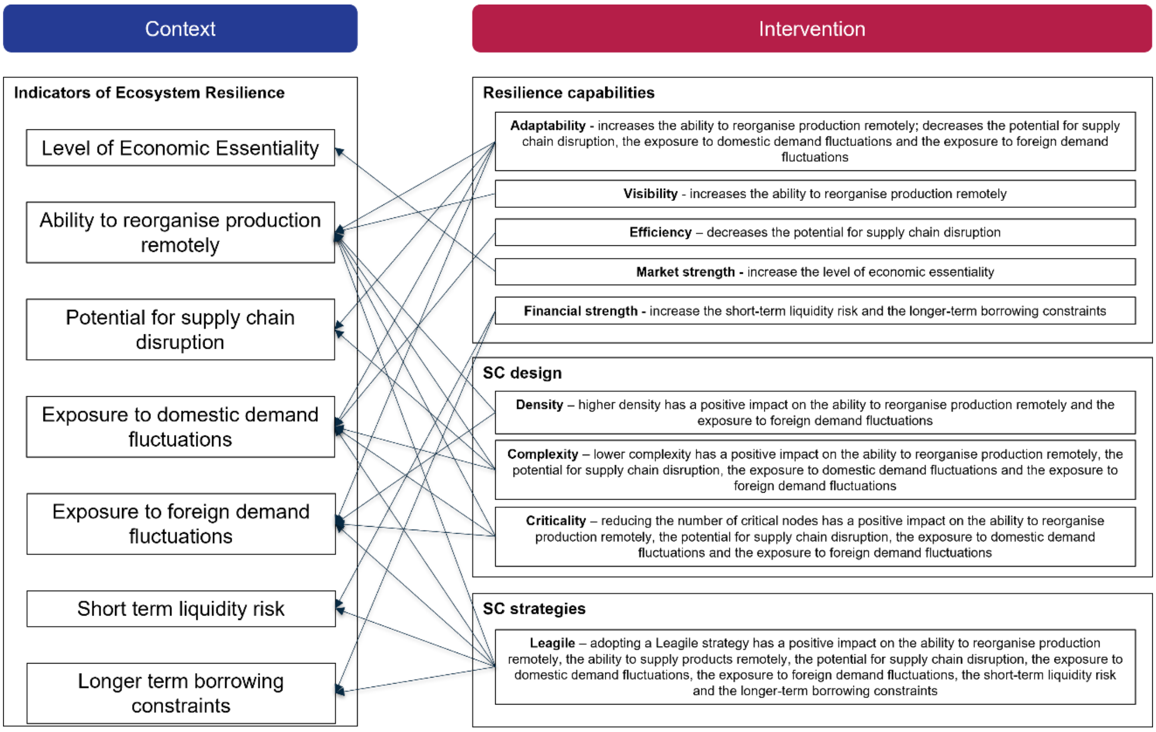


***Figure 10:*** Supply chain fit model for the textile ecosystem

## 3.2 Agri-food ecosystem

### 3.2.1 Overview

The European Union is the number one food and beverages exporter in the world. The agri-food ecosystem covers **all operators in the food supply chains** (farmers, food industry, food retail and wholesale, and food service) and their **suppliers of inputs and services** (raw material, seeds, pesticides, fertiliser, machinery, packaging, repair, transport, finance, advice and logistics). In particular, the ecosystem is divided into food and beverage manufacturing and raw material production (crops, animals). The ecosystem hence has a very long border – and overlaps – with the tourism and the retail ecosystems. Table 12 presents the ecosystem definition according to its NACE codes.

***Table 12:*** *Agri-food ecosystem boarders' definition, NACE codes.*

| Sectors | NACE codes | Sub-sectors |
|---|---|---|
| **I - Manufacture of food products** | C10 | · C10.1 Processing and preserving of meat and production of meat products<br>· C10.2 Processing and preserving of fish, crustaceans and molluscs<br>· C10.3 Processing and preserving of fruit and vegetables<br>· C10.4 Manufacture of vegetable and animal oils and fats<br>· C10.5 Manufacture of dairy products<br>· C10.6 Manufacture of grain mill products, starches and starch products<br>· C10.7 Manufacture of bakery and farinaceous products<br>· C10.8 Manufacture of other food products<br>· C10.9 Manufacture of prepared animal feeds |
| **II - Manufacture of beverages** | C11 | |
| **III - Growing of non-perennial crops** | A01.1 | · A01.11 Growing of cereals (except rice), leguminous crops and oil seeds<br>· A01.12 Growing of rice<br>· A01.13 Growing of vegetables and melons, roots and tubers<br>· A01.14 Growing of sugar cane<br>· A01.15 Growing of tobacco<br>· A01.19 Growing of other non-perennial crops |
| **IV - Growing of perennial crops** | A01.2 | · A01.21 Growing of grapes<br>· A01.22 Growing of tropical and subtropical fruits<br>· A01.23 Growing of citrus fruits |

| Sectors | NACE codes | Sub-sectors |
|---|---|---|
| | | · A01.24 Growing of pome fruits and stone fruits<br>· A01.26 Growing of oleaginous fruits<br>· A01.29 Growing of other perennial crops |
| **V - Animal production** | A01.4 | · A01.41 Raising of dairy cattle<br>· A01.42 Raising of other cattle and buffaloes<br>· A01.43 Raising of horses and other equines<br>· A01.45 Raising of sheep and goats<br>· A01.46 Raising of swine/pigs<br>· A01.47 Raising of poultry<br>· A01.49 Raising of other animals |
| **VI - Forestry and logging** | A02 | · A02.1 Silviculture and other forestry activities<br>· A02.2 Logging<br>· A02.3 Gathering of wild growing non-wood products<br>· A02.4 Support services to forestry |
| **VII - Fishing and aquaculture** | A03 | · A03.1 Fishing<br>· A03.2 Acquaculture |

Within the ecosystem, the most prominent activity is related to *manufacture - food products and Beverages*, as it is the industrialized link of the ecosystem. In Figure 11 is possible to see the economic value of each sector in the ecosystem.

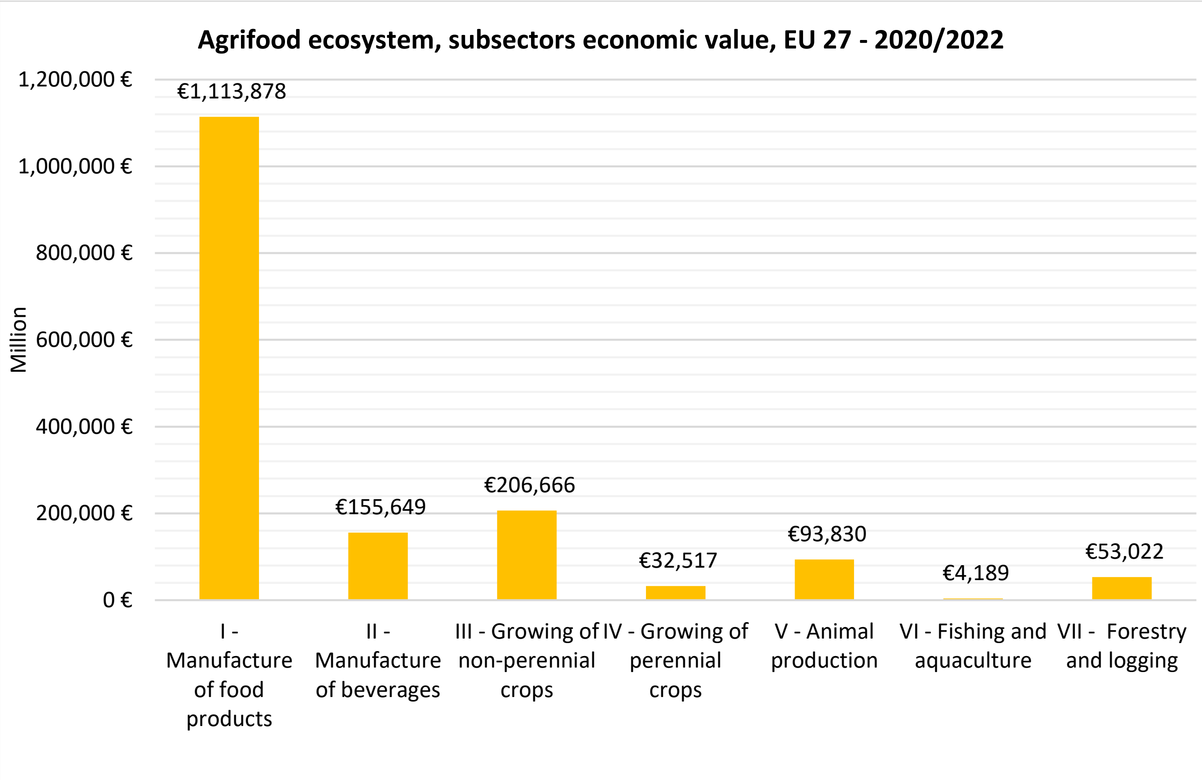

*__Figure 11:__ representation of the economic value of each agri-food subsector. Source: Eurostat:1) [Statistics | Eurostat (europa.eu)](), 2) [Statistics | Eurostat (europa.eu)](), 3) [Statistics | Eurostat (europa.eu)](), 4) [Statistics | Eurostat (europa.eu)]().*

Besides the manufacture of food products, manufacturing of beverages has also a relevant position in the economic value, which shows the industrialization level of this ecosystem. By its turn, growing crops and animal production are other activities that have a relevant contribution to the value chain.

### 3.2.1.1 Facts and figures

SMEs are the backbone of the European agri-food ecosystem. 99% of food and drink enterprises are SMEs, representing 60% of employment and 47.5% of turnover. Of these, 78% are micro enterprises (less than 10 employees), whereas leading large enterprises only correspond to 1%. Yet, these leading large enterprises employ 40% of the workforce and generate 52.5% of turnover of the sector.

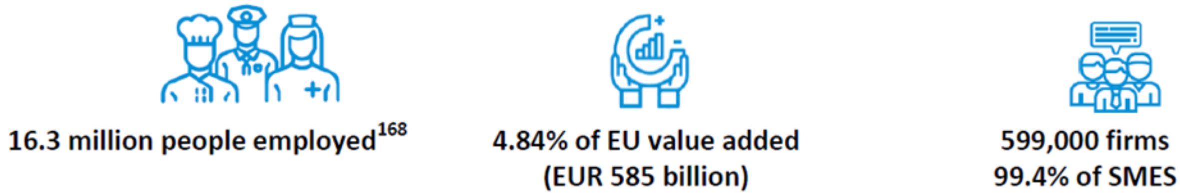


***Figure 12:** Numbers representing textile ecosystem. Source: Annual Single Market Report 2021. ( swd-annual-single-market-report-2021_en.pdf (europa.eu) )*

Analyzing the *manufacturing* subsectors, which present the higher economic value of the ecosystem, it is possible to understand which countries in Europe are the most relevant in terms of employees, number of enterprises and net revenue. Figure 13 emphasize the role of France and Germany as leading countries, followed by Italy and Spain. The diameter of the bubbles represents the number of employees in the country.

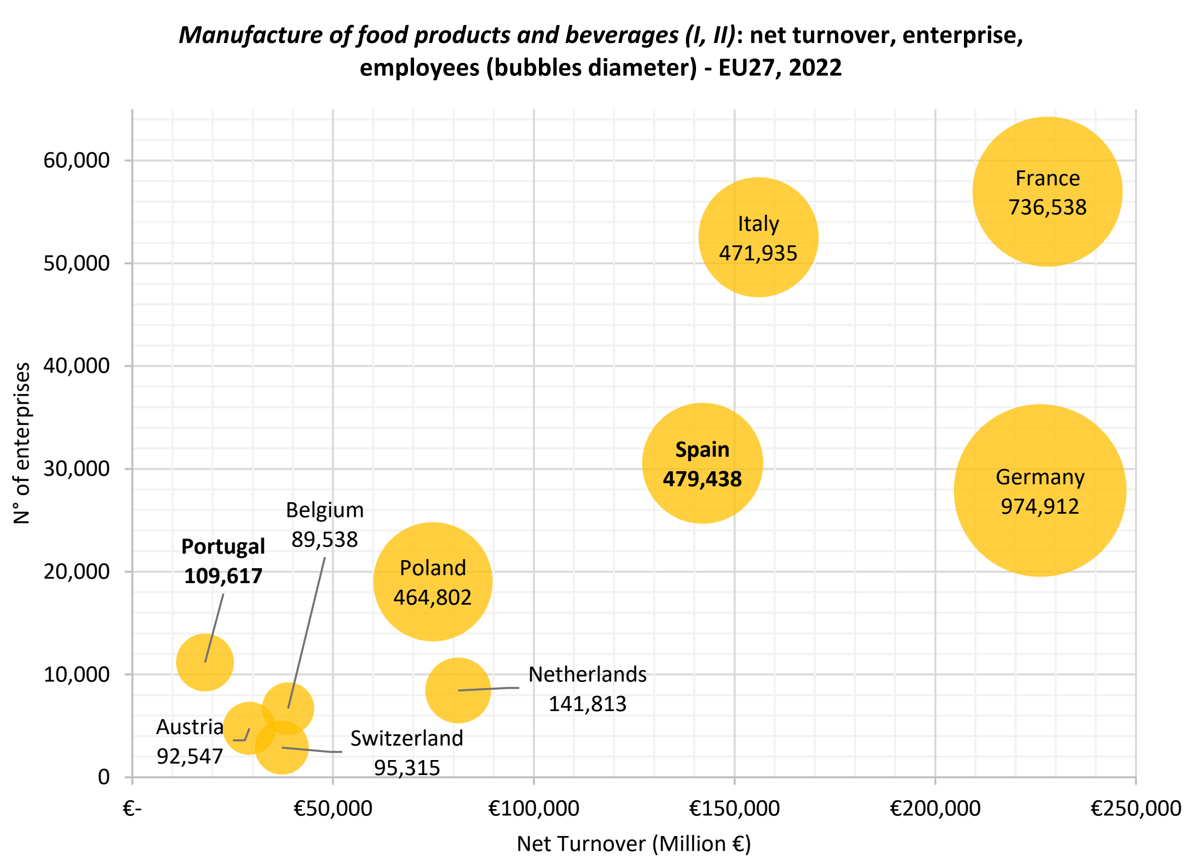


***Figure 13:** nº of enterprises, net turnover, employees of "I, II - Manufacture of food and beverage" subsectors. Source: Eurostat - [Statistics | Eurostat (europa.eu)](#).*

Complementing the information present in Figure 4, Table 13 emphasizes the detailed net turnover for each country and Table 14 shows the relative importance of the agri-food ecosystem in relation to the GDP of the individual country.

***Table 13:** net turnover, enterprises and employees of the agri-food ecosystem in numbers.*

| **Net turnover** | Million | **Enterprises** | | **Employees** | |
|---|---|---|---|---|---|
| France | 227.987 € | France | 56.969 | France | 736.538 |
| Germany | 226.146 € | Germany | 27.895 | Germany | 974.912 |
| Italy | 156.001 € | Italy | 52.536 | Italy | 471.935 |
| Spain | 142.073 € | Spain | 30.547 | Spain | 479.438 |
| Portugal | 18.112 € | Portugal | 11.164 | Portugal | 109.617 |

***Table 14:** Ratio between agri-food economic value and GDP per country.*

| ***Country*** | ***GDP %*** | ***Country*** | ***GDP %*** | ***Country*** | ***GDP %*** |
|---|---|---|---|---|---|
| **EU-27** | 11,3 % | **Italy** | 10,7 % | **Netherlands** | 11,9 % |
| **France** | 11,5 % | **Spain** | 14,9 % | **Belgium** | 10,5 % |
| **Germany** | 7,8 % | **Poland** | 18,6 % | **Portugal** | 11,9 % |

Tables 13 and 14 show that the agri-food ecosystem is a fundamental part of the European economic tissue: it is responsible for 11.3 % of the whole EU GDP. Spain and Poland are way above the EU average value, demonstrating the relevance of this sector for the national economy.

Regarding patent deposits, sustaining an efficient and resilient agri-food ecosystem demands high investments in technology as well. Figure 14 shows the innovation capabilities of worldwide players in this sector through the number of patents, which also demonstrates the region's competitiveness. It also highlights a comparison between EU, USA and China markets when it comes to new patents. The patents are divided into *green* and *digital*, demonstrating a big effort of USA and EU in economic and research terms to provide new ideas and solutions to make the agri-food industry more environmentally sustainable.

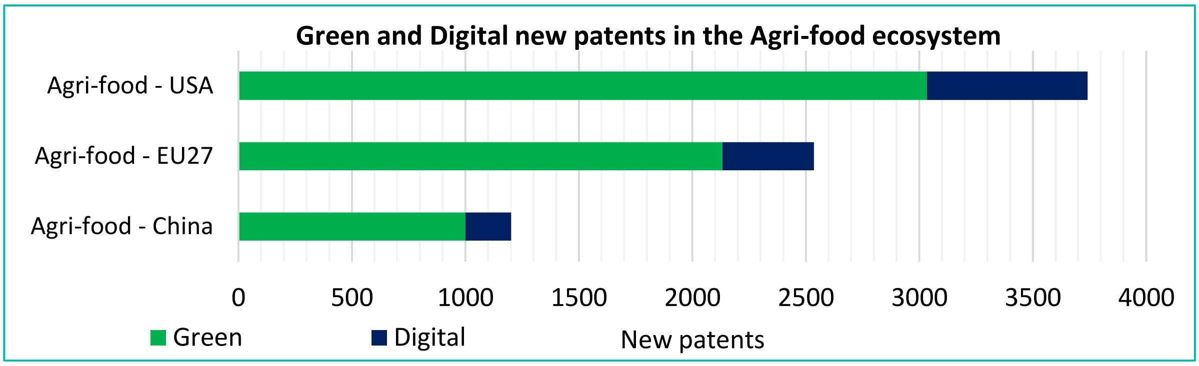


***Figure 14:*** *Patent applications in digital and green technologies per industrial ecosystem for EU 27, the US and China (absolute numbers).* ***Source:*** *data package [Agri-food | European Monitor of Industrial Ecosystems (europa.eu)]*

### 3.2.1.2 Main actors and geographical distribution

This section aims to provide an overview of the composition of the agri-food ecosystem by identifying its main actors and analysing their geographical distribution. This overview is not exhaustive, and present as an example two particularly relevant sub-sectors: meat production and crop ecosystems. The latter encompasses fruits, vegetables, and cereal production.

The main actors of the European meat production supply chain are listed below, being their interrelations presented in figure 15:

- **Feed producers:** Feed materials are primarily of EU origin: cereals, pulses and co-products from the food and bioethanol industries. However, some feed materials are imported from Third Countries, in particular, feed materials rich in proteins like soybean meal as they are not produced in sufficient quantities within the EU. Europe is heavily reliant on fertilizer imports, with up to 50% being sourced from Russia, Morocco, or Belarus.

- **Animal nutrition companies:** They specialize in creating ingredients, products and solutions that enhance the well-being, growth and health for livestock.
- **Integrated industries:** Vertical integration in meat production refers to a business model where a single company controls multiple stages of the supply chain, from production (such as farming or raising animals) to processing, distribution, and even retail. Vertical integration is common in European meat production. However, this industry exhibits varying degrees of vertical integration. While some sectors operate with a high level of integration, others remain less consolidated. The poultry and pig sectors often demonstrate a high level of vertical integration, large companies control breeding, production, processing, and distribution. Beef and lamb production however tend to be less vertically integrated as these sectors involve diverse production systems, making full integration challenging.
- **Food additives and conservatives:** Food additives and preservatives companies specialize in supplying a wide range of substances used to enhance food safety, extend shelf life, and improve sensory properties.
- **Distributors:** While the EU produces substantial amounts of meat, its export volumes are not as dominant as those of other global players (Brazil, US). Distributors in the European market are the main retailer chains.

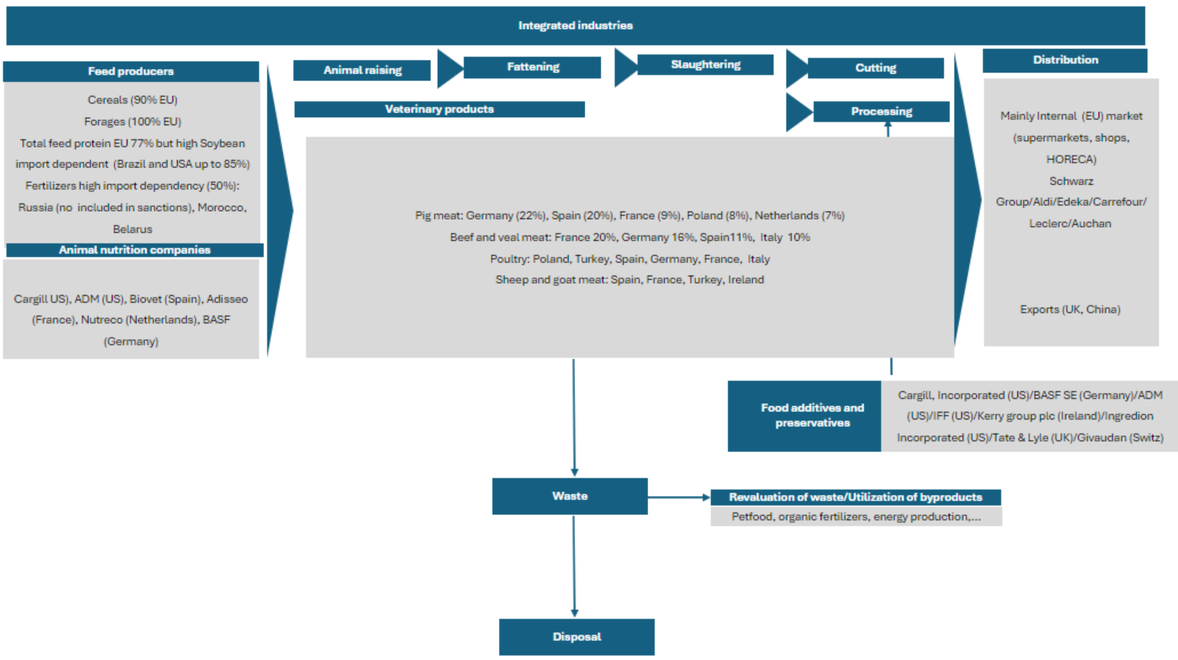


***Figure 15:*** *Example of supply chain map for meat production industry. Source: [27-39]*

The main actors of the European crop supply chain - includes fruits, vegetables and cereal production - are listed below, being a generalized view of their interrelations presented in figure 16:

- **Seed producers**: France and Germany stand out as major seed markets. However, due to the ban on genetically modified organisms (GMO) in many European countries, non-transgenic hybrids dominate the market. Specifically, insect-resistant hybrids are the primary choice for cultivation. In terms of crops, the region grows a diverse range, including potatoes, carrots, cauliflower, broccoli, spinach, peas, wheat, alfalfa, sunflower, corn, and pulses. Regarding the seed market, it is moderately consolidated, with the top five companies holding a combined market share of 51.08%. These major players include Bayer AG, Corteva Agriscience, Groupe Limagrain, KWS SAAT SE & Co. KGaA, and Syngenta Group. Additionally, other important companies in this sector include Advanta Seeds - UPL, BASF SE, DLF, Rijk Zwaan Zaadteelt en Zaadhandel BV, and Sakata Seeds Corporation. However, Europe's own seed production is limited, and it heavily depends on imports to support its agricultural and food industries. Main seeds that Europe imports are oilseeds and protein crops.
- **Fertilizers and agrochemical producers:** As in the case of the meat production, 50% of fertilizers are imported from Third Countries. Main agrochemical companies are Syngenta, Bayer, CropScience, BASF and Corteva.
- **Farm and irrigation equipment**: European manufacturers play a significant role in the farm equipment industry. Kuhn is the largest European manufacturer of field. equipment. Krone, based in Germany, focuses on high-capacity forage harvesting machinery. On the other hand, IRRIFRANCE is a leading French and European manufacturer of irrigation systems for agriculture. The European Irrigation Association (EIA) is a non-profit organization based in Brussels. It represents irrigation professionals across Europe from both the agricultural and landscape sectors. Their mission is to promote the development of sustainable irrigation products, practices, and service.
- **Farms for fresh food:** Spain, Italy, Romania, Greece, and Poland are the key players in specialized fruit production, whereas the top five Member States with vegetable cultivation are Romania, Spain, Poland, Italy, and Lithuania. Specialization in fresh vegetable production is less widespread compared to fruit. More than half of the cereals grown in Europe are wheat. Maize and Barley account for two-thirds smaller quantities of other cereals like rye, oats, and spelt contribute to the remaining third. Main European producers are France, Germany, Poland, Spain, and Italy.
- **Processing companies:** In some cases, the fresh fruit and vegetables that are not accepted for sale as fresh produce are used as inputs for the processing stage, but in other cases, such as orange juice or preserved peaches, a specific variety and grade quality is required, and production occurs separately. Processed fruits and vegetables contribute significantly to the EU's food industry, providing convenience, preservation, and value-added products. PROFEL, the European Association of Fruit and Vegetable Processors, categorizes products as follows: canned vegetables, frozen vegetables, jams and fruit preserves, fruit purees and compotes, dried vegetables, and canned and bottled fruits. Main producers are Belgium, Netherlands, Germany, France, Spain and Portugal, Poland and Italy.

- **Distributors:** The EU traditionally relies on imports for its fruit and vegetable supply. Approximately 44% of fresh fruits and vegetables are imported, with a particular focus on tropical fruits and seasonal vegetables. The United Kingdom serves as the primary destination for European exports. Regarding cereals, the EU is traditionally a net exporter. EU exports of cereals, particularly wheat and barley, have increased after the war in Ukraine, especially to regions like the Middle East and North Africa.

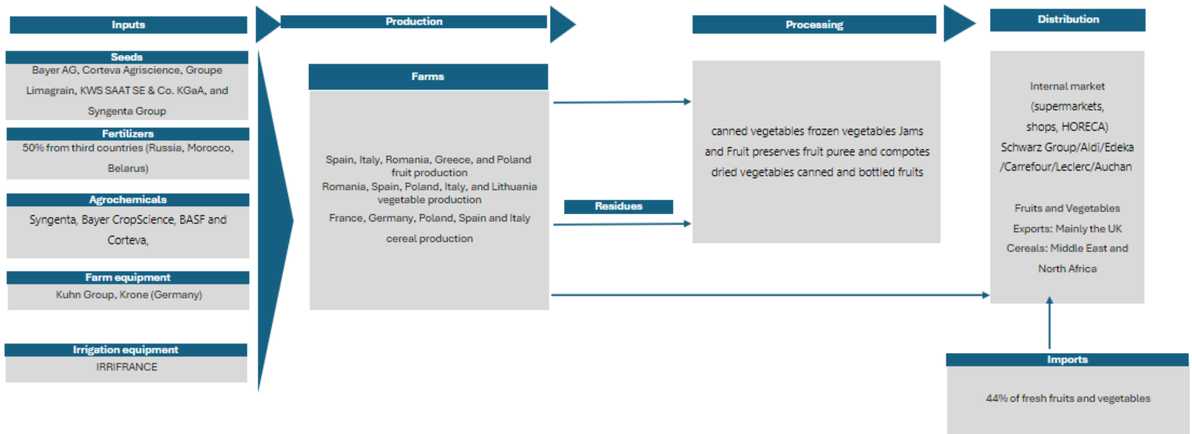


***Figure 16**: Example of supply chain map for crops industry. Source: [27-39]*

## 3.2.2 Indicators of Ecosystems Resilience

Here the resilience indicators of agri-food ecosystems are represented in Table 15, demonstrating its main characteristics.

***Table 15:** Overview of agri-food Indicators*

| Macro Indicators | Ecosystems characteristics | Level |
|---|---|---|
| Ability to produce and supply | Essential industry classification | 9 |
| | Ability to reorganise production remotely | 0 |
| | Ability to supply products remotely | 1 |
| | Potential for supply chain disruption | 3 |
| Exposure to indirect demand shocks | Exposure to domestic demand fluctuations | 1 |
| | Exposure to foreign demand fluctuations | 5 |
| Financial constraints | Short term liquidity risk | 4 |
| | Longer term borrowing constraints | 6 |

Note: 0 means less resilient, 10 means more resilient

Looking into the macro resilience indicators - Ability to produce and supply, Exposure to indirect demand shocks, and financial constraints - key aspects and recommendations emerge for the agri-food ecosystem, as follows:

- Regarding the Ability to produce and supply, during a pandemic situation meat processing plants might implement stringent hygiene protocols and social distancing measures to safeguard workers' health. Similarly, crop production might adopt more automated and remote monitoring techniques to maintain productivity while minimizing physical proximity among workers.
- Regarding the Exposure to indirect demand shocks, a reduction in household consumption due to economic downturns can lead to decreased demand for higher-priced meat products, prompting producers to shift focus towards more affordable options or alternative protein sources. Additionally, fluctuations in export demand for crops due to trade policies or geopolitical tensions may necessitate diversifying export markets or increasing domestic consumption to stabilize revenue streams.
- Finally, Financial constraints involve two types of financial vulnerability. First, the need for short-term liquidity due to the characteristics of the production process, such as managing seasonal variations and supply chain disruptions. For example, crop producers may require immediate liquidity to cover costs during planting and harvesting seasons or to address unexpected weather-related damages. Second, the likelihood of financial constraints in the longer run due to borrowing constraints, affecting future investment and growth. This could include challenges in securing credit to invest in sustainable farming practices, advanced technologies, or expansion of production capacities, impacting the speed of recovery as economic activity resumes.

Tackling these indicators with strategies focused in the particularities of agri-food ecosystem, the industry can boost its resilience, particularly addressing local challenges, ensuring long-term sustainability.

### 3.2.3 Critical factors

The critical factors identified in the agri-food ecosystem are Health and pandemic disruptions, Environmental crises and natural disasters, Political conflicts and crises, Technological disruptions and low digital maturity, Challenges in sustaining existing business model, Supplier and customer concentration (overdependencies), Global and complex supply chains (decentralization of supply and demand), Skills gaps, Waste, Infrastructure and Logistics Disruptions (Table 17).

***Table 16:*** *Agri-food critical factors*

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| Health and pandemic disruptions | • Possible closure of frontiers and lockdowns can impact this ecosystem given its highly interconnected supply chain and significant employment and GDP contributions. | 37, 38 |

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| Environmental crises and natural disasters | • Agriculture significantly contributes to climate change.<br>• Changes in temperature and precipitation, as well as weather and climate extremes, are influencing crop yields and livestock productivity in Europe. These changes also affect water availability for irrigation, livestock watering and food processing. | 30 |
| Political conflicts and crises | • Changes in government policies, along with uncertain fiscal and tax regulations, create uncertainty in trade and market policies.<br>• Changes in food safety standards.<br>• Production costs and packaging costs have increased because of the Russian-Ukrainian war. | 36, 6. |
| Technological disruptions and low digital maturity | • Needed implementation of precision agriculture to reduce wastes and to monitor production processes (i.e. drones, smart sensors).<br>• Needed implementation of advanced processing technologies in factories (i.e. Internet of Things, and advanced manufacturing and robotics.) to optimize processes and reduce wastes. | 31, 34 |
| Challenges in sustaining existing business model | • Difficulties in implementing production processes to produce healthy food as a new sustainable business model (use of ingredients, human health, organic food as well as supplements and additives). These processes are not cheap, and the economic return is still not profitable. | 28, 31, 33 |
| Supplier and customer concentration (overdependencies) | • Small-scale farming in Europe is threatened by land grabbing, a process involving “large-scale purchase or leasing of agricultural land by companies, governments and private individuals”. | 29, 30 |
| Global and complex supply chains (decentralization of supply and demand) | • Incentives for production, global competition based on price, and long supply chains that reduce transparency, together encourage the externalization of production costs on the environment. If economic benefits arise from producing more in a competitive market, there is an incentive to maximize production rather than optimize it for long-term sustainability. | 27, 29, 32 |
| Skills gaps | • Europe has made its agricultural sector competitive and is a significant exporter of value-added products, such as processed food, meat and dairy products. | 30, 31 |

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| | • Ageing workers going to retirement without the possibility to transmit skills, this causes a lower skill level in the younger generations.<br>• Increasing need for high skilled workers such as agronomists, machinery and contact material specialists, C-level employees, sustainability experts, circular and biotech experts, food scientists, food technologists, and high craftsmanship. | |
| Waste | • An implementation of circular economy business models is needed: firms that address food waste, such as platforms that monitor and reduce waste during production, or AI-based solutions that reduce or valorise food waste. In addition, companies that valorise food/agricultural waste to energy are also included in the category, together with waste valorisation for uptake in other industries. | 31 |
| Infrastructure and Logistics Disruptions | • Need to analyse delays, accidents, damages, and system breakdowns. | 36 |

While trusted for providing high quality and safe products, the agri-food ecosystem has longstanding vulnerabilities. In that sense, the critical factors in Table 17 present an overview of the sector, with some aspects that may be emphasized such as:

- The agri-food sector is facing the problem of **knowledge transmission** between different generations of workers. In this specific sector, know-how is based on the personal experience of workers, so it is not digitised or written down, it is knowledge gained from experience in the field. We are now facing a generational change in workers, which makes it difficult to pass on knowledge fluently from older, experienced generations to younger ones. There is also a disparity in digital skills between the two: younger generations are much more practical with new technologies but lack experience on their side and vice versa for the older generation [31].
- During the **COVID-19 crisis**, the ecosystem overcame difficulties, mostly related to the constant supply and availability of food finished products, demonstrating resilience capabilities [30].
- This ecosystem has suffered from sudden changes in demand patterns, disappearance of key outlets, disruptions on cross-border trade and workforce shortages. Many workers are part-time or self-employed, pushing the sector to especially in the agricultural sector. The ecosystem often relies on temporary contracts and precarious employment, in particular due to seasonality of much of the agricultural production (e.g. agricultural seasonal workers). The ecosystem faces challenges linked to an ageing workforce and to attraction of highly skilled staff [32].

- The pandemic has accelerated the uptake of **innovative food business models and digital solutions**, while also fostering solidarity schemes among ecosystem actors. Moreover, new consumer trends are now difficult to be fulfilled from the actual ecosystem, but as every change they can represent opportunities to grow and enlarge and/or adapt businesses. Some examples of new business models for agri-food driven by digital solutions and increased consumer awareness are: online food shopping and direct-to-consumer services, increase in the use of alternative proteins to meat, increased end-customer attention to the sustainability of the production chain, use of new online platforms to buy food while limiting waste, and increase in attention to the material used for packaging [31].
- Regarding imports / exports, the UK and US are the main countries for EU exports while in terms of dependencies, it relies mostly on South and Central America for imports. Agri-food is also a key sector within the European Union itself, with large volumes of trade between the constituent countries [39].

### 3.2.4 Agri-food Supply Chain Resilience Fit Model

Figure 17 represents presents the model for the agri-food ecosystem. The context variables presented are those identified as most relevant to the Ecosystem. Indicators of ecosystem resilience with a score lower than 5 points were inserted, as well as all critical factors identified as potentially impacting the ecosystem. In turn, the intervention variables presented are those that best respond to the context variables relevant to the ecosystem. Moreover, the agri-food ecosystem's intervention factors were associated with the following critical factors: Health and pandemic disruptions, Environmental crises and natural disasters, Global and complex supply chains, Waste and Infrastructure and Logistics Disruptions.

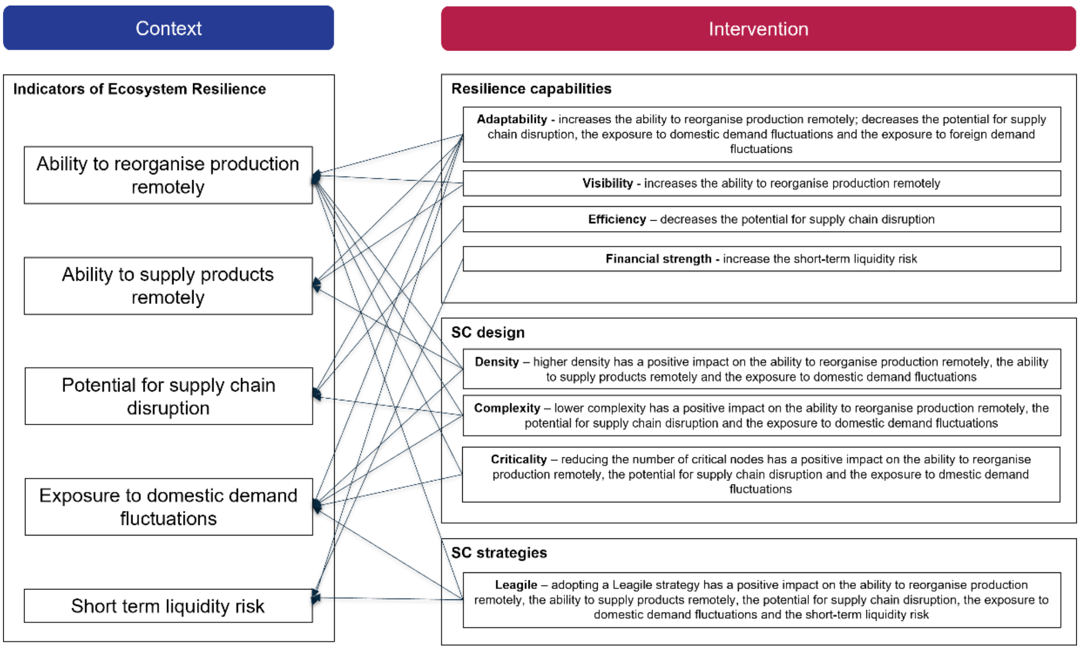


*Figure 17: Agri-food Supply Chain Resilience Fit Model*

## 3.3 Digital ecosystem

This session will present an overview about the digital ecosystem, including overall sector characteristics, its impact in economy and society and the main types of actors. Regarding the resilience characteristics of the digital ecosystem, indicators of resilience and critical factors that could influence it will also be presented.

### 3.3.1 Overview

The digital ecosystem encompasses various sectors, including ICT manufacturing and services, and telecommunications. ICT services accounts for 95% of the total ICT value added. In terms of NACE classifications, the digital industrial ecosystem includes computer programming, consultancy, and information service activities, Telecommunications, and Publishing activities [40]. Additionally, the manufacturing of computer, electronics, and optical products, as well as the repair of computers and personal and household goods, are partially considered within this ecosystem. A more detailed representation of the considered sectors is shown in Table 17, based on NACE classification.

*Table 17: Industries and sub-sectors of the digital ecosystem*

| Industries | Subsectors |
|---|---|
| **I - Computer programming, consultancy and related activities** | **62.0 - Computer programming, consultancy and related activities**<br>62.01 Computer programming activities<br>62.02 Computer consultancy activities<br>62.03 Computer facilities management activities<br>62.09 Other information technology and computer service activities |
| **II - Information service activities** | **63.1 Data processing, hosting and related activities; web portals**<br>63.11 Data processing, hosting and related activities<br>63.12 Web portals<br>**63.9 Other information service activities**<br>63.91 News agency activities<br>63.99 Other information service activities n.e.c. |
| **III - Telecommunications** | **61.1 Wired telecommunications activities**<br>**61.2 Wireless telecommunications activities**<br>**61.3 Satellite telecommunications activities**<br>**61.9 Other telecommunications activities** |
| **IV - Publishing activities** | **58.1 Publishing of books, periodicals and other publishing activities**<br>58.11 Book publishing<br>58.12 Publishing of directories and mailing lists<br>58.13 Publishing of newspapers<br>58.14 Publishing of journals and periodicals<br>58.19 Other publishing activities<br>**58.2 Software publishing**<br>58.21 Publishing of computer games<br>58.29 Other software publishing |
| **V - Manufacture of computer, electronics and optical products** | **26.1 Manufacture of electronic components and boards**<br>26.11 Manufacture of electronic components<br>26.12 Manufacture of loaded electronic boards<br>**26.2 Manufacture of computers and peripheral equipment**<br>**26.3 Manufacture of communication equipment**<br>**26.4 Manufacture of consumer electronics** |

| | |
|---|---|
| | **26.5 Man. of instruments and appl. for measuring, testing and navigation; watches and clocks**<br>26.51 Manufacture of instruments and appliances for measuring, testing and navigation<br>26.52 Manufacture of watches and clocks<br>**26.6 Manufacture of irradiation, electromedical and electrotherapeutic equipment**<br>**26.7 Manufacture of optical instruments and photographic equipment**<br>**26.8 Manufacture of magnetic and optical media** |
| **VI - Repair of computers and personal and household goods** | **95.1 Repair of computers and communication equipment**<br>95.11 Repair of computers and peripheral equipment<br>95.12 Repair of communication equipment<br>**95.2 Repair of personal and household goods**<br>95.21 Repair of consumer electronics<br>95.22 Repair of household appliances and home and garden equipment 9522<br>95.23 Repair of footwear and leather goods<br>95.24 Repair of furniture and home furnishings<br>95.25 Repair of watches, clocks and jewellery<br>95.29 Repair of other personal and household goods |

The technologies that support the digital industrial ecosystem include advanced manufacturing and robotics as the leading technology. This is followed by artificial intelligence, big data, cloud technology, photonics, digital security, blockchain, and the internet of things (IoT) [41]. The twin-transition pathway for the digital industrial ecosystem is driven and structured by the Digital Decade Compass and policy programme. The Digital Decade policy programme sets specific targets and objectives for 2030, guiding Europe's digital transformation in areas such as skills, infrastructure, business, and government [41]. In the digital industrial ecosystem, networking and lock-in effects of digital technologies tend to benefit companies that already hold a dominant position, often at the expense of smaller competitors [46]. However, it is worth noting that many small and medium-sized enterprises (SMEs) are involved in providing niche solutions tailored to specific needs. Additionally, some startups have been highly successful in introducing new products, as evidenced by the emergence of unicorns (startups with a valuation of over $1 billion) [40]. The net turnover of the different industries into this ecosystem is presented in Figure 18.

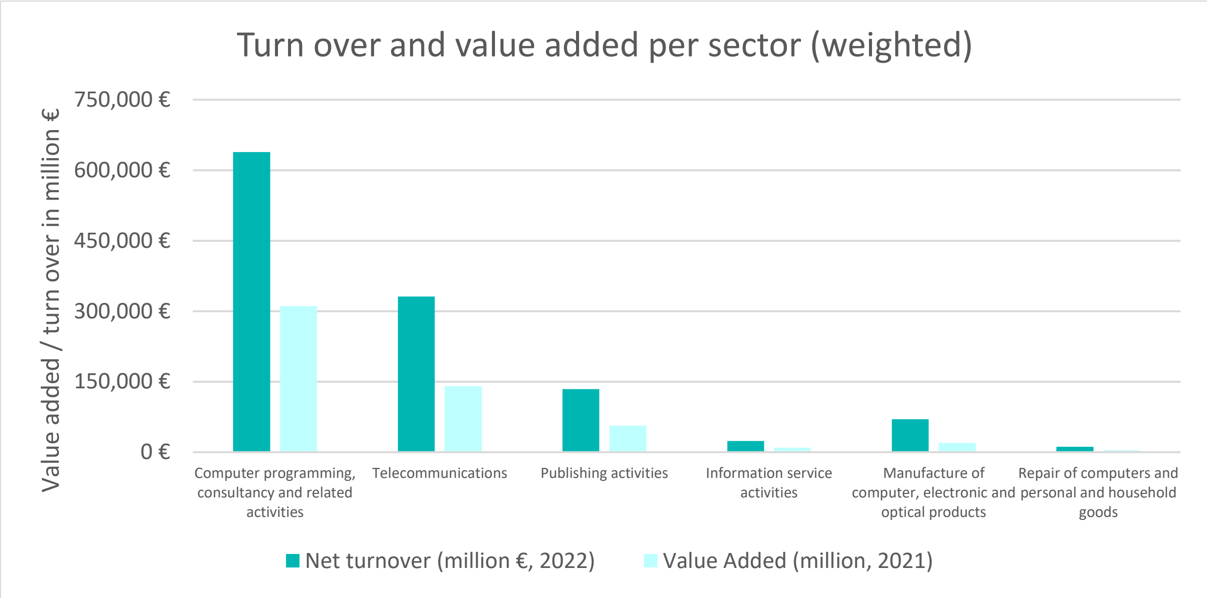


***Figure 18:*** *Net turnover and value added per sector in the digital ecosystems (weighted) Source: [43]*

Regarding the digital ecosystem net turnover, the main major focus is in the areas of *computer programming* and *telecommunication* [43]. Due to the strong change in digital technologies and advancing digitalisation, the turnover and employment figures in this ecosystem are highly variable and change significantly between years.

### 3.3.1.1 Facts and figures

Previously, in 2019, the digital industrial ecosystem within the EU employed 6.6 million individuals and generated approximately EUR 674 billion in value added. When compared to other industrial ecosystems, the digital industrial ecosystem falls somewhere in the middle in terms of employment and gross value added. In 2018, the ecosystem consisted of 1.2 million companies, with 99.8% of them being small and medium-sized enterprises (SMEs) [41]. By 2021, there was an increase in these figures, with the digital industrial ecosystem employing 6.8 million individuals and contributing EUR 625 billion in value added. Furthermore, in 2022, the number of employees further rose to 7.1 million [43].

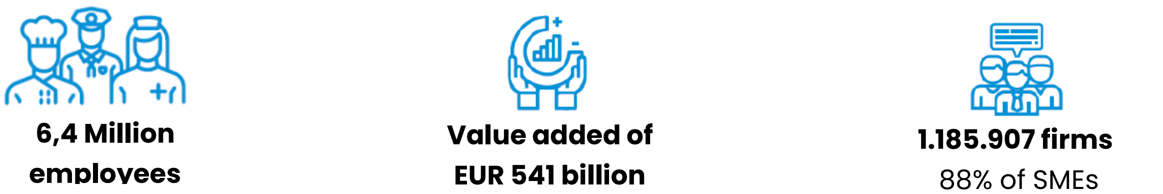


*Figure 19: employees, value added and number of firms in the digital ecosystem (data from 2021 and 2022) Source: [43]*

For the year 2022, Figure 20 shows the net turnover, the number of enterprises per country and the number of employees for each country. The most representative countries in number of employees are Germany, France and Italy, while Poland has a high number of companies and employees but with a reduced net turnover. Both figures show that the top 5 countries employ over 3 million people and generate a net turnover of EUR 8 billion.

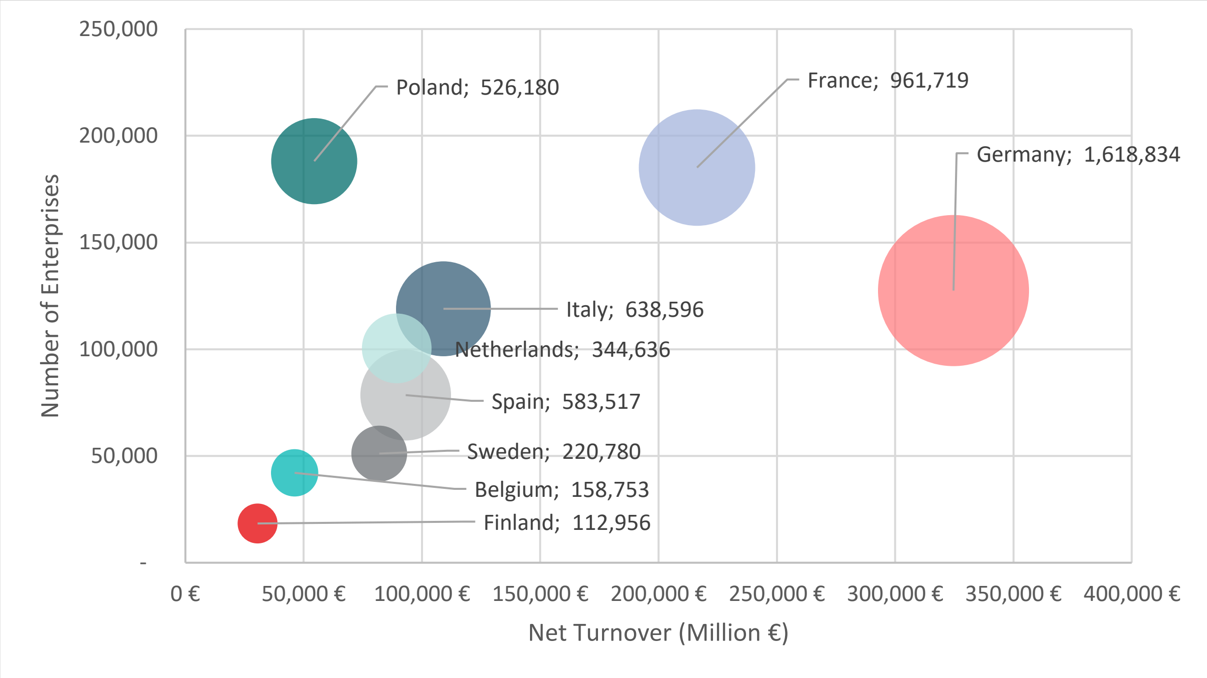


***Figure 20***: *Digital ecosystem, top 15 EU countries (net turnover, enterprises, employees), data from 2022 Source: [43]*

The top 5 countries in the European Union are shown in Table 18 for each category. This shows that the highest turnover across all sectors is in Germany, France, Italy and Spain. In terms of the number of companies, Poland, France, Germany and Italy are in the top places. The list of employees is comparable to the turnover figures with Germany, France, Italy, Spain and Poland having the most employees.

***Table 18:*** *Most representative countries in terms of net turnover, number of enterprises and employees [4]*

| **Net turnover** | Million € | **Enterprises** | | **Employees** | |
|---|---|---|---|---|---|
| Germany | 324.671 | Poland | 188.093 | Germany | 1.618.834 |
| France | 216.248 | France | 185.111 | France | 961.719 |
| Italy | 109.074 | Germany | 127.496 | Italy | 638.596 |
| Spain | 93.115 | Italy | 118.948 | Spain | 583.517 |
| Netherlands | 89.332 | Netherlands | 100.417 | Poland | 526.180 |

Regarding the digital ecosystem innovation capability, it can be seen a big effort in the past 15 years to improve its green capabilities. In that sense, while EU had around 8000 digital patents, it filled 104000 green patents [60]. Figure 21 presents an overview of green and digital patents per EU country in the period 2000-2017

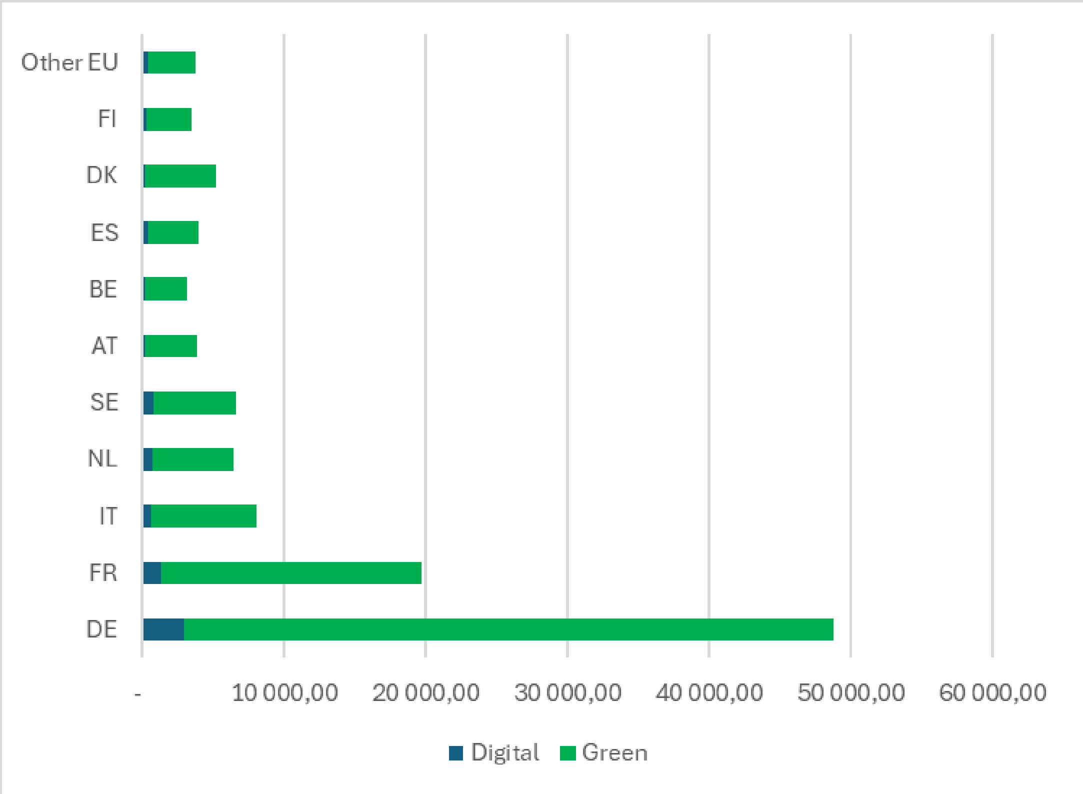


***Figure 21**: Green and digital EPO patent applications by EU country, 2000-2017. Source: [60]*

Figure 21 demonstrates the leading role of Germany in Green Patents, followed by France and Italy. If we consider only digital patents, Germany and France are also leaders, followed by Sweden and the Netherlands.

### 3.3.1.2 Main actors and geographical distribution

Within the digital ecosystem, the methodology of the JRC report [106] on a policy oriented analytical approach to map the digital ecosystem (DGTES) identified three types of activities in the digital ecosystem. These three aspects structure the ecosystem with regards to the innovative technologies [46]:

1. ***business activities***, derived from information on companies' core business and on the production, supply and/or exchange of goods and/or services, and/or on investments and funds financing industrial and business initiatives (i.e. venture capital deals);
2. ***innovation activities***, corresponding to outputs of Research & Development (R&D) activities in the form of patenting initiatives (i.e. filing of priority patents) and/or participation in innovative research projects (i.e. EU-funded projects H2020 and FP7);

3. ***research activities***, reflecting academic contributions of frontier research, such as publications and/or participation in high level international conferences.

**Economic players** represent the second main element (or building block) of the DGTES analytical approach. In DGTES, the term 'economic player' is used to define any economic (market and non-market) actor involved in digitally relevant activities. These 'behaving entities' [61] play an active role in shaping the digital ecosystem and influencing its economic performance, development and future evolution. [7]:
Players can be:

1. companies and firms;
2. academic institutions and research centers;
3. governmental authorities and bodies.

Looking at the geographical distribution of players in digital ecosystems, 11% of the most important players in digital ecosystems are based in the EU. This puts the EU behind China and the US, which are home to more than half of the digital ecosystem players at 36% and 20% respectively.

Considering the different actors and categories, Figure 36 presents an example of an attempt of a digital ecosystem's - International distribution of the semiconductor. The production of semiconductors is a key object of investigation, as there is a high geographical risk for the global production of end products.

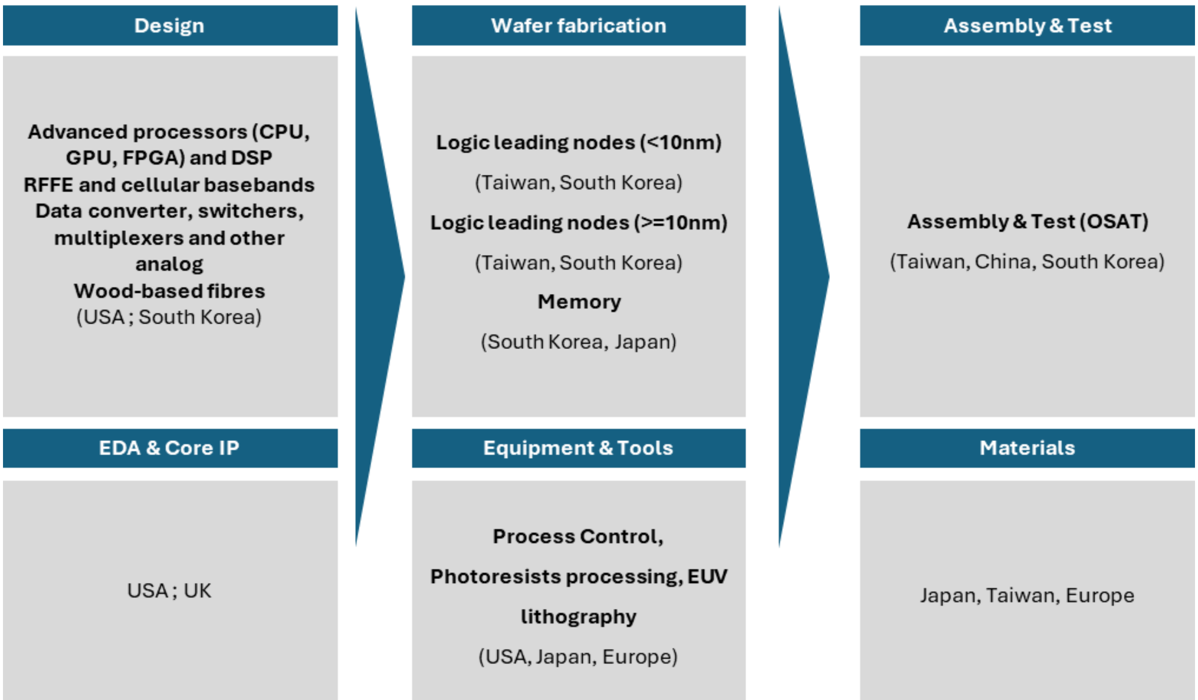


***Figure 22**: International distribution of the semiconductor supply chain [9]*

There are more than 50 points across the semiconductor value chain where one region holds more than 65% of the global market share. These are potential single points of failure

that could be disrupted by natural disasters, infrastructure shutdowns, or international conflicts, and may cause severe interruptions in the supply of essential chips. About 75% of global semiconductor manufacturing capacity, for example, is concentrated in China and East Asia, a region significantly exposed to high seismic activity and geopolitical tensions. In addition, 100% of the world's most advanced (below 10 nanometers) semiconductor manufacturing capacity is currently located in Taiwan (92%) and South Korea (8%). [9]
As can be seen from the depiction of the supply chain, Europe plays a role in the production of semiconductors as a supplier of equipment and materials. Based on the European Chips Survey, demand for chips is forecast to increase significantly by 2030. According to the explanatory notes to the European Chips Act, 10% of chips are produced within the EU [79].

### 3.3.2 Indicators of Ecosystems Resilience

The digital ecosystem is facing critical challenges that hinder its successful transformation and consequently the EU's technological leadership. These challenges can be observed in the key indicators of ecosystem resilience presented in Table 19.

*Table 19: Overview of Digital Indicators*

| Macro Indicators | Ecosystems characteristics | Level |
|---|---|---|
| Ability to Produce and Supply | Essential industry classification | 6 |
| | Ability to reorganise production remotely | 10 |
| | Ability to supply products remotely | 8 |
| | Potential for supply chain disruption | 7 |
| Exposure to Indirect Demand Shocks | Exposure to domestic demand fluctuations | 5 |
| | Exposure to foreign demand fluctuations | 6 |
| Financial Constraints | Short term liquidity risk | 3 |
| | Longer term borrowing constraints | 1 |

Note: 0 means less resilient, 10 means more resilient

Looking into the macro resilience indicators, some examples of possible disruptions and actions for the digital ecosystem can be suggested as follows:

- The Ability to Produce and Supply of digital companies for instance, during a health crisis might shift to remote work, leveraging digital tools to maintain productivity and collaboration. Telecommunications companies may enhance their networks to support increased data traffic from remote work and online activities, ensuring uninterrupted service.
- Considering the Ecosystem's exposure to indirect demand Shocks, it is necessary to understand how different components of demand—such as investment, household consumption, government consumption, and exports—evolve and impact the industry. For example, economic downturns might reduce corporate spending on consultancy services, prompting firms to diversify their client base or offer cost-effective solutions. In publishing, shifts in consumer behaviour towards digital content consumption can lead to increased demand for e-books and online news subscriptions.
- Finally, from the Financial Perspective – encompassing both short-term liquidity needs and long-term borrowing challenges - digital firms may require immediate liquidity to invest in infrastructure upgrades or handle sudden spikes in demand. In the long run, access to credit is crucial for funding innovations, such as developing new software solutions or expanding into emerging markets. Overcoming these financial constraints ensures the industry's capacity to recover quickly and sustain growth.

The analysis of these indicators, and their relation to the Digital Ecosystem's critical factors, resilience capabilities, supply chain design and strategy, can enhance the ecosystem's resilience performance.

### 3.3.3 Critical factors

The critical factors identified in the digital ecosystem are Health and pandemic disruptions, Environmental crises and natural disasters, Political conflicts and crises, Technological disruptions and low digital maturity, Challenges in sustaining existing business model, Supplier and customer concentration (overdependencies), Global and complex supply chains (decentralization of supply and demand), Skills gaps, Waste, Infrastructure and Logistics Disruptions (Table 20).

*Table 20: Digital ecosystem critical factors*

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| Health and pandemic disruptions | • Possible closure of frontiers and lockdowns can impact this ecosystem given its highly interconnected supply chain and significant employment and GDP contributions | 64 |
| Environmental crises and natural disasters | • The global economic crisis, currency devaluation, and concerns about natural disasters impact the development of the supply chain. | 61 |
| Political conflicts and crises | • Pressing need to regulate the use of new technologies, especially their widespread access. | 62 |
| Technological disruptions and low digital maturity | • Customers (in particular SMEs) with limited awareness of the digitalization process and the steps required to complete it. | 62 |
| Challenges in sustaining existing business model | • Difficulties in maintaining the existing business model due to market changes or shifts in consumer expectations. | 62, 63, 64 |
| Supplier and customer concentration (overdependencies) | • Dependence on other regions for critical parts of the hardware supply chain (fiber, electronic components, raw materials)<br>• The dependencies on auxiliary technologies are more pronounced, particularly for AI and big data.<br>• European capacities in key technologies such as AI, cloud, cyber, blockchain, HPC, and quantum need to be developed across all sectors. This will reduce reliance on third countries and create a digitally competitive, resilient, and autonomous Europe. | 62 |
| Global and complex supply chains (decentralization of supply and demand) | • Currently, there is a significant investment gap between the EU and digital frontrunners such as the US and China, amounting to EUR 350-400 billion annually. This gap is especially crucial for financing disruptive innovation and start-ups and shows no signs of closing, which could have adverse effects on the EU's future prosperity, growth, and employment. | 63 |
| Skills gaps | • There is a need for further development of green skills.<br>• Across many ecosystems, the lack of skilled workers is hindering EU industrial competitiveness and the digital and green transitions. | 62 |
| Waste | • Due to the difficulties in the supply of Critical Raw Materials (CRM) and the ever-increasing demand for them, the EU has to face a behavioral and technical change in landfilling: many CRMs that are | 65 |

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| | useful for the digital ecosystem are simply left in landfills instead of being recycled and reused. Landfill can be a valid source of CRMs (urban mining). | |
| Infrastructure and Logistics Disruptions | • Need to analyse delays, accidents, damages, and system breakdowns. | 63 |

Although apparently being highly resilient, given the performance of some digital sectors during the COVID-19, others that rely on materials and components suffered with the logistics limitations. In addition, the lack of digital skills, inadequate infrastructure development, and slow digitalization in both the private and public sectors influence the challenges faced by this ecosystem. In that sense, the critical factors in Table 20 present an overview of the sector, with some aspects that may be emphasized such as:

- The digital ecosystem is facing critical challenges regarding the adoption of digital technologies, including big data, cloud computing, and artificial intelligence (AI), by businesses. As of 2021, the adoption rates for these technologies are as follows: 14% for big data, 34% for cloud computing, and 8% for AI, demonstrating a low adoption rate for all three technologies. Only three countries are close to the target set by the *Digital Decade policy program*, which aims for at least 75% of EU businesses to adopt one or more of these technologies by 2030. [55]
- The shortage of ICT specialists and other technology experts, which has significant implications for the development and utilization of emerging digital technologies, is also an important challenge for this ecosystem. This shortage not only hampers the growth of the digital ecosystem but also exposes companies to increased cyber risks. Even the front runners among Member States are grappling with a critical shortage of digital experts, hindering the adoption and effective use of key digital technologies. [58]
- From a financial perspective, there is a clear gap between the EU and the US and China in the investments at the digital ecosystem. The total investment volume for the EU is estimated at EUR 175 billion, while the US and China have annual investments of EUR 350 billion and EUR 400 billion respectively [51].

### 3.3.4 Digital Supply Chain Resilience Fit Model

Figure 23 represents presents the model for the digital ecosystem. The context variables presented are those identified as most relevant to the ecosystem. Indicators of ecosystem resilience with a score lower than 5 points were inserted, as well as all critical factors identified as potentially impacting the ecosystem. In turn, the intervention variables presented are those that best respond to the context variables relevant to the ecosystem. Additionally, the digital ecosystem's intervention factors were associated with the following critical factors: Health and pandemic disruptions, Environmental crises and natural disasters, Global and complex supply chains (decentralization of supply and demand), Waste and Infrastructure and Logistics Disruptions.

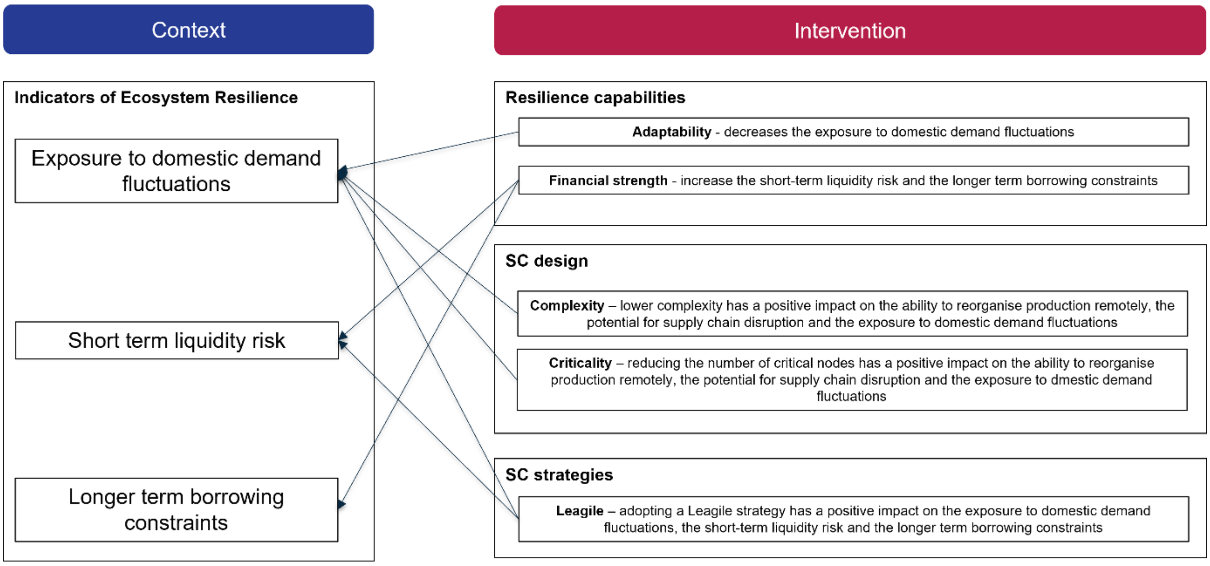


***Figure 23**: Digital Supply Chain Resilience Fit Model*

## 3.4 Mobility ecosystem

This session will present an overview about the mobility, transport and automotive ecosystem, including overall sector characteristics, its impact in economy and society and the main types of actors. Regarding the ecosystem characteristics, indicators of resilience and critical factors that could influence the ecosystem will also be presented.

### 3.4.1 Overview

As stated in the European Commission Annual Single Market Report, the **Mobility Ecosystem** encompasses the automotive, rail, and waterborne sectors, covering the entire value chains. This multifaceted domain involves various stakeholders, technologies, and economic activities that are crucial for the efficient movement of people and goods within the European Union (EU). The ecosystem consists of 1.8 million firms, with 99.7% of them being SMEs [66]. As shown in Table 21, the ecosystem is characterized by complex and extensive supply chains, with a few global players dominating the industry, along with numerous smaller local suppliers, retailers, and aftersales service providers.

***Table 21:*** *Sectors and Subsectors in the mobility ecosystem*

| Industries | Subsectors |
|---|---|
| **I - Manufacture of motor vehicles, trailers and semi-trailers** | **29.1 Manufacture of motor vehicles**<br>**29.2 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers**<br>29.20 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers<br>**29.3 Manufacture of parts and accessories for motor vehicles**<br>29.31 Manufacture of electrical and electronic equipment for motor vehicles<br>29.32 Manufacture of other parts and accessor for motor vehicles |
| **II - Wholesale and retail trade and repair of motor vehicles and motorcycles** | **45.1 Sale of motor vehicles**<br>45.11 Sale of cars and light motor vehicles<br>45.19 Sale of other motor vehicles<br>**45.2 Maintenance and repair of motor vehicles**<br>**45.3 Sale of motor vehicle parts and accessories**<br>45.31 Wholesale trade of motor vehicle parts and accessories<br>45.32 Retail trade of motor vehicle parts and accessories<br>**45.4 Sale, maintenance and repair of motorcycles and related parts and accessories** |
| **III - Water transport** | **50.1 Sea and coastal passenger water transport**<br>**50.2 Sea and coastal freight water transport**<br>**50.3 Inland passenger water transport**<br>**50.4 Inland freight water transport** |

| Industries | Subsectors |
| --- | --- |
| **IV - Land transport and transport via pipelines** | **49.1 Passenger rail transport, interurban**<br>**49.2 Freight rail transport**<br>**49.3 Other passenger land transport**<br>49.31 Urban and suburban passenger land transport<br>49.32 Taxi operation<br>49.39 Other passenger land transport n.e.c.<br>**49.4 Freight transport by road and removal services**<br>49.41 Freight transport by road<br>49.42 Removal services<br>**49.5 Transport via pipeline** |
| **V- Warehousing and support activities for transportation** | **52.1 Warehousing and storage**<br>**52.2 Support activities for transportation**<br>52.21 Service activities incidental to land transportation<br>52.22 Service activities incidental to water transportation<br>52.23 Service activities incidental to air transportation<br>52.24 Cargo handling<br>52.29 Other transportation support activities |
| **VI - Manufacture of other transport equipment** | **30.1 Building of ships and boats**<br>30.11 Building of ships and floating structures<br>30.12 Building of pleasure and sporting boats<br>**30.2 Manufacture of railway locomotives and rolling stock**<br>**30.3 Manufacture of air and spacecraft and related machinery**<br>**30.4 Manufacture of military fighting vehicles**<br>**30.9 Manufacture of transport equipment n.e.c.**<br>30.91 Manufacture of motorcycles<br>30.92 Manufacture of bicycles and invalid carriages<br>30.99 Manufacture of other transport equipment n.e.c |
| **VII - Manufacture of electrical equipment** | **27.1 Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus**<br>27.11 Manufacture of electric motors, generators and transformers<br>27.12 Manufacture of electricity distribution and control apparatus<br>**27.2 Manufacture of batteries and accumulators**<br>**27.3 Manufacture of wiring and wiring devices**<br>27.31 Manufacture of fibre optic cables<br>27.32 Manufacture of other electronic and electric wires and cables<br>27.33 Manufacture of wiring devices<br>**27.4 Manufacture of electric lighting equipment**<br>**27.5 Manufacture of domestic appliances**<br>27.51 Manufacture of electric domestic appliances<br>27.52 Manufacture of non-electric domestic appliances<br>**27.9 Manufacture of other electrical equipment** |

Transportation and mobility activities, along with the automotive industry, contribute significantly to the EU's economy. In 2021, the ecosystem employed 14.6 million people (with at least 16 million including indirect jobs) and generated 7.5% of EU value added (EUR 906 billion) through vehicle manufacturing, sales, and aftermarket services [66]. The turnover and value added (in millions) for the main sectors in the ecosystems are indicated in Figure 24.

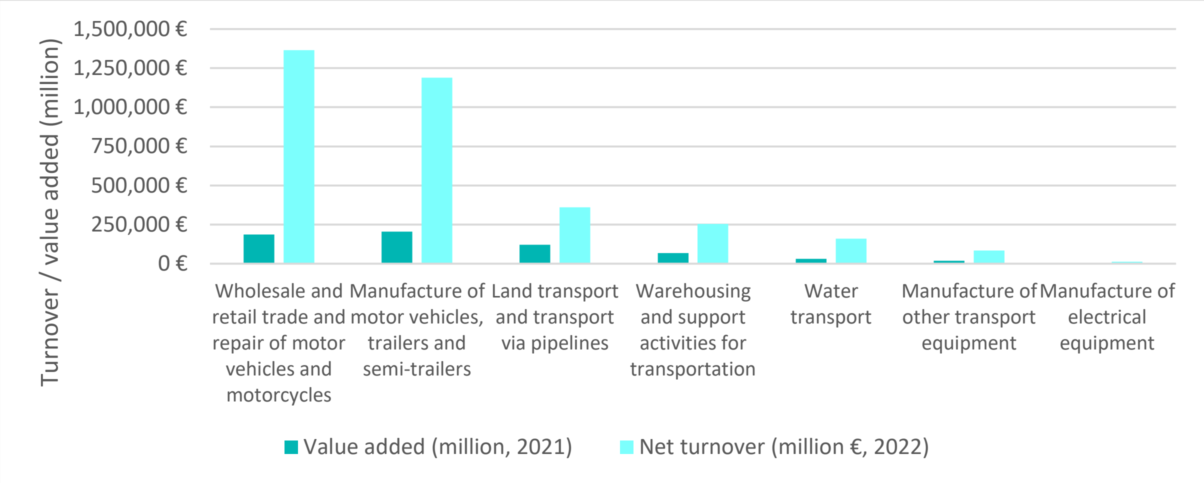


***Figure 24**: Turnover (2022) and Value added (2021) of the different sectors [4]*

This ecosystem plays a crucial role in EU economic and social life, facilitating daily commuting, tourism, global supply chains, and industrial production. The European Union plans to advance towards a sustainable, smart, and inclusive mobility sector, focusing on decarbonization and digitalization. This transition aims to establish an efficient and interconnected multimodal transport system for both passengers and freight, aligning with the goals of the European Green Deal and A Europe fit for the digital age [67].

### 3.4.1.1 Facts and figures

SMEs are also at the core of the ecosystem, with an impressive 99.7% of all enterprises, totalling approximately 1.8 million firms [66, 68]. The **main different value chains** in the ecosystem at a glance [68]:

- The **automotive value chain** is an important pillar of the EU economy, employing 12.9 million people and contributing 1 trillion euros to the EU GDP. It also accounts for nearly one-third of private sector research and development investments in the EU. The industry is highly competitive globally and generates a significant trade surplus for the EU, amounting to 96 billion euros in 2022. The motorcycle sector within this value chain also contributes substantially, providing 133,000 jobs and associated with a GDP of 5.8 billion euros.
- The **waterborne value chain** includes the shipbuilding and repair industry, maritime and inland waterway transport, and port activities. More than 80% of the EU's external trade and 40% of internal trade are carried by sea, making this value chain strategically important. The EU controls 39.5% of the world fleet and has a thriving

maritime technology sector, comprising 300 shipyards and over 28,000 maritime equipment manufacturers and technology suppliers. This sector generates an aggregated production value of 125 billion euros, accounting for 23.8% of the world maritime technology production value.

- The **EU railway value chain** is a global leader in the design, manufacturing, and maintenance of railway systems and products. It provides clean transport solutions and employment to 2.3 million Europeans. With a significant contribution of 143 billion euros to the EU GDP, the railway value chain plays a crucial role in the EU's total economic output. The rail supply industry alone contributes 102 billion euros and employs 659,000 people. Despite the consolidation in the global market, EU manufacturers have maintained a positive trade balance in the past decade.
- The **cycling value chain** is responsible for 1.3 million jobs and contributes 21 billion euros to the EU GDP. In 2022, 20 million bikes were sold, including 5.5 million Electrically Pedal Assisted Cycles (EPACs). The EU is a global leader in bike sharing and has a thriving cycling supply chain with over 1,000 SMEs.

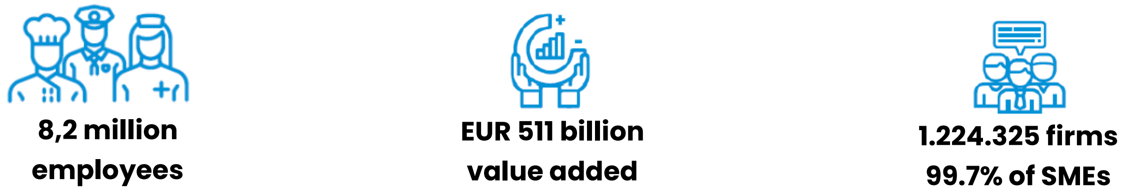


*Figure 25: Overview of economic KPIs for the whole mobility ecosystem, data from 2022 and 2021 [4]*

A comparison of the various EU countries reveals different weightings and significance of the sectors located in the ecosystem. Figure 26 shows the net turnovers, the number of companies and the number of employees for the 15 largest EU countries in the ecosystem.

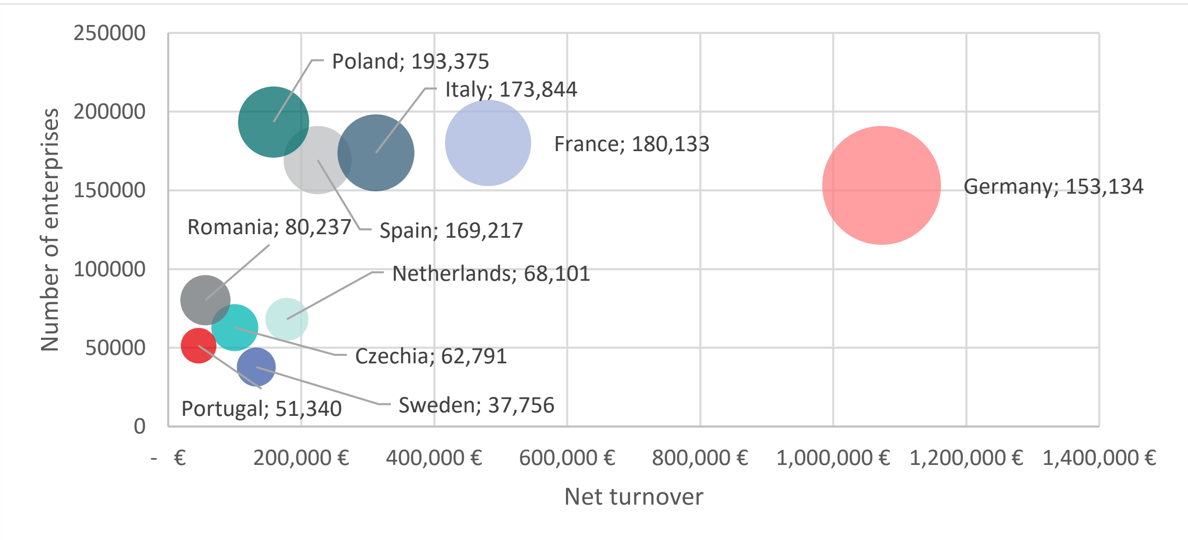


*Figure 26: Mobility ecosystem: Top EU countries (net turnover, enterprises, employees), data from 2022*

Separated by categories, *Table 22* presents the five most representative countries for the indicators of net turnover, enterprises and employees in the EU (values per dimension are calculated using the weights of the NACE2 codes). Across all perspectives, Germany, France, Italy, Spain and Poland are European countries with the highest invest in the mobility ecosystem.

*Table 22: Most representative countries in terms of net turnover, number of enterprises and employees [4]*

| **Net turnover** | Million | **Enterprises** | | **Employees** | |
|---|---|---|---|---|---|
| Germany | 1.072.679 € | Poland | 193.375 | Germany | 2.592.012 |
| France | 480.976 € | France | 180.133 | France | 136.5130 |
| Italy | 312.330 € | Italy | 173.844 | Italy | 108.7158 |
| Spain | 224.774 € | Spain | 169.217 | Poland | 930.073 |
| Netherlands | 178.505 € | Germany | 153.134 | Spain | 854.309 |

The net turnovers of the various sectors within the mobility ecosystem show that the wholesale, retail and repair sector and the manufacture of motor vehicles account for by far the largest share of the ecosystem. These two sectors are also the largest in terms of the number of employees. There is also less turnover but a comparable number of employees in the land and pipeline transport sector. The warehousing, water transport, manufacturing of other transport equipment and manufacturing of electrical equipment sectors are significantly smaller. An overview of net turnover and number of employees in 2022 are shown in Figure 28.

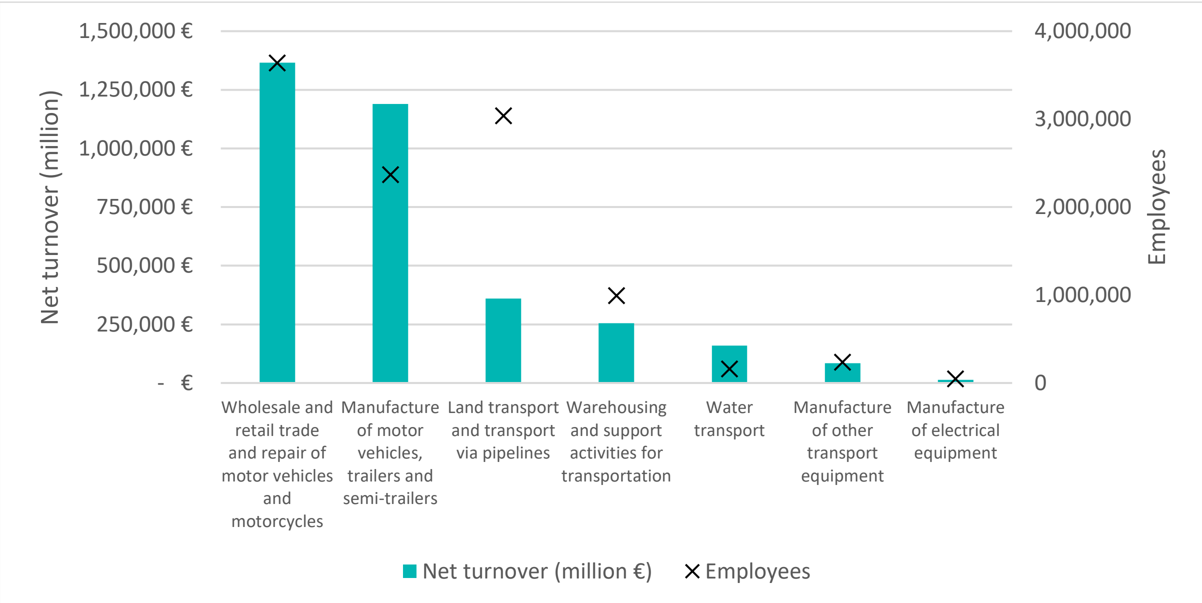


***Figure 27**: Net turnover and employees of the mobility ecosystem, with weights, 2022 [4]*

A comparison of the value added of the various sectors shows that the difference between the various sectors is smaller. Here, the greatest value added is in the manufacture of motor vehicles, trailers, and semi-trailers, followed by wholesale, retail trade and repair of motor vehicles (as shown in Figure 29).

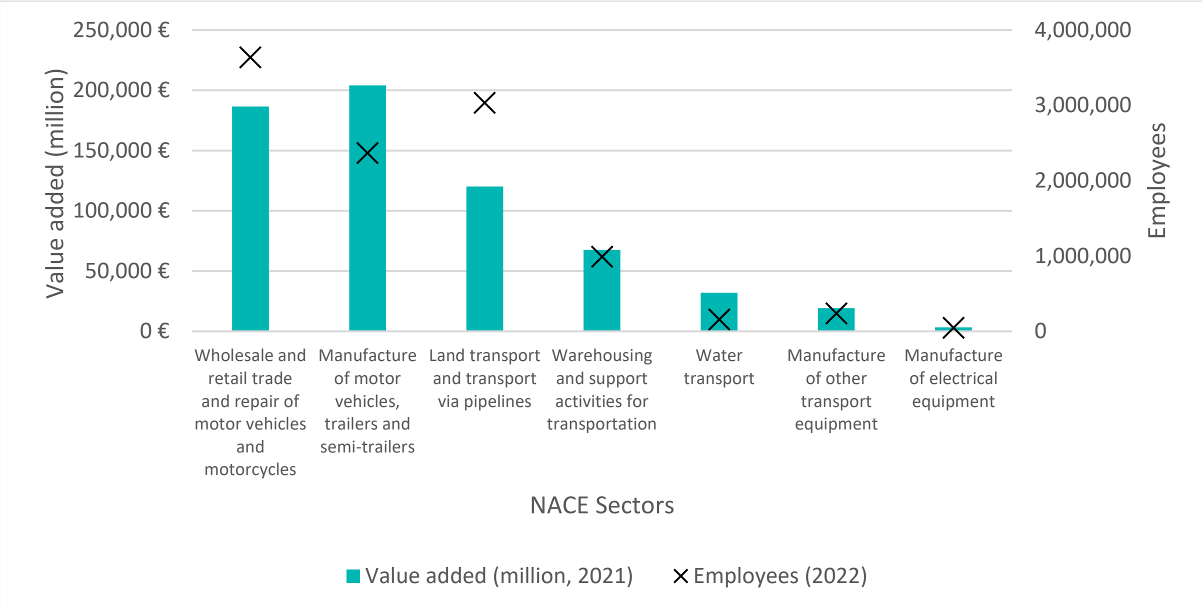


***Figure 28**: Value added and employees of the mobility ecosystem, with weights, 2022 [4]*

### 3.4.1.2 Main actors and geographical distribution

The mobility ecosystem consists of four main sectors, in terms of annual turnover, along with a fifth sector that encompasses other transport segments [70].

- **Automotive:** This sector represents 40% of companies in the industry and generates 79% of the industry's turnover. It also employs 48% of the industry's workforce.
- **Rail:** The rail sector accounts for 29% of companies in the industry and employs 30% of the total workers. However, it has a lower turnover share at 13%.
- **Micro-mobility:** This sector consists of 5% of companies and contributes only 1% to industry turnover.
- **Motorcycles:** The motorcycle sector includes 4% of companies and represents 1% of industry turnover.
- **Others:** This sector encompasses bus, maritime transport, and air mobility. It comprises 29% of companies, generates 6% of industry turnover, and employs 18% of the workforce.

When looking at the types of companies within the mobility ecosystem, manufacturers and distributors make up a significant portion, accounting for 65% of the industry. Operators rank third, followed by mobility services and infrastructure. The mobility ecosystem is characterized by long and complex supply chains, with a few dominant global players and a large number of SMEs.

These complex and specialised supply chains and players mean that the different supply chains within the ecosystem vary greatly from one another. Figure 30 shows a generic approach to mapping a supply chain. The focus here is on the physical value chain, which runs from the internationally sourced raw materials through various tiers to the European OEMs. The products are focussed more and more specifically on their final use. The various suppliers are located throughout Europe and beyond. Even within one sector, there is a large variance in the location and number of suppliers.

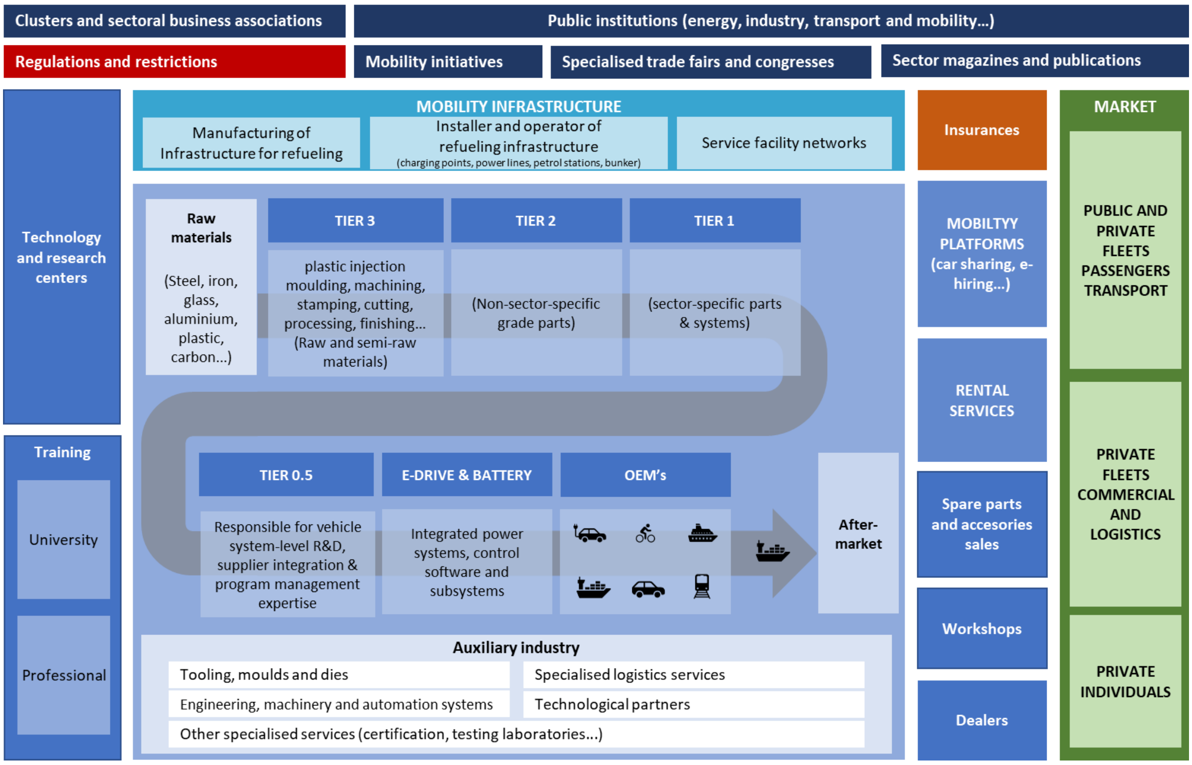


***Figure 29**: General value chain in the mobility ecosystem*

The nature of automotive global value chains is rapidly changing [86]. While individual countries such as Germany, France, and Spain have plans to develop the automotive sector, the EU lacks such a development strategy and hence almost completely delegates its transformation to the market. Consequently, there has been a significant shift in production of vehicles from Western Europe to Eastern and Central Europe - attracted by low labour costs, low unionization rates and local government policies - but ownership of the main carmakers remains for the most part in Western Europe and in Asia.

In the period 1999-2019 all the main Western European countries – France, Italy, Germany and Spain - have reduced their production volumes [86]. On the other hand, Central and Eastern European countries – Check republic, Slovakia, Hungary, Romania and Turkey - have increased the production volumes. Here EU car manufacturers are the main players (Mercedes, BMW, Renault, Volkswagen, PSA), with some Asian (Toyota, Suzuki, Nissan, KIA) and others (Tesla, Ford and Jaguar Land Rover).

The rapid pace of innovation around intelligent systems in cars has disrupted the business flow. Now that electronics account for 40% or more of the total cost of a vehicle, Tier-1s and OEMs are paying much closer attention to the ownership of automotive SoC architectures, the main companies included in Figure 31.


***Figure 30***: *Intelligent systems car suppliers [8]*

In the upcoming decade, the automotive industry is poised for significant transformation driven by four interrelated trends: connected, autonomous, shared, and electric (CASE). These trends, facilitated by advancements in electronics and software technology, will usher in shifts in user behaviors, mobility preferences, and value distribution throughout the supply chain. This evolution will also pave the way for innovative business models and the emergence of new players in the automotive sector. Both original equipment manufacturers (OEMs, Figure 32) and traditional suppliers currently lack comprehensive capabilities to define the software and technology requirements for these new systems. Consequently, enhanced collaboration between OEMs and suppliers is not only expected to increase but also imperative. This shift will lead to the emergence of new business models and evolving supply chain ecosystems, accompanied by heightened competition from newcomers. In this context, mergers and acquisitions (M&A) will play a crucial role in bridging capability gaps, enabling suppliers to deliver comprehensive and fully functional systems [74]

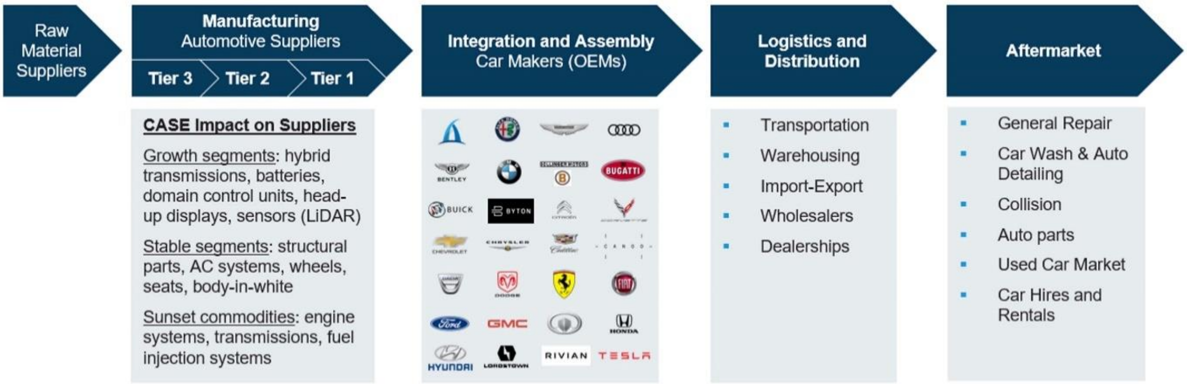


***Figure 31**: Car Makers (OEMs) role in the supply chain. [9]*

## 3.4.2 Indicators of Ecosystem Resilience

The three main pillars of the ecosystem – automotive, rail, shipbuilding industry - face similar challenges in terms of decarbonization, digitalization, and global competition. Consequently, the evaluation of the indicators of ecosystem resilience behaviour (Table 23) are important to define policies and strategies to support its sustainability.

***Table 23:** Overview of mobility Indicators*

| Macro Indicators | Ecosystems characteristics | Level |
|---|---|---|
| Ability to Produce and Supply | Essential industry classification | **10** |
| | Ability to reorganise production remotely | **1** |
| | Ability to supply products remotely | **9** |
| | Potential for supply chain disruption | **3** |
| Exposure to Indirect Demand Shocks | Exposure to domestic demand fluctuations | **10** |
| | Exposure to foreign demand fluctuations | **3** |
| Financial Constraints | Short term liquidity risk | **6** |
| | Longer term borrowing constraints | **2** |

Note: 0 means less resilient, 10 means more resilient

Looking into the macro resilience indicators - Ability to Produce and Supply, Exposure to Indirect Demand Shocks, and Financial Constraints – some examples of possible disruptions and actions for the Textile Ecosystem, as follows:

- Regarding the Ability to Produce and Supply, automotive manufacturers might enhance their digital infrastructure to support remote diagnostics and over-the-air software updates, allowing them to maintain and improve vehicle performance without physical intervention. Additionally, the potential for supply chain disruption can be mitigated by diversifying suppliers and increasing inventory buffers for critical components, such as semiconductors and battery materials, ensuring continuity of production even during global supply chain challenges.

- Regarding the Exposure to Indirect Demand Shocks, a decline in consumer spending during economic downturns can reduce demand for new vehicles, prompting automotive companies to adjust production volumes and focus on aftermarket services. Rail and shipping industries may experience fluctuations in demand for freight and passenger services, requiring them to adapt operations and explore alternative revenue streams.
- Considering Financial Constraints, Automotive, rail, and ship industries may require immediate National and European funds to maintain supply chains and workforce stability. In the longer term, access to credit is vital for investing in new technologies, infrastructure, and sustainable practices, which are essential for staying competitive and fostering growth.

Summing up, the recovery of the ecosystem will heavily rely on investments not only in new technologies but also in the necessary infrastructure and the reskilling of the workforce. Digitalization and automation present opportunities for skilled workers, particularly young workers and women. Also, the adoption of clean technologies, such as electrified vehicles with fewer components, will help reduce assembly costs. Furthermore, enhancing intermodality is crucial for the overall development of the ecosystem.

### 3.4.3 Critical factors

The critical factors identified in the mobility ecosystem are Health and pandemic disruptions; Environmental crises and natural disasters; Political conflicts and crises; Technological disruptions and low digital maturity; Challenges in sustaining existing business model; Supplier and customer concentration (overdependencies); Global and complex supply chains (decentralization of supply and demand); Skills gaps; Waste; Infrastructure and Logistics Disruptions (Table 24).

***Table 24:*** *Critical factors and related disruptions for the mobility ecosystem*

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| Health and pandemic disruptions | • Possible closure of frontiers and lockdowns can impact this ecosystem given its highly interconnected supply chain and significant employment and GDP contributions | 87 |
| Environmental crises and natural disasters | • The global economic crisis, currency devaluation, and concerns about natural disasters impact the development of the supply chain. | 88 |
| Political conflicts and crises | • Pressing need to regulate the use of new technologies, especially their widespread access. | 89 |

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| Technological disruptions and low digital maturity | • Relatively low adoption rates of advanced digital technologies among the SMEs<br>• Current data landscape in the automotive value chain is highly complex, fragmented, and lacks sufficient transparency and interoperability. | 68, 78 |
| Challenges in sustaining existing business model | • Difficulties in maintaining the existing business model due to market changes or shifts in consumer expectations. | 66, 67, 68 |
| Supplier and customer concentration (overdependencies) | • Particularly high demand is for energy, steel, aluminium, and plastic.<br>• Limited control over access to critical raw materials and essential components.<br>• Big technological gaps regarding battery technology for electric vehicles.<br>• Battery technology still relies on scarce and very geographically concentrated raw materials<br>• Need for increased software platform development for vehicles while avoiding the risk of dependency from the Big Techs<br>• Dependence on global trade to both secure and sustain demand for industrial output as well as impacts from reducing demand on export markets.<br>• Disruptions or frictions in the ecosystem's global value chains can affect specific essential products and inputs that are particularly critical for the EU economy.<br>• Raw materials, batteries and semiconductors are key enabling technologies and inputs crucial for the decarbonisation and digitalisation of the mobility industry<br>• Secure access to third country markets<br>• Shortage of semiconductors and need reinforce the EU processor and semiconductor value chain and to expand industrial presence | 68, 78 |
| Global and complex supply chains (decentralization of supply and demand) | • European companies' share in the world patent applications has been constantly decreasing<br>• Strong competition from third countries and<br>• distortive market or trade practices while the EU market is based on fair and rules-based competition and trade. | 68, 78, 79 |

| Main Critical Factor | Detailed Critical Factors | Ref. |
|---|---|---|
| Skills gaps | • Lack of practical experience leading complex transformations, missing change management skills<br>• Large-scale skills gaps exacerbated by skilled workers' geographical imbalances | 68, 78 |
| Waste | • The extraction of raw materials, the emission of particulate matter, and the negative impact on biodiversity have increased in recent years<br>• Ecosystem greenhouse gas emissions are above the global average | 68, 78, 79, 82, 83, 84, 85 |
| Infrastructure and Logistics Disruptions | • Need to analyse delays, accidents, damages, and system breakdowns | 90 |

Although being an essential industry, mobility Ecosystem faces important challenges – and consequent critical factors – that influence's the sector resilience. In that sense, the critical factors in Table 24 present an overview of the sector, with some aspects that may be emphasized such as:

- **Digital maturity of the ecosystem:** EU already has a legal framework for the approval of autonomous vehicles (General Safety Regulation) and for increased interoperability and capacity of rail transport (European Rail Traffic Management System). Ensuring the deployment of key digital enablers and removing barriers to data sharing will be critical to improve efficiency and develop new market opportunities [3].
- **Environmental and social sustainability:** Also impacted by the EU legal framework, significant legislative adaptations are foreseen- Euro 7, CO2 standards, FuelEU Maritime, Rail Freight Corridors regulation, Combined Transport, and batteries regulation. The ecosystem as a whole will require substantial investments in both legacy and green technologies[78, 82, 83, 84].
- **Skills Gap:** The mobility ecosystem faces challenges in terms of a shortage of skilled workers and decreasing sector attractiveness. There is a scarcity of skilled profiles, particularly in advanced technologies, as the mobility ecosystem competes with other industries such as renewables, big tech, and finance for valuable engineering talent [75].
- **Critical dependencies:** The COVID-19 pandemic has highlighted the EU's reliance on third countries for crucial elements of its supply chain, such as specialized engines and electronic components. EU companies are facing competition from Asian countries, even in sectors where they were previously leaders. Certain rail and automotive markets are also experiencing increased competition from China, despite the EU being the second-largest car market and producer after China. The maritime industry serves as an example of the risks associated with relying on a niche strategy, as the pandemic and global crisis have severely impacted the cruise and passenger ship sector. Export markets play a vital role in maintaining the EU's leadership and financing investments in new technologies [79, 80].

### 3.4.4 Mobility Supply Chain Resilience Fit Model

Figure 32 represents presents the model for the mobility ecosystem. The context variables presented are those identified as most relevant to the Ecosystem. Indicators of ecosystem resilience with a score lower than 5 points were inserted, as well as all critical factors identified as potentially impacting the ecosystem. In turn, the intervention variables presented are those that best respond to the context variables relevant to the ecosystem. Additionally, the digital ecosystem's intervention factors were associated with the following critical factors: Health and pandemic disruptions, Environmental crises and natural disasters, Political conflicts and crises, and Technological disruptions and low digital maturity.

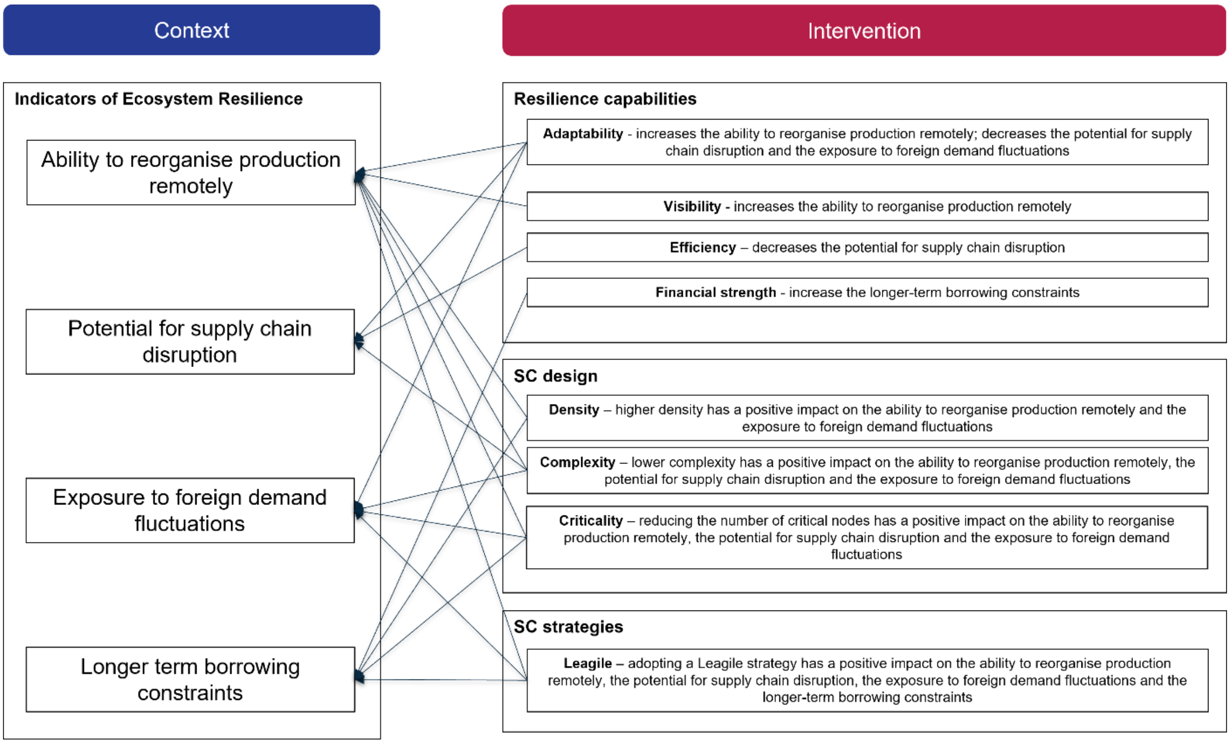


*Figure 32: Mobility Supply Chain Resilience Fit Model*

# 4 Final Remarks

The overall objective of WP1 was to establish a foundational understanding of current and future risks and disruptions in the supply chains of four industrial ecosystems – textile, agri-food, digital and mobility. In addition, Task 1.1 and Task 1.2 collected information from different sources to define: (1) a theoretical fit between context and intervention variables, that would lead to a general supply chain resilience fit model; and (2) a high-level overview of the four ecosystems, including its commercial characteristics, indicators of ecosystem resilience and critical factors related to SC disruptions, that would lead to the design of a Supply Chain Resilience Fit Model for each ecosystem, addressing the particularities of the sectors and possible intervention actions. In order to design a Supply Chain Resilience Fit Model for each ecosystem, particular aspects of each ecosystem were considered, based on the indicators of ecosystem resilience.

Regarding the indicators of ecosystem resilience, it could be observed that textile and agri-food ecosystems are those that present less positive performance. Aspects related to 'Ability to reorganise production remotely' and 'Potential for supply chain disruption' are the more critical for both ecosystems. In addition, for the textile ecosystem, not being an essential industry leaves this sector in a more fragile position concerning public policies and incentives. These factors reinforce the need for robust resilience strategies, including market diversification, the adoption of digital technologies to increase supply chain visibility and efficiency, and the implementation of sustainable practices that reduce dependence on external resources and minimize waste. Additionally, the sector faces growing pressure to innovate, especially in terms of sustainability. The need to reduce its carbon footprint, increase product transparency and traceability, and implement effective recycling systems are challenges that require continuous innovation. The development of new patents, especially in green and digital areas, highlights the sector's competitiveness and its ability to adapt to global changes.

By its turn, the agri-food ecosystem has its limitations in the 'Ability to supply products remotely' and 'Exposure to domestic demand fluctuations'. In addition, the growing demand for sustainable food and the pressure to reduce the sector's environmental footprint drive the need for innovation at all stages of the value chain. Digital transformation, through the adoption of precision agriculture technologies, the Internet of Things (IoT), and big data, is becoming essential to improving the efficiency and sustainability of agri-food operations. The resilience of the agri-food ecosystem depends on the ability to adapt to change, diversify markets, and continuously innovate. The implementation of resilient supply chain models, considering both efficiency and sustainability, is crucial to facing emerging challenges. Additionally, cooperation among the various actors, from farmers to distributors, is essential for building robust supply chains that can withstand future crises.

The two other ecosystems - mobility and digital - main limitations lie in their financial constraints, namely 'Longer term borrowing constraints'. Particularly for the digital ecosystem, the adoption of technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data, are transforming its resilience capabilities. These technologies not only increase the efficiency and flexibility of operations but are also essential for creating new business models that respond to modern market demands. However, rapid technological evolution also brings significant challenges, such as the need for advanced digital skills and vulnerability to technological disruptions, such as cyberattacks. Therefore, the resilience of the digital ecosystem, depends on the flexibility of the actors and their ability to respond quickly to disruptions - ensuring business continuity and competitiveness. Furthermore, collaboration between companies, governments, and research institutions is vital for the development of innovative solutions that can address emerging challenges and seize opportunities in the global market.

Mobility also has limitations in its 'Ability to reorganise production remotely' being critical for its resilience level. In that sense, new technologies such as autonomous vehicles and connected transportation systems may reduce its limitations. The resilience of the mobility ecosystem depends on its actors' ability to anticipate and mitigate risks, diversify supply sources, and invest in technological innovation. Additionally, digitalizing operations and adopting advanced supply chain management technologies are essential to improving the ecosystem's efficiency and flexibility.

In conclusion, considering the context and intervention variables of each ecosystem, four Supply Chain Resilience Fit Model were proposed, establishing a theoretical relation between the context and intervention variables. As a result, it is possible to identify which characteristics and critical factors could be improved by changes in the ecosystem's resilience capabilities, supply chin design and strategies. These four models will be later used at WP2 to support the definition of a methodology for disruption impact quantification and technology scouting.

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## 5.5 General

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