[D2.1] REPORT ON TRENDS, CHANGES AND CHALLENGES FOR THE SUPPLY CHAIN OF THE FUTURE

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List of abbreviations and definitions

Abbreviation	Definition
AI	Artificial Intelligence
AR	Augmented Reality
B2B	Business to Business
B2C	Business to Consumer
C2B	Customer to Business
C2C	Customer to Customer
CAGR	Compound Annual Growth Rate
CBDC	Central Bank Digital Currency
CPI	Consumer Price Index
CRM	Customer Relationship Management
CSR	Customer Social Responsibility
DEI	Diversity, Equity, and Inclusiveness
EAA	European Environment Agency
EC	European Commission
ECB	European Central Bank
EMDE	Emerging market and developing economies
EPR	Extended Producer Responsibility
ESG	Environmental, Social, and Governance
EU ETS	EU Emissions Trading System
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GHG	Greenhouse Gas
GPN	Global Production Networks
GVC	Global Value Chain
IPF	International Project Finance
IoT	Internet of Things
KYC	Know-Your-Customer
OECD	Organisation for Economic Cooperation and Development
PESTLE	Political, Economic, Social, Technological, Legal, Environmental
PTA	Preferential Trade Agreement
SC	Supply Chain
SCM	Supply Chain Management
SDG	Sustainable Development Goal
SME	Small- and Medium-Sized Enterprise
SMEI	Single Market Emergency Instrument
VR	Virtual Reality
WTO	World Trade Organization

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1. EXECUTIVE SUMMARY

The goal of WP2 is to propose innovative models for supply chains shaped by various current trends that comprise significant changes and challenges in supply chain management. This report summarises the results of the tasks T2.1 “Identification of trends, changes and disruptions” and T2.2 “Social and sustainability challenges for the supply chains of the future”. The first step in T2.1 is to investigate the trends and megatrends with respect to socio-economic, technological, political, legal, and environmental factors that impact European supply chains.

A structured literature analysis is conducted to identify the exogenous trends and to ensure the inclusion of newly arising, most current trends taking into consideration recent emerging changes due to sudden disruptions like the pandemic or the Ukraine war. The methodological approach in T2.1 is guided by the PESTLE (Political, Economic, Social, Technological, Legal and Environmental) framework to examine all relevant megatrends and trends that can shape the landscape of manufacturing, process manufacturing, logistics, and supply chain management. The results from the literature review are supplemented by empirically collected insights from various external stakeholders in a workshop.

What emerged from T2.1 activities, in the political dimension trends in the areas of protectionism, political instability, and supranationalism have a significant impact on global supply chains and trade relationships. Especially with respect to the war in Ukraine, the emerging social unrest became a societal concern in many countries and is focused on in this dimension. In the economic dimension, the global trade shift confirms trends like export growth and a reorganized globalization while further emerging trends are the result of the pandemic crises like the increasing inflation. The digital economy paradigm comprises trends such as digital platforms and sharing economy approaches as well as new financial models and cryptocurrencies affecting supply chain processes. The social dimension reveals the megatrends of demographic change, urbanization, consumption patterns, digital society, and knowledge-based society. These megatrends are pointed out as they highlight societal shifts that differ in developing and developed countries, changing consumer preferences, and the importance of knowledge management and continuous learning within the workforce. Given the established pervasiveness of digital technologies, the technological dimension comprises new trends adoption that is grouped in the following megatrends: increasing data, autonomous things and hyperautomation, infrastructure and security-related risks, and technology contributions to

alternative energy sources. These megatrends reflect advancements in technology that drive innovation and automation, as well as the transition to more sustainable energy solutions. The legal dimension encompasses three megatrends: consumer protection, informational regulation, and social and environmental regulations. These megatrends are important because they address issues of data privacy and the growing emphasis on corporate social responsibility. Lastly, the environmental dimension includes two megatrends: climate change and resource scarcity. These megatrends highlight the pressing need to address environmental challenges, such as pollution, global warming, and the efficient management of waste and resources.

The second step in T2.2, following up on the trend analysis is to identify risks for supply chains that arise from those trends identified in T2.1 and affect the European companies. As a methodological approach, systematically derived scientific papers are analysed. The supply chain risks have been clustered per megatrend and have been evaluated according to their impact on supply chain sustainability and according to the probability of occurrence. The identified risks are internal to the companies and to supply chains as derived from exogenous trends and megatrends. Thanks to the validation with the workshop, it was possible to confirm with experts the list of identified risks, and in interaction with them, it was possible to finalise the list. The workshop was the place to start the discussion related to the vulnerability generated by each group of risks on the supply chain grounding it on a probability of occurrence and on the expected impact on SC processes.

Overall, the results of the deliverable demonstrate that the environment in which European companies operate is subject to rapid and constant change. This implies that not only the type and number of risks constantly change, but that there are increasing dynamics companies must cope with taking into consideration the sources of these risks. The results underline the necessity of approaches and strategies with which resilience in supply chains can be increased in a sustainable and targeted manner which will be studied in the next tasks (T2.3 and T2.4). At the same time, they lay the foundation for further conceptual activities of ReSChape project, in which necessary approaches and strategies will be developed and validated (WP3) and policy related (WP4).

This work provides managers in a systematic way with megatrends and trends that are critical for the generation of future supply chains and could offer a starting point to customise specific long-term strategies for their company. Moreover, this work gives a glimpse into the challenges in terms of risks that supply chain managers may face in the future; thus, they can develop an early warning system and develop as well as contingency plans. It provides an opportunity to prepare and respond to a broad range of potential disruptions in the future and to create more resilient and interactive supply chains. Based on these results, it will be possible to formulate also policies that support this evolution and help to face the implications of the identified megatrends and trends on supply chains for the years to come.

2. INTRODUCTION

In today's rapidly changing business environment, supply chain management faces various changes and challenges. Factors such as globalization, technological advancement, and shifting consumer demand significantly impact supply chains and require organizations to continuously adapt to the rising volatility, uncertainty, complexity, and ambiguity (VUCA). The VUCA concept has already been introduced in 1991 by Adrian Reisch to describe new and unknown situations, where one cannot rely on proven methods from the past. Since then, the concept has been adopted by organizations internationally to describe the dynamics of our world. Comparing the world of two decades ago to the present day reveals a radical transformation in our surroundings. Even only a few years ago, our surroundings were significantly different. One approach to describe these changes in categories is the PESTLE approach which supports comprehensively collecting supply chain trends while delivering guidance for a structured categorization. The trends also build the basis to identify concrete risk factors that need to be addressed by businesses operating during these challenging times.

Therefore, in this first ReSChape report, we delve into the most relevant trends and risks of supply chain management that emerge from the described changes in the business environment and that are necessary to address supply chain strategies and approaches to navigate and thrive in this complex landscape. Through this analysis, we seek to provide valuable knowledge and practical insights for organizations striving to optimize their supply chains in an ever-evolving business landscape. Therefore, as a first step, the identified key megatrends, their associated trends, and emerging risks are defined in the context of supply chain management.

- **Megatrends** can be defined as large, slow-forming socio-economic, political, environmental, or technological changes that are particularly useful for forecasting the future of manufacturing, process manufacturing, logistics, and supply chain management. Megatrends are observed over decades, affect nearly all regions of the world, and have a significant impact on business, economy, society, cultures, and personal lives. They are non-sector specific, drive trends and gradually progress over time while providing a basis for future supply chain strategies for more resilience and sustainability [1], [2].
- **Trends** give a direction of movement, development, or change and build more specific subgroups of the overarching megatrends [2]. Trends can emerge from various sources such as technological advancements, changes in consumer behaviour, economic shifts, regulatory changes, or other events. Staying aware of these trends can help organizations to maintain a competitive edge in the market. As an example, the megatrend of climate change will affect the environment as a whole, while a corresponding trend would be the more specific "water, air, and soil pollution" [3], [4].
- **Risks** are utilized in this report in the sense of supply chain risks that may “disrupt or impede the information, material or product flows from original suppliers to the delivery of the final product to the ultimate end-user” [5]. Building upon the principles of the triple bottom line, risks are associated with economic, environmental, and social categories that impact the sustainability of enterprises and enterprise networks [6].

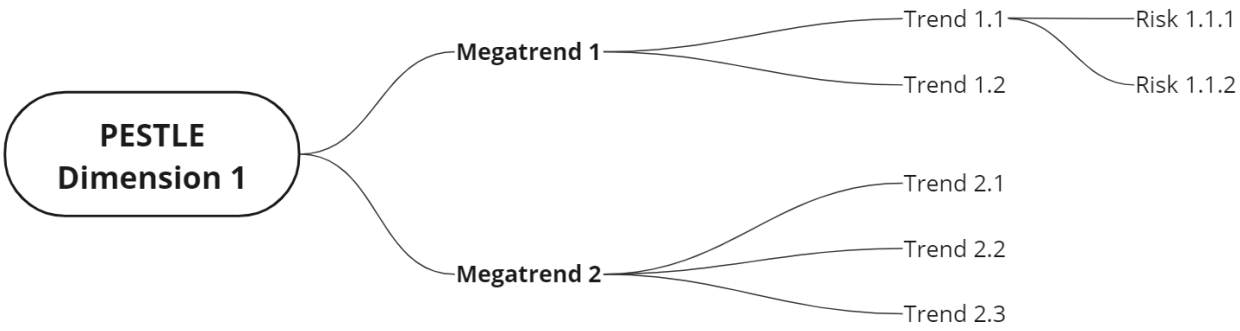


Figure 1: Main components of the report

This report involves the described components to deliver a theoretical basis for understanding changes and challenges in supply chain management. As an example, in the social dimension, the demographic change megatrend would comprise the specific trend of an ageing population boom, whereas knowledge loss would be an associated risk in case no adequate mechanisms are developed. The report builds a basis for developing necessary innovative supply chain strategies in the upcoming work package. The next section details the specific objectives and methodologies applied, section 4 presents the findings, and the final section summarizes the results and future research.

3. OBJECTIVES AND METHODOLOGY OF THIS DELIVERABLE

The objectives of this deliverable are to report the results of the research conducted in T2.1 ("Identification of trends, changes and disruptions") and T2.2 ("Social and sustainability challenges for the supply chains of the future"). In particular, as shown in Figure 2, the activities in T2.1 have been carried out based on PESTLE methodology for trend identification (left side of the Figure 2Figure 2) and the subsequent T2.2 was based on literature review for supply chain risk identification and workshop with experts to validate the results (right side of Figure 2).

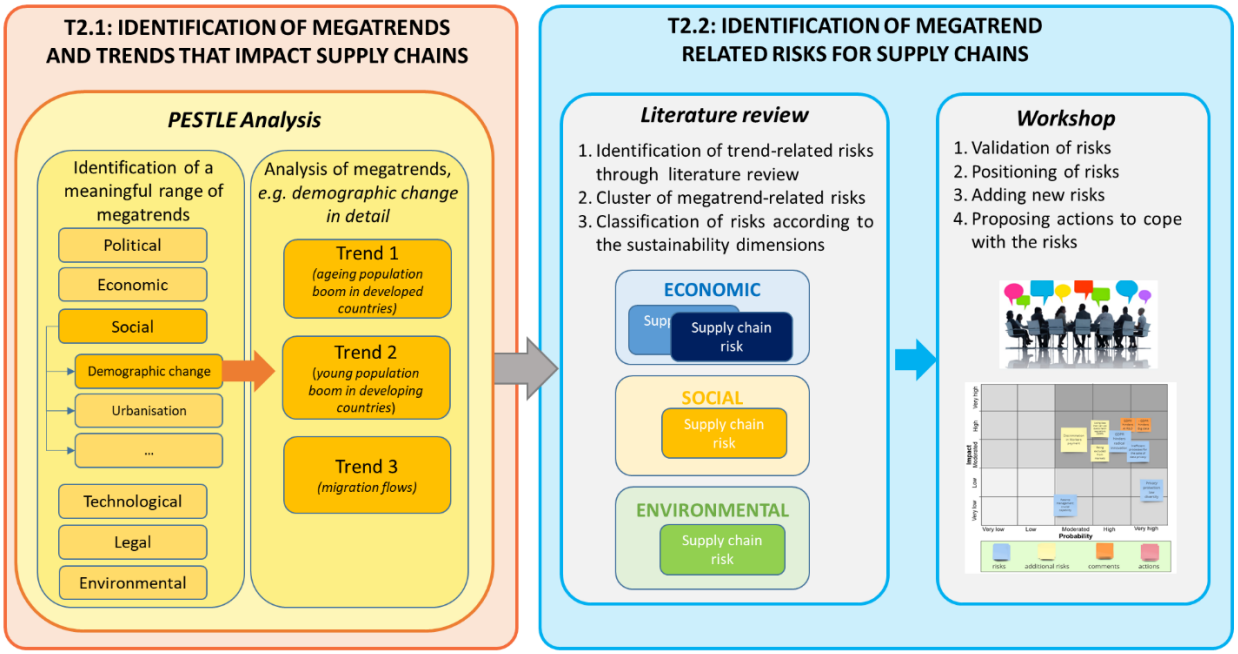


Figure 2: Detailed components and research methodology

3.1 METHODOLOGY FOR PESTLE ANALYSIS

3.1.1 Objectives

How can enterprises effectively manage the key factors impacting supply chains today? Recent events such as the Covid-19 pandemic and the conflicts in Ukraine have led to significant disruptions of supply and demand in global supply chains. Inflation and the cost-of-living crisis have created further problems, while political pressures, including nationalism and autocratic regimes, have also contributed to a more challenging economic, business, and societal environment. The rapid developments in climate matters as well as the ongoing digital revolution towards Industry 4.0 only build the tip of the iceberg. All of these factors have a significant impact on global supply chain performance and urge enterprises and regulators to assess the specific trends and risks they face.

Therefore, in T2.1, the PESTLE framework developed by Carpenter & Sanders [7] is used. This methodology represents an evolution of the prior PEST model by including environmental and legal dimensions and has been proven to be a successful and comprehensive guide for analysing the

environment in various business sectors [8], [9]. It utilizes six dimensions and follows a two-step approach of assessing the applicability of those dimensions involving brainstorming sessions, literature review, and insights from practical experts to identify the factors that have an influence. In the second step, the identified factors are then organized and categorized into a coherent and meaningful hierarchy that aligns with the given context. This grouping is designed to facilitate the handling of the factors, as factors within the same group can be addressed and managed collectively [10]. The utilized dimensions of the PESTLE are the following:

- Political: The political dimension encompasses trends related to government policies (e.g. foreign trade regulations, tax policies, etc.), political stability or instability in domestic and foreign markets, and other related factors.
- Economic: The economic dimension involves trends related to economic factors such as inflation and interest rates, foreign exchange, and economic growth patterns. These factors can influence the demand and supply of products and services in the market.
- Social: The social dimension encompasses trends related to cultural trends, demographics, and population analytics. These factors can have a significant impact on consumer behaviour and preferences.
- Technological: The technological dimension includes the current state and advancements in technology (e.g. investments in technological research, adoption rates of new technologies, and the potential impact of information technology) that can affect the operations of the industry and the market.
- Legal: The legal dimension comprises trends related to consumer protection laws, informational regulation, as well as social and environmental regulations. These factors can impact the enterprise's costs and reputation.
- Environmental: The environmental dimension involves trends that consider the impact of climate, weather, and carbon footprint, as well as the use of specific raw materials. These factors can significantly affect the industry's sustainability.

3.1.2 Workflow of the process

Each ReSChape partner involved in T2.1 is assigned to one of the PESTLE dimensions and works on the identification of a preliminary list of trends before fixing and further detailing them. The process is conducted iteratively in the time frame between the beginning of November 2022 and the end of January 2023 by:

- Selecting keywords and papers;
- Identifying megatrends and trends affecting supply chains and detailing them with a medium-long term horizon (2030-2050);
- Sharing and discussing the trends in regular meetings with all ReSChape partners;
- Iteratively revising the trends with a peer review approach.

As shown in Figure 2, starting from the dimension of the PESTLE analysis, each leader of the 6 dimensions identified current megatrends affecting supply chains, and specified detailed trends. A shared Excel document is used as an internal working document among the partners to collect the following information:

- list of megatrends;
- List of trends and short description with statistics;
- for each trend, related effects on the supply chain;
- references.

Through a peer review approach, reviewers within the research consortium have been appointed to revise the trends for iterative improvement and refinement of the content.

3.1.3 Selection of keywords

The following keywords were used for a literature review that was conducted in a systematic way and involved the major scientific databases Scopus, Science Direct, Emerald and Google Scholar [11]. Moreover, also grey literature and consulting documents have been analysed for the PESTLE analysis.

General keywords for the identification of the megatrends:

- (logistics) OR (supply chain management) OR (manufacturing) OR (process manufacturing) OR (distribution) OR (transportation) AND (trends OR megatrends)
- (future supply chain) OR (next generation supply chains) OR (supply chain innovation) AND (trends OR megatrends)

Dimension-related keywords:

- **Political dimension:** (protectionism) OR (political stability) OR (supranationalism) AND (trends or megatrends)
- **Economic dimension:** (global trade shift) OR (sharing economy) OR (financial Innovation) AND (trends OR megatrends)
- **Social dimension:** (demographic change) OR (urbanisation) OR (change in consumption patterns) OR (individualisation) OR (digital society) OR (knowledge based economy) AND (trends OR megatrends)
- **Technological dimension:** (big data analytics) OR (artificial intelligence) OR (cloud based computer systems) OR (blockchain) OR (Internet of Things) OR (robots) OR (augmented reality and virtual reality) OR (3D printing) OR (drones) OR (automated vehicles) OR (wearable devices) OR (cyber-physical system) AND (trends OR megatrends)
- **Legal dimension:** (consumer protection laws) OR (intellectual property law) OR (environmental regulations) AND (trends OR megatrends)
- **Environmental dimension:** (climate change) OR (resource scarcity) AND (trends OR megatrends)

3.2 METHODOLOGY FOR IDENTIFICATION OF SUPPLY CHAIN RISKS

3.2.1 Literature review

3.2.1.1 Objectives

In the last few years, a growing need determined by the external environment emerges, i.e. resilience. Due to external events, such as pandemics, wars and their consequences, and the dearth of natural resources among others, supply chains have an even more urgent need to assess the risks they face in order to maintain their operations and to anticipate, respond to and recover from disruptions. Developing resilience in supply chains, indeed, means building "the adaptive capability to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function" [12] (p.131). In these terms, resilience can be identified as the opposite of vulnerability: the more resilience develops along the supply chains the more vulnerability reduces [13].

Thus, in light of the last shocks and the growing need for resilience, the project's consortium has identified in T2.1 the current megatrends emerging from the external environment through the PESTLE analysis. Grounding on this work, in T2.2, the consortium studied risks that are currently endangering supply chain sustainability. In particular, this work was aiming to understand how supply chains can develop resilience and thus diminish their vulnerabilities.

As defined by Peck [5], supply chain risk is "anything that may disrupt or impede the information, material or product flows from original suppliers to the delivery of the final product to the ultimate end-user". In order to identify risks that are jeopardizing supply chain flows, firms need to "understand and manage their economic, environmental, and social risks in the supply chain" [14] (p.366). As underlined by Carter and Rogers [14], companies started a decade ago to understand that managing risks is part of their sustainability. Thus, to tackle the current megatrends, the partners agreed to classify supply chain risks (process, control, demand, supply [15], [16] according to their impact on sustainability dimensions (i.e., economic, social, and environmental).

Concerning sustainability, sustainable supply chain management has been defined as "the strategic, transparent integration and achievement of an organisation's social, environmental and economic goals in the systemic coordination of key inter-organisational business processes for improving the long-term economic performance of the individual company and its supply chains" [14] (p. 368). While in the past the economic dimension of sustainability has been widely investigated, environmental and social sustainability still need to be fully integrated into supply chain management. Ashby et al. [17] in their review classified papers that investigate social and environmental dimensions. Supply chains that integrate environmental issues in their processes aim at reducing waste, environmental impacts on their final products, etc., through reverse logistics, life cycle assessment, and other numerous management practices. Besides the environmental dimension, Ashby et al. [17] recognized in the literature the growing emphasis given also to the social dimension of sustainability. Social sustainability concerns humans. The increase in social sustainability means reducing unemployment, protecting employees in the workplace, preventing social exclusion, and adding value by increasing the human capital of people (their skills and abilities for example).

3.2.1.2 Workflow of the process

Each partner leader of a PESTLE dimension worked on the identification of the preliminary list of supply chain risks per trend and then, in a second step, these risks have been clustered by megatrend to reduce overlapping and similarities. This was done iteratively between the end of January to the mid of March 2023 by:

- Selecting keywords and papers (see Section 3.2.1.3);
- Identifying supply chain risks per trends;
- Clustering the risks per megatrend (see Section 3.2.1.4);
- Assigning the risks to the three sustainability dimensions, i.e., economic, social and environmental (see Section 3.2.1.4);
- and revising the risks according to partners' comments and suggestions.

As shown in Figure 3, starting from the trends of the PESTLE analysis, each PESTLE dimension leader identified the trends-related risks for supply chains. Then in the second phase, similar risks belonging to the same megatrends (e.g., the risks associated with "ageing population boom", "young population boom in developing countries", and "migration flow" for the "demographic change") have been clustered.

Finally, the risks have been further classified according to their impact on the sustainability dimensions, as explained in Section 3.2.1.4 (e.g., concerning demographic change, "knowledge loss" have been classified in terms of economic impact, while "Poor workplace ergonomics" in terms of social impact).

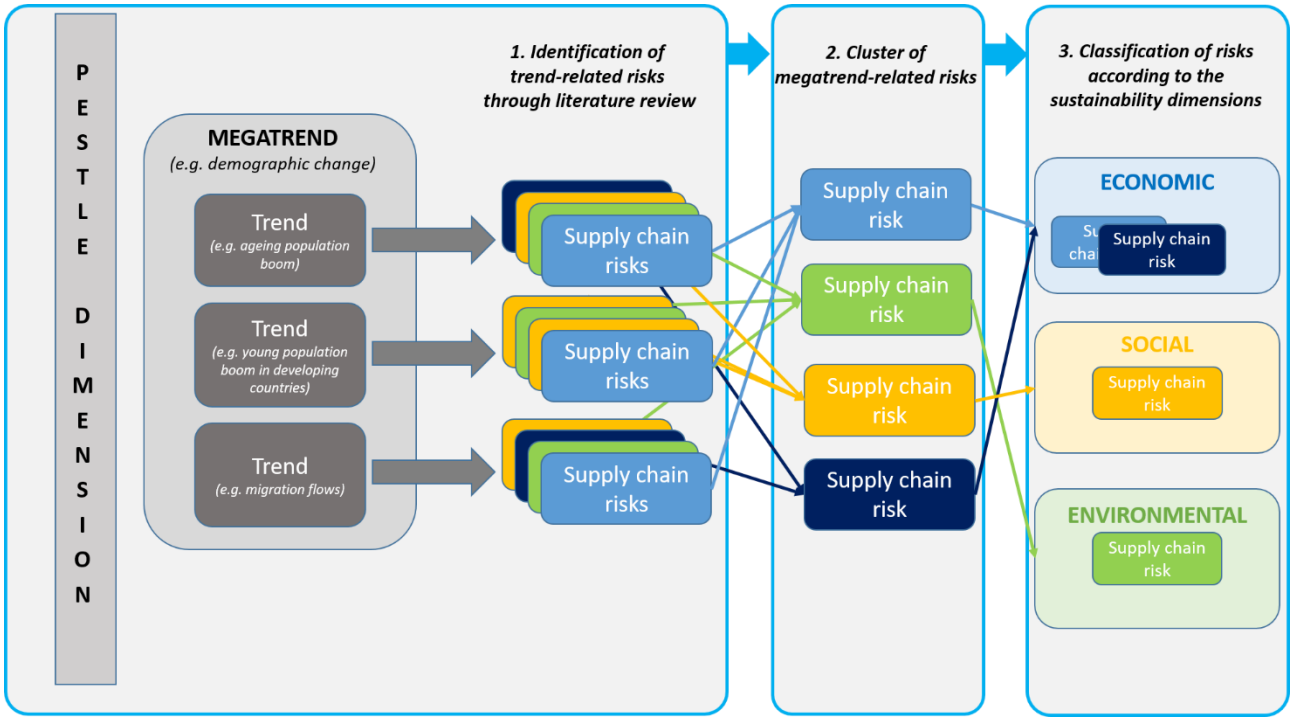


Figure 3: The process to identify the final sample of risks.

The shared Excel file used in T2.1 was integrated with the following information:

- List of risks per trend
- Categorisation of risks according to sustainability dimensions (economic, social and environmental)
- references.

3.2.1.3 Selection of keywords and papers selection criteria

After the identification of the main megatrends and their related trends through the PESTLE analysis carried out in T2.1, each PESTLE dimension leader carried out a literature review in a systematic

way [11] to collect risks for the supply chain. In particular, the partners agreed on three main sets of keywords:

- *Trend-related keywords.* For each trend, a group of keywords which exemplifies the trend-related concept has been identified;
- *Supply chain-related keywords.* For this set, the partners used keywords, i.e. "supply chain*" OR "value chain*";
- *Risk-related keywords.* Although the taxonomy of risk, vulnerability and resiliency reducers is different, some authors argued that the concepts have been used interchangeably in the literature [16]. Consequently, the partners identified "vulnerab*" OR "risk*" OR "challenge*" OR "effect*" OR "resilien*", as the risk-related keywords.

Once identified the keywords, the consortium agreed to search them in the title, abstract and keywords in scientific databases (e.g., Scopus and Web of Science) and grey literature.
An example of the research string is provided below for the trend "Ageing population boom":

(TITLE-ABS-KEY((older OR elder OR ageing OR aging) AND (worker OR employee* OR population* OR workforce OR "labor force" OR "labour force")) AND TITLE-ABS-KEY("supply chain*" OR "value chain*") AND TITLE-ABS-KEY(vulnerab* OR "risk*" OR "challenge*" OR "effect*" OR "resilien*"))*

The search string has been limited to:

- Subject areas which are the main scientific areas of analysis of this project (engineering, business and economics);
- Time frame considering only papers published in the last five years to identify recent risks that are still open (however, if for some search strings there are few results in the last five years, the search can be expanded to articles published in the last ten years).

According to the aim of the review, i.e., the identification of trends-related risks for supply chains, the further selection was based on the discard of scientific papers covering risks, challenges or vulnerabilities, etc. that were not specifically related to supply chains (in terms of resilience).

3.2.1.4 Classification process

Once the risks have been identified through the literature review, they have been further classified.

As highlighted in Figure 3, the consortium agreed to cluster the trends-related risks into megatrends-related risks for supply chains according to their similarities.

For example, the risk "lack of skills and few training opportunities" related to the megatrend "demographic change" has been derived from the clustering of risks from the following trends:

- *Ageing population boom-related risks* [18]: lower ICT and analytical skills than young workers, fewer training opportunities, and lower occupational mobility;
- *Young population boom in developing countries-related risks* [19]: lack of youths due to the lack of skills in agriculture, lack of practical training (like repairing and maintaining farming equipment, production capability, farm management and literacy in information technology);
- *Migration flows-related risks*: lack of training (in terms of safety, job-related training, and soft skill training [20]), language barriers (in terms of training, communication with supervisor [20],

and understanding the migrant worker's rights [21]), low level of safety standards [20], increasing competitive labour market for low-skilled migrants and workers [22].

After that, as highlighted in Section 3.2.1.1, the risks have been classified based on their impact on the sustainability dimensions, according to the following definitions:

- *"Economic sustainability* has been operationalised as production or manufacturing costs" [23]. In general terms, it refers to the impact of the organization's business practices on the economic system [24];
- *"Environmental sustainability* refers to the use of energy and other resources and the footprint companies leave behind as a result of their operations" [23];
- *"Social sustainability* means that organisations provide equitable opportunities, encourage diversity, promote connectedness within and outside the community, ensure the quality of life and provide democratic processes and accountable governance structures" [23].

For example, related to the megatrend "Demographic change":

- The risk of "Decreasing of ageing workers' functional capacities" determines a negative impact on economic sustainability. In fact, the literature says that this risk causes an increase in lead time in manufacturing systems [25] and delivery time in logistics operations [26]. Moreover, it emerged that the rising number of ageing workers decreases the Total Factor Productivity [27];
- The risk of "Poor workplace ergonomics" determines a negative impact on social sustainability, since it is demonstrated that increases the number of health issues and injuries of ageing workers [25], [28].

3.2.2 Workshop

3.2.2.1 Objectives and plan of the workshop

The consortium agreed to validate the identified risks for the supply chain and to map them according to their impact on supply chains and probability to occur. The validation process was carried out both internally to the consortium with a reciprocal process of revision of the risks and through a workshop with supply chain experts from industry and academia. The workshop was also conceived to start the identification of possible actions supply chains could do to tackle risks.
The partners developed the workshop through the following steps:

- *Identification of the theoretical frameworks* by the leaders of the task;
- *Design of the workshop.* This step lasted from the mid of February to the end of March 2023. During this period the tasks leaders conceived the structure of the workshop. The overall framework of the workshop has been shared and discussed with all partners during periodic online meetings. All the involved partners worked to transfer the content generated in the previous months (trends and risks) to the selected software (i.e. Miro). Moreover, an internal survey (developed by INESC – TEC) was structured to help with preliminary validation and to position the risks in the defined framework;
- *Data collection.* Contributions from partners and experts have been collected in three phases to refine step-by-step the list of risks;
- *Data analysis.* Contributions from the workshop were analysed by each PESTLE dimension leader in order to add new information concerning the risks that are harming supply chains. When new risks have been added by experts, the partners searched for evidence in the literature about them to finalise the list.

3.2.2.2 Adopted framework

In the mid of 2000, Sheffi and Rice [29] propose the “Vulnerability assessment framework” in order to identify the vulnerabilities of a company and to identify under which risks it can be considered vulnerable. Sheffi and Rice identify resilience as a strategic initiative to “bounce back from a disruption” [29]. Resilience, thus, can be enhanced only by understanding where the company is more vulnerable. The four quadrants, shown in Figure 4, represent one of the first examples of the categorisation of risks as a way to explain vulnerabilities.

A few years later, in line with Sheffi and Rice [29], Thun and Hoening [30] proposed their own model to classify supply chain risks refining the scoring of impact and probability to occur proposing 5 levels for these two dimensions so to make easier the classification. Moreover, they differ from Sheffi and Rice (as shown in Figure 4 and Figure 5) because they identified three areas of risks, i.e., risks that need immediate actions, risks to be reduced, and risks that do not need any action.

In order to map the risks, the partners agreed to consider both these frameworks for structuring the one for the workshop. As previously explained, the mitigation and control of vulnerability is the aim of supply chain risk management [30], but also the effect of enhancing resilience [13].

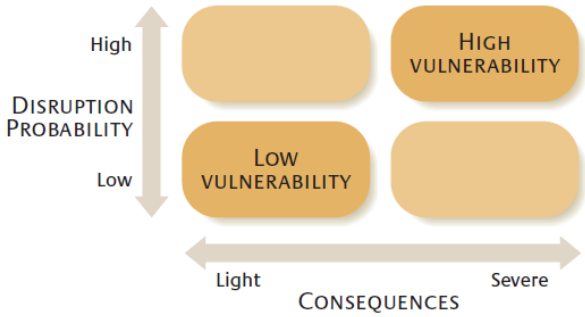


Figure 4: The model adopted by [29] to map supply chain risks.

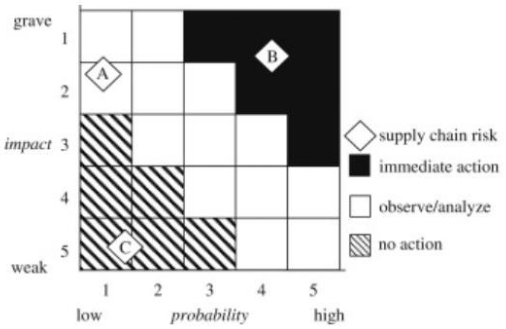


Figure 5: The model adopted by [30] to map supply chain risks.

3.2.2.3 Workshop design

Starting from the frameworks identified in the literature, the partners adapted them to the chart shown in Figure 6 to position the risks. The partners agreed to use the four quadrants for the vulnerability assessment [29] and to adapt the grid with a scale of 5 proposed by Thun and Hoenig [30] for the positioning of risks. Furthermore, the partners decided to have a precautional approach, identifying a wider area where supply chains are more vulnerable (dark grey quadrant).

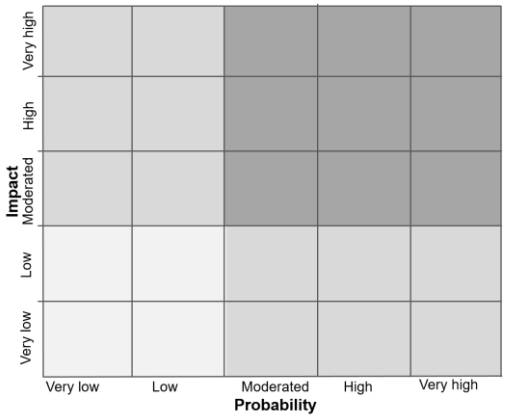


Figure 6: The framework used for the workshop (adapted from [29] and [30]).

After the design of the framework represented in Figure 6, the pre-assessment of risks was held through an internal survey among the consortium. Thus, the internal online survey has been sent to the partners. The structure of the survey is shown in Table 1.

Table 1: Example of the internal survey for the related risks for one megatrend.

Social dimension– Demographic change

Risks	Probability					Impact				
	VL	L	M	L	VH	VL	L	M	L	VH
Decreasing of ageing workers' functional capacities	○	○	○	○	○	○	○	○	○	○
Knowledge loss	○	○	○	○	○	○	○	○	○	○
Lack of skills and few training opportunities	○	○	○	○	○	○	○	○	○	○
Weak or missing control over workers' rights	○	○	○	○	○	○	○	○	○	○
Poor workplace ergonomics	○	○	○	○	○	○	○	○	○	○

VL= Very Low; L= Low; M= Moderated; H=High; VH= Very High

The results from the survey have been used to position the risks in each megatrend chart.

The task leaders proposed to structure in Miro board the material for the experts in the following way:

- Instructions for experts;
- Graphical representation of the megatrends and trends for each dimension;
- Short description of the risks classified per megatrend;
- Chart with preliminary mapping of the risks as from the internal online survey.

Figure 7 below shows a screenshot from the Miro board representing three dimensions, presented each in one specific session.

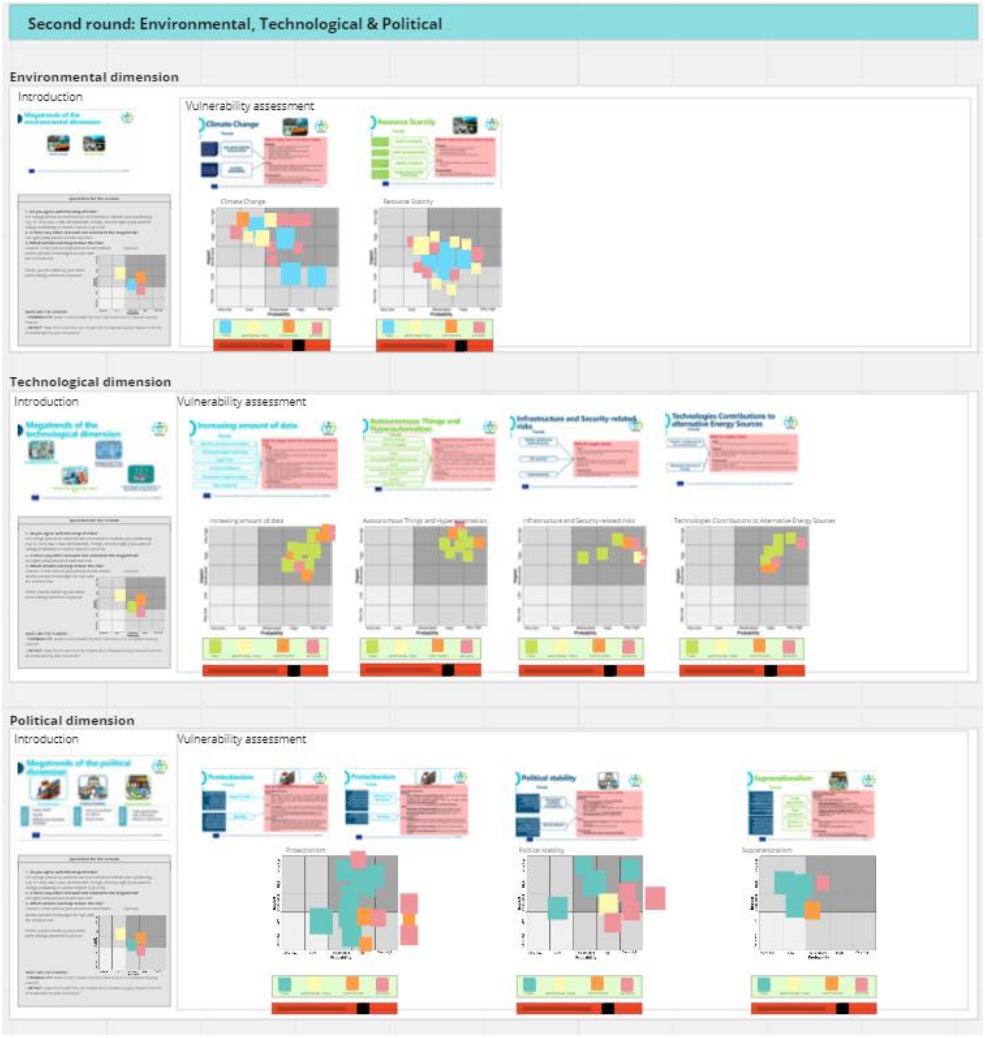


Figure 7: Structure of the workshop in Miro.

The partners agreed to organise the workshop online on the 3rd of April 2023. The workshop was held using the Zoom platform for the functionalities of the creation of parallel sessions. Each partner was in charge of inviting supply chain experts from industry and academia. Moreover, the invitation to the workshop was publicly promoted through project channels (website, social media, newsletter). A total of 35 experts participated in the workshop.

As for the structure of the agenda, in order to optimise the contribution of the experts, it was decided to split the work into two rounds each with three parallel sessions (one for each PESTLE dimension), so the experts could participate in two sessions, one for each round according to his/her expertise. For each session, there was a moderator responsible for guiding the experts through the Miro board. The PESTLE dimension leader acted as moderator.

The workshop was organised as shown in Table 2.

Table 2: Agenda for the workshop.

AGENDA		
Timetable	*Activities*	*Person in charge*
14:00 – 14:05	Get together	Project coordinator
14:05 – 14:15	Welcome speech and invitation to the community	Project coordinator
14:15 – 14:25	Introduction to the workshop	Project coordinator
14:25 – 14:30	Grouping and allocation to channels	Project coordinator
14:30 – 15:10	1st round: • Social • Economic • Legal	Session moderator
15:10 – 15:50	2nd round: • Environmental • Technological • Political	Session moderator
15:50 – 16:00	Debrief and outlook	Project coordinator

3.2.2.4 Data collection

Data have been collected in three phases:

- From the internal survey, for the positioning of the risks. Each PESTLE dimension leader collected the related data;
- From the workshop in the Miro Board;
- From the Miro board after the workshop when the consortium gave two weeks more to the participants to integrate or add new risks, comments or actions.

Data collection during the workshop according to this flow:

- In each session, the moderator of the session shortly introduced the list of identified risks and explained again the rules of the session, available in Miro (Figure 8);
- The participants were asked to comment on the pre-assessment of risks made by the consortium. In this phase, participants should validate the risks, add new ones if needed, and comment on their positioning (Figure 9);
- The participants could also propose actions to be undertaken to cope with the risks;
- The session was closed with a short wrap-up of the participants' comments and suggestions.

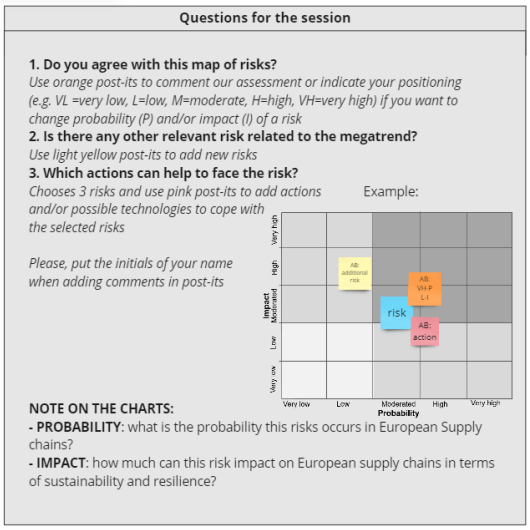


Figure 8: Rules for the workshop participants.

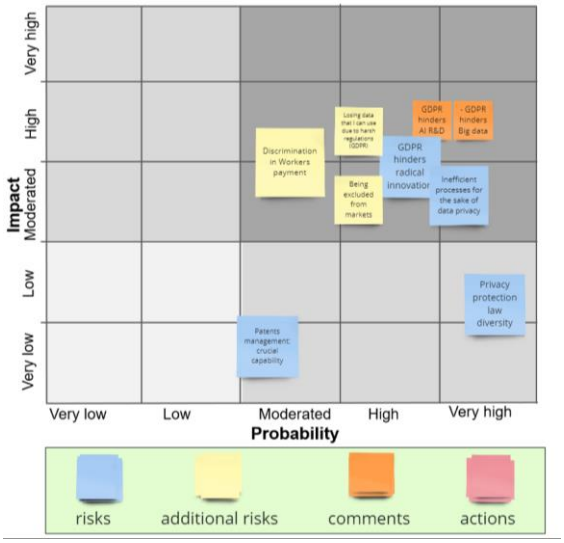


Figure 9: An example of how data have been collected for one of the charts in the Miro board.

3.2.2.5 Data analysis

- Analysis of data from the internal survey results. As in Thun and Hoening's study [30], for each label “VL” – “VH”, a numerical value from 1 to 5 has been assigned. Thus, for each risk, the results from the internal survey have been evaluated through the mean of the values assigned by the respondents. Thus, the mean value allows the positioning of each risk in the related chart.
- Analysis of data collected in the Miro Board after the workshop. When necessary, each PESTLE dimension leader moved the risks to the new positioning according to the experts' comments. In the case of new risks proposed by experts, the PESTLE dimension leader verified in the academic literature whether or not the new risk could be validated by existing studies. The example of the search string is: “new risks” AND “ supply chain-related keywords” AND “megatrend-related keywords” (see 3.2.1.3 for further details); according to the results from the literature, each dimension leader chose for each new risk whether clustering it with existing ones or creating a new categorisation.

4. RESULTS

4.1 OVERVIEW OF THE RESULTS OF THE PESTLE ANALYSIS

In this chapter, we present the results of the PESTLE analysis and the identified related supply chain risks. As an overview of the highlighted megatrends please refer to Figure 10.

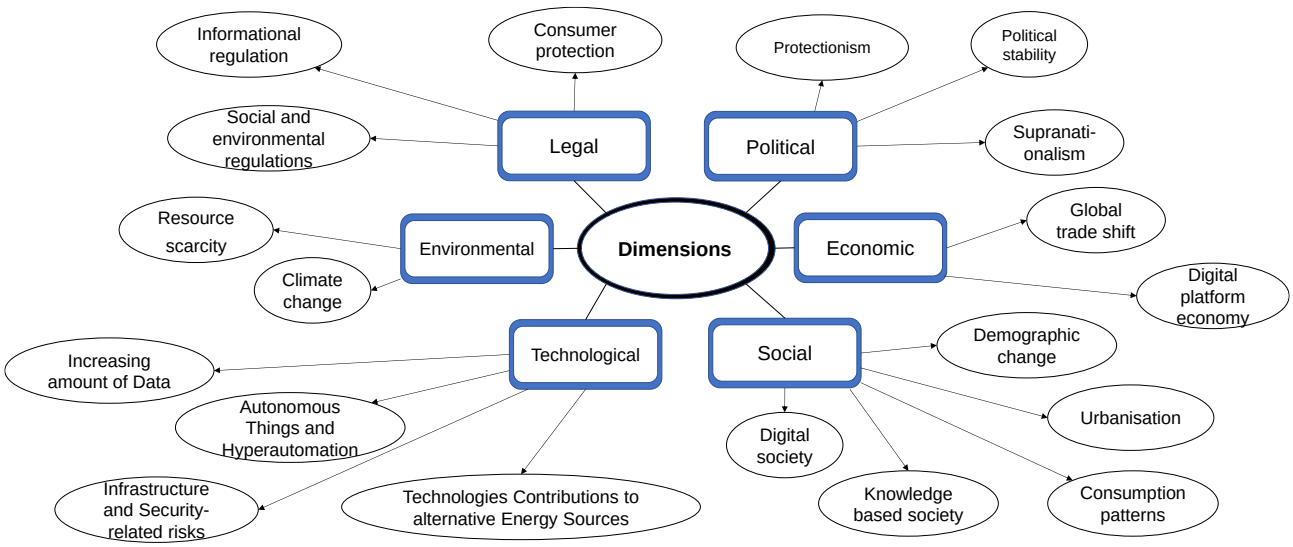


Figure 10: Overview on the megatrends of this report

We have structured the information with respect to the six PESTLE dimensions and the associated megatrends in a standardized format as can be seen in Table 3.

Table 3: Structure of the results' sections.

Structure of the following chapters		
First level	*Second level*	*Third level*
Dimension 1: *Mindmap of the megatrends and related- trends*	Megatrend 1.1: *Short introduction*	Trend 1.1.1 Trend 1.1.2 ... Trend 1.1.n Risks for supply chains from megatrend 1.1
Example: *4.4 Social Dimension*	*Example:* *4.4.1 Demographic change*	*Example:* *4.4.1.1 Ageing population boom* *4.4.1.2 Young population boom in developing countries* *…* *4.4.1.4 Risks for supply chains from demographic change*

4.2 POLITICAL DIMENSION

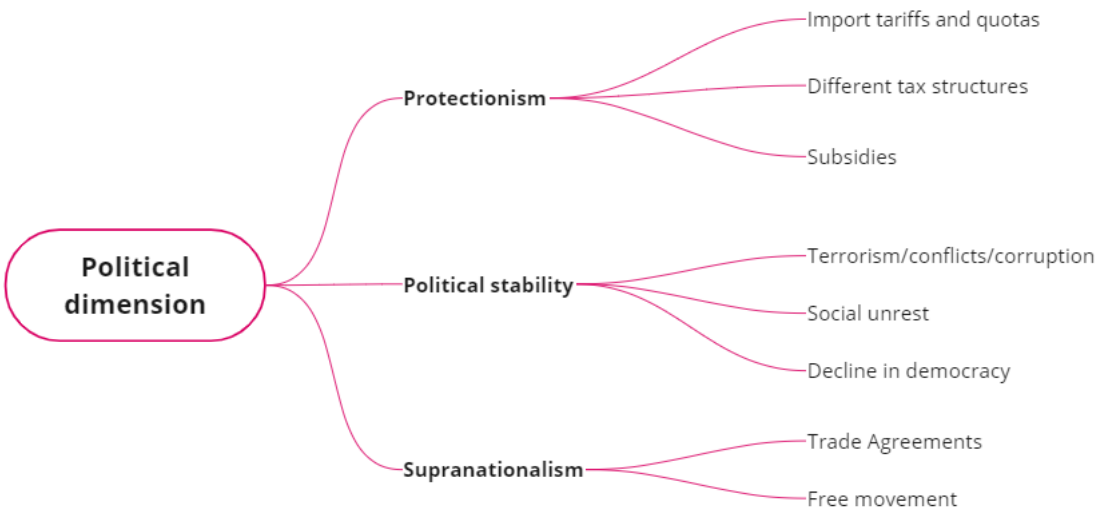


Figure 11: Overview of the trends of the political dimension.

4.2.1 Protectionism

The protectionism megatrend refers to the use of government policies and measures to restrict or control the flow of goods, services, and capital between countries. The measures traditionally used by countries and regions to limit access to their economy from abroad have been import tariffs and quotas. Likewise, subsidies and other aspects of tax systems generate differences in the competitiveness of companies affecting supply chains in numerous ways.

4.2.1.1 Import tariffs and quotas

Protectionism leads to an increase in trade barriers such as import tariffs and quotas. These trade barriers make it more difficult and expensive for companies to import and export goods, which can disrupt supply chains and increase costs. The evolution of tariffs and quotas depends mainly on political and economic factors. Decisions regarding international trade are subject to Trade Agreements between countries or supranational groups.

Trade-distorting interventions by governments in recent years have been a worldwide phenomenon, even though many of these measures tend to fly under the radar. Tariff wars between competing superpowers may attract the most attention, but beyond the headlines lies an extensive and growing web of subsidies, tax incentives and other policies that discriminate against foreign businesses. Although import tariffs constitute the most direct form of protectionism, they account for only 16% of trade affected by jumbo protectionist measures adopted in the populist era. By far, the largest culprit has been tax-based incentives for exporters, accounting for 54% of trade affected.

Geopolitical tension has been a major factor driving the use of higher import and export tariffs. These tariffs are often politicized, and as a result, they are expected to continue to be used. For example, tariffs have increased sharply on the back of United States-China trade tensions [31]. The US

maintains its protectionist policy with high levels of import tariffs while seeking bilateral agreements with other countries.

In the case of Europe, EU-US will continue collaborating bilaterally to address trade and economic issues and shared concerns. There is an EU study about the liberalisation of tariffs on industrial goods between the EU and the USA for the 2033 horizon. There is a special interest to deepen engagement with the African continent and African states [32]. Another of Europe's special bilateral relationships arises in the wake of BREXIT. The EU–UK Trade and Cooperation Agreement (TCA) foresees the avoidance of tariffs and quotas on goods, which benefits several sectors, however, it is currently, too early to understand whether these can compensate for the higher costs. Some products are still under grace periods and the costs might therefore be even higher in the near future once these end [33]. Regional trade is expected to grow in the coming years (see Figure 12).

The WTO Trade Facilitation Agreement (TFA) led to a US$ 231 billion increase in trade, particularly in agriculture, according to estimates for the first couple of years of its implementation presented to the Committee on Trade Facilitation on 22 March 2023 [34].

In response, the firms affected seek to bypass trade restrictions with two main types of strategies: (a) switching production locations, end markets and/or suppliers; and (b) upgrading value chain activities. These firm strategies can prompt the geographic and organizational reconfiguration of Global Value Chains (GVCs), although the way this process unfolds varies by sector and time period [35].

Surprisingly, according to [31], global trade increased in the products targeted by tariffs. Thus, despite ending the trend towards tariff reductions, the trade war did not halt global trade growth.

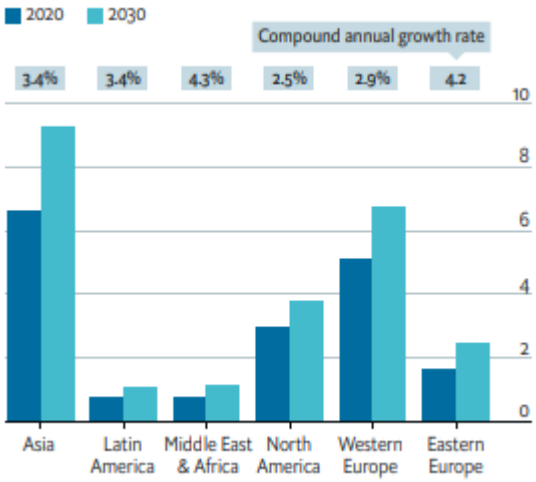


Figure 12: Regional trade growth, 2020-30 (US$ trn; 2010 prices) [36].

4.2.1.2 Different tax structures

Tax structures and their complexity vary across countries and regions. To avoid costs and risks, firms choose to adjust their SC structure and reassess their current offshore production and global procurement strategies. In addition, to enjoy the tax benefits delivered by regional trade agreements and the corresponding preferential tariff areas, the production and procurement of companies must meet the corresponding rules of origin, which usually is costly for many firms.

Data from the OECD's Corporate Tax Statistics database show that there was a slight increase in both the average of Corporate Income Tax (CIT) revenues as a share of total tax revenues and as a share of GDP between 2000 and 2019 across the 114 jurisdictions for which data are available.

Average corporate tax revenues as a share of total tax revenues increased from 12.6% in 2000 to 15.0% in 2019, and average CIT revenues as a percentage of GDP increased from 2.6% in 2000 to 3.1% in 2019. The data from the OECD show the stability of each nation's taxation system since 2001.

The averages mask considerable differences across jurisdictions. In 2019, jurisdictions differed considerably in the portion of total tax revenues raised by the CIT. Corporate tax revenues made up more than one-quarter of total tax revenues in 2019: Bhutan, Chad, Democratic Republic of the Congo, Egypt, Equatorial Guinea, Ghana, Indonesia, Kazakhstan, Malaysia, Nigeria, Papua New Guinea, Singapore, Thailand and Trinidad and Tobago. While in the Bahamas, France, Hungary, Italy, Latvia, Nauru, Tokelau and Vanuatu made up less than 5% of total tax revenues (see Figure 13).

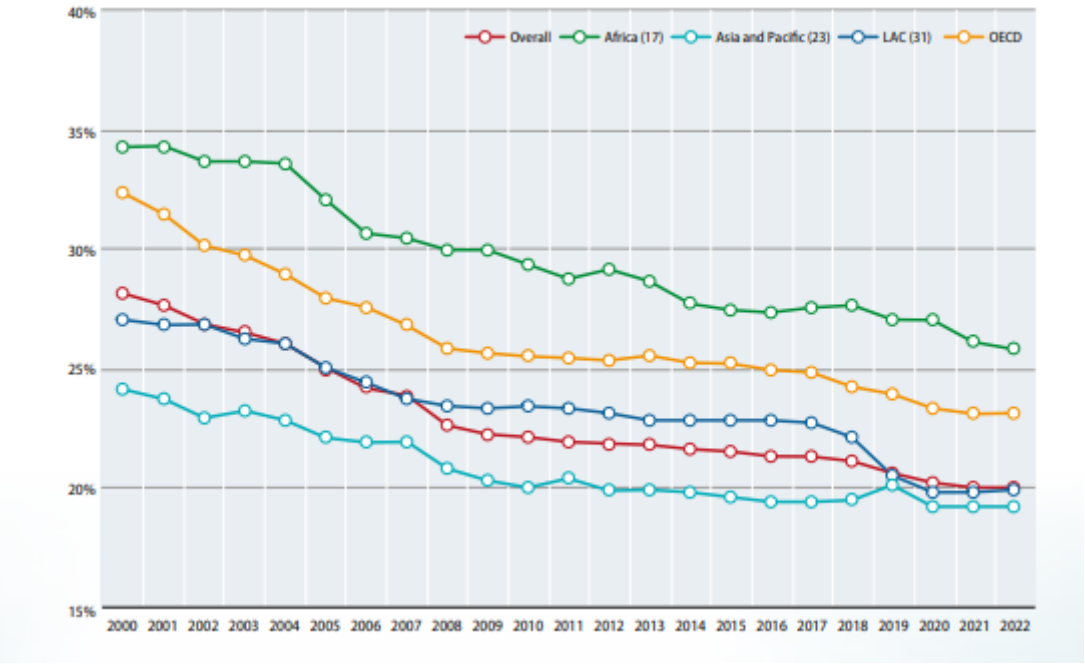


Figure 13: Evolution of the corporate income tax rates by region [37].

Corporate tax revenues are particularly important in developing economies, being an average of 19% in Africa in 2019 contrasting with the less than 10% of the OECD (see Figure 14).

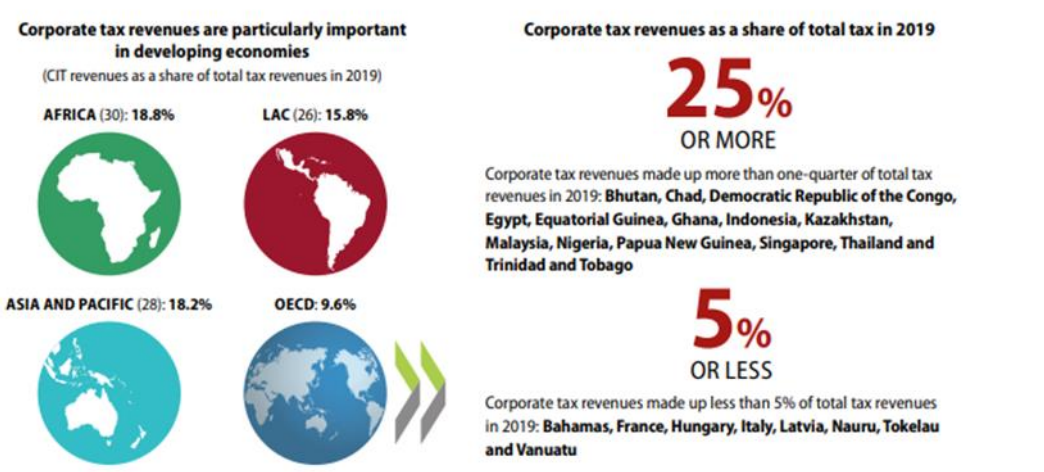


Figure 14: Corporate tax revenues [37].

Financial engineering for multinational enterprises can be limited through international tax agreement harmonisation. The World Economic Forum identifies 12 measures that can promote sustainable and inclusive Global Value chains [31].

An additional complication comes from the tax-avoidance reasons to vest IP in subsidiaries in low-tax havens. Apple, for example, has vested its IP in overseas subsidiaries. From an accounting point of view, Apple's subsidiaries are earning profits in the PRC using IP to organize production, sales, and servicing there. Apple in the US is the ultimate owner of those profits, but there are tax advantages to booking the profits overseas and leaving them there. As of September 2021, 131 countries had agreed to a new global tax regime with a minimum corporate profit tax. This is an important reform that should halt the race to the bottom in corporate tax rates and ensure that large multinational corporations pay a fairer share of taxes. This tax reform, however, will not necessarily change the practices just described. The leaders of the world's 20 biggest economies have endorsed a global minimum corporate tax of 15%. Any compromise will probably leave in place the incentives to vest IP in low-tax havens because it is a low-cost manoeuvre—and as long as there is any tax incentive, the practice is likely to continue.

4.2.1.3 Subsidies

Subsidies can affect the efficiency, sustainability, and resilience of the supply chain. Subsidies can be used to support various stages of the supply chain, such as production, transportation, and distribution, and to promote the adoption of sustainable and environmentally friendly practices.

The subsidies to some products/industries, among other reasons, look for balancing the impact of import tariffs. However, they can provoke inefficiencies in the supply chain.

Despite international agreements, subsidies are common in all sectors, used by countries at all stages of development, take many forms, and affect all countries. National and sub-national entities provide subsidies through—to name a few forms—direct grants, tax incentives, and favourable terms for financing, energy, land, or other inputs [38].

Carbon-intensive technologies continue to receive public subsidies, with over 50 developed and emerging economies committing US$345 billion to fossil fuels in 2020—a figure lower than in previous years largely because of depressed consumption and prices during the pandemic [31].

Current Energy prices are sharply increasing, which slows the transition to cleaner energy sources, even as the world turns against fossil fuels [31]. In addition, some solutions, such as carbon capture, utilisation and storage (CCUS), are already heavily subsidised, but they risk being used for greenwashing as carbon-heavy industries eventually fail to structural change their value chains to reduce their emissions.

The subsidies have been used as a defensive measure to the increase of exportation tariffs (US subsidies to the agricultural industry in 2019 and 2020) [39]. The response of the US Government to the increase of China importation tariffs on agricultural products was to make compensatory payments to US farmers through the Market Facilitation Program (MFP), pushing the United States close to violating its WTO commitments on farm subsidies in 2019 and 2020 [39].

Regarding the subsidies to green items: [40] illustrate how the government subsidy on green products and tax policy on non-green products can influence the profitability of supply chain members. For the first time, the pact reached at the 2021 United Nations Climate Change Conference (COP26, held in Glasgow, the United Kingdom), made explicit mention of the importance of transitioning away from coal, but did not commit to "phase out" inefficient fossil fuel subsidies. However, as the United Nations Environment Programme (UNEP)'s Emissions Gap Report 2021 shows, reaching the 1.5°C target remains unlikely [41].

Some governments look for social advantages and decide on subsidies for green items and taxes for non-green items. In addition, subsidies for digital innovation tend to generate big cross-sectoral spillovers at home and abroad. It is also known the current EU energy subsidies to different purposes and sectors (see Figure 15). After COVID-19 some Governments are increasingly active in seeking and subsidising alternative sources of supply and production for key inputs [38].

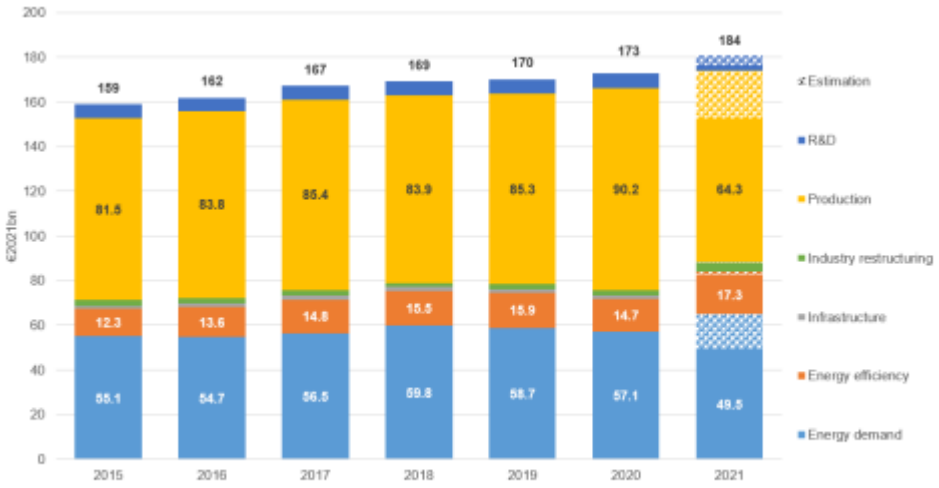


Figure 15: EU energy subsidies by purpose [42].

4.2.1.4 Risks for supply chains from Protectionism

Supply chain management is affected by the protectionism megatrend, so it is important to take its risks into account. Based on the literature review and the experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Disincentive to foreign investment:* When a country imposes tariffs or quotas on imported goods, it makes those goods more expensive, which can increase the cost of production for domestic industries that rely on those imported goods. This, in turn, can reduce the competitiveness and profitability of those domestic industries, making it harder for them to invest in their operations and making them less resilient to disruptions [38]. Furthermore, import tariffs and quotas can also make it more difficult for companies to compete in global markets. This is because tariffs not only change product flows but may also disrupt some supply chains, leading to less flexibility in input sources and in customer and market base. Such disruptions can affect the overall resilience of the supply chain [40]. However, this kind of protectionism often heightened the competitive capabilities of apparel exporters in developing countries, who learned to make more sophisticated items that were far more profitable than simple ones [33]. Another risk of import tariffs and quotas is the possibility of retaliatory measures by other countries. This can lead to trade wars, where countries impose tariffs and other trade barriers on each other, causing further economic damage to all countries involved [40].
- *Dependency on government support:* Dependency on government support can have negative economic effects on companies, including reduced competitiveness, overreliance on subsidies, and market distortions [31]. Subsidies can provoke mismatches in global trade as the benefit-loss relation is altered by these policies. They can also distort the market signals and lead to inefficiencies in the supply chain.

Regarding the social dimension, there are also some risks that should be taken into consideration:

- *Price variation:* protectionism can generate price increases, reducing the purchasing power of families and companies. The welfare of consumers in the country imposing the quota or tariff declines. This can lead to higher costs of living for households and businesses, resulting in lower spending power, which in turn can negatively impact economic growth [41]. Moreover, import tariffs and quotas can also lead to a lower potential for economic growth and loss of competitiveness, which implies a reduced capacity to generate employment and distribute wealth. This can have significant social implications, particularly for vulnerable populations who may be disproportionately affected by economic disruptions [40]. From the businesses point of view, this risk can distort the market signals leading to inefficiencies in the supply chain [43].
- *More vulnerable workers and populations:* protectionism can generate supply chain disruptions with significant social impacts, particularly in regions where certain industries are a major source of employment. In addition, it can lead to job loss in other sectors and a reduction in consumer spending on goods and services. This can have a ripple effect on the entire economy, impacting the whole economy and welfare. And when it especially affects sectors that cover basic needs such as medical or food, it can have a strong impact on vulnerable populations.
- *Increase of informal economy:* high taxes and complex regulations can lead to informal economies, where businesses operate outside the formal regulatory framework. This can lead to reduced social protections for workers, such as minimum wage laws, occupational safety standards, and protections against discrimination [44]. As a result, workers in the informal economy may be more vulnerable to exploitation and abuse.

From the environmental point of view, supply chain risks are the following:

- *Changes in transportation planning:* Import tariffs, quotas, subsidies and tax structures and regulations can cause movements in the location of production, moving it closer or further away and generating greater or lesser transport distances with their consequent environmental effects. Besides, if a country imposes a tariff on a specific imported good, it may incentivize domestic industries to produce that good locally, even if it is not the most environmentally sustainable option. This can lead to increased carbon emissions, air pollution, and other negative environmental impacts [31].
- *Disincentive to adopting environmental standards:* the increased costs of tariffs can reduce the effort to adopt more demanding environmental standards. This is because companies may be less willing to invest in sustainable practices if they are facing increased costs due to tariffs and quotas. Therefore, the use of import tariffs and quotas in supply chains can have significant environmental implications that must be considered [39] On the other hand, import tariffs and quotas can create an artificial advantage for domestic industries, which may reduce their incentive to invest in sustainable practices. In some cases, domestic industries may be able to maintain their market position even if they are not as environmentally friendly as their foreign competitors, as they face less competition due to import barriers. This can create a situation where domestic industries are less likely to invest in sustainable practices, as they do not face the same pressure to meet the environmental standards of their foreign competitors. Therefore, the greater market protection provided by import tariffs and quotas can potentially reduce the incentive for domestic industries to adopt more demanding environmental standards, which can have negative environmental impacts in the long run. It is crucial to consider these implications when designing trade policies that involve the use of import tariffs and quotas. Tax policies and regulations can impact the adoption and deployment of clean energy technologies. For example, tax incentives or subsidies for renewable energy can encourage companies to adopt more sustainable production methods and reduce their carbon footprint. On the other hand, if tax policies and regulations favour fossil fuels or other non-renewable energy sources, this can discourage companies from

investing in clean energy technologies, which can have long-term environmental impacts. Additionally, differences in tax structures and regulations can also impact the adoption of sustainable supply chain practices, such as circular economy models and sustainable sourcing.

According to experts' validations and comments collected during the workshop, most of the validated supply chain risks from protectionism may have from moderate to very high probability to occur and they may cause from moderate to very high impact on supply chains. There is only one risk that was identified as a low probability and low impact in the SC. This risk is related to the complexity for companies to manage different tax structures from different jurisdictions.

Table 4: Risks for supply chains related to each trend of Protectionism.

	Protectionism related risks		
Risk categories	Import tariffs and quotas specific risks	Different tax structures specific risks	Subsidies specific risks
Disincentive to foreign investment	- It is more difficult and expensive for companies to import and export certain goods [45]. - Forced switch of production locations, end markets and/or suppliers [41].	- To avoid costs and risks, firms choose to adjust their SC structure [43]. - Economic effects on developing countries [43]. - Possibility of retaliatory measures by other countries, causing further economic damage to all countries involved [43]. - Displacement of certain industries, which can have negative impacts on local economies and communities, particularly in developing countries where foreign investment is critical for economic growth and job creation [41].	- Potential inefficiencies in the supply chain [43].
Dependency on government support	- Lack of competitiveness and discrimination [43]. - Disincentive domestic industries to invest in their operations and make them less resilient to disruptions. Make it more difficult for companies to compete in global markets [43].	- Can lead to market distortions [41].	- Can provoke inefficiencies in the supply chain [43]. - Eventually companies can fail to structural change their value chains [45]. - Less competitiveness in global markets [43].
Price variation	- It is more difficult and expensive for companies to import and export certain goods [41]. - Protectionism can generate price increases, reducing the purchasing power of families and companies [46]. - Firms affected seek to bypass trade restrictions [41]. - Heightened the competitive capabilities of apparel exporters in developing countries, who learned to make more sophisticated items that were far more profitable than simple one [41].	- Can provoke mismatches in the global trade as the benefit-loss relation is altered by these policies [43].	- Prices variation disrupts SC [43]. - Can distort the market signals leading to inefficiencies in the supply chain [43][43] - Difficulties after grace periods [43].
More vulnerable workers and populations	- Loss of competitiveness, which implies a reduced capacity to generate employment and distribute wealth [41]. - Tariffs and quotas can also lead to a lower potential for economic growth and welfare [46]. - Vulnerable populations may be disproportionately affected by economic disruptions [41].	- Effects on Social expenditure for Financial engineering by multinational companies [41]. - Sharp differences over taxes and subsidies are contributing to global trade tensions that are harming growth and living standards [41], [46]. - Distorted competition among businesses, which can lead to job loss and reduced economic activity in affected regions [47].	- Subsidies can artificially sustain inefficient companies, hindering healthy long-term growth with social effects on employment, social balance and welfare [46]. - Reduced competition can generate job losses in smaller companies [46]. - Subsidies to digital innovation tend to generate big cross-sectoral spill-overs at home and abroad [46].
Increase of informal economy	- Increase of the number of informal workers [44]	- High taxes and complex regulations can lead to informal economies reducing social protections for workers. [47], [10]	- Maintaining an artificial market that, when the subsidies disappear, generates an informal economy. [10]

Protectionism related risks			
Risk categories	Import tariffs and quotas specific risks	Different tax structures specific risks	Subsidies specific risks
Changes in transportation planning	- Supply Chain adjustments affect transport distances with their consequent environmental effects such as increased carbon emissions, air pollution, and other negative environmental impacts [45].	- Displacement of industries may increase transport distances. [48] - Tax or regulatory policy may encourage companies to offshore their production to countries with lax environmental regulations [48].	- Incentivizing domestic industries to produce that good locally is not always the most sustainable option [45]. - Overproduction because of subsidies can lead to increased greenhouse gas emissions from transportation and production [45]. - This can lead to the displacement of smaller or less subsidised industries, potentially disrupting local ecosystems [45].
Disincentive to adopting environmental standards	- The increased costs of tariffs can reduce the effort to adopt more demanding environmental standards [47].	- Taxes to disincentive non-green products and consumption. Differences in tax structures and regulations can also impact the adoption of sustainable supply chain practices, such as circular economy models and sustainable sourcing [47], [49].	- Increases in prices slow the transition to cleaner energy sources [50]. - Overproduction because of subsidies can lead to can further strain of environmental resources such as pollution from excess fertilizer or manure, natural resource depletion from excessive water or soil usage [47].

4.2.2 Political instability

Political instability means the lack of political stability which can manifest in internal conflicts, revolts, civil unrest, coups, or other events that generate instability and weaken governance. In contrast, political stability provides a favourable framework for citizen participation, democratic decision-making, and long-term progress. Political stability is crucial for economic and social development, as it provides a predictable and secure environment for investment, trade, and growth. It implies a strong and effective government, functional political institutions, a stable legal system, and respect for human rights and civil liberties.

4.2.2.1 Terrorism/conflict/corruption

A country's political stability is affected by several factors, including terrorism, conflict, and corruption. Let's see briefly each one of them: (1) Terrorism is a form of violence that seeks to generate fear and destabilize a country or region. Terrorist acts can have various objectives, such as influencing politics, generating social tensions, or promoting extremist ideologies; (2) Internal or external conflicts also affect a country's political stability. Armed conflicts, ethnic tensions, political power struggles, or ideological disagreements can create divisions in society and weaken state institutions. Conflicts that are sustained over time can lead to population displacement (refugees), human rights violations, and deterioration of the economy, which hampers political stability; and (3) Corruption is the abuse of power for personal or private gain in an illegal or unfair manner. Corruption undermines political stability by undermining citizens' trust in government institutions and the political system in general. It can also distort economic development and perpetuate social inequality.

It is estimated that up to 26% of global exports could potentially be relocated in the next five years, amounting to up to US$4.6 trillion [51]. The latest Global Terrorism Index 2023 report [52] shows that although the number of terrorist acts has decreased, the number of victims has increased overall. The Sahel is the most impacted region as it concentrates 43% of global terrorism deaths. The report also shows that those countries experiencing environmental degradation and climate-related shocks provide fertile ground for the flourishing of terrorism. According to [53], terrorist organizations strike supply chains an average of once a week. The report identified 35 countries in

which attacks occur regularly, with Colombia, Egypt, India, and Turkey particularly prone to supply chain terrorism.

Cybercrime requires a separate explanation, not only because of its nature but also because of its exponential growth trend. According to Statista's Cybersecurity Outlook, the global cost of cybercrime is expected to grow in the coming years (see Figure 16), rising from $8 trillion in 2022 to more than $23 trillion in 2027 [54]. Apart from organizations, governments have started to take steps to increase investments in ICT systems related to Industry 4.0 and 5.0. In 2020, the European Commission presented a new cybersecurity policy aimed at addressing the risks and the effective response to cyber-attacks [55]. In that year, the U.S. Government announced a plan to spend $1 billion toward research on newer ICT systems [53]. In relation to conflicts, a key indicator is to observe countries' military spending. According to the Stockholm International Peace research institute, the world military expenditure passes $2 trillion for the first time [56]. Ukraine, Iran, Pakistan, Yemen, and Taiwan are, among others, the conflicts that are setting a dangerous war trend.

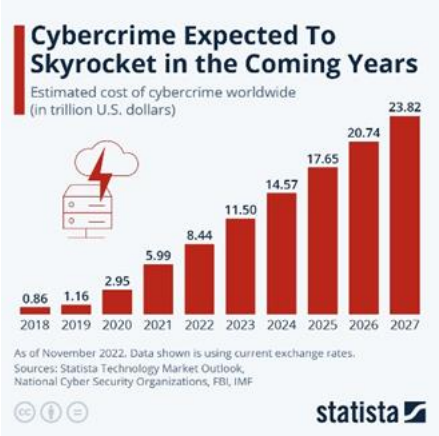


Figure 16: Estimated cost of cybercrime in the World [54].

Another issue that impacts political stability is corruption. The Corruption perception index shows that most countries are not doing well to stop corruption (see Figure 17) [57]. On a scale from 0, which means a very corrupt country, to 100, which means very clean, the global average is 43 out of 100. In fact, this value is very stable, as it hasn't changed for a decade. It costs the world economy approximately 5% of GDP, $3.6 trillion, annually [58].

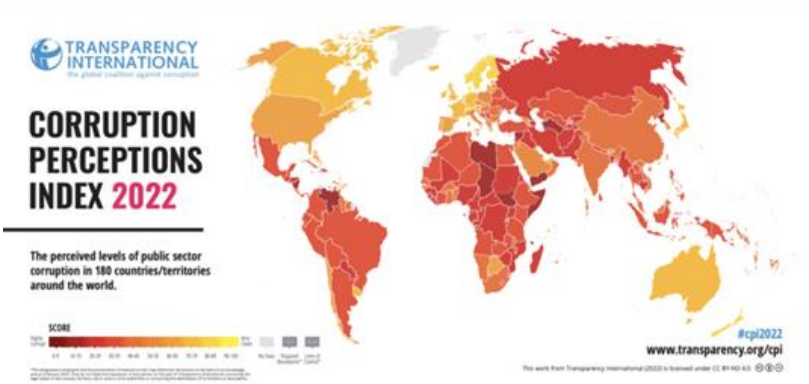


Figure 17: Corruption perceptions index 2022 [57].

4.2.2.2 Social unrest

Social unrest is a societal concern in many countries worldwide. Social unrest can be fed from different sources. It has a natural connection with economic issues, but it can also derive from situations generated by political decisions, such as those taken for the control of COVID at the beginning of 2020 (anti-lockdown) or those decisions which are in the opposite position of taking care about the Nature. Any issue that can be perceived as undermining people's rights can be the trigger for major conflicts (freedom, family income, food, climate change…). The causes of social unrest are multifaceted and predicting unrest is very complicated; however, historical data indicates that substantial rises in food and fuel prices have often correlated with a higher incidence of protests. For example, as a consequence of higher instability, the global inflationary crisis is having profound consequences on the well-being of the population [59].

Social unrest is rising in both advanced and emerging and developing economies, adding risks to the global economy (see Figure 18). There are 37 countries with high pre-existing levels of unrest and poor recovery capacity that face a 'perfect storm' of instability over the next 2-3 years [60]. These countries are mostly located in Africa and Latin America. Despite all, social unrest is lower than pre-pandemic levels.

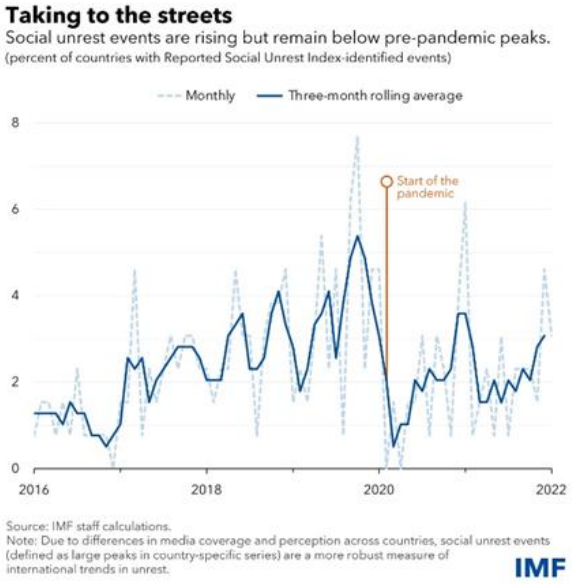


Figure 18: Percentage of countries reporting social unrest events since 2016 [61].

4.2.2.3 Decline in democracy

During the last decade, democracy is falling in favour of autocratic regimes [62] (see Figure 19). The lack of democracy may impact supply chain management. Democracy is characterized by political stability, law and protection of rights, transparency and governance, participation and dialogue, and respect for labour and social rights.

The level of democracy enjoyed by the average global citizen in 2021 was down to 1989 levels [63]. The number of democracies in the world reached an all-time high in 2016, with 96 electoral democracies. In 2022, their number has fallen to 90 countries.

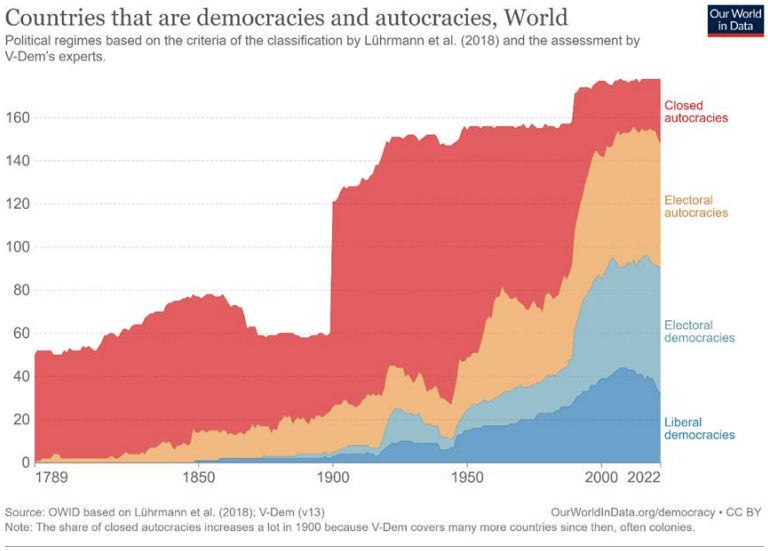


Figure 19: Evolution of the number of Democracies and autocracies in the world [63].

4.2.2.4 Risks for supply chains from political instability

Supply chain managers have to face several risks as a consequence of the political instability megatrend. It seems a key point is the inclusion of the geopolitical facet when deciding about supply chain governance and any other strategy regarding, for example, the re-shoring or off-shoring of part of the value chain.

Based on the literature review and the experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Opportunism in any link of the SC (high price fluctuations):* In this case, as political instability can impact on economic issues, any conflict could induce some organizations in the supply chain to take advantage by artificially increasing their margins. It may lead to a loss of confidence in the supply chain process and members, from the customers' perspective, due to the opportunism of one or various actors in the chain.
- *Reduce the companies' investments in physical goods and workers:* companies that are exposed to political risk reduce hiring and investment, and actively engage in pressuring and donating to politicians to manage this risk [64]. When social unrest leads to looting and destruction, it impacts the investment and hiring decisions of businesses.
- *Raw materials scarcity* [65]: the availability of raw materials is crucial for economic and social development. Nowadays, China represents more the 80% of the graphite production and it holds a dominant position in the processing and refining of other important materials such as rare earths. The Democratic Republic of Congo extracts 70 % of the cobalt consumed on the planet. Russia, in turn, is a major producer of nickel and platinum used to make batteries.
- *Data security*: Due to the significant increase in the number of cyber-attacks, companies, and governments are forced to significantly increase investments in ICT systems.

Regarding the impact of the political instability risks on the social dimension one risk outstand the rest:

- *Social anxiety:* Terrorist attacks, corruption and cyberattacks create a climate of fear and insecurity [66]. Social anxiety influences customers' trust in supply chain processes [67] and institutions which directly impact consumption patterns.

The political instability can also provoke supply chain risks in the environmental dimension:

- *Backtracking on environmental practices:* It has been noted that innovative technology and its access and transfer are highly dependent on political emphasis and degree of credibility regarding the management of projects. Political instability disrupts and/or restrains the design and implementation of green activities or products [68]. It means that the focus can change to another kind of strategy far away from the objective to minimize the environmental impact of companies.

According to experts' validations and comments collected during the workshop, most of the validated supply chain risks from political stability may have from moderate to very high probability to occur and they may cause from moderate to very high impact on supply chains. There is only one risk that was identified as having a low probability to occur and a moderated impact in the SC. This risk is the "Lost of trust in the SC process (from customers' perspective) due to opportunism of the different agents in the SC".

Table 5: Risks for supply chains related to each trend of political instability.

	Political instability-related risks		
Risk categories	Terrorism/Conflicts/Corruption specific risks	Social unrest specific risks	Decline in democracy specific risks
Opportunism in any link of the SC (high price fluctuations)	- Exploitation of security risks (cost of safety) [69] - Influence of corruption: corruption affecting price decisions [70], [71] - Supply chain disruption and the need to find another supplier as soon as possible [72], [73]	- Disruption of the supply chain (difficulties in sourcing raw materials) [74] - Increased cost due to security measures [69] - Changing demand dynamics [72]	- Lack of control in the accomplishment of current trade agreements [75]
Reduce the companies' investments in physical goods and workers	- Higher uncertainty in the business environment [76] - Increase in operational costs [77] - Lack of trust and transparency [78]	- Economic downturn (i.e., due to changes in demand patterns) [74] - Shifting labour dynamics (postponement of decisions affecting worker dynamics until labour uncertainties are resolved) [74]	- Change the policies about foreign investments [79]
Raw materials scarcity	- Product design changes as a consequence of raw materials scarcity [72] - Illicit trade and smuggling (underground market) [80]	- Disruptions in production and transportation (due to strikes, protests, and social unrest) [81]	- Volatile government policies [82]
Data security	- Heightened security threats [83], [84] - Corrupt practices and data manipulation [74]	- Remote work and data access [85]	- Data privacy concerns [86]
Social anxiety	- Fear of violence and security [87] - Economic instability [67]	- Disruption of daily life [87] - Uncertainty and future concerns [87]	- Polarization and social division [88]
Backtracking on environmental practices	- Destruction of sustainable infrastructure [89] - Corruption hindering sustainability efforts [71]		- Repeal or withdrawal environmental laws or global environmental agreements (Kyoto, Paris…) [90]

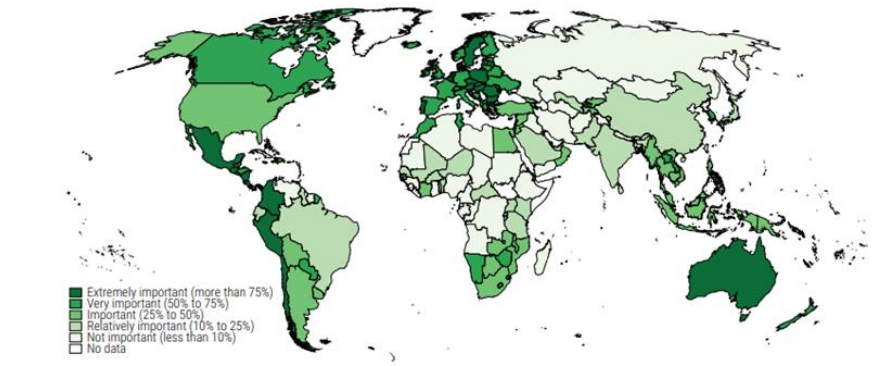
4.2.3 Supranationalism

Supranationalism refers to a system or approach where multiple nations voluntarily pool their sovereignty and decision-making authority to address common challenges. It involves the creation of supranational institutions or organizations that have the power to make decisions and establish regulations that affect its members. These institutions typically operate above the national level and aim to harmonize policies, streamline trade, and mitigate political risks that could disrupt for example, supply chains working together in facing trade barriers, geopolitical conflicts, or regulatory inconsistencies between nations. Supranationalism in supply chain management helps foster collaboration, coordination, and collective action among nations to enhance the resilience and efficiency of global supply chains in the face of political uncertainties and risks.

4.2.3.1 Trade agreements

Traditionally, multilateral trade agreements, such as those negotiated under the auspices of the World Trade Organization (WTO), aimed to create a framework for trade liberalization among a large number of countries. These agreements sought to reduce tariffs, eliminate trade barriers, and establish rules governing international trade. In recent years, there has been a noticeable shift in the approach to trade agreements from a multilateral to a more bilateral and regional perspectives. Bilateral agreements involve negotiations between two countries, while regional agreements involve multiple countries within a specific geographic area. The turn towards Regionalism may foster Regional Free Trade Agreements (FTAs). An example of this shift is the US stance of placing less emphasis on the pursuit of multilateral agreements than on bilateral or regional agreements [91]. It is expected that this kind of agreement or mega-regional trade agreement plays a significant role in the global trading system. However, they will likely continue to be negatively affected by rising transportation costs, logistic disruptions, and geopolitical frictions.

The increasing prevalence of preferential trade agreements (PTAs) has contributed to the growth of GVCs. PTAs refer to regional trade agreements and also free trade areas, customs unions and common markets. This kind of trade agreement has evolved to cover a broader range of policy areas beyond the reciprocal reduction of tariffs, including investment, competition, and intellectual property rights protection [92]. Scholars argue that countries enter into "deep" agreements to promote and facilitate the smooth functioning of GVCs (see Figure 20).



Source: UNCTAD secretariat calculations based on WTO RTAIS and COMTRADE data.

Figure 20: Importance of deep PTAs measured by percentage of trade (2021). [93]

Research conducted by [94] demonstrates that including additional policy areas in a trade agreement enhances both forward and backward linkages within GVCs. Moreover, at the sectoral level, deep trade agreements have a more significant positive impact on industries with higher value-added, indicating that such agreements assist countries in integrating themselves into industries that

generate greater value-added. The number of Preferential Trade Agreements in force has doubled from less than 150 in 2005 to more than 300 in 2021. In 2021, due to Brexit, the United Kingdom substitute its pre-existing agreements as a member of the European Union with new agreements. It is interesting to see that even though the number of PTAs has increased dramatically, the percentage of trade taking place under them has not increased as much (see Figure 21) [93].

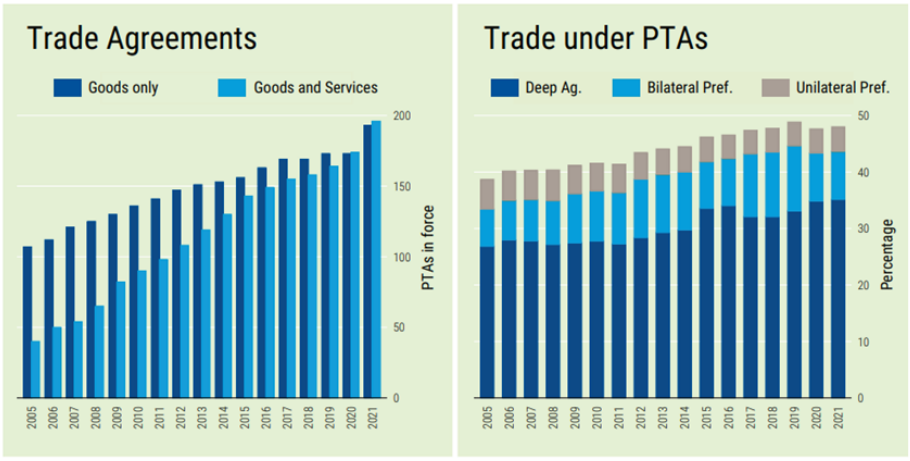


Figure 21: Evolution of Trade agreements and Trade under PTAs in the period 2005-2021. [93]

4.2.3.2 Free movement

Free movement refers to the unrestricted movement of goods, services, capital, and labour across national borders within a specific region or trading bloc. It is a key element of regional integration and is typically facilitated through trade agreements (please see 4.2.3.1 Trade agreements section).

The European Commission calls for supporting diversification and competitiveness by strengthening the multilateral trading system, including Free trade Agreements. In September 2022, the European Commission proposed introducing a Single Market Emergency Instrument (SMEI) to secure critical supply chains in times of crisis. The idea behind this proposal is to understand the supply chains as public infrastructure. Covid-19 has shown the dependence on international supply chains. The pandemic provoked panic reactions, and internal border restrictions for the movement of persons and goods [95].

Usually, supply chain disruptions have limited geographical extent and conform to the standard single-trough, limited-duration profile outlined by Sheffi and Rice back in 2005 [96]. But, on the other side, the impact of the pandemic on supply chains has been global, prolonged, and comprised of a series of major shocks to companies' logistical systems (see Figure 22) [97].

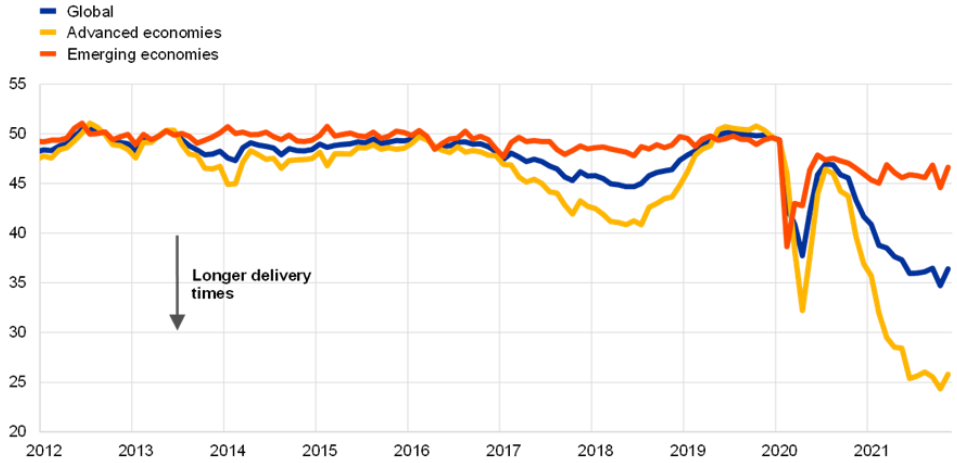


Figure 22: Evolution of suppliers' delivery times from 2012. [98]

4.2.3.3 Risks for supply chains from supranationalism

Supranationalism is the third identified megatrend under the political dimension. It involves talking far beyond the interests of a particular region or nation, to seek consensus at a supra-regional or supra-national level.

Based on the literature review and the experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Trade barriers*: The turn towards Regionalism instead a more global trade agreements can lead to the imposition of tariffs and non-tariff barriers, making more difficult cross-border trade. This fact can increase costs, reduce business competitiveness and limit access to new markets [99], [100].
- *Economic instability*: The focus on bilateral instead of supranational agreements can lead to global economic instability. Without a strong supranational structure, trade flows, investment and financial markets can become volatile and unpredictable, affecting economic stability [101].
- *Imbalances in the supply chain regarding power and operational performance*: The current model of global production fragmentation, the global production network, is being questioned. Supranational governance can mediate between national and international governance of labour standards and in the governance of operations of global value chains [102]. The supranational governance agreements can play a key role in global value chain governance, especially in those issues related with actor behaviour [103].
- *Supplier disruptions because of changes in the trade agreement status*: Global value chains are highly dependent of transfer and enforcement costs which, in fact, are tied to the national and supranational compliance structures [104]. Changes in trade agreements may impact on the natural transactions between the actors of the global value chain.

In addition, there are other risks related to social and environmental approaches. From a societal point of view, the supranationalism-related risks are the following:

- *Reduced labour rights and social protection:* The increase of bilateral agreements compared to supranational agreements complicates the search for harmony in the international regulation of labour rights and social protection [105]. This may mean, in some cases, the reduction of rights and social protection.

Regarding the environmental dimension, the following risks were identified:

- *Lack of common vision about global climate change*: This fact translates into difficulties for global cooperation and action to combat climate change. The proliferation of bilateral agreements despite talking about global problems can lead to difficulties in implementing policies and agreements to address the environmental challenge. which also deals with reduced environmental protection and the risk of increasing exploitation of natural resources, pollution, and reduced biodiversity, affecting the long-term sustainability of supply chains.

According to experts' validations and comments collected during the workshop, most of the validated supply chain risks from supranationalism may have low probability to occur and they may cause by moderate to high impact on supply chains. Thus, risks related to imbalances in the supply chain, job related conditions or lack of common vision about global issues should be taken in consideration because their possible impact more than the probability to occur.

Table 6. Risks for supply chains related to each trend of supranationalism

	Supranationalism-related risks	
Risk categories	Trade agreements specific risks	Free movement specific risks
Trade barriers	- Protectionist policies [99] - Dispute settlement challenges [99] - Changing regulatory standards [100]	
Economic instability	- Uncertainty in trade relations [101] - Market volatility [101]	- Immigration restrictions [100]
Imbalances in the supply chain regarding power and operational performance	- Power asymmetries [102]	- Restrictions or limitations to the movement of workers [102]
Supplier disruptions because of changes in the trade agreement status	- Disintegration of supply chains [106]	- Limitations to the movements of goods and workers [104]
Reduce labour rights and social protection	- Weaking of labour standards [105] - Disparity in labour conditions [105] - Erosion of workers' rights [107] - The strain on social welfare systems [107]	
Lack of common vision about climate change	- Inadequate environmental regulations [108] - Lack of sustainable trade practices [108]	- Inconsistent climate policies for transportation [109]

4.3 ECONOMIC DIMENSION

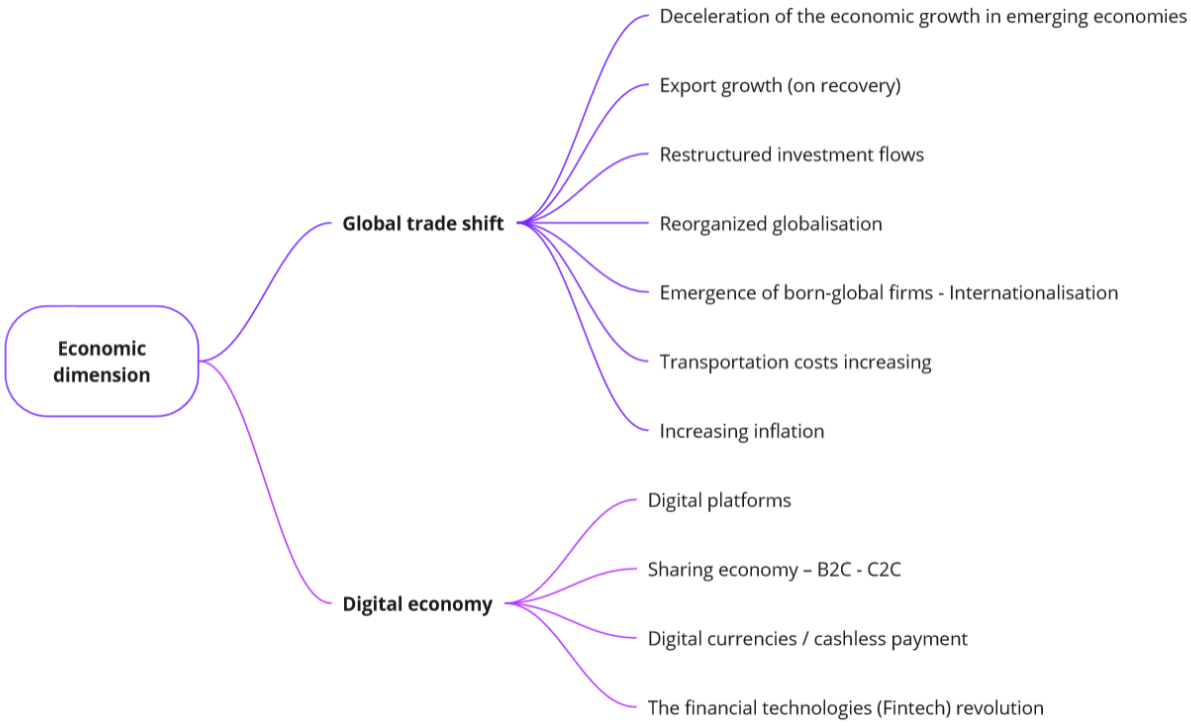


Figure 23: Economic dimension, megatrends and trends.

4.3.1 Global trade shift

The global trade shift megatrend concerns the progressive shift of local and nearby trade to a global one without restrictions on localization. Global trade has a worldwide effect on all sectors and services favouring the establishment of global supply chains. Internationalization of trade as an exchange of goods or services across national jurisdictions includes imports and exports. International trade has been occurring as part of economic and cultural history, from ancient trade routes such as the Silk Road, when trade was limited by demand and transport capacity. Commercial and technological developments allowed to increase in the trade scale till becoming an active tool of economic globalization.

4.3.1.1 Deceleration of the economic growth in emerging economies

Emerging market and developing economies (EMDE) have been strongly impacted by the current economic environments and affected by a common set of external shocks: rising energy and food prices; tightening in global financial conditions caused by the prospect of sharper interest rate hikes and anticipation of "quantitative tightening"; and intermittent restrictions on mobility in China, on account of the Covid zero policy, leading to decelerating the growth and weakening one of the primary growth drivers for the other EMDE.

Growth in emerging markets is forecast to slow but continues to outpace the expansion in developed economies. According to the forecast of MGI (2018), the global economy would have experienced a bounce, growing at an average of 3.5% a year, compared with consensus forecasts of 2.8%. That

growth could directly add $11 trillion to global GDP by 2030. About $8 trillion of that would come directly from the 53 hither to middling and underperforming emerging economies [110].

Deteriorating global economic conditions will limit emerging markets' near-term growth prospects, but the forecast is that they will expand more rapidly than developed economies in the longer term. Most emerging economies in Asia are set to grow by 2-3% per year in 2022-50; by contrast, growth in the US and much of Western Europe will average only about 1-2% [111].

Figure 24: Long-term growth: fast-growing markets. [111]

Emerging economies will play key roles in the global value chain, take solid steps to expand the middle class, and realize its goals of modernization (e.g., China) [112]. New technology adoption can deeply impact on economic growth, for example automation has the potential to increase productivity in developing economies by 0.8 to 1.2 percentage points a year between 2015 and 2030 [110].

After a short-lived period of financial stress in March 2020, most emerging markets were able to return to global financial markets and issue new debt to meet their financing needs. However, in a global recovery in which some countries are rebounding faster than others and uncertainty is high regarding the pandemic, there is likely to be more market volatility. This will test the ability of policymakers in emerging markets to navigate a shifting landscape, manage their policy trade-offs, and achieve a durable recovery [113].

4.3.1.2 Export growth (on recovery)

The global economy's gradual recovery in Europe from both the pandemic and Russia's invasion of Ukraine remains on track. China's reopened economy is rebounding strongly. Supply chain disruptions are unwinding, while dislocations to energy and food markets caused by the war are receding. Simultaneously, the massive and synchronized tightening of monetary policy by most central banks should start to bear fruit, with inflation moving back towards targets.

Supply bottlenecks and shortages produced by COVID-19 negatively affected goods export growth. The estimated cumulated shortfall for the level of goods exports amounted to 6.7% for the euro area and 2.3% globally in 2020. Shipping volumes have recovered since the trough in mid-2020. By the

start of 2021 European air cargo traffic had once again reached its pre-crisis level thanks to firms partly switching from sea freight to air transport [114].

Global real GDP growth is expected to increase in the first quarter of 2023 but remains subdued. The increase reflects the fact that the recent pandemic-related disruptions in China appear to be abating already and that labour market performance in advanced economies remains strong. It is also in line with the indications derived from the latest Purchasing Managers' Index (PMI) surveys, which suggest an improvement in economic activity globally [115]. According to Figure 25 below service sector increasing, but manufacturing is not following with the same pace.

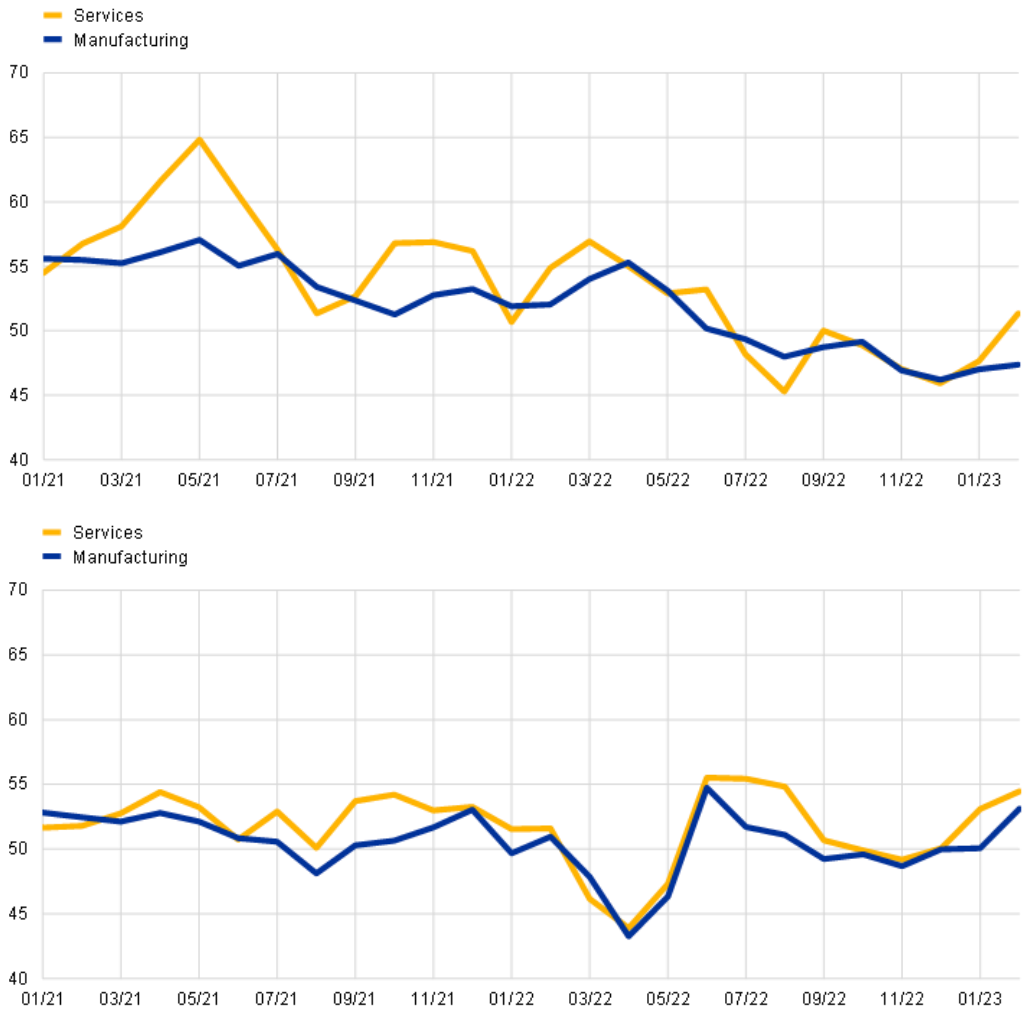
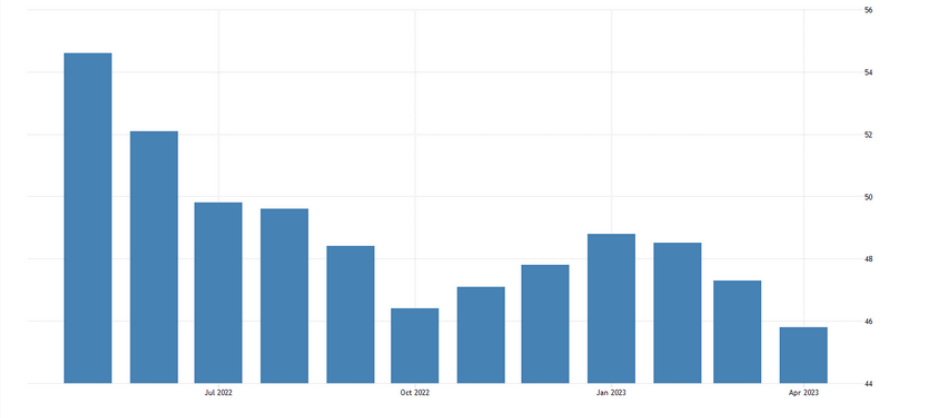


Figure 25: Global (excluding the euro area) output PMI by regions and sectors. Top: Advanced economies (excluding the euro area); Bottom: Emerging market economies. [115]

Regarding the euro area, the Manufacturing PMI in April 2023 was 45.8 continuing to point to the worst performance for the manufacturing sector since May 2020. It also marks the tenth consecutive month of contraction in the factory sector, as production volumes fell for the first time since the beginning of the year amid deteriorating demand, consumer hesitancy and high client inventory levels. Demand from international markets also dipped again and employment slowed. Meanwhile, backlogs of work fell for an eleventh month, capacity at vendors freed up which facilitated speedier deliveries and supplier delivery times shortened the most since 1997. On the price front, input costs fell the most in almost three years, helped by improving supply conditions. Manufacturing PMI in Euro Area is expected to be 50.20 points by the end of this quarter, according to Trading Economics global macro models and analysts' expectations [116].



Related	Last	Previous	Unit	Reference
Services PMI	56.20	55.00	points	Apr 2023
Manufacturing PMI	45.80	47.30	points	Apr 2023
Composite PMI	54.10	53.70	points	Apr 2023

Figure 26: Manufacturing PMI in the euro area [116].

The global growth outlook for 2023 and 2024 indicates that while the economic reopening in China will support global growth in 2023, world economic activity remains sluggish, with growth rates over the projection horizon still below historical averages. According to the March 2023 projections [115], global real GDP growth is projected to be 3.0% in 2023, slightly below the growth rate of 3.3% estimated for 2022, before increasing very gradually to 3.2% in 2024 and 3.3% in 2025. Compared with the December 2022 projections, this represents upward revisions for 2023 (by 0.4 percentage points) and 2024 (by 0.1 percentage points), but no change for 2025. A key factor behind the previsions is the improved outlook in China, with the pandemic-related disruptions seen at the turn of the year expected to pave the way for a faster recovery later in 2023, given that the Chinese economy will be less constrained by the risk of renewed lockdowns.

Regarding the impact on the global value chains related spillovers, which are also likely to have magnified the impact of the COVID-19 shock, will amplify the decline in global imports and exports by some 25% for the world's economy [117].

Due to the shipping cost increases, the shipping routes experiencing the most severe strains are those from Asia to North America and from Asia to Europe producing an increase in the delivery time and arising the need for trade protection measures [114].

Risk mitigation concerns related to the COVID-19 pandemic have sparked debates about the reshoring of production among others due to the need of enhanced the resilience of supply chains [117]. Likewise, some global supply chains have started to map and evaluate relocation of activities to countries where economic and political alliances are strong, i.e., friendshoring [118].

4.3.1.3 Restructured investment flows

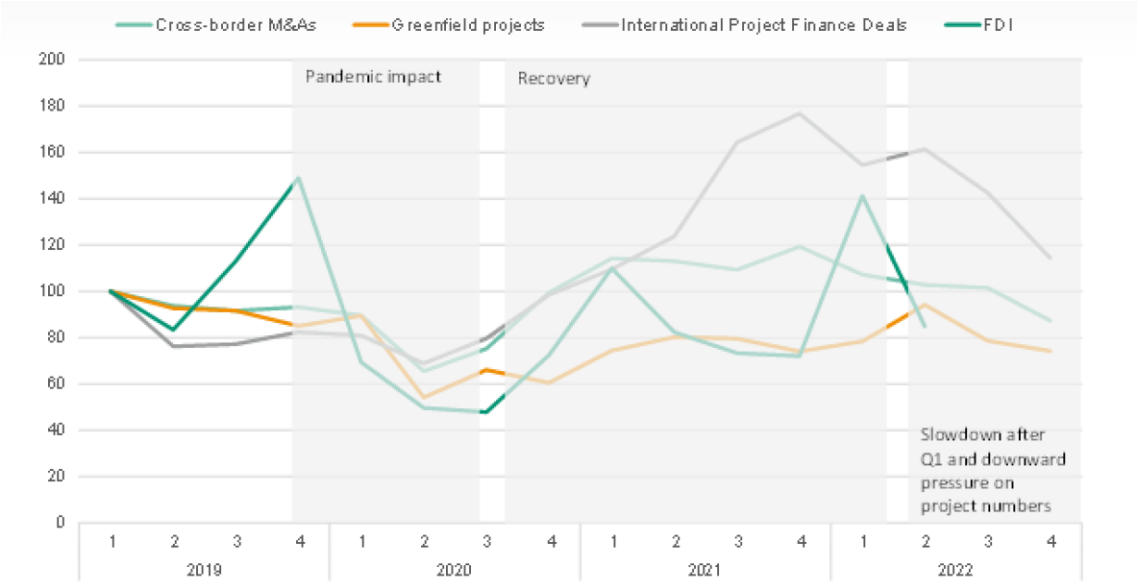
Global flows of foreign direct investment (FDI) recovered to pre-pandemic levels in 2021, reaching $1.6 trillion [119]. Cross-border deals and international project finance (IPF) were particularly strong, encouraged by loose financing conditions and infrastructure stimulus.

The global environment for international investment changed dramatically with the onset of the war in Ukraine, which occurred while the world was still reeling from the impact of the pandemic. The war is having effects well beyond its immediate vicinity, causing a cost-of-living crisis affecting billions of people around the world, with rising prices for energy and food reducing real incomes and aggravating debt stress. Investor uncertainty and risk adversity could put significant downward pressure on global FDI.

After suffering double-digit declines across almost all sectors, the recovery in areas relevant to Sustainable Development Goals (SDGs) in developing countries remains fragile. After a big drop in 2020 caused by the COVID-19 pandemic, global FDI reached an estimated $852 billion in the first half of 2021, showing a stronger than expected rebound. It shows the increase in the first two quarters in FDI, recovered more than 70 % of the losses stemming from the COVID-19 crisis in 2020. [120]

The multitude of crises on the global stage – the war in Ukraine, food and energy prices, financial turmoil and debt pressures – inevitably affected global FDI in 2022. IPF deals and cross-border mergers and acquisitions (M&As) were especially affected by deteriorating financing conditions, rising interest rates and growing uncertainty in financial markets. Cross-border M&A sales were 6% lower worldwide and IPF values more than 30% lower in 2022 [121].

Global FDI flows in the second quarter of 2022 were down 31% from the first quarter and 7% less than the quarterly average of 2021. The negative trend reflects a shift in investor sentiment due to the food, fuel and finance crises around the world, the Ukraine war, rising inflation and interest rates, and fears of a coming recession [122].

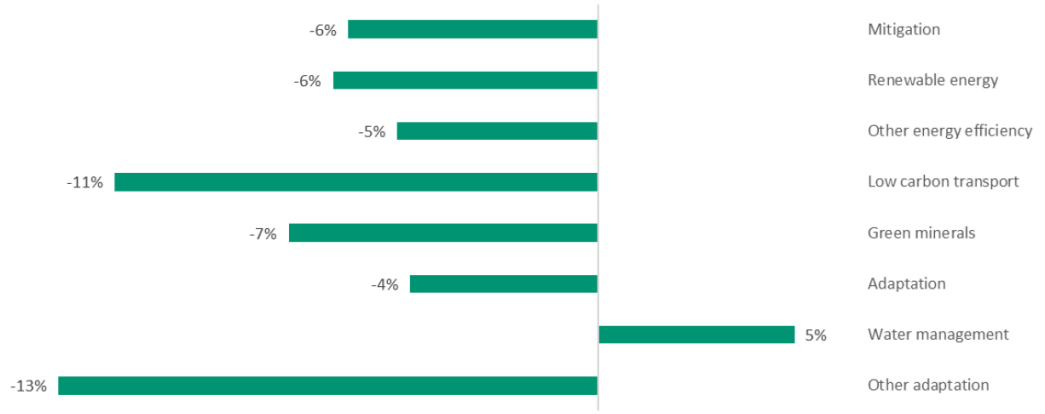


Source: UNCTAD, FDI/MNE database (www.unctad.org/fdistatistics) for FDI, information from the Financial Times Ltd, fDi Markets (www.fDimarkets.com) for announced greenfield projects and Refinitiv SA for international project finance.

Note: Project data for 2022 in this monitor are preliminary; greenfield data is estimated based on 11 months. Full-year FDI data, normally presented in the January monitor, are not included because of significant ongoing revisions for 2021 and incomplete 2022 availability – 2022 FDI data will be included in the *World Investment Report 2023*.

Figure 27: Investment trends, 2019-2022 (Indexed, 2019: Q1=100) [121].

Greenfield investment activity remains weak across industrial sectors, especially in developing countries. While the higher number of greenfield megaprojects in renewables in 2022 is encouraging, IPF in the sector – the bulk of climate change mitigation investment in recent years – is suffering. IPF numbers in renewables declined by 5% and values by almost 40%. As a result, overall international investment in climate change mitigation and adaptation shrank by more than 9% in terms of announced values and by 6% in project numbers. In contrast, several large projects in extractive industries, coal, oil and gas, were announced against the backdrop of the ongoing energy crisis [121].



Source: UNCTAD, based on information from the Financial Times Ltd, fDi Markets (www.fDimarkets.com) for announced greenfield FDI projects and Refinitiv SA for international project finance deals.

Figure 28: Climate change investment trend, 2022 vs 2021, greenfield project announcements and international project finance deals (project numbers) [121]

The global outbreak of the COVID-19 pandemic has slowed down international investment and trade, and partially disrupted the global supply chain affecting political risk and bilateral relations [123].

4.3.1.4 Reorganized globalisation

The cumulative effects of the past trade disruptions (the US-China trade war, the Covid-19 pandemic, supply chain disruptions, Russia's war with Ukraine, duelling sanctions and export controls) are driving a deep rupture between free-market democracies and Chinese/Russian-style authoritarianism that's dividing the global economy along geopolitical fault lines.

It seems that the current phase of globalisation is coming to an end and the world economy is entering into a phase of deglobalisation, decoupling, reshoring and fragmentation. Evidence of pro-reshoring and policies seeking to domesticise/regionalise value chains are visible in the major economies today.

Between 1990 and 2018, the globalization measured by a globalization index per country has increased. However, the outbreak of the coronavirus pandemic is throwing the global division of labour off track. Exports collapse, while deliveries of urgently required products from abroad are delayed or may not come through at all. As a result, globalization is increasingly classified as a risk [124].

Nowadays, there is a temporary pause in globalization as we knew it, a re-alignment of geopolitical alliances is taking shape (leading to regionalization and diversification) [125]. However, cross-border and regional trade along with domestic consumption has exceeded even the most optimistic projections leading to an urgent need to revisit the supply chain structures [126].

Diversification is maturing the way we approach resilience. The reality is the propensity to source goods and services from places where they are most abundant, cheapest and in ready supply. Reshoring is an obvious choice because making domestic manufacturing more self-sufficient – as evident in China's dual circulation strategy – lowers reliance on imports. The UK, US, India and the EU have all tried to boost self-sufficiency by incentivising manufacturers to set up domestic manufacturing units. But in practice, this may be a long-term solution to a short-term problem [127].

The reorganized globalization will be a real mix of onshoring, regionalisation and diversification [127]. Research on international trade found that 48% were using diversification as their primary supply chain reconfiguration strategy. Only 12% were primarily regionalising, while just 5% were reshoring [128].

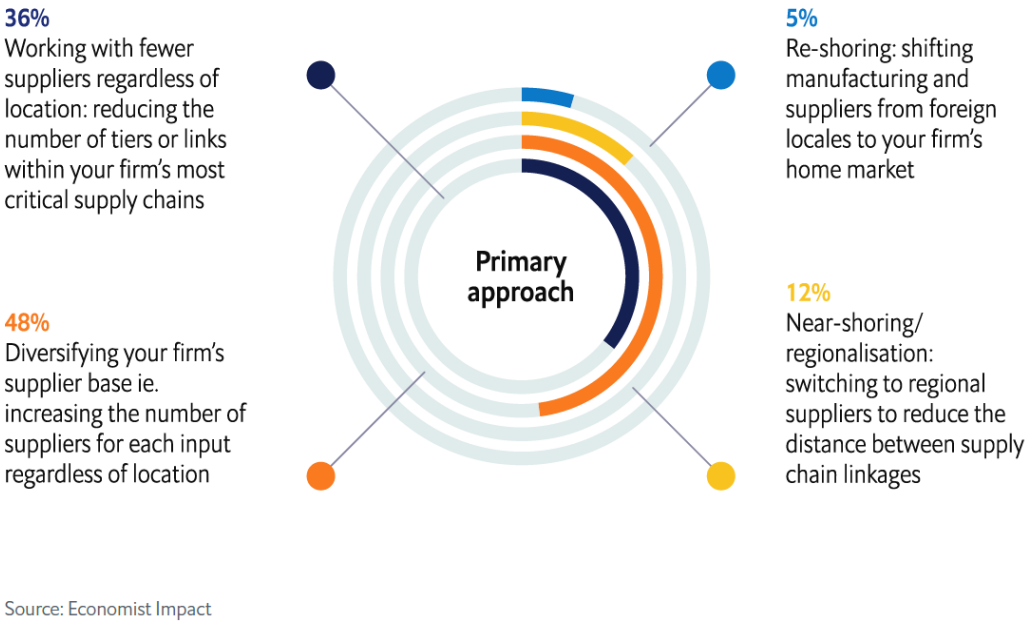


Figure 29: Primary approach to supply-chain reconfiguration [128].

Four main forces are contributing to the reconfiguration of GPNs (Global Production Networks) and GVCs (Global Value Chains): geopolitical uncertainties, climate change, technological change, and crises and shocks. [129]

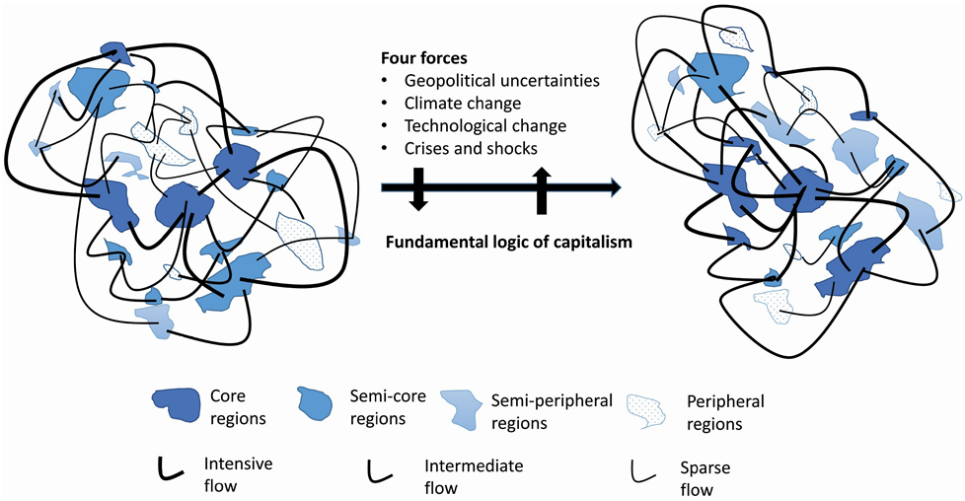


Figure 30: Forces contributing to the reconfiguration of GPNs/GVCs [129].

4.3.1.5 Emergence of born-global firms – Internationalization

Internationalization of companies is becoming a necessity on purpose to play an active role in the market and maintain a competitive advantage. A rapid rise of small and medium-sized enterprises (SMEs) undertaking international business at or near their founding has been interpreted like a born global phenomenon. In the past two decades, born global have emerged in substantial numbers worldwide, in conjunction with evolutionary trends in globalization and advanced information and communications technologies.

Since the pandemic, tech companies grew 2.3 times more than their non-tech counterparts. A record 540 companies achieved unicorn status in 2021, up from 150 in 2020, with 113 ecosystems producing at least one $1 billion+ behemoth. The Global Startup Economy Value Creation in 2022 was $6.4 Trillion. Since 2012, global average Series A rounds have tripled to more than $18 million [130].

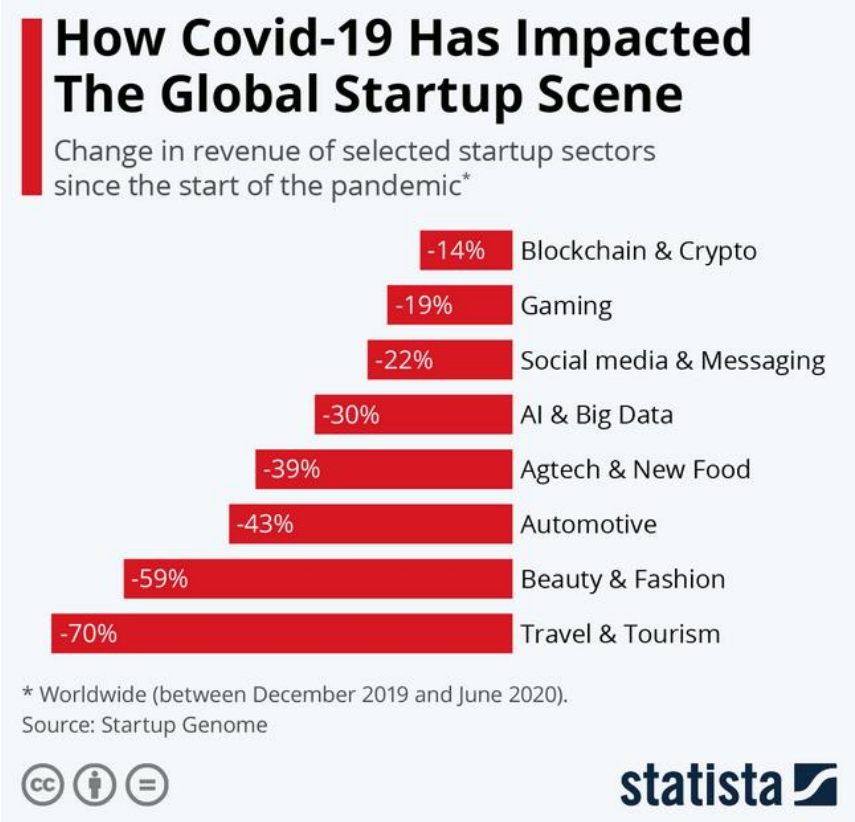


Figure 31: How Covid-19 has impacted the global startup scene [131].

Europe has 42.6% of the top 1000 startup ecosystems, but only 18.3% of startup funding. The European region has a total of 426 startup economies in the global top 1000 in 2022, up from 386 in 2021 [130].

The World Economic Forum estimates that 70% of new value created in the economy over the next decade will be based on digitally enabled platform business models [132].

Potentially larger and more established firms can learn how to quickly adapt in times of crisis from the Born Globals who achieved rapid international growth during the Covid-19 pandemic [133], [134], since these born global firms contribute to technological developments (R&D) and gain insight into market internationalization.

4.3.1.6 Transportation costs increasing

Shipping costs have risen in the last two years as a result of a combination of the current post-crisis situation and the Ukranian war including breakdowns in supply chains, higher oil prices, drivers' shortage, EU Mobility Package 2022 implementation and high demand with lower capacities. The logistics industry is currently experiencing the highest constant peak in increased cost and companies have to brace for more steep increases in shipping and logistic costs.

From January to June 2022, the price of regular motor gasoline rose 49% and the price of diesel fuel rose slightly more by 55% [135]. The estimated increase in the price of road transport services was between 10% and 15% by 2022 [136]. However, since transportation costs had risen by 25% or more, almost three-quarters (71%) of logistics firms are reporting an increase in shipping costs that "many businesses will not be able to absorb". An important challenge, especially for SMEs. Simultaneously, 35% of logistics companies reported a decrease in orders, with 12% saying orders had fallen by at least a quarter [137].

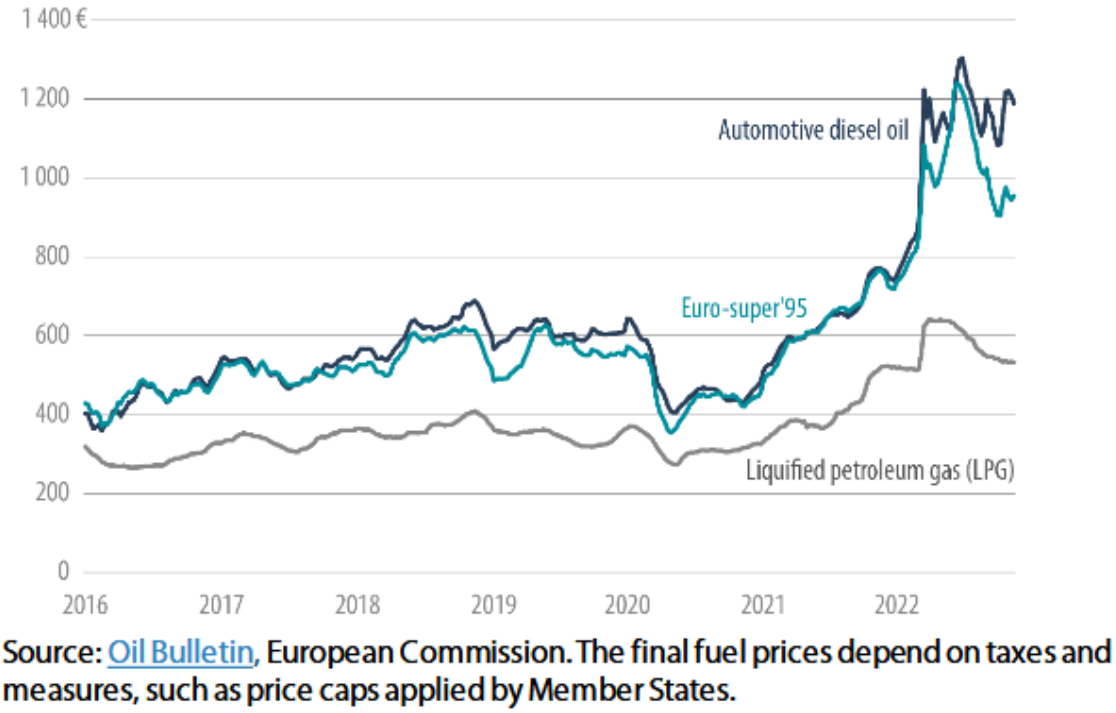


Figure 32: Fuel price without taxes – EU weighted average. Source: Oil Bulletin.

Figure 33: Freightos Baltic Index (FBX): Global Container Freight Index (Source: FREIGHTOS DATA).

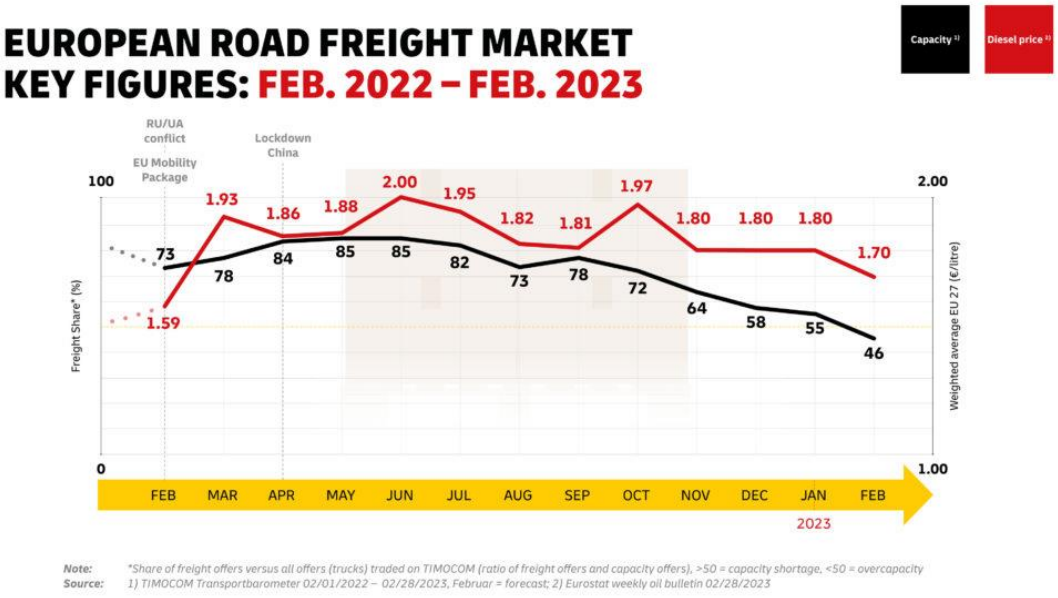


Figure 34: European road freight market Feb 2022 – Feb 2023. Source: DHL

While demand for trucking services is very high, labor remains in short supply and the trend is not expected to reverse anytime soon, at least not dramatically by 2022 [136]. Europe's driver shortage continues to worsen. According to industry organizations, heavy goods vehicles (HGV) drivers are still in very short supply across Europe, with a shortfall of 400,000 all over the continent [138].

The last data released by EUROSTAT indicates that the transportation sub-index of the Consumer Price Index (CPI) basket in the European Union increased to 126.31 points in March of 2023 from 126.12 points in February of 2023. In the long-term, the European Union CPI Transportation is projected to trend around 128.86 points in 2024 and 129.50 points in 2025 [139].

The increase in transportation cost generates an increase in the products price along the supply chain affecting all the actors. This is translated into less frequent transport services, changes in the service area coverage [140] and shortages [141] unveiling a need to supply chain optimization to keep working properly.

Regarding the customers, an increase in transportation cost has produced changes in consumer buying patterns [141]. Consumers purchasing power has decreased substantially, leading to reduced spending in non-basic goods/services like loungewear, furniture, and home improvement.

4.3.1.7 Increasing inflation

Inflation is the increase in the price of goods and services over a period. Inflation is rising and the prospect of a cost-of-living crisis looms for many people across the world. It has been provoked by the extraordinary demand for goods in 2021 as countries emerged from lockdowns, shops opened, and people were able to go out and shop again. The severe inflationary crisis combined with a global slowdown in economic growth – driven in part by the war in Ukraine and the global energy crisis – are causing a striking fall in real monthly wages in many countries. Higher interest rates increase borrowing costs for companies and consumers, slowing economic activity. Inflation is also biting into the purchasing power of minimum wages.

A contraction in aggregate demand will help dampen inflation, there will remain upward pressure on price growth as long as global supply bottlenecks and the multitude of crisis on the global stage – the war in Ukraine, food and energy prices, financial turmoil and debt pressures – will persist [142].

HICP inflation is projected to average 5.3% in 2023, before decreasing to 2.9% in 2024 and 2.1% in 2025. The baseline projection sees headline inflation declining from 10.0% in the fourth quarter of 2022 to 2.8% in the fourth quarter of 2023, then hovering around 3.0% in 2024, before falling to the European Central Bank's (ECB) inflation target of 2.0% only in the third quarter of 2025 [143].

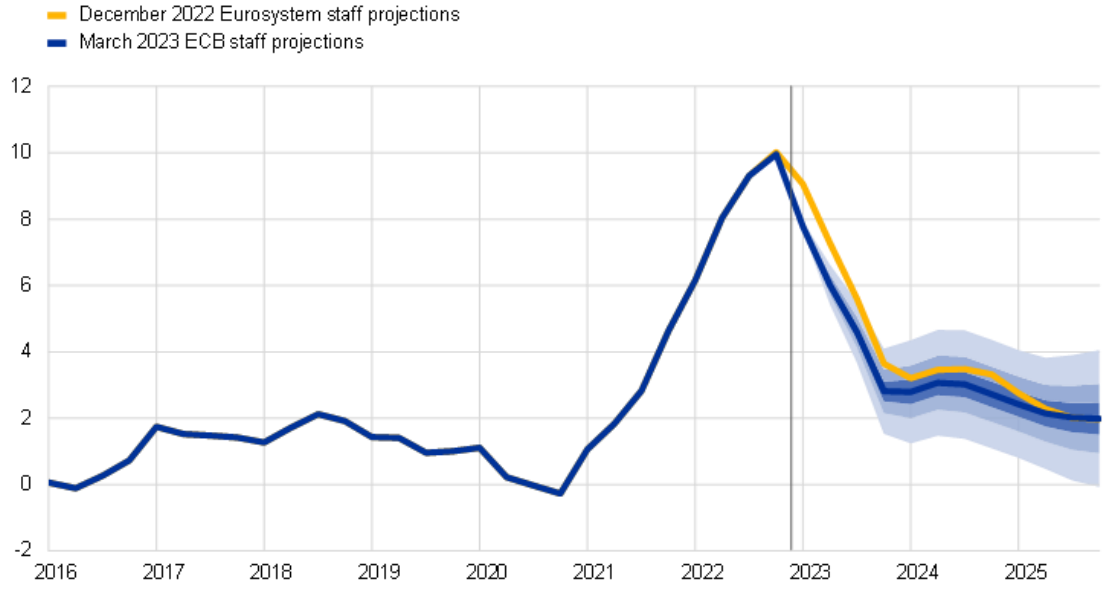


Figure 35: Euro area HICP inflation (annual percentage changes) [143].

However, despite the previous forecast inflation in Europe keeps increasing and Euro area annual inflation reached 7.0 % in April 2023, up from 6.9 % in March 2023. Looking at the main components of euro area inflation, food, alcohol & tobacco have the highest annual rate in April (13.6 %, compared with 15.5 % in March), followed by non-energy industrial goods (6.2 %, compared with 6.6 % in March), services (5.2 %, compared with 5.1 % in March) and energy (2.5 %, compared with -0.9 % in March) [144].

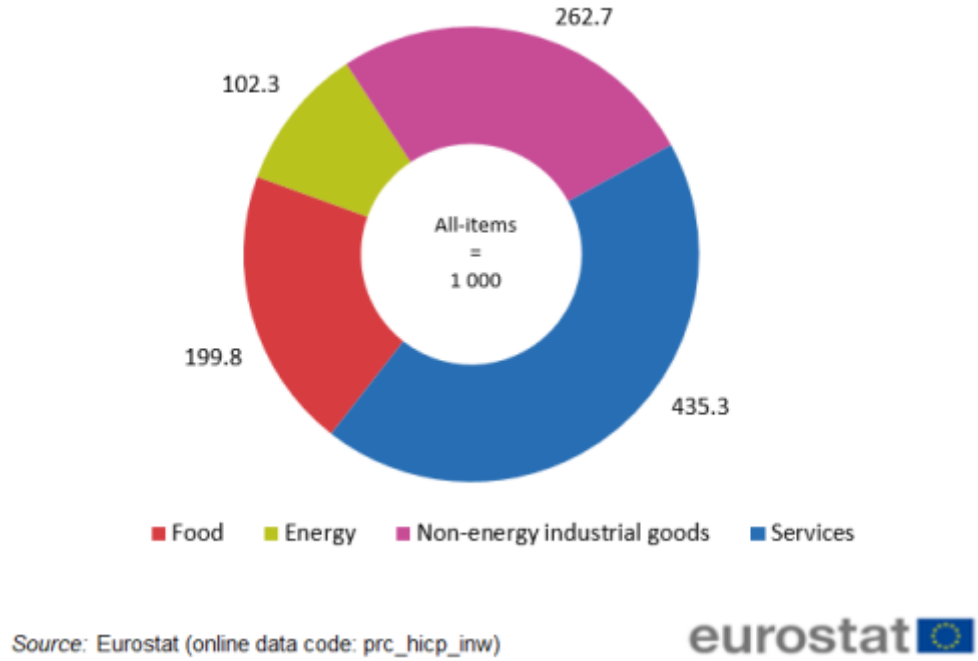


Figure 36: Weights of the main components of the euro area HICP-2023 (%) [144].

The increasing inflation is associated with an increase in prices, producing demand fluctuations [142], capacity constraints, supply chain instability, longer lead times, delayed orders, and continued issues with shipping containers [145].

4.3.1.8 Risks for supply chains from global trade shift

Based on ReSchape's literature analysis and experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Capacity constrains / shortages and in some chains difficulties to access essential products:* This risk is common to all the trends contemplated in the global trade shift megatrend. Interruption of the main components of the global supply (i.e., production, logistics, and transportation), changes in demand and renewed bottlenecks, increased price of product and transportation, increased inflation, decreased economic growth and lower investment in emerging economies/markets, changes in value chains and costs of reshoring/re-localization. This has a clear impact on the global economy, supply and demand, operations and customers, destabilizing the market and regular commerce, enlarging the social disparities and raising concerns in society.
- *Financial instability / (monetary tightening):* This risk is common to many of the trends in the global trade shift. Financial instability refers to stagflation, financial strains, continued fiscal pressures, and weak investment in many countries. The impact of this risk is higher in vulnerable countries. Financial instability can lead to increased cost of capital, disruptions in trade and logistics, decreased consumer spending, and economic downturns. The risk for bankruptcy of smaller entities but important suppliers is also considered.
- *Supply chain instability and reduced efficiency (longer lead times, delayed orders, and continued issues with shipping containers)*: This risk is common to many of the trends in the global trade shift. Effective supply chains maintain the stability of the market and commerce, unstable supply chains increase the possibility of disruptions and supply chain failures, which can have far-reaching impacts on businesses and society. For example, disruptions in the

supply chain can result in reduced productivity, shortages of essential goods, increased costs for businesses, decreased economic activity and reduced welfare and customer satisfaction.

- *Products/services price increase:* An increase in the price of products and services can contribute to inflation and reduce the purchasing power of consumers (changing customers' behaviour and demand), which can have a ripple effect on the economy. This can result in decreased demand for goods and services, lower profit margins for businesses, and reduced economic growth. It can also result in supply chain disruptions, increased competition and the need to optimize / reorganize the supply chains to remain competitive.
- *Lower investment in emerging economies endangering supply chains:* Lower economic growth in emerging markets and developing economies could contribute to temporary adverse deviations from the current baseline scenarios and even to a shock to the EU's potential growth in the long term. It also endangers a sustainable recovery due to a higher risk of global/local disruptions contributing to poor quality, unsafe and inhumane working conditions.
- *Difficulty to adapt to rapid changes in supply chain, demand and conditions:* Changes in customers' preferences and demand, business environment, shortages, price volatility or supply chain reconfiguration (for example need to look for a different supplier) among others require rapid reaction / adaptation from the organizations to remain competitive. These changes may come unexpectedly and require managers to adapt their operations to fit in with the change and the new situation. It is a challenging, continuous task, further complicated by increasing competition. Supply chain activities are particularly exposed to such challenges, as any firm's adjustments need to consider the potential and actual impact on relationships within the network. Besides, due to the fast-changing business environment occurred by the recent crisis, investments – R&D&I, infrastructure, SC configuration - may not pay off in the medium/long term.

Besides the economic dimension, the risks of global trade shift have an impact related to the social dimension such as:

- *Product price increased endangering domestic economy:* The current increase in the prices of products and services due to inflation and supply chain disruptions is translated into a reduced purchasing power and increased cost of living for society. This can produce changes in customers consumption/purchasing patterns and products demand (weaker than expected in general with an increase of some specific products), which can also translate into increased inflation, delays and shortage of specific products. This weakening domestic conditions (cost-of-living increases), will be intensified for low-income groups as well as EMDEs and vulnerable countries.
- *Reduced customers' trust (no guaranties of being paying the right price):* When a supplier brings a price increase to a merchant, especially in this economic environment, the buyer may not have the right tools, capacity, or time to determine whether a price increase is warranted. This me have an effect on the image of the brand/company or even on the whole economic system due to the mistrust of the consumer.
- *Changes in consumption/purchasing patterns:* An increase in the price of products and services and inflation reduces the purchasing power of society leading to a change in customers' preferences (towards more economical and essential products) and changing the demand (weaker than expected in general with an increase of some specific products), which can also translate into an even more increased inflation, delays and shortage of specific products. Trends and different needs of the society will also lead to different consumption patterns in a very short time. Supply chains need to increase their flexibility, to rapidly adapt to these changes, while remaining competitive and cost-efficient.

According to experts' validations and comments collected during the workshop, most of the supply chain risks from global trade shift are expected to have a moderated to high probability to occur and cause a moderated to high impact on supply chains. However, the risk "Capacity constrains / shortages and in some SCs / difficulties to access essential products" after the evaluation of the experts resulted in a very high probability to happen with a very high impact on supply chains. Also, with a very high probability to happen and high impact we found two risks "Changes in consumption/purchasing patterns" and "Reduced customers' trust (no guaranties of being paying the right price)".

Table 7: Risks for supply chains related to each trend of the global trade shift.

	Global trade shift-related risks (I)		
Risk categories	Deceleration of the economic growth in emerging economies (EC) specific risks	Restructured investment flows specific risks	Reorganized globalization - fragmentation/regionalization (deglobalization) specific risks
Capacity constrains / shortages and in some SCs / difficulties to access essential products		Higher risk of global/local disruptions (Information related and financial barriers that may impede emerging economies perform ERM (Enterprise Risk Management) with less investment and resources) [19]	Developing countries may experience significant shortages as their customers reshore activities to developed countries. This, in turn, may make it more difficult to access essential products, which may result in policies aimed at securing strategically important activities and creating barriers to reshoring. At the extreme, governments may implement restrictions on such repatriations [20]
Financial instability / worsening of global financial conditions	Collaboration in SC plays an essential role for sustainable development achievement. However, in emerging economies it is suggested that it may not always be "good" because in some instances it could increase the risk of corruption [21]	Risk for the sustainable recovery [22] Lower economic growth in emerging countries [23], could contribute to temporary adverse deviations from the current baseline scenarios and even to a shock to the EU's potential growth in the long term [24]	Where resilience is a significant concern, i.e. pharmaceuticals, the possibilities for economic upgrading may be reduced to a certain extent, which could have negative effects on employment [20] Regionalization would cause large value-added losses for some developing countries such as China, India, and Vietnam but bring value-added gains for some developed countries, enlarging the economic gap between developing and developed nations [25] Unproductive re-shoring of SCs could put the financial system under strain and disrupt the supply of commodities [23]
SC instability and reduced efficiency	Small states are especially vulnerable because of their reliance on external trade and financing, limited diversification, elevated debt, and susceptibility to natural disasters [23] Access to resources, inefficient legal framework, sociopolitical instability, the quality and availability of infrastructure, and weak institutions [26] More trade policy uncertainty could cause companies to delay establishing new relationships that require some up-front investment [27] When uncertainty increases, firms tend to diversify more (loss of economies of scale in production and possibly distribution) among foreign sources [27]		Reshoring will include increased divestment and a shrinking pool of efficiency-seeking FDI (foreign direct investment). Regionalisation will reduce the physical length but not the fragmentation of SCs. The geographical distribution of value added will increase. This trajectory will affect regional processing industries, some GVC-intensive industries and even the primary sector [28]
Products/services price increase	Volatility of price and cost, fiscal changes [29] Customers location is critical to GSC decisions (leading to significant changes in the costs and revenues for the firms depending on where customers are now) [27]		
Lower investment in emerging economies endangering SCs	EMDE investment growth is envisaged to remain below its 2000-21 average pace, dampened significantly by weakening activity, heightened uncertainty, and rising borrowing costs [23]	Lower economic growth in emerging countries [23], could contribute to poor quality, unsafe and inhumane working conditions, late deliveries [30]	
Difficulty to adapt to rapid changes in SC, demand and conditions	EC are characterized by rapid changes in the business environment, requiring adapt their operations to fit in with the change and the new situation [26] Difficulty to trust building in uncertain periods. Rapid changes in the business environment with an implicit collaboration requirement to meet demand while increasing competitiveness [26] Increased reaction/adaptation time when change in customer preference [29] Reshoring or redistributing global SCs among foreign sources [27]		Costs associated with introducing new infrastructure and technologies as well as seeking out new, reliable suppliers (regionalization) [20] Cost associated to reshoring (will be supported by technology with the associated challenges) [20]

	Global trade shift-related risks (I)		
Risk categories	Deceleration of the economic growth in emerging economies (EC) specific risks	Restructured investment flows specific risks	Reorganized globalization - fragmentation/regionalization (deglobalization) specific risks
Other			Government policies to reinforce national security and competitiveness may force GSC to regionalize (re-routing) [20] Exacerbation of the existing unequal distribution [31] Complete regionalization would decrease carbon emissions in Asia and Europe, but increase the emissions in NorthAmerica [32]

	Global trade shift- related risks (II)			
Risk categories	Export growth (on recovery) / Decelerated global trade growth specific risks	Emergence of born-global firms – Internationalisation specific risks	Transportation costs increasing specific risks	Increasing inflation specific risks
Capacity constrains / shortages and in some SCs / difficulties to access essential products	Interruption of the main components of the global supply (i.e., production, logistics, and transportation) [146]		Capacity shortage [130], [147] Bottlenecks in SCs [148]	Shortage of services and materials [149] Capacity constraints [150]
Financial instability / worsening of global financial conditions	Weaker-than-expected global demand and renewed SC bottlenecks pose downside risks [149] Slow-down in consumption of overseas customers [146]	Monetary risk and country risk [151] Exchange rate risk, raises in taxes, price raises and drops [152]	Smaller and more vulnerable economies are more negatively affected by capacity shortages and freight rate increases [147] Average unit revenue increased for operators [153] Surge in freight rates benefited the largest shipping companies associated with the World Shipping Council [154]	Financial instability: stagflation, financial strains, continued fiscal pressures and weak investment in many countries. Higher impact in vulnerable countries [149] EMDEs: financial stress featuring rapid capital outflows, currency depreciation, and difficulty servicing debt [149] Monetary policy tightening (rapid and synchronous around the world) worsening global financial conditions, which is exerting a substantial drag on activity (this drag is set to deepen given the lags between changes in monetary policy and its economic impacts, and the fact that real rates are expected to continue to increase) [149], [155]
SC instability and reduced efficiency	Low control of the activities compared to the current massive forces of economic disruption from the organization and SC managers. Extended SCs and less responsive are more exposed to impacts of political decisions of governments of another country [156]	Political risk and country's susceptibility to exports [157]	Decrease of SC efficiency. Increased lead times and exposed shipments to longer delays [158], [159]. Disruptions to SC transportation [160] Imbalance between supply and demand for freight transport services. More costly for firms to offshore production across different jurisdictions. Reduced reliance on imported inputs [117] Capacity issues due to the lack of truck drivers [159]	SC instability, longer lead times and delayed orders, and continued issues with shipping containers [150]

	Global trade shift- related risks (II)			
Risk categories	Export growth (on recovery) / Decelerated global trade growth specific risks	Emergence of born-global firms – Internationalisation specific risks	Transportation costs increasing specific risks	Increasing inflation specific risks
Products/services price increase	Increased trade costs and slow trade growth due to intensification in trade protectionism, fragmentation of trade networks and security concerns about SCs [149]		Higher costs for producers (transport, materials, E) [161], [147] Delays in the SC increase costs [159]	Broad-based price pressures across swaths of the economy due to specific commodities would experience sharp price increases [162] Rate and price increases [150]
Difficulty to adapt to rapid changes in SC, demand and conditions	Failed to meet corporate social accountability standards [163]	Adaptation to rapid changing condition in all the countries, including documentary and sanitary [152] Lack of information of foreign clients and lack of market knowledge [152]		
Product price increased endangering domestic economy	Transfer prices, tax rates, duties, exchange rates, and inflation [163]		Higher costs for producers flows to increased consumer prices [161], [147], resulting in reduced purchasing power	Weakening domestic conditions (Cost-of-living increases), intensified in EMDEs and vulnerable countries [149]
Customers' trust (no guaranties of being paying the right price)				When a supplier brings a price increase to a merchant, the buyer may not have the right tools, capacity, or time to determine whether a price increase is warranted [164]
Changes in consumption / purchasing patterns	Weaker-than-expected global demand [149]		Higher costs for producers flows to increased consumer prices [161], [147], resulting in changes in demand	Capacity constraints and shortages [133] [150]
Other		Cultural and human capital [152], lack of trained personnel, time and resources [151]		

4.3.2 Digital economy

Digital economy refers to the use of information technology to create or adapt, market or consume goods and services. The digital economy is transforming age-old production sectors and innovating not only how companies do business but also personal finance. Digital novelties include digital banking, e-commerce, virtual education, smartphone apps and collaboration platforms. The World Economic Forum estimates that 70% of new value created in the economy over the next decade will be based on digitally enabled platform business models [132].

4.3.2.1 Digital platforms

Digital platforms are systems and interfaces that form a commercial network or market facilitating business-to-business (B2B), business-to-customer (B2C) or even customer-to-customer (C2C) transactions. Conceptually, digital platforms are tech-based business models connecting interests and people, and promoting valuable interactions between those involved. Today, there are many different types of digital platforms, each of which meets the different needs of its users within different contexts. This allows products and services to be made available digitally.

Today, 1 million EU businesses are already selling goods and services via online platforms, and more than 50% of small and medium enterprises selling through online marketplaces sell cross-border [165].

More than a half of enterprises (59%) derived more than 25% of their revenues from online platforms compared to 50% of companies in November 2019. Online platform sales exceeded 75% of the revenues of 13% of companies in 2020 compared to 10% in 2019 increasing the dependency of business users on online platforms, which may have been accelerated by the COVID-19 crisis and lockdown measures in 2020 [166].

It was projected that the revenue of the digital experience platform industry would increase at a compound annual growth rate (CAGR) of 10.9 percent between 2019 and 2025. In 2019, the market value amounted to 8.49 billion U.S. dollars and was expected to nearly double by the end of 2025 [167].

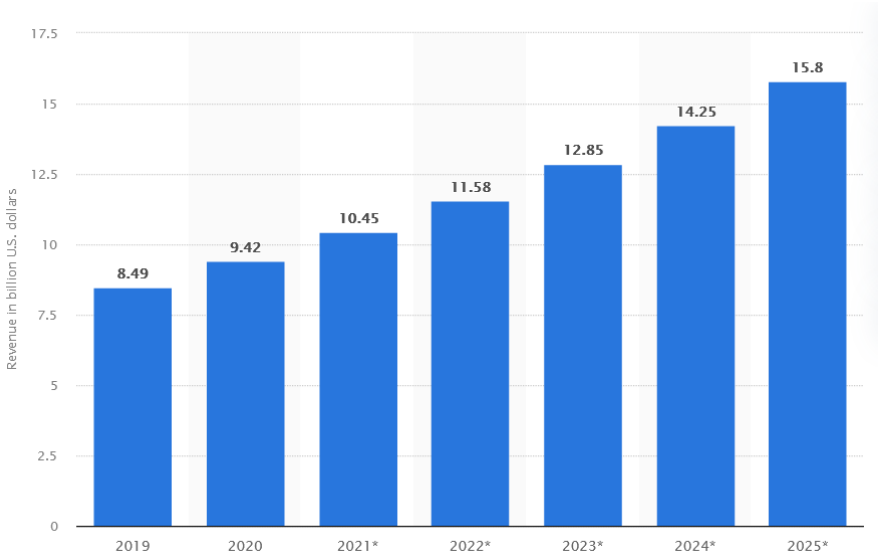


Figure 37. Digital experience platform revenue wordwide from 2019 to 2025 (in billion U.S. dollars). Source: Statista 2023 [167].

Platforms enable much smaller enterprises to participate in global trade without investing in their own supply chains [168] focusing on customer needs, collecting data to understand customers.

The platform economy business model will reform traditional industries, further develop advanced manufacturing, support platform enterprises in the consumer sector, and continue to unleash consumption potential in the future [169], as well as increase visibility along the supply chain.

4.3.2.2 Sharing economy – B2C – C2C

Increasing digitalization of the economy and society is changing the ways people act and interact. As a result, the sharing economy was born as a new model of consumption related to the development of the internet and new technologies of information and communication. The sharing economy is defined as an economic system in which assets and services are shared between private individuals, using both business-to-customer (B2C) and customer-to-customer (C2C) models. The sharing economy has revolutionised current business models around the world resulting in many different types of digital platforms, each of which meets the different needs of its users within different contexts allowing products and services to be made available digitally.

Initial real-time payment growth has been primarily in peer-to-peer settings and online transactions. The next steps will be the consumer-to-business point-of-sale and billing spaces (the latter representing a B2B opportunity as well), and their more straightforward paths to monetization. The pandemic has pushed businesses to reorient their payments operations and customer interactions. 50 to 70 % of digital commerce will be conducted on these platforms by 2025, albeit with differences between markets [142].

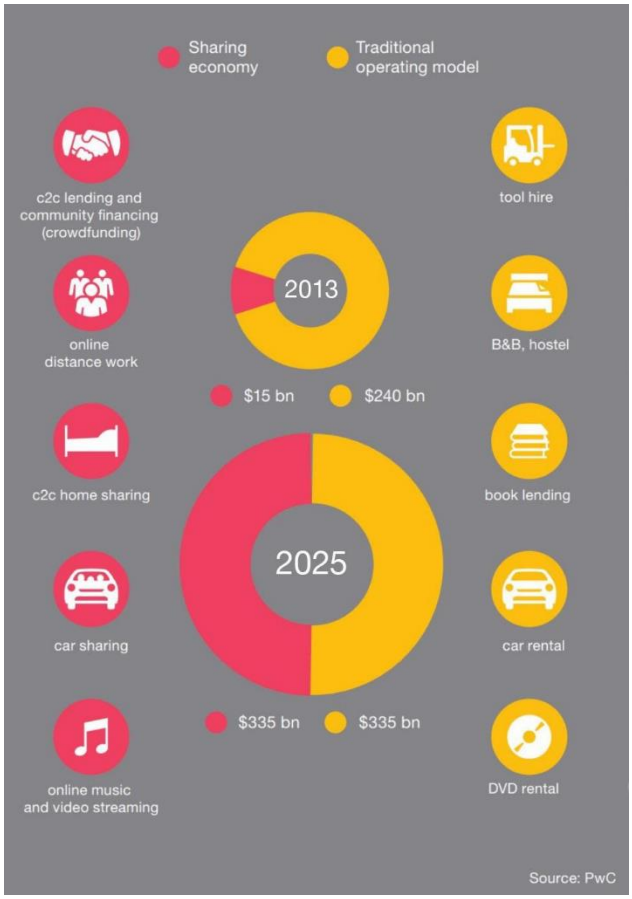


Figure 38: Sharing Economy Versus Traditional Operating Business Model (Source: PwC) [170]

Sharing economy is enabling the incorporation and integration of finance into consumer driven supply chains [142] promoting second-hand products, and decarbonization [145].

Revenue generated from companies within the shared economy theme could reach $335 billion by 2025, according to PwC [170]. The shared economy model will have profound societal and economic benefits and potentially improve the lives of countless individuals. The total value of the global sharing economy predicted to increase to 600 billion U.S. dollars by 2027, from 113 billion U.S. dollars in 2021, with a CAGR of approximately 32 percent [171].

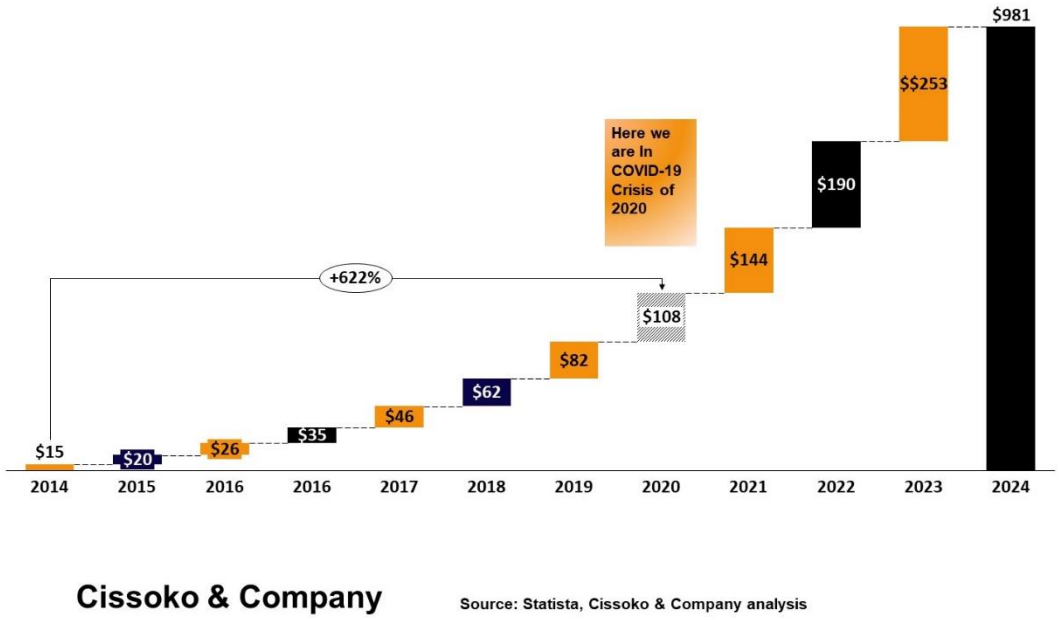


Figure 39: The value of sharing economy from 2014 to 2023 in billion U.S. dollars. [172]

4.3.2.3 Digital currencies / cashless payment

The financial landscape is transforming because of digitalization envisioning the future of money as a digital paradise. A world in which all financial transactions are carried out purely digitally, a veritable cashless society. Aligned with this, we are seeing traditional banks and physical cash losing out to digital currencies. The fact is that the majority of central banks around the world have already started exploring the possibility of launching a state-owned digital currency comes as a response to the increased adoption of digital.

The Covid-19 pandemic has boosted the use of digital and contactless payments. The pandemic has added to the motivations of central banks to develop central bank digital currencies (CBDCs) [173].

Global cashless payment volumes are set to increase by more than 80% from 2020 to 2025, from about 1tn transactions to almost 1.9tn, and to almost triple by 2030 [174]. Two-thirds of adults worldwide now make or receive a digital payment, with the share in developing economies grew from 35% in 2014 to 57% in 2021. In developing economies, 71% have an account at a bank, other financial institution, or with a mobile money provider, up from 63% in 2017 and 42% in 2011 [175].

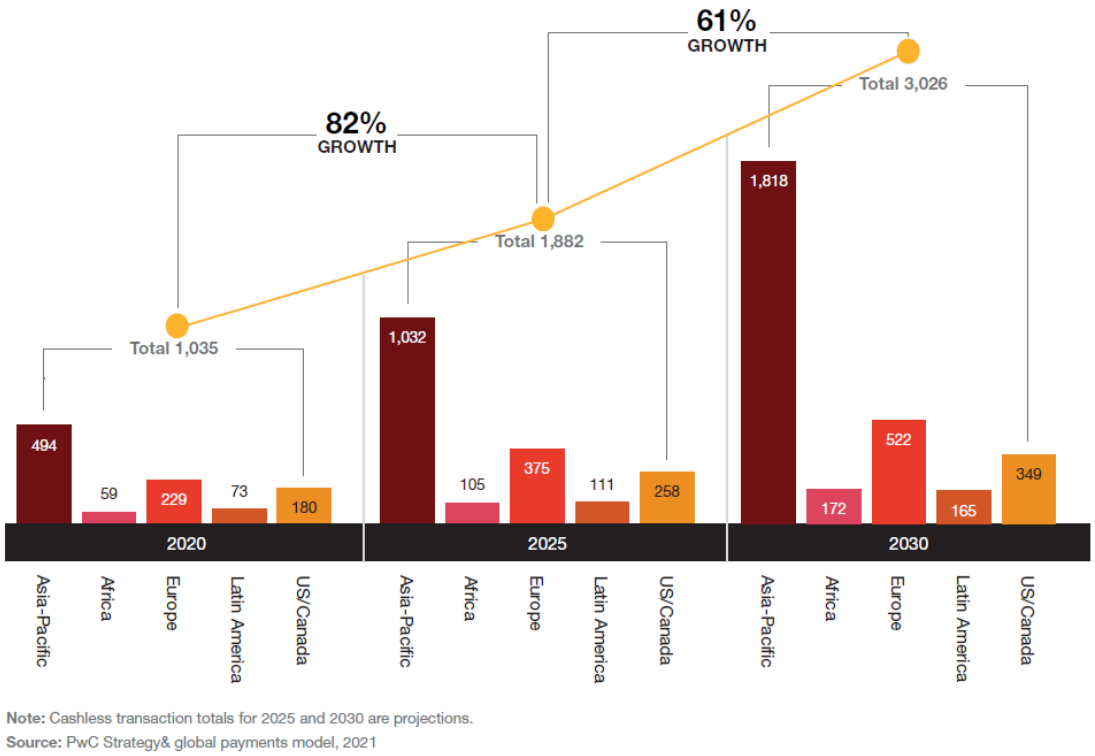


Figure 40: Cashless transaction volume will be more than double by 2030 (Number of cashless transactions in billions). [174]

ECB launched the digital euro project in 2021. In the first quarter of 2023, the European Commission will propose a regulation to establish the digital euro, which is expected to help achieve the digital euro objectives [176].

Many central banks are exploring the potential of and need for a digital form of cash, a retail central bank digital currency (retail CBDC) that would provide consumers with the same protection as cash does today, while allowing them to make payments without carrying physical banknotes and coins [173]. This will enhance market efficiency [177]. Cashless payments support B2B payments and the digitisation of supply chains [174] while blockchain eliminates the need of intermediaries to verify cross-border payments [178], [179].

4.3.2.4 The financial technologies (Fintech) revolution

Financial technology, Fintech, was originally a term “given to technology applied to the back-end software of established financial institutions”. Currently, Fintech refers to the application of digital technology to financial services. The ongoing digitization of financial services and money creates opportunities to build more inclusive and efficient financial services and promote economic development. Fintech is transforming the financial sector landscape rapidly and is blurring the boundaries of both financial firms and the financial sector. Thanks to fintech, it’s never been easier to establish and manage a business. The rise of fintech, changing consumer behaviour, and advanced technologies are disrupting the insurance industry.

U.S. FinTech founders attracted less than $1 billion in total venture funding in 2010. That number grew over 9x to $8.5 billion in 2015—and then more than doubled to $20.5 billion in 2020 [180].

BigTech firms have grown rapidly in recent years. The largest BigTechs have a significantly greater market capitalisation than the world's largest financial groups. Financial services represent 11% of revenues among a sample of the largest BigTechs [181].

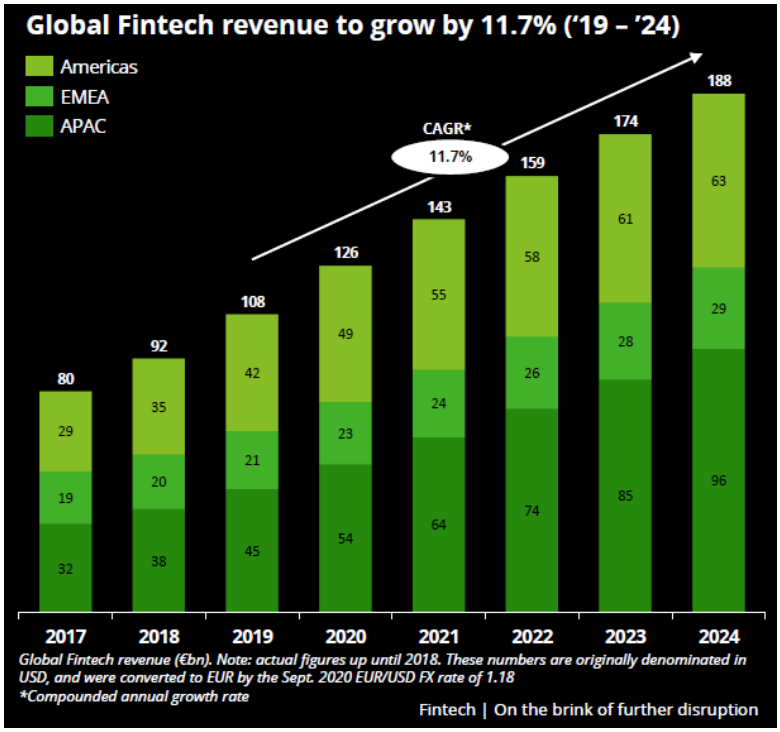


Figure 41: Global Fintech revenue from 2017 to 2020 and forecast. [182]

The prospects for Fintech are very promising as far as the future is concerned. Global Fintech revenues in 2018 were about €92 billion in 2018 and are expected to grow to more than €188 billion in 2024 (pre COVID 19 forecast) according to Deloitte [182]. AMR (Allied Market Research) reported a global fintech lending industry generated $449.89 billion in 2020, and forecasted a generation of $4,957.16 billion by 2030, witnessing a CAGR of 27.4% from 2021 to 2030 [183].

Financial technologies deliver greater efficiency and cheaper product offerings for consumers [184] improving financial services, reducing customer constraints, and operating costs [185].

Fintech provides improvements in connectivity and computing can help to enhance efficiency and competition in the supply chains. Financial services have seen an unbundling of different products and services [181]. FinTech allows for increased integration with consolidated digital solutions that can satisfy various needs, while reducing frictions, such as transaction fees, endless paperwork, external software dependencies and manual processes [186].

4.3.2.5 Risks for supply chains from digital economy

Based on ReSChape analysis and experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Security issues:* data breaches, hacking and fraud are risks to the supply chain and important concerns for users and customers. Solutions combating AML/CFT (Anti-Money Laundering/Combating the Financing of Terrorism) transactions and avoiding double transactions by the users are missing. Customer privacy and data security must be guaranteed to gain their trust. Security issues can cause disruptions to the organization's

operations, this can include system downtime or service disruptions, which can impact the ability of the organization to manage its supply chain effectively.

- *Lack of standard policies:* lack of standardization, rules and regulations (like anti-trust and anti-monopoly laws) endangers supply chains arising risks such as inefficiencies, quality issues, compliance issues, supplier and customer management issues. The lack of standardization in digital supply chain technologies can complicate the seamless communication and collaboration of different companies and systems. Companies may use different Internet of Things (IoT) protocols and data formats, making it difficult to share data and collaborate effectively.
- *High dependency on certain technology and IT infrastructure providers:* as organizations increasingly digitize their operations, they become more dependent on technology and IT infrastructure providers to ensure their supply chains operate smoothly. Organizations are vulnerable to the risks faced by those providers, such as system downtime or service disruptions. In the event of a failure or outage, the organization's supply chain may be impacted, leading to delays or other disruptions. Technology is constantly evolving, and organizations may find themselves dependent on outdated technology or systems that are no longer supported. Also, organizations may have limited control over their supply chain.
- *Poor infrastructure and low capital:* if organizations lack the infrastructure and capital to support digital technologies, they may experience poor performance in their supply chain operations. This can result in delays, inefficiencies, and increased costs. If organizations lack the capital to invest in digital infrastructure, they may struggle to scale their operations as demand grows. This can limit their ability to take advantage of new opportunities and compete effectively in the marketplace. Digital technologies are constantly evolving, and organizations that lack the resources to keep up with these changes may fall behind competitors. This can limit their ability to innovate and adapt to changing market conditions.
- *Lack of integration and collaboration among SC (reluctancy to share data/trust issues):* digitalization of the supply chain requires integration and collaboration among supply chain partners to be successful. If organizations are reluctant to share data or lack trust in their partners, this can create risks for the supply chain like limited visibility (not sharing data can difficult to getting a complete view of the supply chain creating blind spots, making it more difficult to identify potential risks and opportunities), inefficiencies (duplicate efforts, costs increased...), cybersecurity risks, slow adoption of new technologies (limiting the ability of the supply chain to evolve and adapt to market conditions), and disruption of operations (bottlenecks).
- *Fast market evolution and difficulty to adapt:* digitalization in a fast-evolving market can create significant risks for the supply chain. The use of outdated technology can create inefficiencies and limit the ability to compete effectively in the market. Missing out new opportunities can limit the ability to grow and expand operations. Organizations that are not able to adapt quickly may find themselves at a disadvantage compared to more agile competitors. Adaption to the fast market evolution can be expensive and preset a risk to the financial stability of the organization. Also, customers may request fast adaptation to new features like transparency or real-time information which could fail in delivering these expectations and loss the customer trust.
- *Structural bank disintermediation, monetary policy, financial stability, international (cross-border) spillovers and capital flow volatility.* There is a complex relationship between changes in the structure of the banking industry, monetary policy, financial stability, and cross-border capital flows. As banks become less central to the financial system, monetary policy can become less effective, and financial stability can be threatened. Additionally, capital flow volatility can increase, creating spillover effects across borders and potentially destabilizing the global financial system. This can endanger financial stability and translate into prices increased and availability and cost of credit (among other) that could produce delay in production, increased costs and difficulties to obtain financing.

Besides the economic dimension, the risks of digital economy have an impact related to the social dimension such as:

- *Safety concerns and reticence to adoption:* safety perception reflects consumers' perceptions regarding the uncertainty that the system used can securely transact. Perceived risk negatively impacts the adoption of the technology, cybersecurity and payment fraud are the main concerns. Reticence to adoption could result in resistance or scepticism towards digital technologies, which could slow the pace of innovation and limit the potential benefits of digitalization for the supply chain.
- *Risk of exclusion:* a risk of the digital economy is the exacerbation of existing inequalities, particularly if certain groups are left behind or excluded from the benefits of digitalization. For example, if digital technologies require high levels of education or technical expertise, there could be significant disparities in access to employment opportunities and economic benefits. Also, there is a danger that people will be unable to keep up with the constant technological change, digital knowledge will lag behind, digital exclusion. Low-income groups' preference for cash and older people unable to adapt to the digital developments are the most affected.
- *Resistance to change:* adopting digital supply chain technologies can be challenging for organizations, as it requires changes to established processes and may require training and reskilling employees. For example, in some cultures, there may be a preference for face-to-face interactions and a mistrust of digital communication. This could create a barrier to the adoption of digital technologies in the supply chain. Many people may not understand the benefits and implications of digitalization for the supply chain. This could lead to a lack of interest or support, as well as a reluctance to adopt new technologies or processes.
- *New skills/capacities needed:* implementing a new digital platform or technologies may require employees and users to learn new skills and adapt to new approaches. This can be a challenge for organizations that have a large workforce that is not familiar with new technologies, difficult and time-consuming. Additionally, if training is not provided, employees and users may become frustrated and disengaged, which can lead to reduced productivity and customer satisfaction resistance to change and reducing buy-in for new technologies.
- *Unsatisfactory customer experience (uncertain quality of shared products):* sharing economy service providers are significantly suffering from the volatile product quality problem which is a risk. Uncertain product quality of the shared products (products used by consumers without the control of the platform or the brand owner) brings huge negative impacts on the consumption experiences of consumers, thus affecting market demand and the development of platforms. C2C markets can be targeted by counterfeiters or fraudsters. Service providers may lose users. Similarly, consumers that have unknowingly purchased counterfeit goods, could associate an experienced dissatisfaction with the brand itself; resulting into a loss of reputation. Hence, second-hand or counterfeit markets created by C2C applications may lead to 1) loss of quality control, and 2) revenue losses from sales due to cannibalization or depreciation of new products. All of this can have different effects as reputation damage (brand damage), liability issues, decreased customers trust, cost of quality control and compliance with regulations and other legal penalties.

According to experts' validations and comments collected during the workshop, most of the supply chain risks from digital economy are expected to have a low to high probability to occur and cause a low to high impact on supply chains. However, the risk "Security issues" was evaluated by the experts with a very high probability to happen and a very high impact on supply chains. Also, with a very high probability to happen and high impact we found two risks "Lack of integration and collaboration among SC" and "Fast market evolution and difficulty to adapt".

Table 8: Risks for supply chains related to each trend of the digital economy.

	Digital economy-related risks			
Risk categories	Digital platforms (DP) specific risks	Sharing economy - B2C - C2C specific risks	Digital currencies / Cashless payment specific risks	Fintech revolution specific risks
Security issues	Cybersecurity/data breach [187]		Hacking, fraud [188]. Combating AML/CFT transactions and avoiding double transactions, customer privacy and data security [162][189]	Security issues, hackers and attacks [190]
Lack of standard policies	Lack of Standardization, rules and regulations (anti-trust and anti-monopoly laws) [187], [191]			No compliance due to a lack of explicit standard policies [192]
High dependent on certain technology & IT infrastructure providers				High dependent on certain technology & IT infrastructure providers [193], [194]
Poor infrastructure and low capital	Cost of implementation/management [187] Need of data management [187]		Technological challenges and costs associated with a truly digital currency [162]	Poor infrastructure and low capital [195]
Lack of integration and collaboration among SC (reluctancy to share data/trust issues)	Lack of integration and collaboration from all the stakeholders of the SC [196] Reluctance to share data from organizations [197] DP needs both the complementor and the consumer side to ensure a valid value proposition, but neither side is willing to join as long as the other side is not populated [198]			
Fast market evolution and difficulty to adapt	Capacity to adapt to new/emerging technologies and ensure profitable implementation (value creation and capture) [165], [198]	Need to continuously update and understand the market conditions (pricing mechanism for dynamic demand conditions is crucial) [199]		
Structural bank disintermediation, monetary policy, financial stability, international (cross-border) spillovers and capital flow volatility			High levels of volatility of certain types of cryptoassets, lack of safeguards, and operational issues [189] Potential risks for monetary policy, financial stability, consumer rights and environment [189] Economic and financial bubbles, systemic bank runs [200] Currency substitution and structural bank disintermediation [189], [200], international (cross-border) spillovers and capital flow volatility [189] Cashless society [200]	
Safety concerns and reticence to adoption		Difficult to build trust among product owners and consumers [199]		Reticence to adoption due to safety risk concern [201]
Risk of exclusion			Design features such as limits on access and usage [189]	
Resistance to change	Resistance to change (organizations and/or employees) [187]		Low-income groups' preference for cash [162]	

Digital economy-related risks				
Risk categories	Digital platforms (DP) specific risks	Sharing economy - B2C - C2C specific risks	Digital currencies / Cashless payment specific risks	Fintech revolution specific risks
New skills/capacities needed	New skills/capacities for employees & users [187]			
Unsatisfactory customer experience (uncertain quality of shared products)		Negative impacts on customers' consumption experiences and brand image: volatile product quality [199], customer intention [202], counterfeiters or fraudsters [203], loss of quality control [204]		
Other		Revenue losses due to cannibalization or depreciation of new products [204]		

4.4 SOCIAL DIMENSION

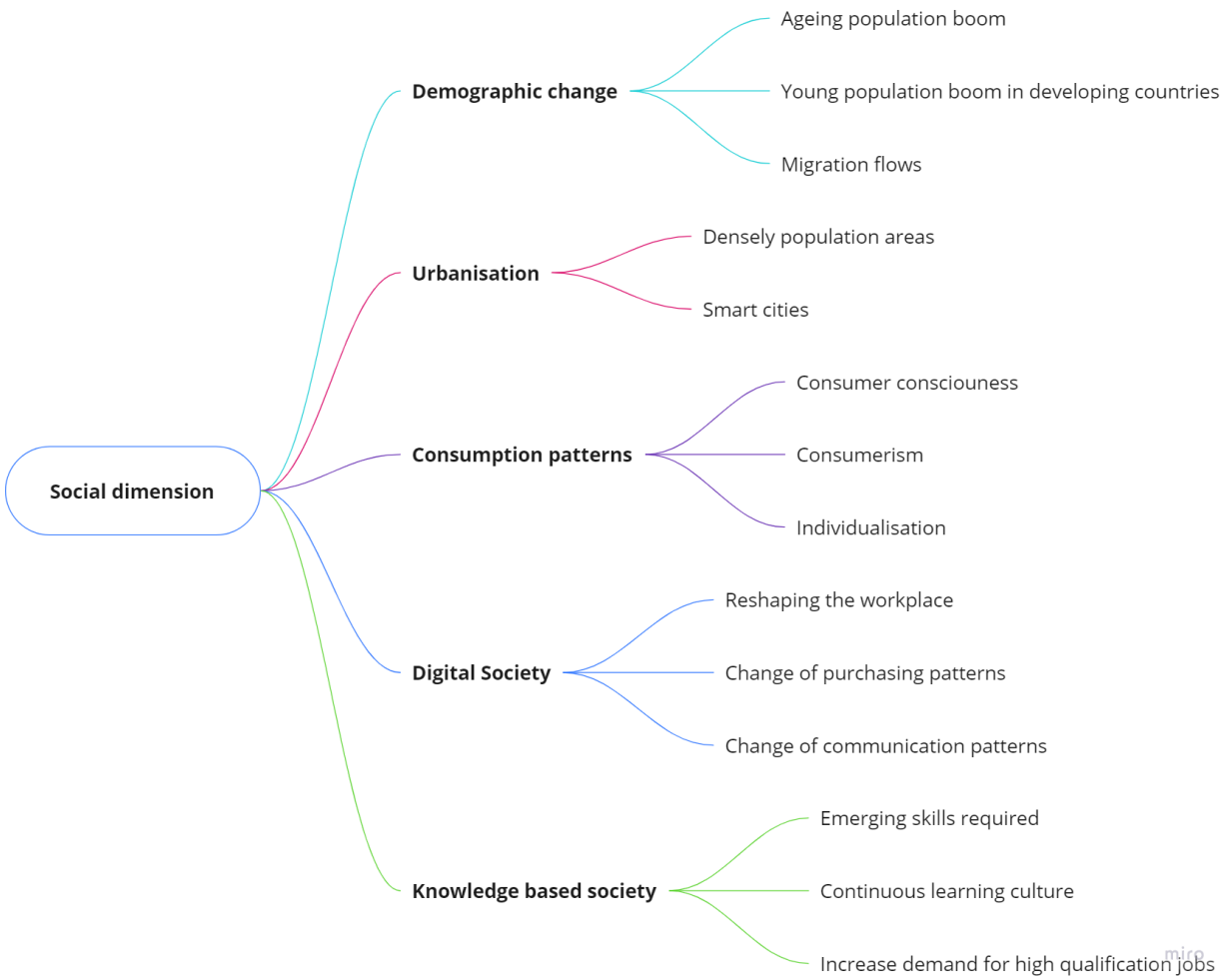


Figure 42: Overview of the trends in the social dimension

4.4.1 Demographic change

The demographic change megatrend concerns how human populations change over time. Demographic-related trends do not affect every region in the same way albeit they all have a powerful impact on our economies and relevant effects on supply chains. Ageing and the consequent decrease in the working-age population have indeed significant economic and social costs in developed countries. Also, countries with growing youth populations face challenges such as poverty and unemployment. In addition, the social and political significance of migration has increased and migration flows connected dynamics have become more variegated in an interconnected world.

4.4.1.1 Ageing population boom

Population ageing is a global phenomenon and represents the most pervasive and dominant demographic trend. Drivers of global ageing are declining fertility rates and increasing longevity due to improvements in healthcare and better living conditions. Profound implications relate to this trend

not only for individuals but for economic growth, productivity, inequality within and between generations and the sustainability of public finances.
According to statistics, life expectancy at age 65 is projected to increase in all countries. Globally in 2020, there were 728 million people aged 65 years or over and this is projected to double to 1.5 billion in 2050 [205]. Moreover, the number of persons aged 80 years or older is expected to triple between 2020 and 2050 to reach 426 million [206] and it is projected that there will be nearly half a million centenarians in the EU-27 by 2050 from 96.600 in 2019 [207]. Although population ageing is a global phenomenon affecting every continent, regionally, population distributions vary widely (see Figure 43). While Africa remains the continent with the highest share of a younger population, Europe's population is and will remain the oldest one (Figure 44) [205]. The population age structure has changed radically over the years: global life expectancy has grown from 34 years in 1913 to 72 years in 2022 and is expected to continue on that way [208]. Retirement ages will also continue to rise in most countries for both men and women, even if at different rates [205]. Population ageing is a long-term trend that started several decades ago in Europe with multiple effects on society as the declining share of working-age people. Indeed, old-age dependency ratios will rise in all G20 members in the next future, even if at different paces, putting the financing of adequate pensions, health and long-term care under high pressure [209]. By 2050 more than two-thirds of the EU Member States are projected to have an old-age dependency ratio above 50.0% (compared with 34,1 in 2019) meaning that there will be less than two persons of working age for every person aged 65 years or more [207]. In addition, seniors (>65) represent an increasing market target with specific needs: by 2030, they are projected to spend just under $15 trillion (in 2011/PPP), up from $8.7 trillion in 2020 [210].

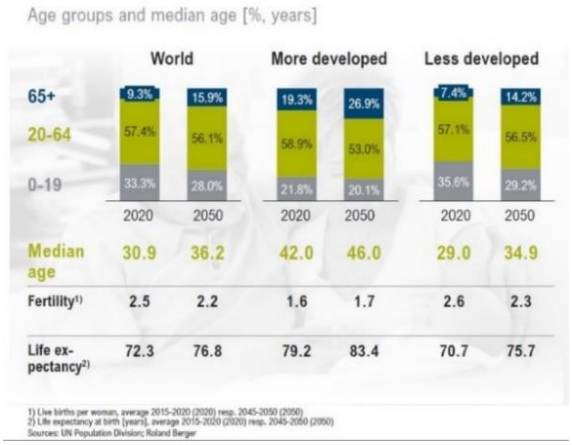


Figure 43: Age groups and median age (%, years). [205]

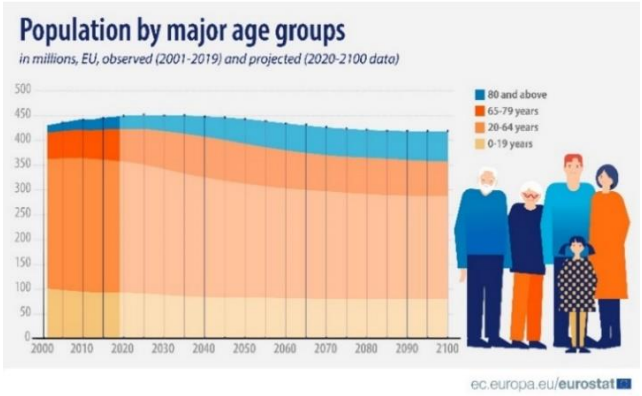


Figure 44: EU population by major age groups 2000-2100. [211]

4.4.1.2 Young population boom in developing countries

The world population is projected to reach 8.5 billion in 2030 and 9.7 billion in 2050 and this growth is substantially due to the rise in less developed countries, where young generations have to face challenges such as the risk of poverty and leaving a condition of underdevelopment. Such large numbers of young people represent both a challenge and an opportunity for the growth of these countries. In particular, youth empowerment represents a relevant issue to realise the potential of new generations and provide proper opportunities for work and innovation.

Even though an agreed definition of youth is missing, the UN Secretariat, for statistical reasons, refers to people aged between 15 and 24. Currently, the world hosts the largest generation of young people in history, accounting for 1.2 billion people. Nearly 90 per cent of young people lives in developing countries and there represents a relevant population share [212]. Africa has the youngest

population in the world, with 70% of sub-Saharan Africa under the age of 30 [213]. In 2021, most births worldwide occurred in the two most populous regions—Central and Southern Asia (28 per cent of global births) and Eastern and South-Eastern Asia (18 per cent)—and in sub-Saharan Africa (29 per cent), the region with the highest fertility level [214]. In 2050, a vast majority of the 9.7 billion of the projected world population will live in less developed regions where it is expected to grow by 20.4%. In particular, 30% of total worldwide population growth between now and 2050 is expected to take place in three countries: India, Nigeria and Pakistan [205]. Moreover, the world's poorest countries have some of the fastest-growing populations that will increase by nearly 80% towards 2050 [215]. In particular, the population in Sub-Saharan Africa is projected almost to double by 2050, accounting for most of the global increase expected by the end of the century [215]. In 2022, around 40% of the population was aged 15 years and younger, in comparison to a global average of 25%. Although the median age on the continent annually increases, it is still at 20 age [216] and is projected to slightly increase to 22 by 2040 (Figure 45). By this date, more than one-third of Sub-Saharan Africa's population will be younger than 15, while in East Asia this quote will account only for 14% [217]. Africa's demographic characteristics considerably differ from one country to another. Niger and Uganda have for example the lowest median age of just 15.4 and 15.8 years [216], [218]. Other populous countries that most likely will still be below the median age threshold in 2040 are Afghanistan, Egypt, and Pakistan [217].

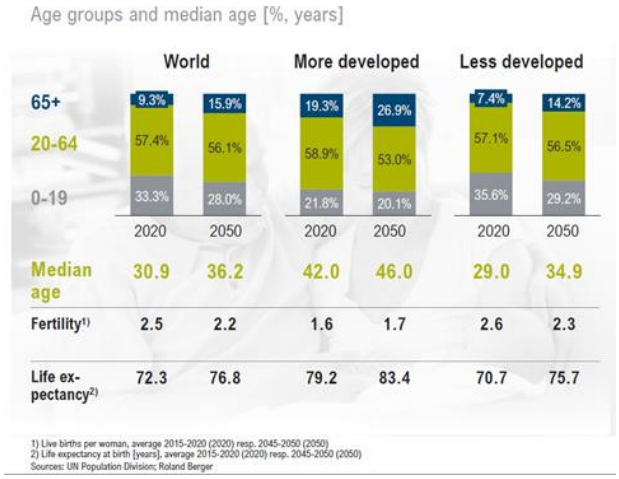


Figure 45: Age groups and median age (%, years). [205]

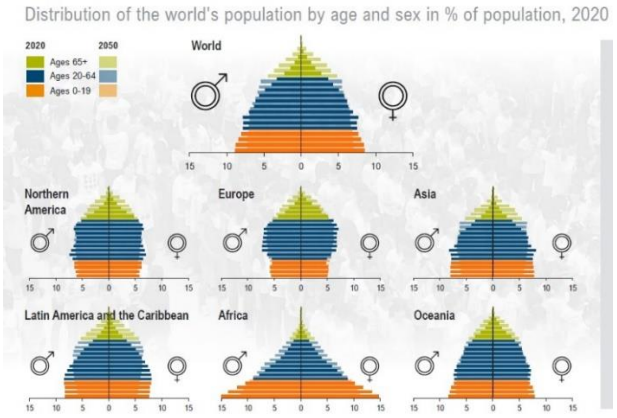


Figure 46: Distribution of the world population by age and sex in % of population, 2020-2050. [205]

4.4.1.3 Migration flows

Migration is a complex and global phenomenon driven by multiple factors. It is linked to globalization and reflects economic disparities and rising inequalities between different countries with people moving in search of better economic opportunities. Migration has disruptive potential and important impacts on our societies. On one side, it can lead to better allocation of labour and a positive impact on economic and social development. On the other side, migration flows imply complex challenges such as governance and migrant workers' protection.

Today, more people than ever live outside their country of birth. The current global estimate is that in 2020 there were around 281 million international migrants (or 3.6% of the world's population) and this number has increased over the past five decades (128 million more than in 1990 and over three times than in 1970) [219], [220]. Nearly two-thirds of these were labour migrants [221]. The OECD countries currently host more than half of the global international migrants and probably will remain preferred destinations because of their economic opportunities and high living standard. Migratory flows are mostly intraregional, for example, in 2019, 68% of all African migrants resided in other

African countries, and only about 16% lived in Europe [222]. Concerning future projections, it is expected that migration will exceed 4% of the global population by 2030, namely more than 350 million people [223]. Moreover, international net migration flows between regions are expected to be at a higher level toward 2050 (see Figure 47) [205]. People move for different reasons: climate change with related natural disasters and other extreme events expected to increase in the years ahead represents an increasingly powerful driver of mobility. Future forecasts vary from 25 million to 1 billion environmental migrants by 2050 with 200 million representing the most cited estimate [224]. In particular, by 2050, Sub-Saharan Africa could see as many as 86 million internal climate migrants; East Asia and the Pacific, 49 million; South Asia, 40 million; North Africa, 19 million; Latin America, 17 million; and Eastern Europe and Central Asia, 5 million [225]. Refugee flows are also increasing: Russia's invasion of Ukraine has provoked the largest displacement of people in post-war Europe. By mid-September 2022, almost 5 million refugees from Ukraine had been recorded by the OECD and the EU [226].

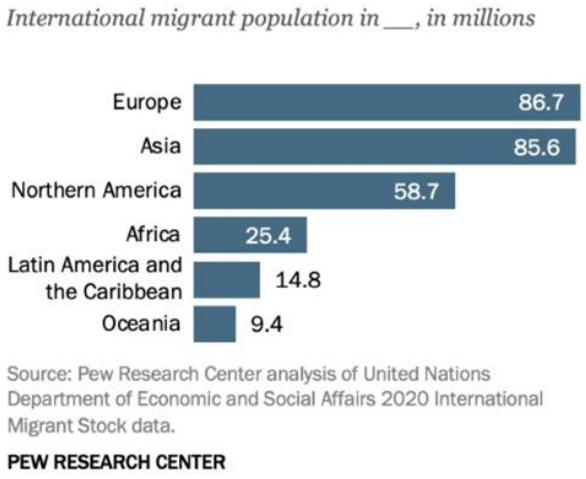


Figure 47: International migrants population (millions) 2020. [227]

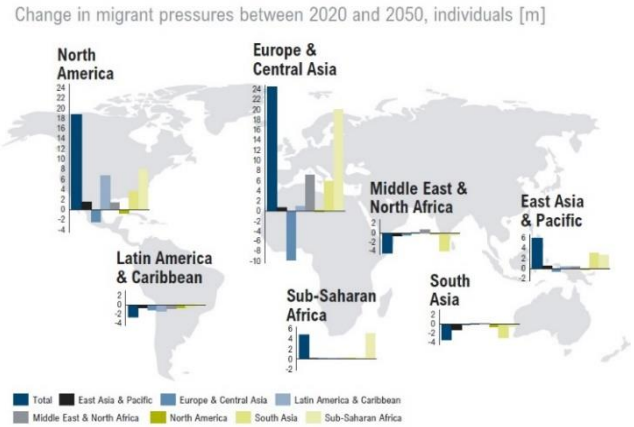


Figure 48: Migrant pressure 2020-2050. [205]

4.4.1.4 Risks for supply chains from demographic change

Nowadays, supply chains have to cope with several risks linked to demographic change-related trends (see Table 9 for the entire list of trend-specific risks). According to the sustainability dimensions, demographic change-related risks investigated in the literature belong to the economic and social dimensions of sustainability.

Based on the literature and the experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Decreasing of ageing workers' functional capacities.* Due to the decrease of workers' functional capacities with age [25], [228]–[230], i.e. "the characteristics related to workers' capabilities of performing a certain set of tasks, requiring physical and/or cognitive efforts" [230] [p.730], some studies put emphasis on the rise of lead time in manufacturing systems [25], as well as the delivery time due to the more frequent injuries of aged workers caused for examples by traffic crashes in case of logistics operations [26]. The increase in time leads to a decrease in productivity: e.g., in assembly lines due to the ill health of ageing workers

[28]. As the International Monetary Fund highlighted [27], the rising number of ageing workers decreases the Total Factor Productivity.

- *Knowledge loss*. The lack of inadequate investments in knowledge transfer generates a loss of knowledge in companies/SC either in manufacturing [231] or agriculture [232] linked to senior workers' retirement. Scholars highlight that in agriculture, the risk for the agriculture value chain is the "missing inter-generational cross-pollination of knowledge and experiences to engender future communities of practice" [19]. The departure of senior workers without succession plans determines knowledge loss [233]. Thus, it is crucial to manage the retention of critical knowledge [234], [235]. As highlighted in [234]'s review, knowledge is one of the most relevant success factors, however, the success of the knowledge transfer process is affected by many specific factors, such as the individual, knowledge, relationship and contextual characteristic. Retaining organizational knowledge ensures organizations remain competitive [236].

Besides the economic dimension, the risks which have an impact related to the social dimension concern mainly the skills of ageing workers and their labour rights. The main risks have been clustered as follows:

- *Lack of skills and few training opportunities*. The generation of workers named "ageing workers" (45-64 years) is characterised by lower digital skills than younger workers. This implies lower occupational mobility among ageing workers than among young workers and also a growing share of routine intensive jobs. It is worth noting that poor opportunities for training ageing employees do not improve their level of learning in digital skills, thus, value chains need to invest in on-the-job training and lifelong learning. As a challenge for the next years, it is necessary to increment the skills of ageing workers to be prepared for the de-routinisation of jobs in European countries [18].
  Regarding young workers, in the agriculture sector, there is a lack of young workers due to their lack of skills in agriculture as well as their lack of practical training like repairing and maintaining farming equipment, production capability and farm management [19].
  Finally, regarding migration flows, migrants often lack training opportunities in terms of safety standards of the hosting country but also job and soft-skilled training [20]. Moreover, migrants' difficulties in comprehending the language affect their work in terms of training, communication with supervisors [20], and their understanding of labour rights and duties [21].
- *Weak or missing control over workers' rights*. This risk is mainly related to migrants and refugees as vulnerable workers but affects also the youths. Regarding migrants [22], temporary migrants [237] and refugees [238], workers are often exploited in terms of low wages [20], [22], [237]–[239], overtime work [22], on-time payments [239], wage theft [20], [21], passport retention [21]. The missing control over labour rights affects the most vulnerable workers: refugees (in terms of asylum rights [238], work permit issues [239]), migrants (in terms of wage cuts, harassment [22], equal treatment between migrants and native workers [20]), temporary migrants (in terms of accessibility to representatives' bodies, in terms of accessibility to knowledge about their rights due to language and culture barriers [237]), and children (in terms of labour exploitation [240], [241]). Supply chains need to select suppliers that do not exploit vulnerable workers [240], [241].
  The risk of modern slavery, indeed, involves human trafficking [21] and also deceptive recruitment (in terms of different conditions and lower wages than promised). For example, in countries like Australia that hire several temporary migrants, there is strong pressure on the supply chain to hire intermediaries who do not provide labour standards (e.g., low wages) [237]. Moreover, the spread of COVID-19 had the effect to diminish workers' rights during disruptions to favour supply chain resilience (simplifying labour laws, selection of abundant suppliers, and loss of labour standards [242]).

Finally, migrants and young workers are affected by job insecurity and unemployment. Due to the increasingly competitive labour market migrant workers face the risk of unemployment [22], [238], [242] because they can be replaced easily (particularly for those with low skills [22]). Concerning migration flows, workers lack knowledge about their labour rights due to language barriers and therefore, sometimes they incur deceptive recruitment procedures [21], [237]. Moreover, a common risk for young workers in developing countries is the lack of written contracts [243], thus, they maintain the status of casual workers [243], without having a fixed job position.

- *Poor workplace ergonomics*. The risk related to poor workplace ergonomics is the increase in the number of health issues and injuries of ageing workers. Ergonomics risks can cause serious health issues for workers such as musculoskeletal disorders which affect productivity [25], [28]. Albeit the initial investment, ergonomics provides ageing workers with the best age-friendly workplace, for performing their tasks without incurring serious damage to health [230].

According to experts' validations and comments collected during the workshop, most of the supply chain risks from demographic change are expected to have a moderated probability to occur and cause a moderated impact on supply chains. However, the risk of "lack of skills and few training opportunities" has been evaluated by the experts as very highly probable and it potentially determines a very high impact on supply chains.

Table 9: Risks for supply chains related to each trend of demographic change.

	Demographic change-related risks		
Risk categories	Ageing population boom specific risks	Young population boom in developing countries specific risks	Migration flows specific risks
Decreasing of ageing workers' functional capacities	- Increase in time: lead time in manufacturing systems [25] and delivery time in logistics [26] - Decrease of productivity in assembly line [28] and decrease of Total Factor Productivity [27] - Diminishing functional capacities [25], [228]–[230]		
Knowledge loss	- Knowledge loss in case of no effective knowledge transfer from ageing to young workers [231] - Knowledge loss due to the departure of older workers without succession plans [233] - Loose of competitiveness [236]	- Lack of inter-generational cross-pollination of knowledge [19]	
Lack of skills and few training opportunities	- Lower ICT and analytical skills than young workers [18] - Less training opportunities than young workers [18] - High share of routine intensive jobs [18] - Lower occupational mobility than young workers [18]	- Lack of skills and practical training, like repairing and maintaining farming equipment, production capability, farm management and literacy in information technology [19]	- Lack of training (in terms of safety, job-related training, and soft skill training [20]) - Language barriers (in terms of training, and communication with supervisor [20]) - Increasing competitive labour market for low-skilled migrants and workers [22] - Low level of safety standards [20]
Weak or missing control over workers' rights		- Lack of written contracts [243] - Status of casual workers [243] - Child labour among suppliers [240], [241]	- Human trafficking (in [21]) - Diminishing workers' rights during disruptions to favour SC resilience (simplifying labour laws, selection of abundant suppliers, loss of labour standards [242]) - Labour/workers exploitation (refugees [238], migrants [22]) in terms of low wages[20], [22], [237]–[239], overtime work [22], on-time payments [239], wage theft [20], [21], passport retention (in [21]) - Lack of labour rights for refugees (in terms of asylum rights [238], work permit issues [239]), migrants (in terms of wage cuts, harassment [22], equal treatment between migrants and native workers [20]), and temporary migrants (in terms of accessibility to representatives' bodies [237]) - Job insecurity in terms of unemployment risk [22], [238], [242] - Deceptive recruitment (in terms of different conditions and lower wages than promised) (in [21]) and intermediaries which do not ensure labour standards (mainly low wages) for temporary migrants [237] - Language barriers (in terms of understanding the migrant worker's rights [21])
Poor workplace ergonomics	- Increasing health/injuries of aged workers [25], [28], [230]		

4.4.2 Urbanisation

The main reason for growing urbanisation is economic development and different factors such as natural population increase, rural-urban migration and conversion, and international migration drive this phenomenon. Urbanisation represents a transformative process that will require differentiated responses according to the challenges and opportunities that cities face. According to recent studies, two trends have been identified related to the Urbanisation megatrend: densely populated areas and smart cities.

4.4.2.1 Densely populated areas

Considering that more than 80% of global GDP is generated in cities, densely populated areas need to be properly managed to contribute to sustainable growth through increased economic activity, employment and wealth. Cities represent the centre of innovation however they also represent attractive destinations for migrants who experience political discontent and crime. Megacities, in particular, face specific challenges due to their huge dimension, including resource supply (e.g., water and energy), pollution and waste management, and security.

Today, 55% of the world's population lives in urban areas; this quote is expected to increase to 68% by 2050 (about two-thirds of the global population), accounting for 6.7 billion people [244] with nearly 90% of this rise taking place in Asia and Africa [245]. In particular, Africa is the least urbanised, but most fast urbanising country. The urbanisation process is more advanced in the world's developed regions where currently 79% of the population resides in urban areas and this quote is projected to reach 87% by 2050 [246] as, for example, in Northern American, European and also Latin American countries (see Figure 49) [205].

Figure 49: Inhabitants living in Urban areas, 2020 and 2050 (% of total population). [205]

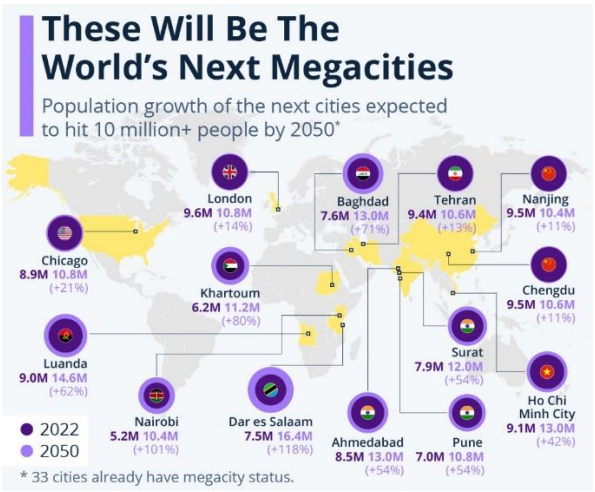


Figure 50: Population growth of the next cities expected to hit 10 million+ people by 2050. [247], [248]

In developing regions, showing the fastest rate of urbanisation, the population share currently living in urban areas is 52% and will increase to 57% by 2030 and to 66% by 2050 [249]. The number of megacities, which are defined as metropolitan areas with a population of more than 10 million inhabitants, will increase from 33 in 2022 to 43 in 2030, mainly in developing regions [250], and 47 in 2050 (please see Figure 50) [248].

Anyway, it has to be underlined that almost half of the urban populations now reside in cities of less than 1 million people [246], while only about 1/8 of world urban people (just over 500 million) live in megacities globally and this share will not exceed 8% of the global population in 2030 [248]. Future urbanisation will indeed principally occur in small and intermediate cities of 500,000 to 1 million inhabitants that represent the fastest-growing urban agglomerations, with twice the pace of growth of the megacities. This trend characterizes also European countries and will stay stable in 2030: most citizens already live in cities between 100,000 and one million and only 7% resides in cities larger than five [251]. Finally, it is important to highlight that even if cities represent just 2% of the world's land surface, related activities impact more than 75% of the earth's resources, consuming 89 billion tonnes by 2050, and will account for 70% of the world gross domestic product and 35% of GDP growth [252].

4.4.2.2 Smart cities

The smart city represents a key policy paradigm for technology-driven urban innovation and development. Smart cities, through the adoption of digital technologies such as IoT, Big Data, smart grids and Autonomous vehicles, are designed to improve urban life, enhance citizens' well-being, and provide more efficient, sustainable and inclusive urban services and environments, to enable the creation of a citizen-centric society. Considering that cities are responsible for more than 60% of greenhouse gas emissions and 78% of global energy consumption, technological innovation has an essential role towards sustainable urbanisation.

The smart city trend is highlighted, in particular, by the fast growth in the global market of the request for smart city technology. Indeed, the demand for smart city systems and solutions is projected to rise annually by 25%, with an overall market value of about US$517 billion [246]. The global smart cities market is expected to account for 1380.21 billion U.S. dollars by 2030 (see Figure 51) [253]. The projected global revenue for smart city technologies, products, and services is forecasted to reach 89 billion U.S. dollars in 2023. In particular, the growth in cities' smart technology adoption is characterized by the strong demand for IoT technology, with a forecast for the years to come of more than 20% of annual growth. In the same way, blockchain technology is expected to increase by more than 30% [246]. By 2028 is projected that there will be more than 4 billion connected IoT devices in commercial smart buildings. Moreover, thanks to the rise of autonomous driving in Smart cities it is expected that by 2040 about 80% of kilometres travelled in cities will be in shared autonomous vehicles [254]. Depending on different factors such as customer acceptance of shared mobility and regulations, and the progress of technology, spending on shared-mobility services could rise to $500 billion to $1 trillion in 2030 [255]. For what concerns EU regions, according to a recent survey on smart-city development involving 550 city representatives from 10 European countries, 88% of participants reported having already started a digital transformation journey. Moreover, 70% of included cities are planning to invest in smart solutions and half of them will spend between 2 and 10 million Euro [256]. To support European cities in the transition to becoming climate-neutral by 2050, the European Commission launched in September 2021 the Mission for 100 climate-neutral and smart cities by 2030 as experimentation and innovation hubs [257]. Selected cities [258] are represented in Figure 52.

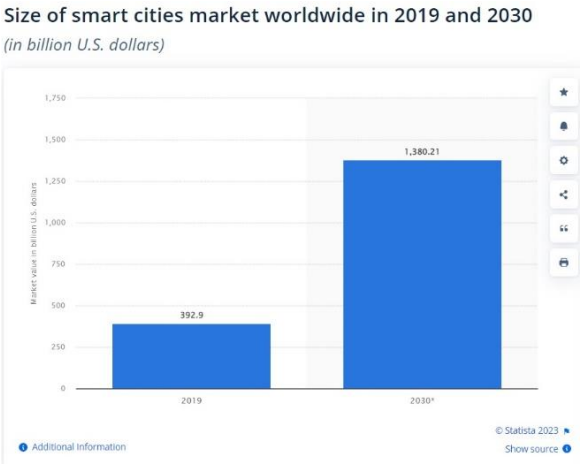


Figure 51: Global smart city market 2019 – 2030. [253]

Figure 52: 100 cities participating in EU Mission for climate-neutral and smart cities by 2030. [258]

4.4.2.3 Risks for supply chains from urbanisation

Nowadays, supply chains have to cope with several risks linked to urbanisation-related trends (see Table 10 for the entire list of trend-specific risks). According to the sustainability dimensions, urbanisation-related risks investigated in the literature impact the economic, social, and environmental dimensions of sustainability.

Based on the literature and experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Lack of ad-hoc regulation*. Regulation brings a number of risks for supply chains when related to urbanisation. For example, in the adoption of block chain technologies, the lack of regulation represents a serious issue in understanding how to manage them [259], [260] while in using drones for last-mile delivery the current regulation restricts their full exploitation as a means to decrease transportation costs [261]. Moreover, the growth of densely populated areas also requires ad-hoc policies and related regulations. For example, the missing ad-hoc regulation may not facilitate logistic activities development in urban areas [262].
- *Increasing network complexity*. Due to urban areas always being more densely populated and to the hyper-connected smart cities solutions, increasing network complexities emerge bringing with them a number of risks for supply chains.
  Regarding densely populate areas, the risks may be derived from complexities in demand (such as demand fluctuations and changes in demand [263], [264]), complexity in delivery operations (such as few just-in-time [265] and late deliveries [266], [267]), complexities in logistics (such as

losses [268], transport spoilage [269] and disconnections between cities and countryside [270]) and complexities in space allocation (such as difficulties in finding spaces for the final disposal of waste [271] and in findings parking for freight vehicles [266]).
Moreover, common to both urbanisation-related trends are the complexities generated in managing and sharing information in the network. On the one hand, in densely populated areas this determines risks such as missing information sharing between companies [263], [265], [267] and lack of transparency [270]; on the other hand, in smart cities numerous risks related to technologies integration emerge, such as interoperability [259].

- *Security and privacy issues*. Nowadays, risks related to the security of stored and shared data [272], and privacy issues [259], [260] are growing with the increase of technology adoption. Among these, there are risks related to cyber-attacks [273], and risks related to the openness of data which may affect technology adoption for not sharing confidential data [272]. There is, thus a trade-off between transparency and privacy [260] that has to be accounted for.
- *Reliance on non-skilled/semi-skilled labour*. Small or individual players rely on low-skilled workers, however, even if the labour cost is low, it affects the efficiency of operations in supply chains [265].
- *Technology implementation limitations.* The risks for supply chains related to technology implementation emerged with the increase in the number of new technologies that can be used to favour supply chain processes. As examples of these risks, in the literature scalability [259], [274], [275], reliability of data [272], throughput [260] and storage [259], [260] issues related to the amount of data emerged. Moreover, also the cost of implementation may represent a barrier to technology implementation [260].

Besides the economic dimension, the risk of poor working conditions affects directly the social dimension of sustainability as follows:

- *Poor working conditions*. In delivery operations, workers had to work frequently over time and this affects the workers' well-being [267]. Moreover, the adoption of new technologies affects the tasks of workers in some cases by deskilling them due to, for example, the automation of some procedures [272].

Finally, the increase in urbanisation around the world determines a well-known risk for supply chains, i.e. pollution and poor energy efficiency that directly affects environmental sustainability as follows:

- *Increased pollution and poor energy efficiency*. Regarding densely populated areas, pollution represents an important issue that has a huge impact on environmental sustainability. Notwithstanding new truck restriction policies and in general the environmental policies to reduce emissions and air pollution, there is a risk of an increase in air water and soil pollution, and CO2 emissions due to the complexities related to the densely populated areas. Moreover, if the distance between rural and urban areas continues to increase, also this can generate new emissions due to transport, deriving for example in an increase in the food mile [269] (i.e., the indicator to evaluate the distance between the harvest and the sellers of food products).
Finally, although the great emphasis put by technologies on energy efficiency, redundant consensus mechanisms of some technologies, e.g., blockchain, generate high consumptions of electricity [259], [260].

According to experts' validations and comments collected during the workshop, most of the validated supply chain risks from urbanisation may have a high probability to occur and they may cause a moderate to very high level of impact on supply chains.
The experts validated poor working conditions as the only risk with a moderated probability to occur and a moderated impact. However, they consider security and privacy issues and non-skilled or semi-skilled labour respectively as very highly probable with a high impact on supply chains and as very probable with a very high impact on supply chains.

Table 10: Risks for supply chains related to each trend of urbanisation.

	Urbanisation-related risks	
Risk categories	Densely populated areas specific risks	Smart cities specific risks
Regulatory issues	- Lack of ad hoc regulation for managing the business in densely populated areas [262]	- Limit the adoption of some technologies [261] - Lack of ad hoc regulation for using smart cities technologies [259], [260]
Increasing network complexity	- Complexity in demand: demand fluctuations, changes in food demand of food products [263]; changes in consumers' demand (increase in smaller, more convenient sizes of food products, and healthier food products [264], low quantities, high variety products and direct delivery to their homes with minimal costs [263], [265]); and changes in consumer needs due to multi-ethnicity of megacities inhabitants [from the workshop] - Complexity in delivery operations: low inventory levels and fewer just-in-time deliveries [265]; freight theft due to criminality [267]; late deliveries [266], [267]; - Complexity in logistics: losses due to traffic in perishable food transport [268]; disconnection between cities' food supply systems and the countryside, which leads to the passage through several intermediaries [270]; difficulties in food energy water provision [276]; increase the period between harvest and purchase in food SC with potential transport spoilage [269] - Complexity in space allocation: increasing in urban traffic, and difficulties in finding parking spaces for both passenger and freight vehicles [266]; difficulties in finding spaces for the final disposal of waste [271] - Complexity in information management: Lack of information sharing and coordination between companies/partners [263], [265], [267]; lack of information sharing for detouring, load/unload interfaces (e.g., lack of parking, loading/unloading areas) [277]; lack of transparency in food supply chains [270]	- Complexity in information management: numerous interactions between stakeholders with competing goals [278], redundant transportation networks due to integration between Big Data, SC and smart city [278]; integration between information systems of different actors [272]; the presence of numerous distributed ledgers that limit the adoption of block chain technology in large organisations [279]; interoperability [259]; incentive mechanisms to encourage the data verification between the nodes [259], [260]
Security and privacy issues		- Cyber attack-related risks [273] - Security and privacy issues [259], [260] - Openness of block chain-based platforms that make data available to anyone in the network [272] - Trade-off between transparency and privacy [260] - Data security [260] and security in data storage [272]
Reliance on non-skilled/semi-skilled labour	- Reliance on non-skilled/semi-skilled labour that affects the efficiency of operations [265]	
	-	

	Urbanisation-related risks	
Risk categories	Densely populated areas specific risks	Smart cities specific risks
Technology implementation limitations		- Scalability [259], [274], [275] - Reliability [272] - Throughput [260] and storage [259], [260] issues - Costs [260]
Poor working conditions	- Overtime work in delivery operations [267]	- Deskilling for workers [272]
Increasing pollution and waste, and poor energy efficiency	- CO2 emissions and air pollution [265], [277] - Increasing in the food mile [269] - Pollution due to waste movement [271] - Waste of resources (in waste management area) [271] and food [263]	- High energy consumption due to poor energy efficiency in the blockchain consensum mechanism [259], [260]

4.4.3 Consumption patterns

The consumption patterns megatrend refers to the evolution and shifts of consumers spending habits and their related impacts on global economy and society. Multiple drivers are reshaping consumer values and buying behaviours affecting specific business and growth opportunities for supply chains. This megatrend is associated to three main trends: consumer consciousness, consumerism and individualization.

4.4.3.1 Consumer consciousness

Consumers, in particular younger generations, show an increasing concern about how their own consumption impacts society at environmental, social, and governance (ESG) levels. As the attitude of consumers towards sustainability is growing, supply chains are consequently pushed to review their practices through all the different phases of product manufacturing and sales. Product traceability is thus getting significant and consumers tend to prefer brands that provide them with added information on products and services with full transparency about the sourcing and supply chain, enabling them to consume more consciously through sustainable choices.

According to a recent global research commissioned by World Wide Fund for Nature (WWF), in the last five years, there has been on the web a rise of 71% in the searches for sustainable goods and this trend has grown steadily during the COVID-19 pandemic [280]. Environmental, social and governance (ESG) funds are also receiving the best-ever inflows and are expected to account for $50 trillion by 2025, signifying more than 30% of total assets [281]. Attitudes towards sustainability differ across generations: usually, younger consumers give priority to social issues such as diversity and inclusion, while mature consumers focus on health and environmental aspects [282]. For example, a survey on Dutch consumers revealed that, although rising inflation, 40% of interviewed are willing to pay more for sustainable products and brands, in particular, Gen Z and Baby Boomers (43%) and generally higher income consumers (more than €50,000). About 50% of consumers increasingly pay attention to sustainability when purchasing. Moreover, 60% (70% for Gen Z) declared they would buy recycled or refurbished products [283]. As shown in Figure 53, a survey from PwC confirmed this trend reporting that about 58% of core (aged 27-32) and “young” (23-26) millennials affirm that they consciously consider sustainability while they shop. This percentage is 10 to 20% higher compared with responses provided a couple of years before (2019) [284]. Relevant trade-offs between sustainability and cost are also highlighted in [285] where in 18 of the 20 countries studied, higher-income consumers were more willing to buy sustainably. In some countries such as Japan, the gap was particularly significant: 20% of lower-income consumers bought a sustainable product with respect to 45% of higher-income. Several brands are setting sustainability targets. In the fashion sector, for example, H&M declared that by 2030 will use 100% recycled or sustainable materials [286] and aims to be climate positive by 2040. Stella McCartney also committed to using 100% recycled polyester by 2025 [287].

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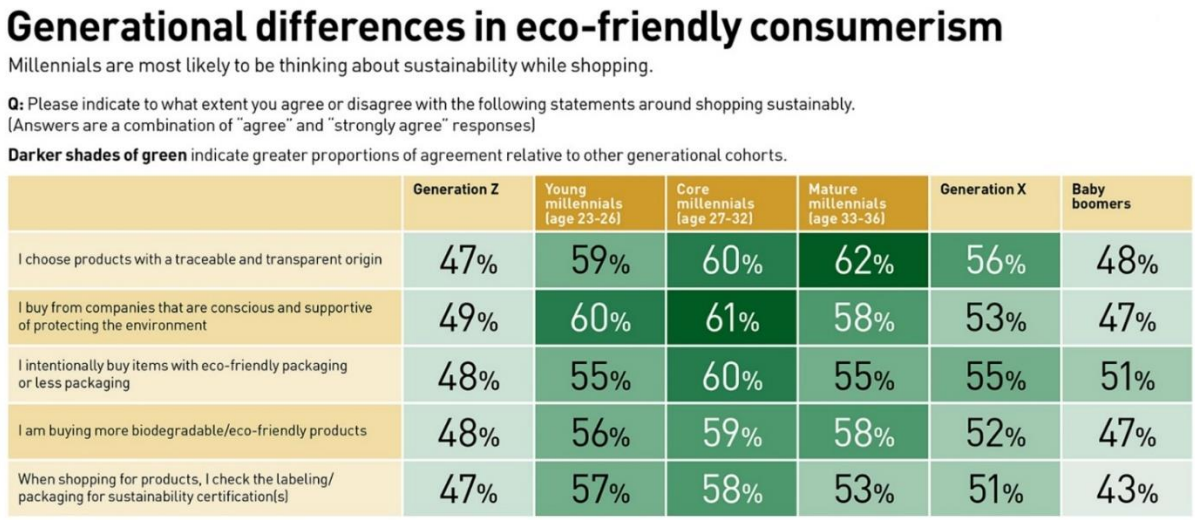

Generational differences in eco-friendly consumerism

Millennials are most likely to be thinking about sustainability while shopping.

Q: Please indicate to what extent you agree or disagree with the following statements around shopping sustainably. (Answers are a combination of "agree" and "strongly agree" responses)

Darker shades of green indicate greater proportions of agreement relative to other generational cohorts.

	Generation Z	Young millennials (age 23-26)	Core millennials (age 27-32)	Mature millennials (age 33-36)	Generation X	Baby boomers
I choose products with a traceable and transparent origin	47%	59%	60%	62%	56%	48%
I buy from companies that are conscious and supportive of protecting the environment	49%	60%	61%	58%	53%	47%
I intentionally buy items with eco-friendly packaging or less packaging	48%	55%	60%	55%	55%	51%
I am buying more biodegradable/eco-friendly products	48%	56%	59%	58%	52%	47%
When shopping for products, I check the labeling/ packaging for sustainability certification(s)	47%	57%	58%	53%	51%	43%

Figure 53: Generational differences in eco-friendly consumerism. [288]

4.4.3.2 Consumerism

Consumption patterns such as consumerism are constantly relevant in shaping global supply chains due to the concurrent middle-class growth, especially in emerging economies, the rise in business models targeting low-income consumers [289] and the growth of real-time micro trends. Recently a generation of ultrafast-fashion brands has emerged, with even more relevant implications in terms of impacts.

The recent, increasing rise of inflation prices represents the major concern for 58% of European consumers, compared to 53% one year before. This pattern is almost steady across countries, and related shopping behaviour changes towards brands and retailers offering better value are mostly touching young generations as Gen Z and millennials [289]. The sectors that are projected to be most affected in 2023 are Luxury and premium products, travel, and fashion with 90% of consumers adopting cost-saving behaviours and 69% narrowing non-essential purchases [290]. In the grocery sector, for example, 60% of consumers changed stores and essentials brands, 72% of them switching to lower-cost products in the last months [289]. According to a recent survey, more than 70% of Dutch consumers (almost 80% of Millennials and Gen Z) would choose the cheapest product although it's not sustainably sourced or produced [283]. In line with this tendency, 45% of fashion executives reported that will update their product mix to adapt to lower consumer purchasing power. Consumerism particularly affects some industry sectors such as fashion, increasing the request for affordable and stylish products with significant effects at social and environmental levels. Therefore, in the fashion sector, in order to meet the demand for new styles, especially from younger consumers, fast and ultra-fast fashion players are continuously increasing their inventory turn realizing annually billions of garments to provide their consumers with the latest trends [291]. Indeed, the core business model of fast fashion brands, such as H&M and Zara, is driven by low prices, rapid

consumption and fast-changing trends appealing to consumers with cheap, stylish and mass-produced clothes [292]. The growth of cheaper, ultra-fast fashion brands such as Boohoo, Pretty Little Thing and Shein has even more accelerated this consumerism pace with serious implications in terms of impacts [293]. In particular, the Chinese fashion player Shein, recently valued at $100bn, reaching the value of Zara and H&M combined [294] together introduces more than 6,000 new products per day in limited units to its website reaching almost 315,000 styles this year alone [291]. Considering that global fashion is the second-most polluting industry after oil one garbage truck of clothes is dismissed every second [292], critics from different actors underline that such mass production pushes consumers to renew their wardrobes nonstop [295] and promotes the idea that clothes are disposable encouraging extreme waste [292]. As an example, more than 50% of fast fashion items are thrown away in less than a year. Moreover, environmental issues are also worsened by multiple ethical concerns [293]. At this rate, the fashion industry will increase water usage by 50% by 2030 [296] and use nearly 25% of the world's carbon budget by 2050 [293]. Due to this, in 2022 the European Commission adopted a new EU strategy for sustainable and circular textiles in order to end fast fashion by 2030 [297].

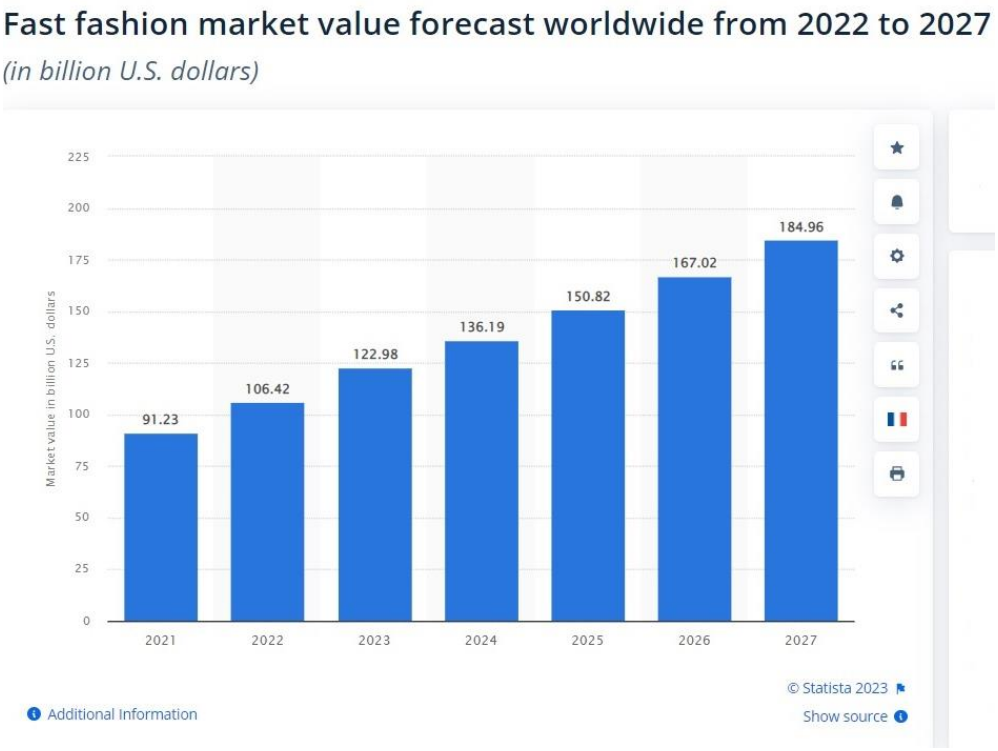

Figure 54: Fast fashion global value forecast 2022-2027. [298]

4.4.3.3 Individualisation

Individualization is one of the current trends in product development and purchase. Nowadays customers do not want to be considered anymore as part of a customer group but perceived and treated as individuals [299]. Therefore, meeting the needs of individual consumers is more important than ever and individualization is expected for more and more products and services together with a personalized experience in the shopping phase extending individualisation also to sales and marketing [300]. According to recent surveys, 71% of consumers expect personalization from the brands they purchase from and 72% assume those brands identify them as individuals and know their interests. Personalization also affects the tendency to recommend and repurchase (78%). Moreover, firms that exploit personalization at best create tailoring their product and service offer to the right individual at the right moment with the right experience 40% more revenue than their

competitors [301]. Data mastery has enabled brands to unlock personalised experiences that are essential to build deeper customer relationships [291] and currently, the early involvement of customers in the production process is applied in both B2B and B2C [302]. As an example, Nestlé involved 100.000 consumers in a pilot project in Japan offering to provide personalized nutrition to those who send the company a DNA sample [303]. Nike has also embraced personalization to deliver individual products by enabling customers to configure their own clothes and shoes. The brand launched a 3-D sneaker-customization platform that allows creation of real-time snapshots of finished footwear [300]. Digitalization is increasingly playing a central role in the ability to deliver personalized products and services. 78% of companies are already planning or adopting personalization initiatives and pilots, moreover, 34% of brands are pursuing fully individualized manufacturing approaches, aiming to realize lot-size-one or individualized products [304]. The so-called hyper-personalization thus further enables custom experiences, through data analytics, AI, and automation [305]. Therefore, the future shopping experience will be more individualized and technology-driven, leveraging technology such as AR and VR to create unique customer experiences, and have then product personalized and rapidly delivered at home [306].

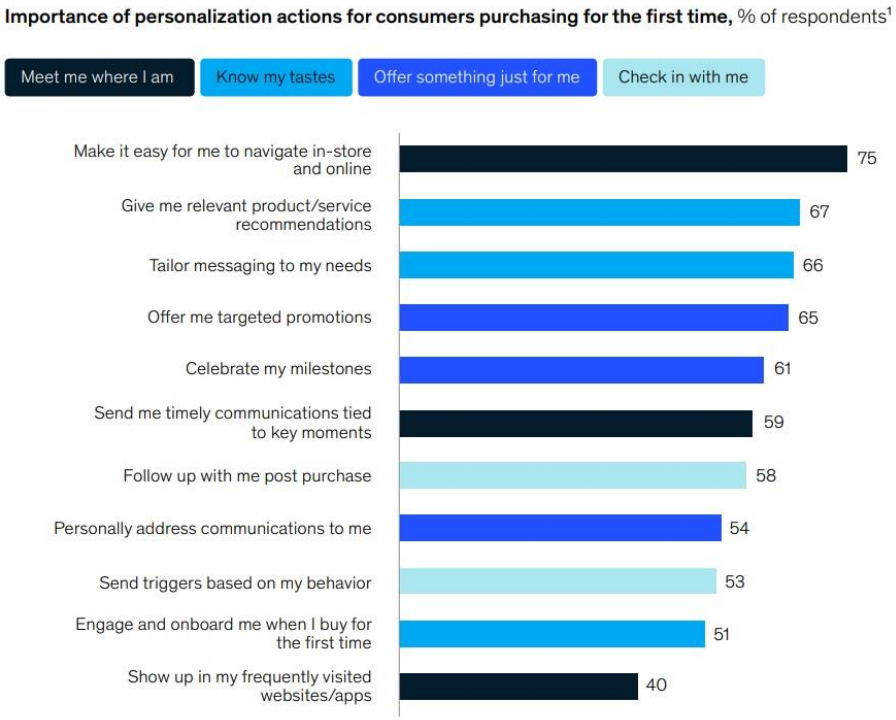

Figure 55: Importance of personalization actions for consumers. [301]

4.4.3.4 Risks for supply chains from consumption patterns

Nowadays, supply chains have to cope with several risks linked to consumption patterns-related trends (see Table 11 for the entire list of trend-specific risks). According to the sustainability dimensions, consumption patterns-related risks investigated in the literature impact all three dimensions of sustainability, mainly on the economic dimension.

Based on the literature and the experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Continuous re-adaptation of the supply chain network*. Consumption patterns-related trends generate risks related to the need to continuously re-adapating the configuration of supply chain networks [307]–[323]. Among them, one of the main risks for supply chains belonging to all consumption patterns-related trends is the selection of suppliers that may cause difficulties in incorporating reverse logistics [307], may endanger the sustainability of the supply chain [314], or may cause difficulties in the production processes [317]. Other risks associated with supply chain configuration refer to: the number of manufacturers that may cause collusion between partners [308], the design of the network between supply chain actors which determines risks related to perishability in agrifood supply chains [310], the increasing in delivery times [313], new challenges in distribution due to the presence of grey market [316], and risks related to collecting mode of used customized products in closed loop supply chains [321]. Finally, another issue related to individualization is proximity sourcing which impacts the economic dimension of sustainability by limiting the material availability and industry competence and by increasing lead times [318].
- *Lack of information sharing and traceability.* The lack of information sharing and the consequences it generates has been stressed by all three trends (i.e., consumer consciousness, consumerism, and individualisation). The risk refers to the suppliers-focal firms' relationship [314], [324], or to brands and supply chain partners where it may affect efficiency in production and among upstream and downstream suppliers' tasks [325]. Moreover, the lack of information sharing makes supply chains vulnerable in their relationships with consumers: it may affect consumers' confidence in products [326], consumers' awareness of sustainable processes [324], or consumers' needs [325]. Finally, the lack of traceability systems decreases trust and transparency about the quality of products [309]. As investigated in [310], [318], the lack of spreading information can be generated also by the lack of digital capabilities to manage a large amount of data.
- *Lack of stakeholder involvement*. Regarding consumer consciousness and consumerism, the lack of stakeholder involvement can make supply chains vulnerable. Concerning the consumer consciousness trend, the lack of stakeholder involvement is needed to increase the demand and create redistribution markets [309], [327] and increase consumers' willingness to pay [260], [328]. Finally, concerning consumerism, the lack of stakeholders' involvement affects the shift towards sustainable processes [311], [329], [330] and the decreasing level of tolerance related to nonconformities [313].
- *Demand variability*. The risks are mainly related to the individualisation trend; however, it is determined also by conscious consumers and it may generate inventory excess or shortages among downstream supply chain actors and it may result in the bullwhip effect among upstream supply chain actors [331]. Besides, related to consumerism, demand variability determines a poor capability of forecasting [312].
  Pushed by the individualisation trend, this supply chain categorisation of risks determines a high level of customer need diversity [332], increasing product complexity [333], small volume order quantities [318], increased production costs and lead times [325] high production costs and long completion times [317]. Some scholars underlined the related issues of consumers' time-sensitive behaviours [334], poor capabilities in inventory management [335], and risk attitudes of the manufacturer and the consumers [334], which may cause variability in customized product demand.

The risks which have an impact related to the social dimension concern mainly the required capabilities to make the supply chain socially sustainable. The main risks have been clustered as follows:

- *Lack of interest in working conditions.* It is pushed by the consumerism trend. While in recent years environmental issues are stressed, consumers care less about the vulnerability and the working conditions of humans over supply chains [311]. Some scholars highlight the lack of consumer interest in labour exploitation [336] and welfare [328]. Safety [311], pricing and fairness issues [337] in supply chains are still an issue that makes them vulnerable.

- *Difficulties in introducing social sustainability within supply chains.* This categorisation of risks relates to consumer consciousness and consumerism. It refers to the risks related to improving or introducing social sustainability within the supply chains [309], [314], [315], [324], [329], [330]. Among the risks, there is the lack of managerial capabilities which affects the dissemination of sustainability standards along a supply chain [324], the lack of trained employees in order to introduce the circular economy in the textile sector [329], the lack of technological capabilities [315], and the lack of knowledge and information on circularity in the Textile Supply Chain [329].

Finally, the categorisation of supply chain risks associated with the environmental dimension of sustainability relates to the required capabilities to make the supply chain environmentally sustainable. The main risks have been clustered as follows:

- *Difficulties in introducing environmental sustainability within supply chains.* This categorisation of risks relates to consumer consciousness and consumerism. It refers to the risks related to the introduction of environmental sustainability within the supply chains [311], [329], [338]. Among the risks, there is the risk of closing down an unsustainable organisation within the supply chain [338], the difficulty in accounting for negative environmental externalities and in separating materials [329]. Moreover, the changes of consumer patterns that determines a high level of demand variability (small volume orders, long delivery times, etc.) impact also on the environmental dimension of sustainability. They increase the number of deliveries and, as well as in urbanisation-related risks, they may increase the pollution levels.

According to experts' validations and comments collected during the workshop, all the identified supply chain risks from consumption patterns generate a high impact on supply chains. However, they differentiate for the probability to occur. On the one hand, the risks related to sustainability introduction, the lack of information sharing and traceability, and the risks related to the supply chain network configuration and demand variability are expected to be very highly and highly probable; on the other hand, the risks related to the lack of interest in working conditions and the lack of stakeholder involvement result to have a moderated probability to occur.

Table 11: Risks for supply chains related to each trend of consumption patterns.

	Consumption patterns-related risks		
Risk categories	Consumer consciousness-specific risks	Consumerism specific risks	Individualisation specific risks
Continuous re-adaptation of the supply chain network	- Selection of suppliers [307] - Manufacturer collusion in the two-echelon green supply chain [308] - Lack of a sufficiently large number of manufacturers [308] - Lack of distributors and partners' remuneration as per support towards sustainable practices [309] - Related to AgriFood supply chains: fresh food perishability, production seasonality, variability in quality and quantity, and transportation requirements [310]	- Lack of fast and effective decision-making [311], [312] - Raw materials, components and geographical factors: they generate an increase in delivery times [313] - Short life cycles of goods [313] - Low inventory targets [313] - Selection of suppliers [314] - Lack of on-shoring production and collaboration with retailers [315] - Presence of grey market [207]: it affects the official distribution channel strategy	- Supplier selection and scheduling [317] - Trade-off between different priorities [318] - Customer-Order Decoupling Point positioning [319], [320] - Supplier dependence risks due to limited supplier alternatives [318] - Lack of proximity to consumers [318] - Lack of readiness in mass personalization: it determines high production cost of complex designs [323] - Increase in uncertainties in mass personalization processes due to the growing number of suppliers, personalized materials, and personalised production processes [322] - Pricing issues related to collecting mode of used customized products [321] - Proximity sourcing issues [209], e.g., limited industry competence, material availability and long lead-times
Lack of information sharing and traceability	- Lack of capabilities to manage high volumes of data [[310] - Supplier responsibility risk [339], i.e., the lack of sharing private information - Limited information with consumers [324] - Lack of consumers' confidence in products [326] - Consumers' scepticism towards CSR [340] - Inadequate traceability systems [309], [310], [341] - Lack of transparency and trust [326]	- Lack of information sharing with consumers [329] - Sustainability risks associated with lack of transparency with suppliers [314] - Lack of supply chain transparency [337] - Lack of information sharing in the distribution network: it brings distribution network issues and lot sizing issues [342]	- Disrupted information or long and complex procedural flows: affect production efficiency, the ability to cope with changing demands, and reduce suppliers' efficiency in fulfilling their tasks [325] - Untimely information transmission between brands and consumers [325] - Lack of efficient collaboration to facilitate information sharing among supply chain partners [323] - Data security and cost challenges with customer integration [318] - Lack of digitalization capabilities to deal with data management and security [318]
Lack of stakeholder involvement	- Lack of consumer interest in creating collaborative fashion consumption, redistribution markets to cater to responsible consumers, education of consumers and improvements in consumer footprint [309] - Consumers' willingness to pay [328], [343] - Lack of consumers' EPR awareness of recycling [327]	- Shift of responsibility from brands to consumers [311] - Social and environmental criticism towards fashion retailers [330] - Decreasing the level of tolerance of consumers related to non-conformities in the supply chain [313] - Lack of regulation to introduce a circular economy [[329] - Difficulty in aligning and motivating stakeholders [329] - Problematic consumer attitudes from lacking awareness [337]	
Demand variability	- Inventory excess or shortage due to consumers' reactions to a CMC (cause-related marketing campaign) [331] - Increased variability in the order size due to consumers' reactions to a CMC [331]	- Poor forecasting due to variability in consumer demand [312]	- High level of customer need diversity that influences operational coordination and organizational agility [332] - Increase in product complexity and value premium of products [333] - Limited development and expansion [318]
	-	-	-

	Consumption patterns-related risks		
Risk categories	Consumer consciousness-specific risks	Consumerism specific risks	Individualisation specific risks
Demand variability			- Small volumes-related risks (minimum order quantities, costs, and volumes) [318] - Increasing in product variety and uncertainty [334][331] - Time-sensitive behaviours [334] - Increased production costs and lead times [325] - High production cost and long completion time [317] Poor capabilities in inventory management [335]
Lack of interest in working conditions		- Lack of consumer interest in workers' exploitation [336] and welfare [328] - Prioritization of circularity at the expense of vulnerable workers' welfare [311] - Unsafe working conditions [311] - Pricing and fairness issues [337]	
Difficulties in introducing social sustainability within supply chains	- Lack of ethical sourcing [309] - Lack of managerial effort and extra costs for the dissemination of sustainability standards along a supply chain [324]	- Need to be prepared for EPR legislation [330] - Failure in the extension of sustainable strategies and practices to other supply chain partners [314] - The lack of knowledge and information on circularity [329] - Lack of trained employees in order to introduce a circular economy [329] - Lack of technological capabilities [315] - Lack of capital to invest in new infrastructure [329]	
Difficulties in introducing environmental sustainability within supply chains	- Risk of SC disruptions [228] due to the closing down of unsustainable organisations	- Complexity of separating materials from different garments and technological obstacles in order to introduce a circular economy in the textile sector [329] - Failure to address issues at earlier stages of supply chains, such as chemical inputs [311] - Difficulty of accounting for negative environmental externalities in the Textile Supply Chain [329]	- Increase in the number of deliveries due to high level of demand variability that generates an increase in the pollution levels [derived after the workshop]

4.4.4 Digital society

"Digital society" megatrend captures both the digital natives i.e., young people born into the digital age are assumed to be technology-oriented [344] and digital immigrants i.e., people who had learnt to use computers at a stage in their adult life [236]. The trends in this megatrend can be categorised as: change of purchasing patterns, change of communication patterns, and reshaping the workplace.

4.4.4.1 Change of purchasing patterns

Consumer behaviour has changed drastically over the last years, especially after Covid-19, and consumers developed the habit of purchasing more products and services online. Digital technology enabled an environment for consumers to shop online easily [345]. Moreover, social media and social platforms such as WeChat made it possible for the consumers to buy their favourite products even quicker [346]. Due to changes in the purchasing patterns of the consumers, companies are trying to increase the diversity of the services they offer in the marketplace. For example, Walmart announced its partnership with Shopify and TikTok to provide their users the ability to shop directly from Walmart fashion without leaving the application [239]. Online buyers (87% of individuals are 25-34 years) were 75% in the EU in 2022, an increase of 20% over the last 10 years see Figure 56.

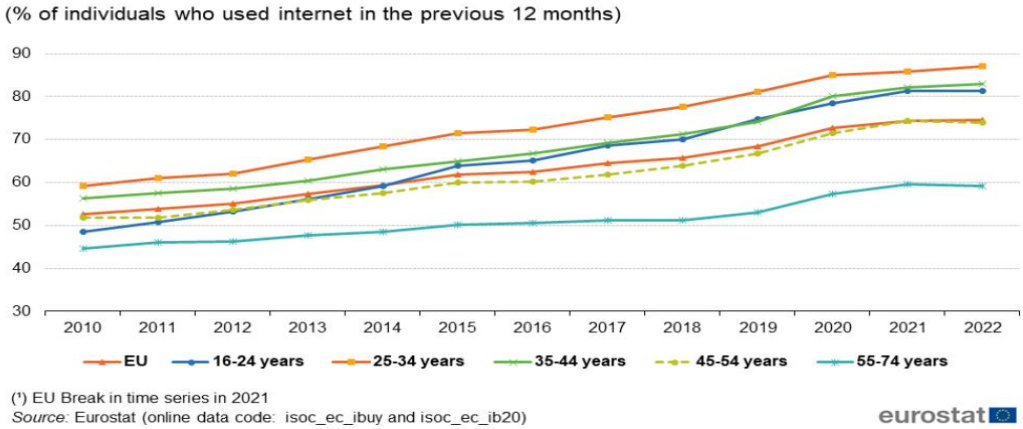

Figure 56: Internet users who bought or ordered goods or services for private use in the previous 12 months by age group, EU(¹), 2010-2022. [347]

Apart from the B2C transactions, the same pattern is followed in the B2B transactions. Gartner analysts suggest that, the B2B sector are more willing and likely to rely on digital sales channels of the platforms such as Amazon, Alibaba, and Exporthub [348].

Finally, it is significant to state that personal computers and laptops are not the only popular technological devices that consumers are buying from. According to [242] smartphones are widely used for shopping in Europe and the rate of using smartphones is more than doubled in a few years in many countries (Figure 57).

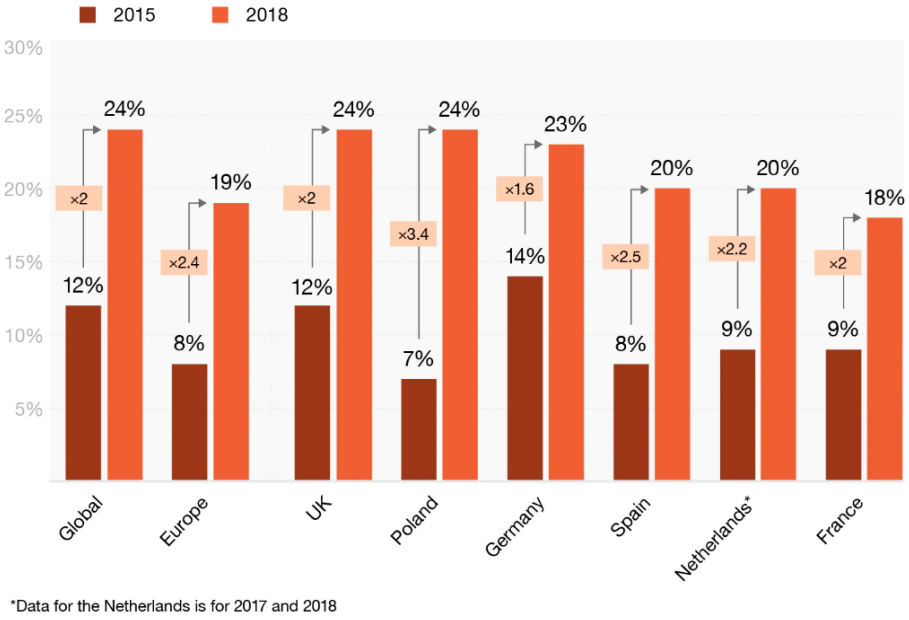

Figure 57: Use of smartphones in shopping in EU. [349]

4.4.4.2 Change of communicating patterns

This trend is analysed from two perspectives which are workers and consumers. For workers, organisations should think about technology while designing the working environment and creating virtual workplaces. Employers' tech preferences affect how they handle themselves while communicating and working with others, and how they work most effectively. 73% of the companies are expected to have remote workers by 2028. Virtual workplaces, supported by technology and innovation, will become more important and desirable in the following years [350].

Being mobile while working is enabled by modern information and communication technologies [351]. These virtual tools go beyond e-mail, chat, and video functions to include various management systems (e.g., knowledge and customer relationship management) and collaboration software which provide and enhance real-time access to shared information, synchronous data communication, and virtual teamwork environment [351]. Moreover, these tools are now being used more and more in our daily lives. According to a March 2021 survey of working adults worldwide [245], 46 percent of respondents regularly used Zoom both at work and in their private life. Microsoft Teams followed in second place, with 29 percent of respondents indicating they used the platform for communication purposes whereas Skype ranked third (Figure 58).

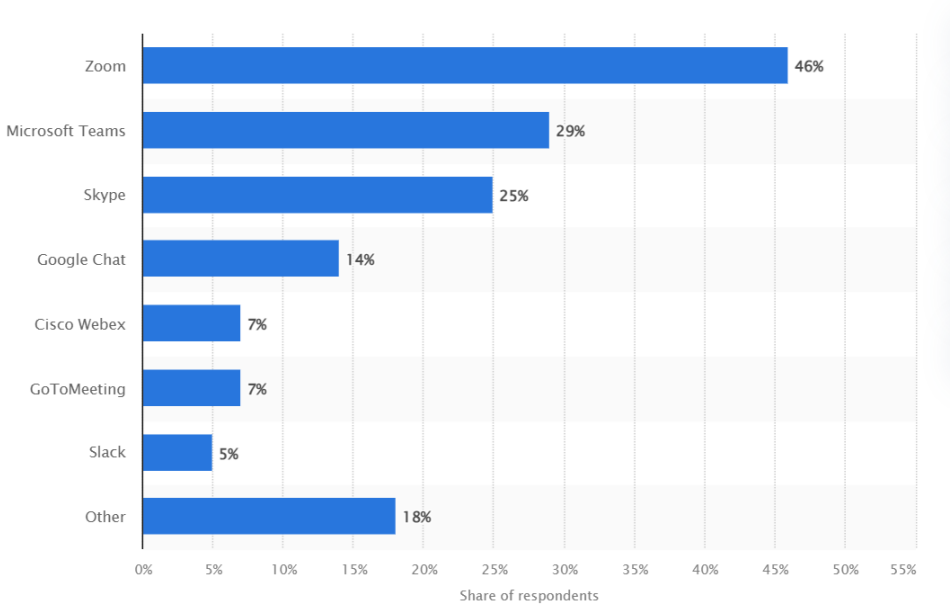

Figure 58: Virtual tools in use by the working adults. [352]

Further, studies predict that 25% of people will be spending more than an hour a day in the metaverse by 2026 either for shopping, work, education, social purposes, or entertainment [353]. Therefore, development teams in metaverse platforms are expanding and refining their applications about workforces and optimising their efficiencies. It is anticipated that by 2030 5B people will interact in the metaverse platforms and the value of the industry will be $8T-$13T [354]. Employers are using the metaverse to more smoothly onboard employees with virtual human resources applications, training employees on processes or procedures through virtual games and tests, and for improving efficiency through the use of AI to support employee performance. Some companies also benefit from the metaverse through building teams and increasing their level of collaboration [248]. Especially GenZ are quite positive to metaverse, and they believe that at least a part of their work will be in a metaverse environment in the next two years (Figure 59). On the contrary, only 16% of all people surveyed do not believe that they will be working in the metaverse in any capacity in the future (Figure 59).

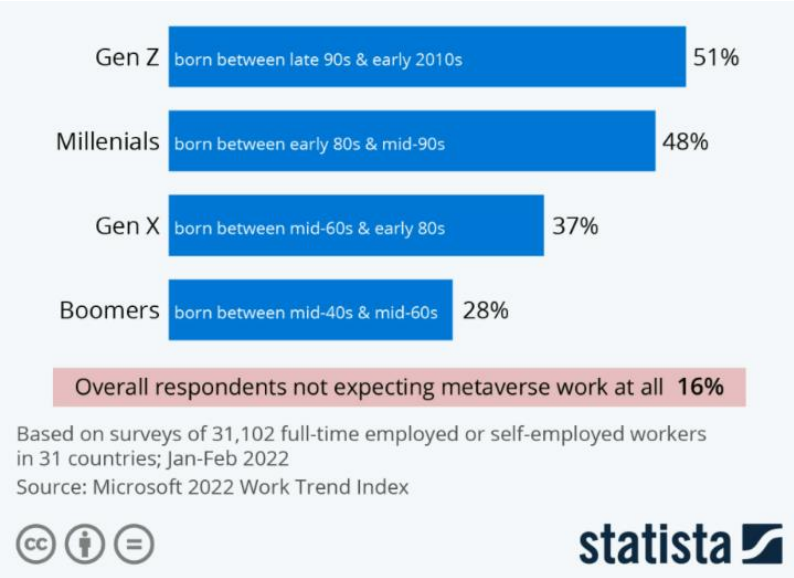

Figure 59: Metaverse work expectations of people from different generations. [355]

From the consumers' perspective, communicating patterns have also shifted a lot with social media. Consumers share their purchasing experience, information on brands, and products on social media sites and a study showed that 54% of social browsers use social media to research products [356], [357]. Moreover, 71% of consumers rely on the information on social media to make their purchase decisions [356]. What consumers seek is honesty while they browse the social media before their purchase decisions. This trust should be built by the company and/or the brand. Companies should develop their image on social media and collaborate with popular social media aspects such as influencers to highlight their products or services [356], [358].

4.4.4.3 Reshaping the workplace

Remote working has become very popular during the Covid-19 pandemic, and a new generation of digital nomads has emerged from the existing workforce [250]. Statistics show that, labour forces in advanced economies tend to spend more time working remotely compared to the employees in emerging economies (Figure 60).

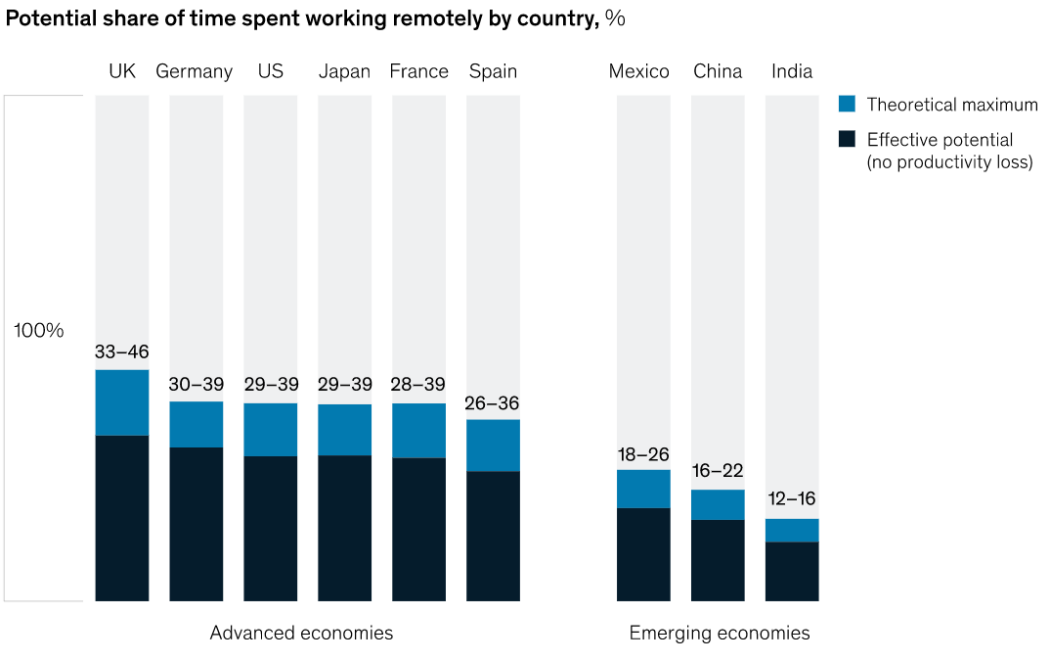

Figure 60: Time spent working remotely by country in percentage. [359]

As technology continues to evolve, it will be likely to see more people working remotely, and there is an expectation to see other ways of working in the near future. MBO Partners estimates that almost 64 million Americans will become digital nomads over the next three years [360]. In conjunction to these facts and estimations, younger workers are now expecting a digital employee experience, ergonomic tools, and job satisfaction. Europe faces an estimated 400,000 shortage of lorry drivers, and a research study on warehouse modernisation strategies revealed that 83% of respondents are increasing or planning to increase their number of employees by 2024 [361].

4.4.4.4 Risks for supply chains from digital society

Based on these trends, the following risks are determined through economic, social, and environmental perspectives. Risks were identified through vulnerabilities of these trends, and then, they are validated and enriched by the supply chain experts in the workshop. Table 12 is developed as an overview of how these risks relate to the trends of the digital society megatrend.

The extant literature and the experts evaluation in the workshop, bring these risks that have an impact on the economic sustainability of the supply chain:

- *Need for channel Integration and change in supply base structure.* As the number of consumers on social platforms increases, the number of consumers in offline channels decreases accordingly. The impact of e-commerce means pressure continues to mount on warehouses, logistics companies and supply chains [362]. Consumers want interconnected and seamless shopping experience. An omnichannel retail strategy provides an integrated and consistent shopping experience across different channels and devices [363]. There is also a need for companies to develop a better supply base structure investing more in returns when setting up omnichannel logistics system. Thus, they should provide easy-to-use product return opportunities from different platforms [364].
- *Inventory management challenges.* In addition, customers expect a product to arrive as soon as possible (e.g., same day or the next day). Therefore, companies need to have the correct amount of inventory of products not to face stock-outs. The most challenging parts of selling across different channels is providing speedy delivery, managing product catalogue across different channels, aligning inventory and delivery of orders, coordinating with suppliers, manufacturers, and third-party logistics (3PL), as well as connecting in-store purchases and pickups with online orders and even international demands [364].
- *Tax and legal risks.* The digital nomad model, where someone works for an employer while based in another country, can present significant challenges for workers and employers as they navigate the immigration, tax, and social security rules of multiple jurisdictions [365].

Further to the economic sustainability risks, there also are risks that affect to the social dimension of sustainability:

- *Data breach.* Organisations have little or no control over the narrative that is shared on these various sites and social media platforms [366]. With a larger remote workforce and a growing amount of information stored, Complying with employment and labour laws, Enforcing rules around health and safety becomes more challenging in a remote setting, for example, while questions of liability stand around issues such as injuries of an employee working remotely at home or damage to personal property that is used to work (such as a personal laptop) [365].
- *Unemployment.* Even though e-commerce has contributed to the creation of new career paths with more technical skills requirements, it also reduced some of the traditional retail jobs [367].
- *Job burnout.* Job burnout is a state of physical or emotional exhaustion, and it also involves a sense of reduced accomplishment and alienation from the goals of the organisation. An evaluation of Microsoft concluded that the shift to remote work caused business groups to become less interconnected. Further to that, 69% of employees working from home are identified to experience symptoms of job burnout [368]. Remote work also reduced the informal collaboration network and caused individuals to spend less time collaborating. As a result, it is expected that the effects that are observed on workers' degree of collaboration and communication patterns will impact productivity and, in the long-term, innovation [369].
- *Different generations expectations from the workplace.* The industry is not well prepared for the current shift towards hybrid or remote work since it is built around physical locations. Young workers view remote work as a key pillar of flexibility [370].

Finally, increased amount of last mile deliveries has a significant environmental impact due to the flexibility companies try to provide to the consumers and the rise of e-commerce:

- *High levels of energy consumption and high environmental impact of last mile deliveries.* External costs relate to environmental burdens in last mile delivery, such as, congestion, accidents, air pollution, noise, and climate change, that tend to be higher in urban areas compared to rural areas [367], [371]. Returns are environmentally costly due to the high

levels of energy consumption they entail in shipping, re-manufacturing [372], and packaging [373].

According to experts', other than the risk of unemployment, most of the risks have high probability to happen in the near future and also have high impact in the supply chains.

Table 12: Risks for supply chains related to each trend of digital society.

	Digital society-related risks		
Risk Categories	Change of purchasing patterns (including share of social commerce, use of e-commerce) specific risks	Change of communication patterns (including open communication) specific risks	Reshaping the workplace specific risks
Need for channel Integration and change in supply base structure	- organisations have little or no control over the narrative that is shared on these various sites and social media platforms [362] - creation of new career paths with more technical skills requirements [363] - consumers have become more favourable in mobile payment and contactless delivery [374] which is also supported by asset-light 'sharing business models' of startups that trigger 'uberization' [375] - managing multiple social media accounts to cater to the different market segments [374]	- the industry is not well prepared for the current shift towards hybrid or remote work since it is built around physical locations [376]	- remote workers may also shift consumption patterns [361]
Inventory management challenges	- consumer demand and uncertainty [377] - pressure continues to mount on warehouses, supply chains and logistics companies [362] - manufacturing capacity, and ports are congested and causing delays [378]		
Tax and legal risks		- platform workers may have multiple jobs, work long hours which is the source of high stress [379]	- immigration, tax, and social security rules of multiple jurisdictions challenges [365]
Data breach	- security challenges related to social media in a B2B supply chain [374] - keep the personal information of consumers collected in business activities strictly confidential has become a matter of close concern to consumers [345]		- privacy violation risks [365]
Unemployment	- reduce some of the traditional retail jobs [363]		
Job burnout		- individuals spend less time collaborating [379] which will impact productivity and, in the long-term, innovation [380], [381] - business groups become less interconnected [380]	- embody psychological safety through an anti-oppressive and anti-racist organizational culture—and address the issue of burnout and mental health in the workplace [382]
Different generations expectations from the workplace		- metaverse seems set to reshape the world of work [383]	
		-	

	Digital society-related risks		
Risk Categories	Change of purchasing patterns (including share of social commerce, use of e-commerce) specific risks	Change of communication patterns (including open communication) specific risks	Reshaping the workplace specific risks
High levels of energy consumption and high environmental impact of last mile deliveries	- high levels of energy consumption they entail in shipping, re-manufacturing [367], [372], [373] - customers now expect to get goods delivered within one to three days and are demanding more flexible delivery options, at low or no additional cost [375] - external costs relate to environmental burdens in last mile delivery [367]		

4.4.5 Knowledge based society

According to [275] knowledge-based society refers to a society that competes and aims to succeed in the altering economic and political dynamics of the modern world. It relates to societies that are well-educated, and hence, trust in the knowledge and capability of their members to drive the innovation, entrepreneurship, and dynamism of the economy. The megatrend knowledge-based society emerging under the social dimension have the trends: 1) emerging skills required, 2) increased demand for high-qualification jobs, and 3) continuous learning culture.

4.4.5.1 Emerging skills required

As the supply chains adapt to new innovative and technology-oriented business models, employers would like to see supply chain employees with tactical and operational expertise as well as analytical skills. However, according to a DHL report, 58% of employers are struggling to find candidates with these expertise [384]. Moreover, Gartner points out that the personnel currently working in supply chains are not skilful enough to manage innovative technologies in supply chains, and they predict in large companies that, by 2021, 60% of the AI implementations will fail because of inadequate skills of the personnel [385]. Therefore, and to be able to adapt to innovations, companies need to have personnel with the skills to design, configure, and maintain innovative technologies. Further to that, the personnel should also continuously scan the horizon for innovations to potentially create a competitive advantage [385]. For instance, Amazon is planning to launch, scale and invest in skills training programs that enable their employees to make meaningful career changes into more technical roles, whether at Amazon or elsewhere. They are doing this by dedicating $1.2 billion to provide 300,000 employees with access to free training programs, and college education [386]. Additionally, Price Waterhouse Coopers, one of the biggest finance companies globally, invested $3 billion in digital upskilling of their employees [279]. A McKinsey survey also suggests that 55% of 71 supply chain leaders of global companies (Figure 61) prefer reskilling their workforce the most.

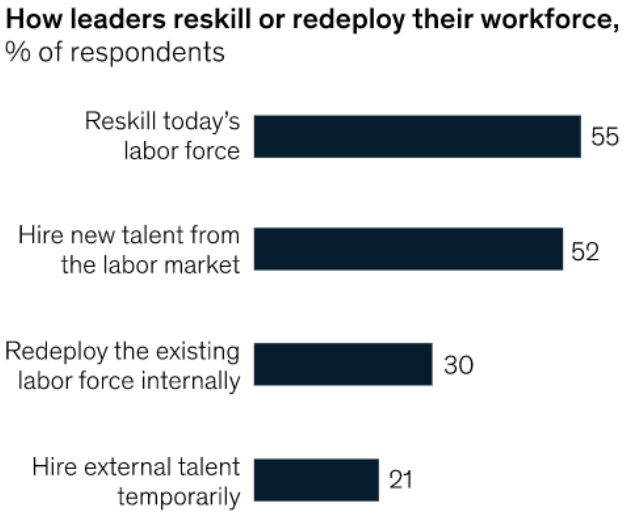

Figure 61: How leaders reskill or redeploy their workforce. [387]

4.4.5.2 Increase demand for high-qualification jobs

Almost 90% of global leaders believe that their companies are not prepared to tackle the digital skills gap [388]. McKinsey proposes that about 50% of current supply chain activities could be automated by 2030, which would drastically change the definitions of supply chain jobs. However, approximately 45% of the global supply chain workforce has a skill set that is too traditional to meet the emerging

technology-oriented expectations [281]. Therefore, even though part of the job openings is related to the high turnover rate, there is a substantial increase in job offerings in Europe in general (Figure 62). A study including 34 manufacturing companies showed that, among these job opportunities, the level that supply chain managers are seeking is mainly the mid-level positions (Figure 63).

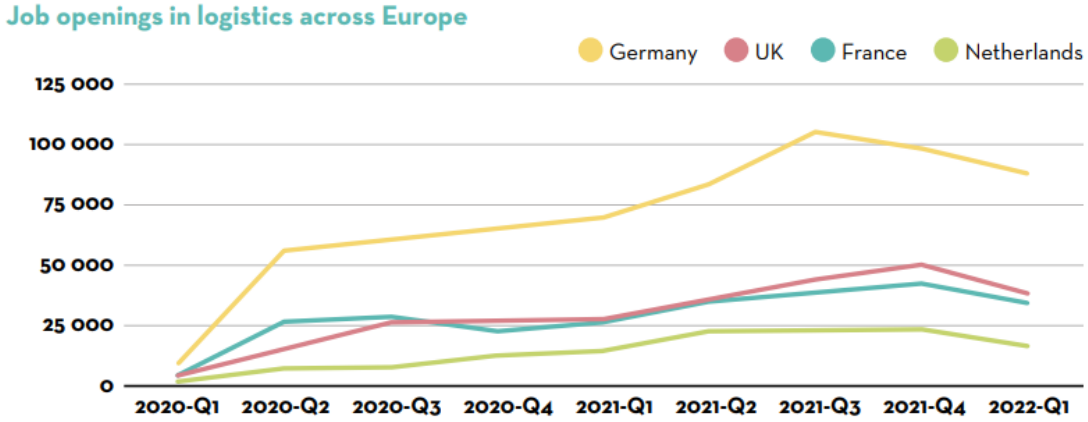

Figure 62: Job openings in logistics across Europe. [375]

Figure 63: Levels of supply chain talent shortage. [389]

4.4.5.3 Continuous learning culture

As expected, adult gen Z and millennials value updating their professional skills more compared to gen X and baby boomers. A survey showed that 58% of millennials and 52% of adult gen Z believe success in their careers is interconnected to continuous development of their skills and knowledge whereas in gen X and baby boomers these percentages are around 35%. On the other hand, it is younger workers who are feeling more stress about the need to continuously develop themselves in terms of new skill and knowledge [390].

Most of the potential employees associate supply chain and logistics sector with low-paying, physically demanding jobs, which causes image problems and low worker loyalty [370]. Moreover, social, and environmental values matter a lot to adult gen Z compared to older generations. A 2018 survey of Deloitte [391] mentions that 77% of gen Z find it significant to work at organisations whose values are similar to theirs. In particular, the issue of climate change concerns them. In the UK in 2021, the health insurance company Bupa found that 64% of gen Z value actions on environmental issues, and 59% would work longer for those responsible employers. Supporting that argument, in Australia, young workers have left companies that are not doing enough to respond to climate change [391].

4.4.5.4 Risks for supply chains from knowledge based society

Based on these trends, using the same logic, the following risks are determined through economic, social, and environmental perspectives. Risks were identified through vulnerabilities of these trends, and then, they are validated and enriched by the supply chain experts in the workshop. Table 13 is developed as an overview of how these risks relate to the trends of the knowledge based society megatrend.

The extant literature and the experts evaluation in the workshop, mentioned the following risks that have an impact on the economic sustainability of the supply chain:

- *Skills gap and talent shortage.* Results from employers in the Logistics Employer Skills Survey showed they suffer from skills gaps across all occupational levels. At least one of five companies' operational staff are not fully proficient. Further to that, this rate increases to 31% for middle and junior management jobs [392]. Therefore, it should be noted that recruiting the right talent especially at management levels is very difficult. New technologies transformed the fundamental areas of supply chain, and those areas now necessitate a person with much broader skill set than before [393].
- *Misalignment and shortage of skills needed to operate in a more automated, digitally enabled environment.* 55% of the employers are having hard times recruiting supply chain professionals with the right skills with regard to a study conducted in the University of Northampton. The underlying reason of the issues in recruitment is the requirement of a different and complex skill set in the industry. More and more companies are including big data while they seek industry insights which is urging the hiring teams to seek candidates with mathematical and data driven backgrounds [384].
- *Productivity can decline and lead to increased operation costs, slower production times, and other performance issues.* Supply chains' optimality and continuity now depends on the skilled professionals' constant guidance and management of innovative technologies such as IoT, robotic process automation and machine learning [394]. If an organisation does not have these skilful professionals, then both that supply chain's performance, effectiveness, and competitiveness will be put at a great risk [388].
- *Growing popularity of lower-skilled jobs.* This risk is mentioned by the supply chain experts during the workshop. Among gen Z, even though they do not have a full degree of the subject, it is very common to see potential employees that take short courses to work in a particular area. The opportunity of having an easier way to find a job, decreases the average skill set of the employees in the sector.

We found it suitable to merge social and environmental risks as they are interrelated:

- *Sector's unfavourable image.* In 2015, Randstad Award have conducted a survey involving more than 225,000 job seekers globally, Logistics is not an attractive sector to work in, ranking 13th out of 15 sectors. Even though companies in Logistics form the backbone of the other sectors, potential employees generally associate the sector with traditional trucks and warehousing. Moreover, job seekers believe that the job opportunities in Logistics sector involve only operational functions, and they are not intellectually challenging [395].
- *Managing training and developing employees across generations.* Many work-related skills have a shelf life. When companies do not develop a training policy for every worker, it means they are overlooking the requirements of some workers which results in bringing risks to the company. Keeping this in mind, the evidence also suggests that the lower-skilled workers, older workers, and those on part-time or temporary contracts require particular attention [396].
- *Mindsets are changing with more support for businesses that address eco anxiety internally and externally.* As previously mentioned, younger generations have more eco-anxiety than the previous generations. Furthermore, this anxiety is sometimes decisive in terms where and how they can work [391].

In the workshop, our experts offered a new risk that is ‘growing popularity of lower-skilled jobs’ as mentioned in economic sustainability related risks. It is discussed to have a moderate probability and impact. Other than the new risk, our experts validated all the risks having high impact. Also, after their assessment, ‘managing training and developing employees across generations’ risk has been validated to carry a very high possibility of happening in the near future. On the contrary, ‘Productivity can decline and lead to increased operation costs, slower production times, and other performance issues’ risk identified as having a moderate probability of happening which is the lowest when compared to the other risks.

Table 13: Risks for supply chains related to each trend of knowledge based society.

	Knowledge based society-related risks		
Risk Categories	Emerging skills required specific risks	Increase demand for high-qualification jobs specific risks	Continuous learning culture specific risks
Skills gap and talent shortage	- organisations do not have the labour or skill set to effectively manage, process, and unload imported products [397] - employers are struggling to fill manager roles due to a lack of qualified potential employees [397] - focus on soft skills will be required as supply chain professionals take on more prominent roles [398]	- need for supply chain professionals with a diverse range of skills in order to do their jobs and advise business leaders about regulatory and compliance strategies [399]	
Misalignment and shortage of skills needed to operate in a more automated, digitally enabled environment	- skills gap: the skills required to manage emerging technologies are in short supply [385] - organizations and workers need to adapt or even drastically differentiate themselves to succeed in the evolving digital environment [400]	- global supply chain workforce has a skill set that is too traditional to meet new expectations [388]	
Productivity can decline and lead to increased operation costs, slower production times, and other performance issues	- slow delivery times and shipping delays ripples the entire supply chain [376]		
Growing popularity of lower-skilled jobs	- The opportunity of having an easier way to find a job, decreases the average skill set of the employees in the sector.		
Sector's unfavourable image		- ensuring that positions in this sector are financially rewarding [365] (e.g., warehouse work and driving must be made more desirable to retain and engage staff [361])	- employees associate supply chain and logistics sector with low-paying, physically demanding jobs, which causes image problems and low worker loyalty [384] - convincing candidates that Logistics sector is modernised, and employees can have high flexibility [384] - Moving away from manual reporting and investing in fully digital and end-to-end hiring solutions [384]
Managing training and developing employees across generations		- employees worry that automation will impact their job in the future [375]	- focus on developing talents to build resilient teams with the correct skill sets [382] - engaging with the education sector [401] and focus on developing talents to build resilient teams with the correct skill sets [382]

		Knowledge based society-related risks	
Risk Categories	Emerging skills required specific risks	Increase demand for high-qualification jobs specific risks	Continuous learning culture specific risks
Mindsets are changing with more support for businesses that address eco anxiety internally and externally			- organizations should rethink their approach to recruiting, attracting, and retraining talent [401] - younger workers have higher eco-anxiety. Social values matter deeply to this population [391]

4.5 TECHNOLOGICAL DIMENSION

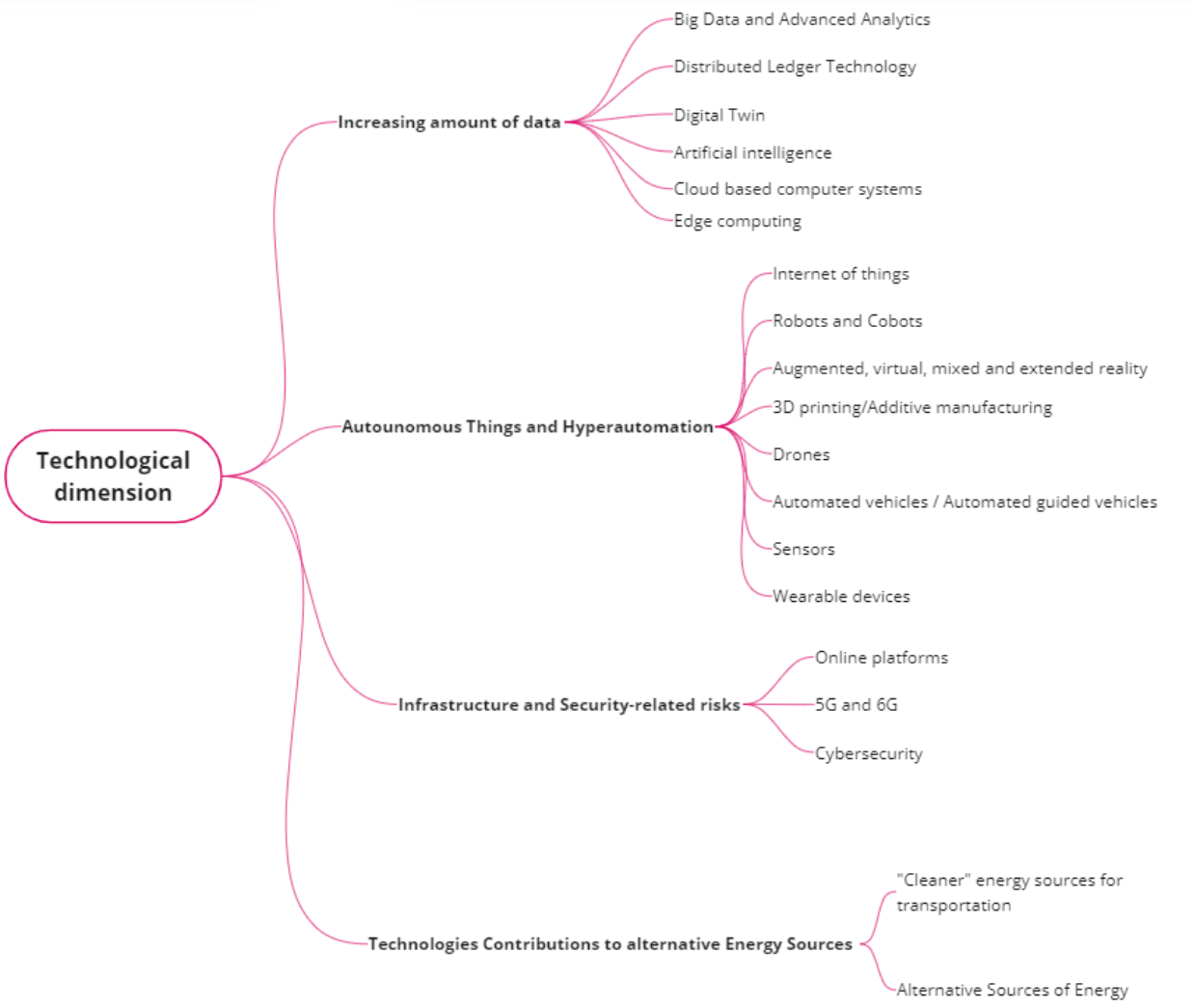

Figure 64: Overview of the trends in the technological dimension.

4.5.1 Increasing amount of data

The megatrend “Increasing amount of data” is related to the complexity and dynamism of current business environments, which generates an ever-increasing amount of data that can be used by managers in their decision-making process. However, the proper use of data is a challenging task, and the adoption of a set of technologies is essential to successfully deal with this growing amount, transforming it into quality data. At the same time, the adoption of these technologies represents a challenge itself, as they also contribute to increasing the complexity and availability of information. A set of emerging technologies were identified as the trends within the megatrend “increasing amount of data”, as their adoption along the next years is foreseen as the companies’ and SCs’ response for this phenomenon.

4.5.1.1 Big Data and advanced analytics

Big Data and Advanced Analytics can increase the quality, quantity, and timeliness of information exchanged between SC partners, leading to better levels of visibility, trust, and collaboration [402]. Considering the decision-making process, big data and advanced analytics can provide managers with different types of information, including production capacity and processes, inventory, purchase and sales orders, contracts (governance), logistics, and track and trace (linked to other technologies) supporting daily decision making, simulation and strategic planning actions [403]. Additionally, the growing need for data tends to impact the selection of suppliers, as there is a demand for partners who can provide the necessary information on time and with the required quality [404].
In 2019 the big data market in Europe was valued in €13.6 billion, with the expectation to increase annually 25,7% in the period between 2020 and 2025 [405]. Around 64% of organizations inquired by the European Banking Authority are adopting big data and analytics solutions and it is expected that the remaining organizations will use it in the future [406]. By 2029, the expected value for the big data and analytics market is over 655 billion U.S. dollars, up from around 241 billion in 2021 [407].

4.5.1.2 Artificial intelligence

Artificial Intelligence has received high attention from the public in general, and in particular in the supply chain management field, mainly because of its disruptive impact on organizations. The contribution of AI to supply chains include aspects such as reducing uncertainty and enhancing SC resilience; increasing transparency, improve last-mile delivery, and offering personalized solutions to both upstream and downstream stakeholders which will ultimately minimize the impact of disruption and facilitate an agile procurement strategy [408].
Europe has 7,23% of the world patent related to AI. It is presumed that 24% of the organizations are adopting initiatives related to this technology and that other 24% are considering and planning to adopt it in a short to medium term [409]. The changes that AI brings to enterprises will affect jobs with an expected automatization of 14% and changing other 32%. The global AI market was valued in 95.60 billion U.S. dollars in 2021 and is expected to reach 1,847.58 billion U.S. dollars by 2030, registering a CAGR of 32.9% from 2022 to 2030 [410].

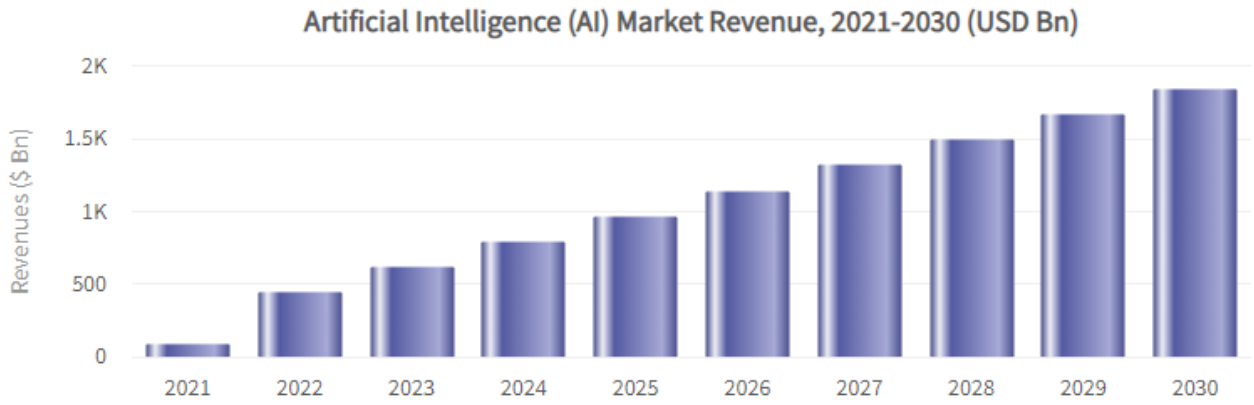

Figure 65: AI Market Revenue, 2021-2030 (USD Bn) Source: Next Move Strategy Consulting [410]

4.5.1.3 Cloud based computer systems

Cloud-based computer systems are perceived as an accessible technology that favours supply chains to develop a strategic approach to collaboration by supporting operations integration; on-

demand services; scalability, flexibility, and efficiency [411]. In terms of market, it has the capacity to change consumers' behaviour, for example in on-demand services.
European enterprises are increasing their use of cloud-based computer systems annually. In 2016, 19% of the European companies applied this technology, compared to 36% in 2020 and 42% in 2021 [412]. In 2021, 79% of the use was mainly related to e-mail systems, followed by 68% for storing files solutions, 61% for office software, and 59% for security software. The sector where the use of cloud bases computer systems has increased more in Europe is retail [412].

4.5.1.4 Blockchain and Distributed Ledger Technologies

Distributed Ledger and Blockchain technologies can increase the visibility across the product lifecycle [413], positively affecting systems efficiency [414], and reducing operational costs [415], with a special impact on international transactions. In general, this trend allows SC managers to develop data modularization, prioritization, monitoring, reporting, data security, traceability, transparency; smart contracting, and compatibility with governmental entities although it still causes issues related to governance and compliance [416], [417].

There is an increase of EU-funded blockchain-related projects still ongoing and more projects in the production stage, being 5% in 2018 and 14% in 2021 [409]. The global market of blockchain technology was valued at 5.85 billion U.S. dollars in 2021 and is expected to reach 1,235.71 billion U.S. dollars by 2030, representing a CAGR of 82.8% [418]. There is now an investment of 347 million euros by the EC to support projects in this area [419], [420].

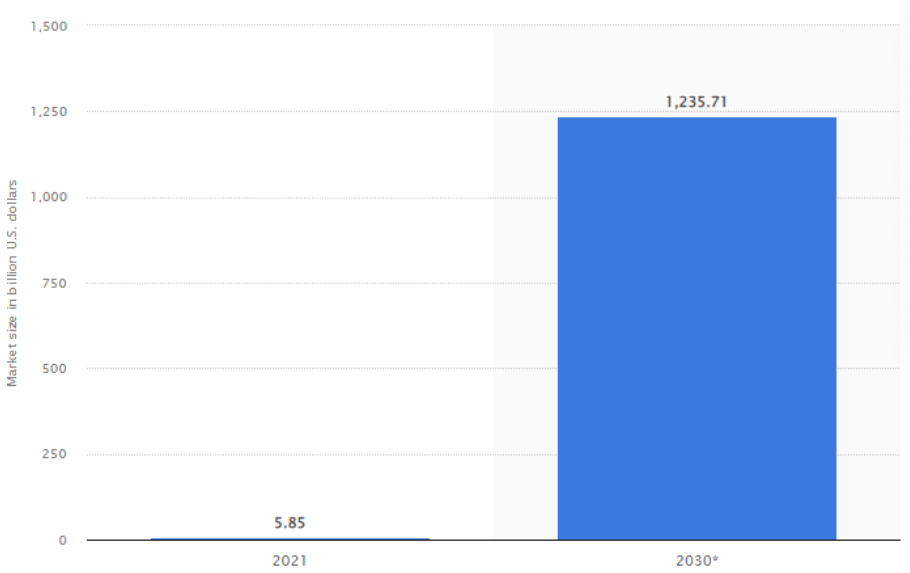

Figure 66: Global market of blockchain technology [418]

4.5.1.5 Edge Computing

Edge computing can reduce the amount of data that is sent to the cloud, bringing real-time operations to the edge, leading organizations from the whole SCs to improve their security and privacy, and simultaneously reducing their expenses in terms of value and costs of energy in the use of future systems [420].
The edge computing market is still in development, being predictable that its value will increase from 36.5 billion dollars, in 2021, to 83.7 billion dollars in 2026, with a CAGR of 19.0% during this period [421].

4.5.1.6 Digital Twin

Digital Twin can be used across SCs to increase end-to-end visibility and collaboratio between partners, contributing to improve resilience and sustainability (for example, digital twins can be used to test contingency plans and circularity practices adoption; e.g., reducing uncertainty regarding the availability of materials for remanufacturing) [422].
It can also enable better visualization of risks that affect SC as the ones concerning the assessment of supplier disruption, and prediction of possible interruptions. From another point of view, it helps the computation of alternative supply network topologies and backup routes with an assessment of estimated times of arrival [420]
Digital Twin allows integration and interactions between physical and digital worlds, with an expected grow in US dollars from 6.9 billion in 2022 to 73,5 billion in 2027, with a CAGR of 60,6% [423]

4.5.1.7 Risks for supply chains from Increasing amount of data

Based on the identified trends, the following risks are determined through economic, social, and environmental perspectives. In particular, the following risks have a direct impact on the social sustainability of the supply chain:

- *Safety of personal/confidential data.* Considering the growing amount of data of the most varied types, and the consequent complexity of technology-based solutions, the risk of not guaranteeing the security of personal and/or confidential data, which can lead to ethical issues, should be considered a strategic concern of companies and supply chains [424][425]
- *Lack or high demanding (current or future) regulatory frameworks.* As relevant external issues that impact companies' processes and relationships, the lack of regulatory frameworks on information sharing-related aspects can represent a risk to supply chain collaboration. On the other hand, the existence of high demanding legislation and standards can represent high costs and create barriers to technology implementation. Additionally, companies should develop mechanisms to be updated regarding new regulatory frameworks [424][425].

Beside social, based on the literature and the experts' validation, a set of risks with a direct impact on the economic sustainability of the supply chain have emerged:

- *Poor data analysis affecting decision-making.* The adoption of digital technologies is fundamental for the decision-making process in the current context of high amount and complexity of data. On the other hand, lack of digital knowledge and data literacy, among other factors, can lead to poor data analysis and, ultimately, poor decision making. Thus, companies should invest in digital knowledge and data literacy, considering that having poor quality data can be even worse than having no data [425][426].
- *Lack of shared data standards*. The lack of common data standards among supply chain partners increases difficulties related to operations planning and scheduling[424].
- *Low data visibility due to poor adoption of technology.* Visibility throughout supply chains depends on the quantity, quality and timeliness of the information shared among partners. Besides aspects such as collaboration and trust, digital technologies are a critical factor to allow higher levels of visibility. On the other hand, the poor adoption of technologies has a strong impact on supply chain visibility, especially in the quality of the information shared among partners [427] [275].
- *High investment for the analysis and storage of data*. Companies need to invest to ensure that their data is properly stored and well analysed. However, managing the trade-off between the value of the investment necessary to increase storage and analysis capacity and the benefits of using data is a complex challenge for managers to face. The risk is that

required investments are greater than the expected benefits they can bring to organizations. [428].

Concerning the environmental dimension, the following risk has also arisen:

- *High energy consumption due to storage and processing needs.* The large amount of data stored and processed daily requires greater infrastructure capacities that, consequently, consume more energy. Thus, the risk of high energy consumption due to data storage and processing needs must be seen by managers as a potential growing environmental impact of companies and supply chains [429][430] .

According to validation and expert feedback collected during the workshop, most of the risks related to the "increasing the amount of data" megatrend are classified as having a high probability of occurrence and also a high impact on supply chains. In particular, the risks: “Safety of personal/confidential data”; “Poor data analysis and decision-making"; and “High investment for the analysis and storage of data” were placed at very high probability and very high impact on supply chains.

4.5.2 Autonomous Things and Hyperautomation

The megatrend Autonomous Things and Hyperautomation is related to the increasing adoption of technologies that tend to reduce the human interference in production and supply chain processes. Human-centred approaches have been applied to ensure that these processes place the wellbeing of the worker at the centre of the production process. Thus, instead of adapting the workers’ skills and needs to new technologies, a human-centric approach is used, wherein technology is used to adapt production processes to the needs of workers and, at the same time, ensure that new technologies do not conflict with the fundamental rights of workers, such as the right to privacy, autonomy and human dignity. The following technologies were identified as the trends within this megatrend: **Internet of Things, Robots and Cobots, Augmented, Virtual, Mixed and Extended reality, 3D Printing/Additive Manufacturing, Drones, Automated Vehicles [AVs]/ Automated Guided Vehicles (AGV), Sensors, Wearable devices**. On the one hand, these trends can improve supply chain activities but, on the other hand, they also entail a new set of risks and challenges related with security and integration with other parts of the company.

4.5.2.1 Robots and Cobots

Robots have gradually been incorporated into various industrial processes, especially in manufacturing companies. With the development of advanced technologies such as artificial intelligence, machine learning, visual recognition and collaborative robots (cobots), robots have had their capabilities significantly improved. Robots and cobots have differences regarding their level of interaction with humans. Robots are stand-alone workstations without close interaction with humans within a shared work zone. Cobots are considered an advanced manufacturing technology that is primarily characterized by the fact that the robots’ and operators’ work zones overlap, creating a common workspace[431]. Despite these differences, their general contribution to SC can be similar, such as: promoting process optimization and improving process efficiency [432].

In 2019 2.7 million industrial robots where in operation in factories around the world – an increase of 12% in comparison with 2018 [433], [434]. By 2026, 75% of large enterprises will have adopted some form of intralogistics smart robots in their warehouse operations [434]. The global sales volume for the worldwide robotics market was US$ 45 billion in 2022, representing an increase of 44% from

2018 to 2022 [435]. Between 2017 and 2020, cobots' installations worldwide doubled, from around 11,000 in 2017 to 22,000 in 2020.

The high growth of industrial robots is mostly driven by the automotive and electronics sectors, respectively representing 23% and 31% of new installations in 2020 [436]. Therefore, industrial robots are particularly adopted in countries with strong expertise in those sectors, such as Japan, China, South Korea, Germany, and the United States.

4.5.2.2 Internet of Things

The IoT is a network of physical objects that are connected by means of digital technologies allowing to sense, monitor and interact both within a company and between supply chain partners. IoT can contribute to improve agility, visibility, tracking and information sharing to facilitate timely planning, control and coordination of the supply chain processes [437]. It can be adopted by SCs to address challenges related to security and privacy between partners. Its connectivity capabilities enhance real-time visibility which will aid in preventing capacity fluctuations risks. IoT can also bring to SC an increase in operational efficiency by decreasing the costs and providing savings during the production process and optimizing product recovery operations [438].

Europe responds for 25,41% of global patents related to IoT, with 36% of European companies using IoT solutions by 2019 [436]. The amount of worldwide IoT devices is forecasted to increase from 9.7 billion in 2020 to more than 29 billion by 2030 [439]. IoT devices have been applied in multiple sectors such as healthcare, electricity, gas, water supply, waste management, retail & wholesale, transportation & storage, agriculture and government.

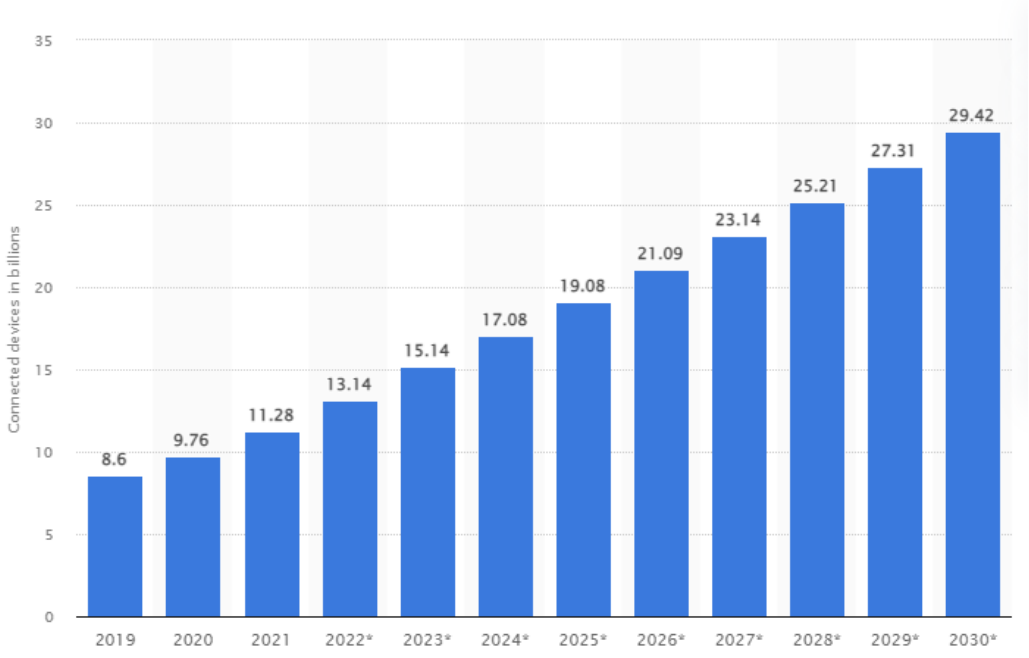

Figure 67: Amount of worldwide IoT devices [439]

4.5.2.3 Augmented reality and virtual reality

The development of reality-virtuality technologies, as augmented, mixed, or extended, is expected to have an important role in future SCs. Notably, the European Commission foresees that these technologies will support remote on-field operators and provide more detailed step-by-step instructions to workers [440]. Virtual and augmented reality have several potential applications that can possibly increase SC efficiency and be able to address challenges such as improper planning and scheduling, lack of process integration, and inefficient use of resources. Thus, these technologies can be applied into: warehouse operations, manufacturing tasks, sales and outdoor logistics, planning and scheduling, product and process design, and training of human resources [440]. In practice, they can provide assistance to operations through, for instance, order picking, routing, maintenance, sales and delivery of goods, which may increase the allocation of resources and improve operations, while also benefiting from step-by-step implementation and software-printer compliance.

Since the early 1990s, EU research funds have supported more than 450 projects with more than €1 billion allocated budget dedicated to virtual reality (VR) and augmented reality (AR) initiatives [441]. The European VR and AR market is projected to reach a value of approximately €43 billion by 2026. Worldwide, VR and AR market revenue is expected to show an annual growth rate (CAGR) of 13.72% (2023-2027) [442]. The current VR and AR market consists of a 30% AR to 70% VR split in terms of spending. However, AR market share is expected to surpass the VR one as global AR revenues are catching up with VR. Indeed, from 2020 to 2025, the global VR market is expected to grow at a CAGR of 27.9%, while the AR market is expected to grow at a CAGR of 38.1% [441].

4.5.2.4 3D printing/additive manufacturing

Organizations have been increasing their use of additive manufacturing/3D printing in their operations. 3D printing can rise the speed and flexibility of production and allow companies to respond quickly to supply disruptions without holding costly inventory of parts that may not be needed [443]. The adoption of additive manufacturing and 3D printing in SCs can aid in improving and developing products with high levels of product optimization. They can also help with optimizing supply chain flows while improving environmental performance, leading to the adoption of green supply chains. However, market-ready 3D printing and additive manufacturing solutions should be considered at a strategic level and not as a substitute to current production processes [444].

When considering the 3D printing market, EU27 is particularly strong, boasting the highest share (30.5%) of world patent applications [436]. The global 3D printing market is projected to grow from US$ 18.33 billion in 2022 to US$ 83.90 billion by 2029, at a CAGR of 24.3% [445]. The worldwide market for 3D printing products and services was valued at approximately US$ 12.6 billion in 2020.

4.5.2.5 Drones

Drones and Unmanned Aerial Vehicles (UAVs) are becoming an alternative for SCM in terms of transportation due to their high flexibility, increasing levels of efficiency related to payload capacity of vehicles, as well as delivery routing and optimized scheduling [446]. Additionally, they have an effect in decreasing greenhouse gas emissions.

Drone logistics and transportation market amount to US$ 11 billion in 2022, and is expected to reach US$ 29 billion by 2027, representing a 21.01% CAGR for the period [447]. With the right framework in place, the drone services' market in Europe could reach a value of € 14.5 billion by 2030, with a 12.3% CAGR, and create 145,000 jobs in the EU. The different segments of this market are constantly growing in terms of companies and volume of operations [448].

4.5.2.6 Sensors

When applied to SCs, sensors have a significant contribution to improving tracking and traceability of products and components used in different phases of the network. These solutions are critical to increase SC visibility and can have an important role in the implementation of circular supply chains through the ability to provide real-time information [449]. Machine-generated sensor data is becoming a significant part of the big data that must be managed within companies daily. Sensors can contribute to ensure the right type of information, improve information quality, provide better timing, speed and ease of access to required information, and control over information sharing and privacy protection [450].

Sensors market size was valued at US$ 151 billion in 2021 and is projected to reach US$ 324 billion by 2030 (8.8% CAGR). The global agricultural sensor market is valued at € 1.12 billion in 2018, reaching € 2.34 billion by 2026 [451].

4.5.2.7 Automated guided vehicles

Automated Vehicles (AV) and Automated Guided Vehicles (AGV) present several potential advantages when applied to SCs, most notably in intralogistics. These automated solutions can aid operations by providing logistics support and autonomously establishing distribution/operations routes within the shopfloor. Data can be obtained remotely, which will help to prevent hard to detect failures, as well as to reduce greenhouse gas emissions. As examples, Audi and Daimler are using these vehicles for more efficient warehouse transportation [452].

Recent studies show that consumers consider AVs to be safer than the average driver. Connected and cooperative AVs enable efficient vehicle platooning, reducing aerodynamic drag forces, fuel consumption, and exhaust emissions [453]. Different studies estimate a possible energy reduction between 10-25% [454]. It is expected that the total cost per-vehicle for both software and hardware will start roughly at £3,000 by 2025 and will decrease to half by 2035 [455]. The global autonomous vehicle market was valued at US$ 76.13 billion in 2020 and is projected to reach US$ 2,1 trillion by 2030 (40.1% CAGR) [456].

4.5.2.8 Wearable devices

Wearable devices are described as simple technologies that have their main application with the public, but when adopted in SCs they can have a positive effect on collaboration and communication among partners [457]. The use of these technological tools can also have a specific application in industry production fields by drastically improving occupational safety and health management in physically demanding and dangerous activities, by, for example, tracking workers' locations in risky working areas and monitoring their physiological ranks like fatigue or stress or other health metrics [457].

Wearable technology market is expected to reach US$ 415 billion by 2029. In 2020, almost one-fifth (19%) of people aged 16-74 in the EU had used wearable devices. Younger people (aged 16-24) used these smart wearables to a larger extent (28%) than people aged 25-54 (23%), followed by people aged 55-64 with 11%. Only 5% of people aged 65-74 used such smart wearables [458].

4.5.2.9 Risks for supply chains from Autonomous Things and Hyperautomation

Based on the literature and the experts' validation of risks during the workshop, the automatization has a direct impact on the social sustainability of the supply chain as follow:

- *Automatization removes or drastically reduces the human factor*. The introduction of autonomous things and automation in various production and supply chain processes tend to replace part of the work that currently depends on human intervention to occur. The replacement of human beings by autonomous "things" can have a direct impact on job creation and also an indirect effect on workers' sense of security and stability. As a process that tends to happen more and more in the coming years, companies and supply chains must manage this transition from a human-centred and sociotechnical systems perspective [440].

A set of risks described here below was also identified for what concerns the economic perspective:

- *High automatization costs*. Implementing and operating technologies brings additional costs to organizations. The complex balance between costs and benefits of investing in these technologies must be carefully managed. [440] [459][460] .
- *Inadequate use of equipment's leading to poor decision-making/operationalization*. The inadequate introduction and use of technologies – such as 3D printing, sensors, robots, drones – *resulting* from the inefficient implementation and/or the lack of digital skills, may lead to poor decision-making and poor operationalization of different types of processes [459] [460][461].
- *Poor integration of shopfloor/logistics data into the enterprise system*. This risk is related to the poor integration of data due to the lack of semantic and brokerage options that conduct and connect the shopfloor/logistics to the rest of the enterprise system, within and outside its borders[462] [463].
- *Scarcity of electronic components.* Recent crises (such as the COVID 19 pandemic and the war in Ukraine) have shown that the current predominant global supply chain models are unable to properly respond to disruptive events. The expected occurrence of this type of event, combined with the strong dependence that some markets, including Europe, have on geographically distant countries, represents a serious risk of shortages of electronic components in the future [463].

Besides the economic dimension and social dimensions, the risk of increasing amount of discarded electronic component affects directly the environmental dimension of sustainability as follows:

- *High amount of discarded electronic components.* The more electronic components are used, the more electronic waste and end-of-life products are generated. Improper disposal of these components poses a serious environmental risk that needs to be addressed by all stakeholders, including companies, end users and policy makers [463].

In the workshop, the experts reinforced that the majority of the identified risks associated to the "Autonomous Things and Hyperautomation" megatrend have a high probability to occur and a high impact on supply chains. The risks "automatization removes or drastically reduces the human factor"; "scarcity of electronic components" and "high amount the discarded electronic components" were classified with a very high probability to occur and with high impact.

4.5.3 Infrastructure and Security-related risks

When it comes to digitalization, some of the biggest concerns of managers are issues related to security and infrastructure. Technologies like **Online platforms, 5G and 6G and Cybersecurity** are directly related with this concern. Although, these technologies can mitigate some challenges they cannot eliminate them.

4.5.3.1 Online platforms

Online platforms have played a key role in the development of new consumption habits and in the way SCs are designed. According to the European Commission, the development of business-to-business (B2B) digital platforms in the manufacturing industry contributes to more collaborative relationships between partners. In terms of advantages, they can promote better control of operations, high visibility for the SCM and flexibility [464].

The COVID-19 has led EU organizations to increase the use of online platforms, reaching approximately 1 million businesses that negotiate goods and services in 2022. Additionally, more than 50% of medium and small companies can negotiate easily beyond their internal market thought online platforms [465].

4.5.3.2 5G and 6G

The major contribution that 5G and 6G are expected to bring to SCs is the capability of increasing the exchange of data in terms of rapidness and larger data volumes. These communication technologies can be implemented by organizations at a lower cost [466].

Nowadays, there are approximately 236 million 5G subscriptions worldwide, with European Commission funding projects related with these technologies with values around € 4 billion. While 72% of the EU27 population is already covered by 5G access, the Smart Networks and Services Joint Undertaking (SNS JU) has been supported by the EC to advance 6G research in Europe [467] [468].

4.5.3.3 Cyber security

Cybersecurity is becoming essential to SCs in relation to producing better decisions, especially concerning perceived threats and vulnerabilities [469]. Cybersecurity draws attention to organizations improving their security behaviour and efficiency response.

Europe holds 23,76% of existing patents related to cybersecurity. According to the European Report Advanced Technologies for Industry, 62% of the organizations with more than 10 employees in Europe are adopting initiatives related with cybersecurity technology [465].

4.5.3.4 Risks for supply chains from Infrastructure and Security-related risks

Based on the literature and the experts' validation of risks during the workshop, the following risks have a direct impact on the social sustainability of the supply chain:

- *Safety of personal/confidential data (ethical issues)*. The enormous amount of data available and managed by companies every day requires companies to pay special attention to ensuring the security of personal and/or confidential information. The security of this data involves practical and ethical issues [470][471][472].

- *Hacking, ransomware.* This risk is related to external threats from malicious individuals or entities seeking to steal information for harmful use, affecting operations and/or safety of data [471].

The risks which have an impact related to the economic dimension concern mainly the need for an adequate supporting infrastructure and have been clustered as follows:

- *Low supporting infrastructure.* Organizations need adequate infrastructure for the operationalization of technologies. To this end, continuous investments are needed, both by public and private entities, in order to keep the infrastructure updated to keep up with the continuous technological development and in order to protect the existing structures from degradation [470] [471] [467] [473].

Finally, the categorisation of supply chain risks associated with the environmental dimension of sustainability concerns the infrastructure degradation and can be summarized as follows:

- *Degrading physical infrastructure.* The proper functioning of the technology is correlated with the condition of its physical infrastructure, which can be affected by aging and climate/weather related events. At the same time, infrastructure degradation poses an environmental risk as it generates large amounts of waste, including electronic waste. Companies need to ensure structures are properly maintained and updated due to operational and environmental issues [466].

According to experts' validations and comments collected during the workshop, most of the validated supply chain risks from "Infrastructure and Security-related risks" megatrend have a dispersion that goes from moderate to a high probability to occur and a high or very high impact on the supply chains. It was considered that the risk "Safety of personal/confidential data" is highly dependent on specific countries' regulations. The risk "hacking, ransomware" was suggested by the experts.

4.5.4 Technologies Contributions to alternative Energy Sources

The last megatrend addresses the contribution of technologies to the development of alternative energy sources. The seek for alternative sources of energy for storage and industrial processing and cleaner options for transportation, like batteries for electric vehicles, Hydrogen Fuel Cell Electric Vehicles, and Hybrid vehicles is more important every day, specially at the supply chain level.

4.5.4.1 "Cleaner" energy sources for transportation

The application of cleaner energy sources in the transportation field will help to reduce the use of diesel fuel and its related carbon emissions which will ultimately make the entire SC more sustainable [474].

Europe had observed a reduction in the percentage of new passenger cars powered by diesel from 44% to 35,9% in the years 2017 and 2018, respectively. In parallel, an increase has also been noted in the electric car registrations from 2020 to 2021, with a total rise of 668,000. Considering other segment of transportation sector, almost 35,000 electric vans were sold in 2021 in the EU-27 [475]. There is an expectation for the future that the European market for electric batteries will reach values surrounding EUR 250 billion annually from 2025 and on [475]

4.5.4.2 Alternative sources of energy

SC organizations intend to achieve better levels of environmental sustainability. For that, they tend to change their sources of energy from fossil fuels to alternative sources of energy. This modification

will reduce the emissions of C02 along SCs and the dependence faced by the countries that produce this kind of energy [476].

The share of renewable energy sources in EU reached 21.8 % of the gross final energy consumption in 2021 [477]. These numbers are around 0.3 percentage points lower than in 2020 (22.1%). According to Eurostat (2022), "the lifting of the restrictions linked to the COVID-19 pandemic probably played a role for this decrease". Despite these figures, the EC foresees an increase in the use of alternative energy sources in the coming years, with a target for the use of renewable energy representing 32% of EU consumption in 2030 [477]. When it comes to transportation, the share of energy from renewable sources in the EU reached 9.1 % in 2021 [478].

4.5.4.3 Risks for supply chains from technologies contributions to alternative energy sources

Based on the literature and the experts' validation of risks during the workshop, the following risks have a direct impact on the economic sustainability of the supply chain:

- *Lack or high demanding (current or future) regulatory frameworks*. As relevant external aspects that impact companies' processes and relationships, the lack of regulatory frameworks can represent a risk when it comes to the contribution of technologies to alternative energy sources. The existence of high demanding legislation and standards can represent high costs and create barriers to these energies. Additionally, companies should develop mechanism to be updated regarding new regulatory frameworks [477] [479] [480]
- *Variability of prices and availability of alternative energy sources.* Market volatility in terms of price and availability of components necessary for the use of alternative energy sources will end up affecting the correct functionality of organizations and their mechanisms on an industrial scale [477] [479].
- *Lack of specialised technical staff for alternative energy adoption.* Risk of inefficient adoption of alternative energy sources given the poor specialization and/or expertise of technical staff [477] [480]

Finally, the categorisation of supply chain risks associated with the environmental dimension of sustainability relates to the required capabilities to make the supply chain environmentally sustainable. The main risks have been clustered as follows:

- *Predatory exploration of natural resources*. Risk of predatory exploration of natural resources hindering technological development for alternative energy sources [477] [479].
- *Inadequate handling/discard of alternative energy solutions*. One of the most important aspects related to the environment in relation to alternative sources of energy is the disposal and management of waste. The risk of environmental impact related to the inadequate handling/discard of alternative energy solutions has to be properly managed [477] [479] [480]

The experts' validations and comments in the workshop classified the majority of risks from the "Technologies Contributions to Alternative Energy Sources" megatrend with high probability to occur and high impact on supply chains. The risk "Lack or high demanding (current or future) regulatory frameworks" had special attention, generating concerns about the heterogeneity of regulations among countries.

4.6 LEGAL DIMENSION

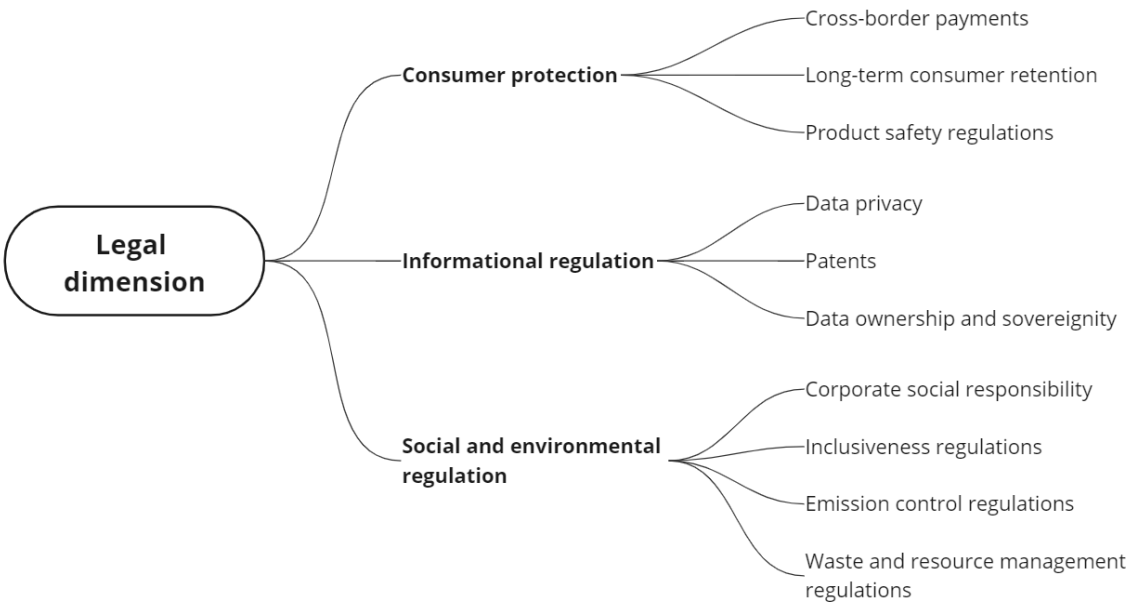

Figure 68: Overview of the trends in the legal dimension

4.6.1 Consumer protection

Consumer protection is a rising trend in global markets that has become more important in recent years. As multiple emerging technologies converge and evolve at an accelerated pace, the uncertainty surrounding their benefits and the potential negative effects on society, especially on its most vulnerable members, also increase. Citizens trust governments to guarantee their safety and security.

With rising cross-border payments, consumers nowadays purchase products from anywhere in the world and create an incentive for companies to develop innovative consumer retention strategies while considering product safety regulations from different countries. These trends are increasingly shaping the business landscape, and companies that prioritize consumer protection are likely to benefit from increased customer trust and loyalty.

4.6.1.1 Cross-border payments

In many areas, the exchange of payments plays a decisive role. This applies to private individuals as well as to public authorities or companies. Due to the emergence of new players, including an increase in new customers abroad, cross-border payments are playing an increasingly important role. Not only customers are located abroad, but also goods ordered abroad must be paid for via transactions.

In the EU, goods worth of 345.5 billion euros have been exchanged in February 2023, which represents an increase of 7.9% year-on-year [481]. In 2022, the member countries with the highest export volumes within the EU were Germany (863.4 billion euros), the Netherlands (659.7 billion euros) and Belgium (413.0 billion euros) [482]. Looking at trade with third countries outside the EU shows a transaction volume of approximately 207.7 billion euros for exports and approximately 202.9 billion euros for imports. This also represents a year-on-year increase of 8% and 2.8% respectively

[481]. In 2022, goods worth over 500 billion euros were shipped to the USA, making the USA the largest trading partner for the EU in terms of exports. In contrast, goods worth over 600 billion euros were imported into the EU from China, which in turn makes China the EU's largest trading partner in terms of imports. Here, too, the year-on-year comparison shows an increase in transaction volumes with the main trading partners on both the export and import sides. Only the export of goods to Russia decreased, which is due to the export restrictions imposed because of the war in Ukraine [483]. In summary, both intra-European trade and foreign trade show high cross-border transaction volumes, which are constantly increasing.

According to EY consultancy from 2021, also the worldwide cross-border payments rise significantly. An annual growth of 5% was expected for the period between 2018 and 2022. This progression is clarified and illustrated in Figure 69. The growth is driven by changing consumer behaviour, a growing focus on emerging markets and easier access to banking services and e-payments because of increasing smartphone penetration. For emerging markets, cross-border payments were even expected to grow by 10% between 2018 and 2022 [484].

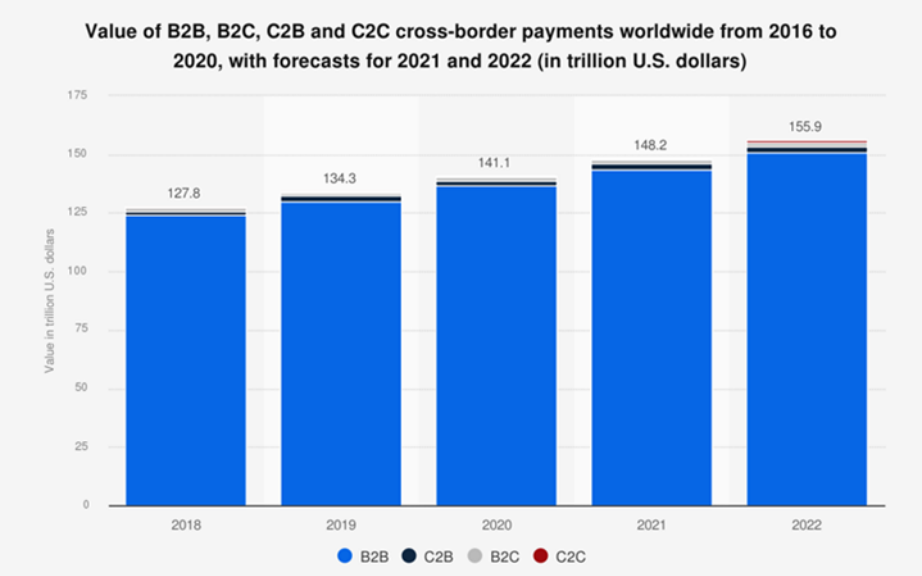

Figure 69: Value of cross-border payments. [485]

To circumvent risks of frauds, trading risks and capital risks literature proposes and explores digital currencies and applications in the field of financial innovations for cross-border payments. So-called CBDCs are developed that can be described as Central Bank-Issued Digital Currencies like the Digital Euro or Digital Dollar [486], [487].To circumvent risks of frauds, trading risks and capital risks literature proposes and explores digital currencies and applications in the field of financial innovations for cross-border payments. So-called CBDCs are developed that can be described as Central Bank-Issued Digital Currencies like the Digital Euro or Digital Dollar [486], [487]. The increasing international trade leads to increasing cross-border payments. The increasing international trade leads to increasing cross-border payments. One of the reasons for this could be that companies set up their supply chains more internationally or have subsidiaries in other countries. Based on the data, cross-border payments are increasing in total every year [485].

4.6.1.2 Long-term consumer retention

In recent years, long-term consumer retention established as a corporate goal and showed positive effects on company's profits as consumers that buy regularly over a longer period have more impact than several different consumers. In addition, the reliability of a single consumer is higher compared to several different ones. While companies, in some cases, aggressively advertise for consumers,

regulators look to strengthen customers' protection rights. Therefore, the Consumer Rights Directive is already in place that harmonizes certain aspects of consumer rights across the EU and provides consumers with the right to withdraw from even long-term contracts within a period of several days. Moreover, the Unfair Commercial Practices Directive prohibits unfair business-to-consumer practices and provides consumers with protection against misleading or aggressive marketing techniques. Similarly, the E-Commerce Directive establishes protective rules for online services and electronic commerce within the EU.

Still, long-term consumer loyalty plays a decisive role in the success of a company and is therefore increasingly seen as a strategic target. If consumer loyalty increases by 5%, profits can rise by 25% up to more than 90%. In addition, depending on the industry, it is 5 to 25 times cheaper to retain an existing customer than to acquire a new one [488], [489]. The reasons for this, according to Reichheld, are that existing customers tend to buy from the company more often, which goes hand in hand with falling operating costs [490]. In his study [490], recommends the company to others and to be prepared to accept a more expensive price. In 2018, the industries with the highest customer retention rates were media (84%), professional services (84%), automotive and transportation (83%), and insurance (83%). In contrast, significantly lower customer retention rates were seen in the hospitality, travel and restaurant (55%), retail (63%) and manufacturing (67%) industries in the same year [491].

The fact that a high level of consumer loyalty plays a major role today and in future becomes clear when considering the market for Customer Relationship Management (CRM) software. The software is used by companies to increase customer retention rates, among other things. Figures from 2021 estimated a market volume of over US $49 million in 2025, which represents an increase of US $4 million from 2020 and a compound annual growth rate of 1.7 percent. By comparison, the market volume for CRM software in 2015 was just over 24 million US dollars [492]. The progression is illustrated in the figure below (Figure 70).

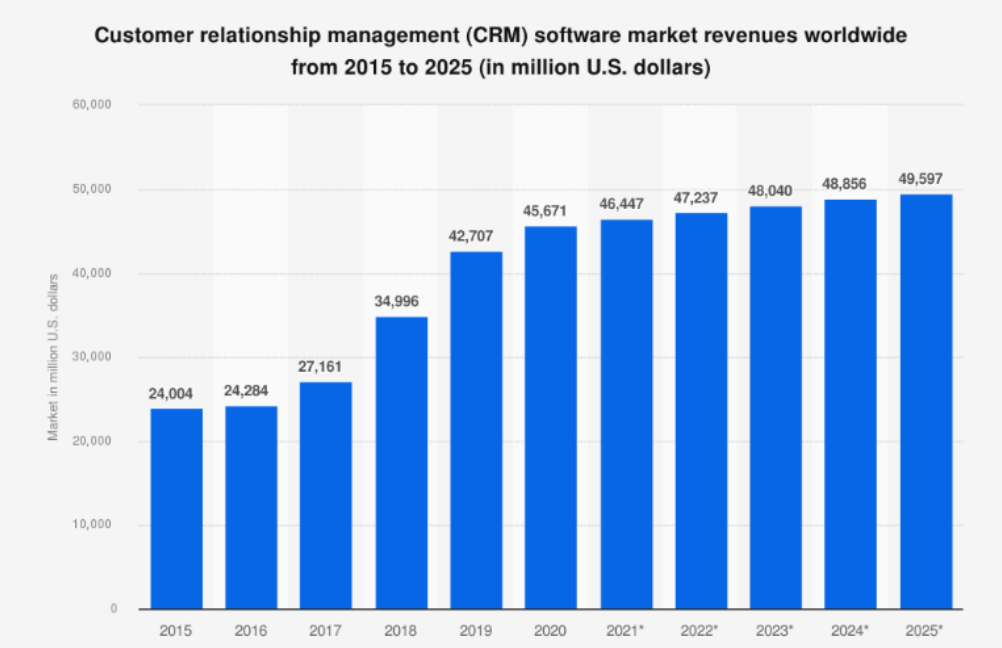

Figure 70: Customer relationship management (CRM) software market revenue worldwide. [492][492]

Long-term measures can positively influence customers' brand perception and brand trust. So it is a strategy in the retail industry to offer free shipping and free returns, even if this reduces profit [493]. This is illustrated by the following figures from 2022: Globally, 68.2% of respondents prefer free delivery over next-day delivery and easy online checkout, which were chosen by only 37.3% and

38.2% respectively of respondents. On a national level, the situation is very similar in almost all of the countries surveyed (Germany, Italy, France and others) [494].

4.6.1.3 Product safety regulations

Most products sold in the EU need to receive regulatory approval to ensure that they are relatively safe to the consumers. In some cases, like pharmaceuticals or aviation, this regulatory process may take up to a decade, while in others it is enough to certify that products follow pre-defined safety standards. After the product reaches the market, government needs to establish mechanism to recall faulty products from the market, such as the recent case of Philips mechanical ventilators for patients with respiratory difficulties [495]. Given the length, human resources and financial costs of obtaining regulatory approval, regulators have been accused in multiple times of hindering innovation. Regulatory agencies, on their end, are constantly looking at ways to streamline their processes, for instance by using technologies such as digital twins and big data analytics.

As a result of these tensions, the product safety regulations are in a permanent state of adaptation. In 2022, the EU agreed on a change to the product safety regulations that is to come into force in 2024 and increase the safety of products, provide for clear rules for all businesses and enable better enforcement by authorities. Currently, dangerous products cause annual damage of 11.5 billion euros in the EU [496].

Changes in regulations have an impact on various SC parties involved and mostly serve to protect customer groups from illegal products. Companies are forced to make organizational changes in order not to lose access to the market. This also applies to platforms that will soon have to remove illegal goods in the EU within a period of 2 days. Authorities are changing their strategy from a reactive stance to a proactive one [497].

In 2022, a total of 2117 alerts because of dangerous products were sent to the European Union via the EU Safety Gate system. By far the most alerts came from Germany, with a total of 430 alerts which is a decline of more than 22 percent compared to the previous year. This was followed by France with 202 alerts and Poland with 156 alerts. The most alerts were created because of products from the product categories “Toys” (23%), “Motor Vehicles” (16%) and “Cosmetics” (10%). That means that especially the number of alerts for the category “motor vehicles” dropped significantly compared to 2021 (26%). This drop also has a strong correlation with the fact that risks related to injuries has fallen from 32% to 25%. On the other hand, the share of the risks related to chemicals has increased from 25% to 35%, which is mainly due to alerts relating to cosmetics. When looking at the places of origin of the dangerous products, half of the alerts happened because of Chinese products. The EU and European Environment Agency (EEA) ranks second with 22 % [498], [499]. The number of reports of fatal occupational accidents involving products in Germany recorded by the Federal Institute for Occupational Safety and Health has been 75 in 2022, which is 7 fewer than the year before [500].

Figure 71: Alerts validated on safety 2022. [498]

In Germany, the Product Safety Act was passed to comply with European directives. The law obliges all manufacturers, importers and dealers to observe high consumer protection and safety requirements when bringing products onto the German market [501]. Nevertheless, the above facts show that an improvement in product safety is still necessary.

The purpose of product safety regulations is to protect the consumer by minimizing risks associated with the use of consumer goods. As can be seen, nearly 80% of the dangerous products are coming from outside the EU. This leads to the importance of international safety regulations [498].

4.6.1.4 Risks for supply chains from consumer protection

Supply chains face risks in the context of consumer protection, driven by trends such as cross-border payments, long-term consumer retention, and product safety regulations. These risks can be categorized into three dimensions of sustainability: economic, environmental, and social. Understanding and addressing these risks is crucial for ensuring the integrity and resilience of supply chains, fostering trust among consumers, and promoting sustainable business practices.

Drawing from extensive literature and expert insights obtained through validation during the workshop, the identified risks have a direct and significant influence on the economic sustainability of the supply chain:

- *High costs and missing transparency of cross-border payments:* Cross-border payments pose great risks for supply chains, as they are currently characterized by high costs, low speed, limited access and insufficient transparency [502]. Laws and regulations for online payments vary from country to country. Carelessness and own internal errors can lead to high losses in cross-border mobile payment platforms at home and abroad [499]. Financial risks: Financial risks relate to corporate and supply chain financial flows and include foreign exchange risk, higher borrowing costs, as well as operational risks and inflation through CBDC. A CBDC can be created at the press of a button and distributed widely, inflating the money supply without any corresponding increase in GDP [503]. Relevance and challenges of currency conversion: International payments are typically done in international currencies, implying local currency conversion relying on banks offering such services at a cost to the end user.
- *Speed of mobile developments and security of assets*: Since mobile payments legislation does not meet the requirements for the development of such payments, consumer rights cannot be fully protected. Once losses occur due to technological gaps, the user is in a weak position and is unable to protect the security of assets [504].
- *Non-compliance with product safety standards:* The GPSR (General product safety regulation) places greater responsibility on business (particularly manufacturers, importers,

distributors, and retailers) in the supply chain to ensure that products are safe for consumers and creates the need to implement processes and controls to ensure compliance, which can add complexity to the supply chain operations. It also tightens existing regulations and strengthens the position of end consumers. Product testings, certifications, and quality improvements mean higher costs for companies and the increased risk of product recalls also pose a financial threat to companies [505].

- *Complex processing of compliance checks*: Cross-border payments are subject to strict compliance regulations, particularly those to combat money laundering (AML) and counter terrorist financing (CFT) [506]. AML/CFT and other compliance checks have been perceived as heavy by banks, also as their implementation across jurisdictions is heterogeneous, creating high costs and legal risks [507]. In order to comply with these rules, it is important that banks and financial service providers are able to unambiguously identify their customers by performing know-your-customer (KYC) checks [506].
- *Long transaction chains:* Several correspondent banks needed in an international payment chain before settlement, delaying settlement and making it more expensive as each intermediary requires to be compensated (including for compliance related work), and making the chain less traceable and more opaque [507]. A multilateral platform can potentially shorten transaction chains by allowing participants in different jurisdictions to send or receive payments directly instead of via multiple intermediaries [508].
- *Weak competition in banking:* Weak competition, which can contribute to higher prices for end users and underinvestment in related processes, has been identified as a key friction in cross-border payments [509]. The high costs and risks associated with AML/CFT regulation and fines applied to banks led to a withdrawal of many banks from the cross-border payment industry (“de-risking”), providing the remaining actors more market and thus pricing power [507]. Broadening direct access to payment systems could help alleviate this friction [509]. Financial risk and uncertainty: The de-risking approach creates uncertainty and increased financial risk within supply chains. The limited number of banks willing to engage may result in a lack of financial stability and options for businesses involved in international trade.

In addition to the economic aspect, the following risk has an impact on the environmental sustainability:

- *High cost to the environment & climate due to (intentional) returns & logistics:* Excessive product returns pose a risk to supply chains. Encouraging free returns can lead to excessive production levels where orders and sales exceed actual demand. This overproduction not only generates more waste, but also negatively impacts supply chain profitability. In addition, certain items, especially clothing, often remain unsold after they are returned, resulting in a significant environmental footprint. The production, transport and subsequent disposal of these products contribute to environmental degradation and waste accumulation. It is critical for supply chains to address this risk by implementing strategies to minimise returns, optimise production volumes and explore sustainable disposal methods [510].

Based on the evaluations of the experts and the feedback gathered during the workshop, the majority of consumer protection risks associated with the supply chain are considered highly probable but have a relatively low to moderate impact. Among these risks, the failure to consider cross-border legal diversity was identified as the risk with the highest likelihood of occurrence, as highlighted by the experts' assessments.

4.6.2 Informational regulation

The rise of devices in the IoT and their interconnection via cloud and other decentralized IT infrastructures has generated vast amounts of data in supply chains, raising concerns over how data is collected, used, and protected. In this context, data privacy regulations have become increasingly important, as they provide guidelines for how companies should manage and protect data in their supply chains. Additionally, data ownership and sovereignty have emerged as critical issues, as companies seek to maintain control over their data and ensure compliance with regulatory requirements. Finally, patent management has become a crucial consideration in supply chain management, as companies seek to protect their intellectual property and avoid infringement.

4.6.2.1 Data privacy

The focus on customer data and its security is becoming an increasingly important issue as the business community focuses more on data-driven systems. Private customer data offers companies new opportunities for action but is restricted by existing data protection laws. Despite existing laws, approximately 40% of AI used by companies violates these laws. It is anticipated that approximately 75% of the world's population will have their personal data to data covered under protection regulations.

Companies are confronted with the establishment of data protection regulations, which they may have to adapt for each country individually. Above all, this must be taken into account when designing and purchasing/renting clouds or running blockchains. Before releasing systems, companies must plan where the data can be stored in order to comply with all regulations. Companies will also use privacy-enhancing computations for data analysis.

The amount of data in the world increases significantly. An analysis by IBM in 2016 shows that 90% of the total data in the world was generated in the two previous years [511]. It also mentions, that with the increasing progress and the resulting digitalisation, which includes the use of sensors etc., the amount of generated data is accelerating. Also, data is poised to become even more essential due to generated data by networked end-user devices and through the internet of Things. Based on this information, certain individuals postulate that amassed data may present the novel most valuable commodity within the contemporary economy, as data can be infinite and reused [512].

As the collection of data offers advantages, it is important to protect those against cyber-attacks. With increasing data collection, the number of cyber-attacks increased through recent years. There were counted 230.000 new malware infections during January 2019 and April 2020 [513]. To be prepared for the increasing amount of cyber-attacks, over 50% of the companies are expanding their cybersecurity teams [514]. Of the responses, 51% would increase their cybersecurity teams, while 31% would prefer to maintain its current size. The remaining would either decrease their cybersecurity teams or had not decided yet.

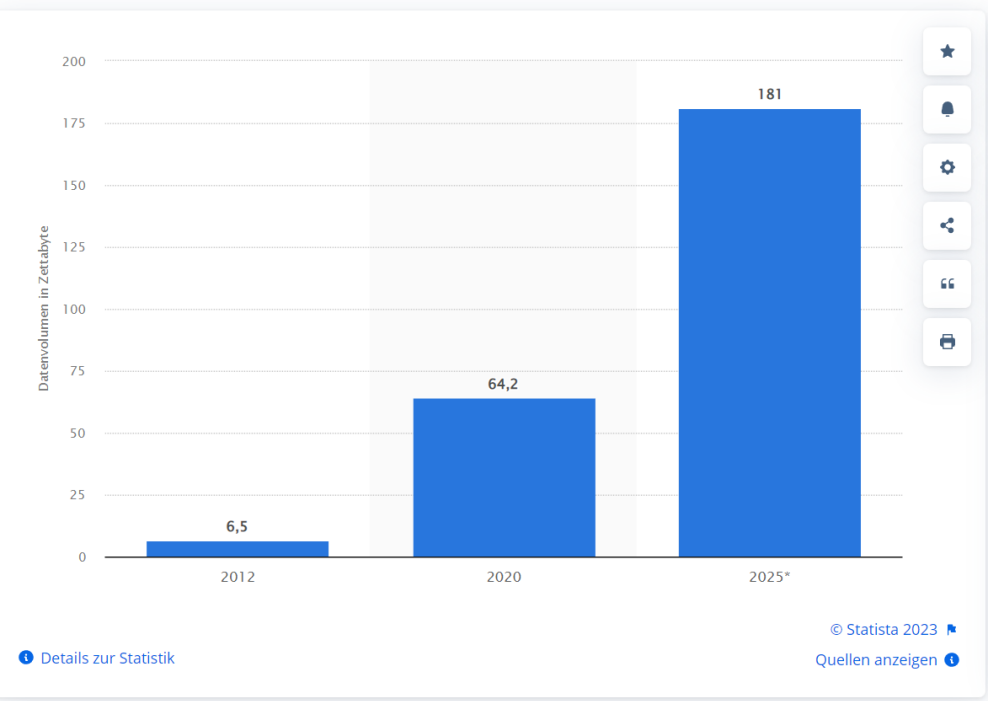

Figure 72: Worldwide data volume in zetabytes. [515]

4.6.2.2 Patents

One of the ways for companies to appropriate their knowledge is via patenting their innovations. In exchange for making the information about their inventions, public patentees gain exclusive rights to their financial exploitation. In the past years, new logistics trends are constantly establishing and also being patented. One of the latest trends in logistics is micro fulfilment and the optimization of distribution routes to improve last mile logistics and establish unmanned deliveries.

Based on the patent applications and research, logistics service providers can preventively derive trends in logistics and identify vacant fields. The logistics sector should be viewed as a development investment with vacant patents in the field of unmanned delivery and the associated algorithms, as well as intelligent sorting systems [516]. Supply chain stakeholders have to be careful about fights about intellectual property [517]

On average, the number of patent applications worldwide increases every year. In 2021, the number of patent applications peaked at around 3.4 million applications. By comparison, in 1990 there were only about 1 million applications. Since the beginning of the last decade, the number of patent applications has been increasing more strongly [518].

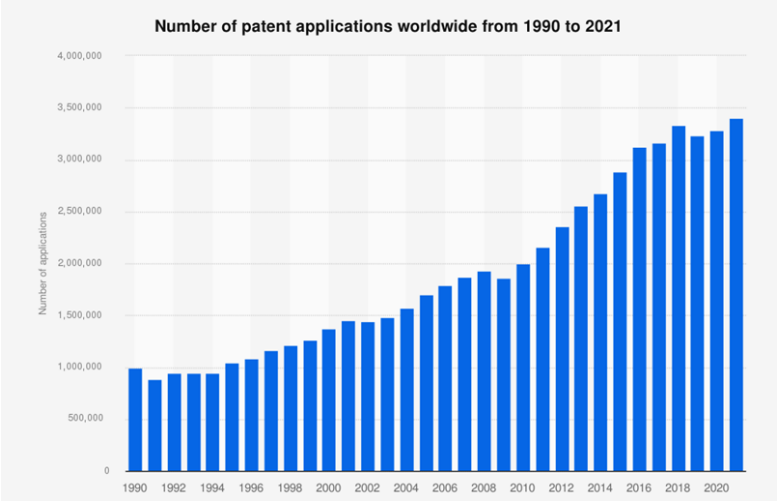

Figure 73: Number of patent applications worldwide from 1990 to 2021. [518]

Artificial intelligence is one of the innovations that will have a strong impact on logistics in the coming years. In the field of AI, the number of patent applications has risen sharply since 2010. While just 2560 patent applications were recorded in 2010, this figure had already risen to 141241 by 2021. The last few years in particular have seen strong growth in patent applications [519].

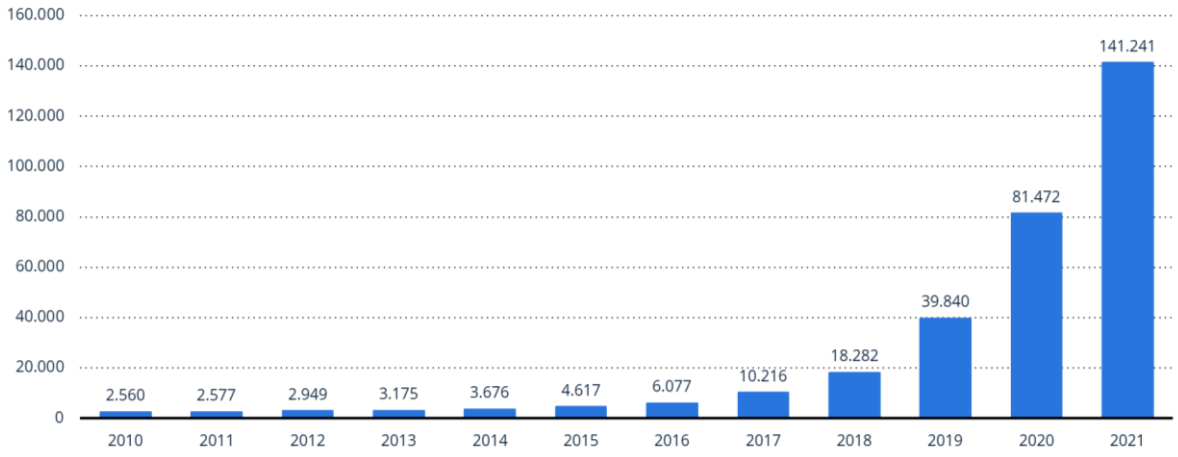

Figure 74: Number of patent applications in the field of AI worldwide from 2010 to 2021. [519]

Also, in relation to the last-mile delivery already mentioned, the following figures indicate that there will be an increasing number of innovations in the coming years and that an increasing number of patents may go hand in hand with this. So, the market for last mile opportunities is expected to grow in the next years. Current forecasts assume that the last-mile market for the year 2023 will be 140 billion USD. Further, by the year 2027, the market for last mile delivery opportunities is expected to increase to 200 billion USD [520]. Comparing to the other continents, the investments in startups operating in the last-mile sector in Europe are relatively low. The investments in Europe are reaching 2,9 billion USD while the highest investments are in north America with a total amount auf 9,4 billion USD. Also, the investments in Asia amount to 8,3 billion USD in total [521].

4.6.2.3 Data ownership and sovereignty

Businesses grow co-dependent and form digital business and data ecosystems. Therefore, the questions about the capabilities of being self-determined concerning its data becomes more critical. The required capabilities are summarized under the term data sovereignty that is necessary to

manage predicted 181 Zettabyte of data in 2025 [515]. While the data economy only made up 2.6% of the General Data Protection Regulation (GDPR) in 2019 it is expected to grow to 9.1% in 2025. Over 100 countries therefore already apply data sovereignty rules to determine exchanged data is subject to their regulations. Business partners do not only need to specify access rights toward shared data but also need to set usage control policies, which specify how third parties can use their data.

The amount of data generated and replicated is growing very fast. While it was already 6.5 zettabytes in 2012, it has increased almost tenfold to 64.2 zettabytes by 2020. Forecasts even predict an increase in the amount of data worldwide to 181 terabytes by 2025 [515]. The large volume goes hand in hand with a growing interest in the exploitation of the data. However, this also raises questions about data ownership and data sovereignty [522].

One technology that uses large amounts of data and is particularly interrelated with data sovereignty and data ownership is artificial intelligence [523]. The global market for artificial intelligence amounted to 383.3 billion US dollars in 2021. The market is expected to grow to US$450 billion in 2022 and US$554.3 billion in 2024 (Figure 75) [519].

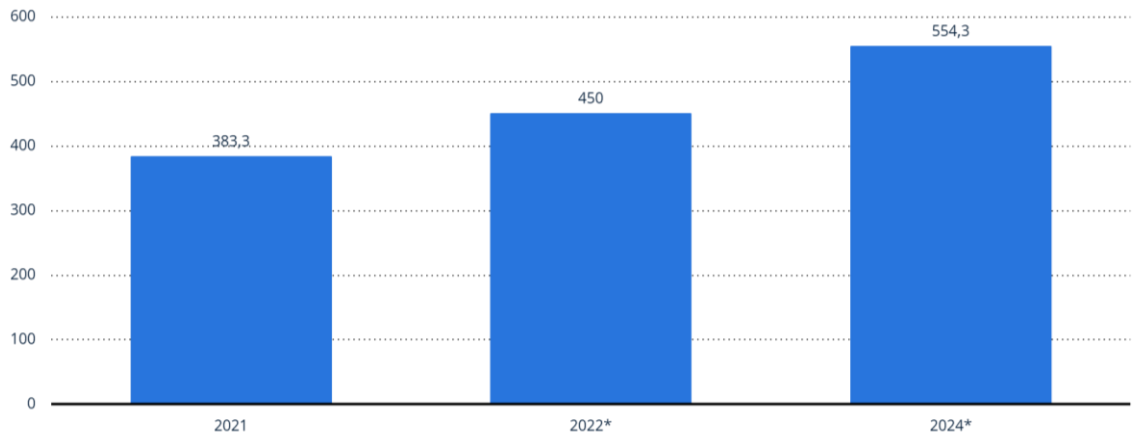

Figure 75: worldwide revenue in the industry for Artificial Intelligence in billion US Dollar. [519]

The Cisco Data Privacy Benchmark Study of 2023 has produced some exciting key findings. The study is based on a survey of over 4700 security experts in 26 countries worldwide. Already today, 98% of companies report data privacy metrics to their board of directors, while 92% say they need to do more to inform their customers about how their data is being used. Furthermore, 94% of companies see data protection as fundamentally important, believing that their customers would not buy from them if their data was not properly protected [524].

4.6.2.4 Risks for supply chains from informational regulation

There are several risks associated with information regulations that can impact European supply chains. These risks of these information regulations affect supply chains mainly in terms of economic sustainability:

- *Customer trust erosion due to privacy concerns:* Companies' data collection methods, especially involving tracking technologies like cookies and GPS trackers, have raised customer concerns about privacy protection. Such apprehensions can significantly impact customer trust in companies, potentially leading to reduced customer loyalty and decreased sales. [525]
- *Increasing cost of compliance with regional regulations:* Variances in data privacy, protection, and localization regulations across countries and regions necessitate local-level

considerations. Companies must invest significant time, energy, and management attention to understand and comply with the unique aspects of each jurisdiction in which they operate. This complexity drives up compliance costs, adding financial burdens to organizations. [526]

- *Impaired innovation due to GDPR restrictions:* The General Data Protection Regulation (GDPR) has led to a reduction in the volume of app submissions, potentially hindering innovation. The unpredictable nature of app quality at the time of entry, combined with the stringent requirements of GDPR, poses challenges for companies to develop and offer new and valuable apps to consumers, limiting innovation possibilities. [527]
- *Shift in innovation focus to incremental improvements:* The complexities introduced by GDPR compliance can impede radical innovation efforts. Organizations may divert their innovation focus towards incremental improvements to mitigate the risks associated with regulatory compliance, thereby compromising the potential for disruptive innovations. [528]
- *Reputational and financial fallout from data security and privacy breaches*: As data becomes increasingly important, organizations face significant risks associated with data security and privacy breaches. Failing to ensure adequate data protection measures can have severe economic and legal consequences for companies. Customers prioritize data privacy, as highlighted by the Data Privacy Benchmark Study 2023. Concerns about privacy and data protection may lead customers to refrain from making purchases, resulting in potential financial losses for businesses [524]. Additionally, non-compliance with the GDPR can expose companies to legal disputes and substantial financial penalties. Recent years have seen major tech firms facing massive fines, with an average fine of 1.5 billion EUR between 2018 and 2022 [529].

Based on the evaluations of the experts and the feedback gathered during the workshop, the majority of risks associated with informational regulations and their impact on the supply chain are considered to have a moderate probability of occurrence and a moderate impact. However, the risk of impeding radical innovation due to GDPR was identified as likely by the experts and could potentially have a moderate to strong impact on supply chains.

4.6.3 Social and environmental regulations

In recent years, there has been a growing concern about the social and environmental impact of business activities. As a result, European governments have implemented various regulations aimed at ensuring that companies operate in a socially and environmentally responsible manner and enforced by corporate social responsibility regulations as an instance. This regulation is designed to ensure that companies are accountable for the impact they have on society and includes areas such as labour practices, human rights, and community involvement. Furthermore, inclusiveness regulations focus on ensuring that companies are inclusive of all people, regardless of race, gender, or other factors. Emissions control regulations aim to reduce the amount of pollution that companies generate. This includes regulations on air emissions, water pollution, and hazardous waste. Waste and resources management regulations focus on reducing waste and promoting recycling and sustainable resource use.

4.6.3.1 Corporate social responsibility

Corporate social responsibility (CSR) has become increasingly important for companies in Europe, with social legislation being a key driver of this trend. CSR encompasses a company's responsibility to conduct business in an ethical, socially responsible and environmentally sustainable manner that goes beyond legal requirements. Social regulations such as labour laws, human rights standards and environmental regulations aim to promote responsible corporate behaviour and hold companies

accountable for their impact on society. This introduction explores the growing importance of CSR in Europe and the role of social regulations in promoting this trend.

This prioritization of CSR is a response to growing consumer expectations that companies should take their social responsibilities seriously. A survey by Edelman (2021) found that nearly 70% of European consumers expect companies to meet their social obligations [530]. In general, the number of people who, when buying a product, find it important that the company behind it acts in a socially and ecologically responsible manner has risen steadily since 2016 [530]. This trend is likely to continue as companies seek to differentiate themselves in an increasingly competitive marketplace [531].

Furthermore, the CSR and the SDGs are interlinked concepts that aim to promote sustainable development and address global challenges. The SDGs are a set of 17 goals set by the United Nations in 2015 to promote sustainable development and address global challenges such as poverty, inequality, climate change and environmental degradation. The SDGs provide a framework for governments, businesses, and individuals to work together toward a more sustainable and equitable future [532].

Figure 76 shows that about 70% of the SDG targets have been achieved across Europe, although there is still room for improvement in all countries. Finland is the leader in the overall achievement of the SDG targets with a compliance rate of 81.68% [530], [533].

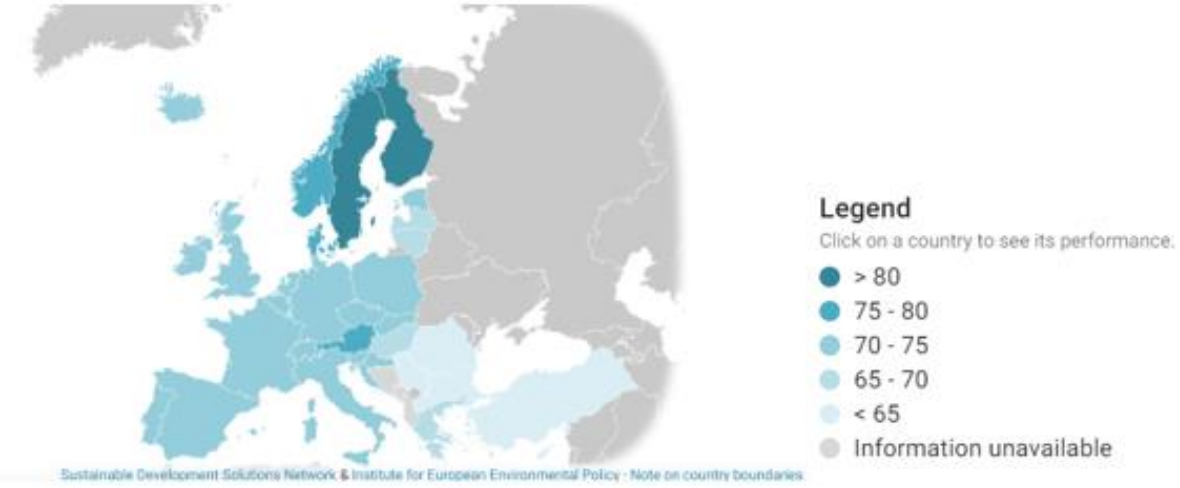

Figure 76: Overall SDG Scores in European Comparison in percentage. [533]

Taken together, the trend suggests that CSR is becoming increasingly important for European companies and is having a positive impact on sustainability practices and consumer attitudes.

4.6.3.2 Inclusiveness regulations

Inclusiveness regulations have gained significant attention in Europe as a key aspect of social regulations. These regulations aim to promote equality and non-discrimination in the workplace, ensuring that employees from all backgrounds are given equal opportunities to succeed. With the rise of diversity and inclusion as important business imperatives, many companies in Europe are now taking steps to foster a more inclusive workplace culture. This introduction will explore the growing importance of inclusiveness regulations in Europe and their role in promoting greater diversity, equity, and inclusion in the workplace.

Gender parity remains a significant issue in Europe and globally. The global gender gap has been closed by only 68.1% in 2022, and it will take another 132 years to close it completely [534]. Action to advance gender equality could add $12 trillion to the global GDP in 2030 compared to the baseline.

However, between 40 million and 160 million women may need to transition between occupations by 2030, often into higher-skill roles, due to automation [535].

Underrepresentation of women in executive positions is a concern, and projections show that gender parity on corporate boards may not appear until 2039 at best, until 2069 at worst, and under normal progress not until 2045. Inclusiveness, diversity, and equity initiatives are essential for promoting representation of minorities in top-level carriers. In 2021, women accounted for around 46.1% of all workers in the European Union. However, only one in three managers (34.7%) was female in 2021, with significant intra-European differences as in Figure 77 [536].

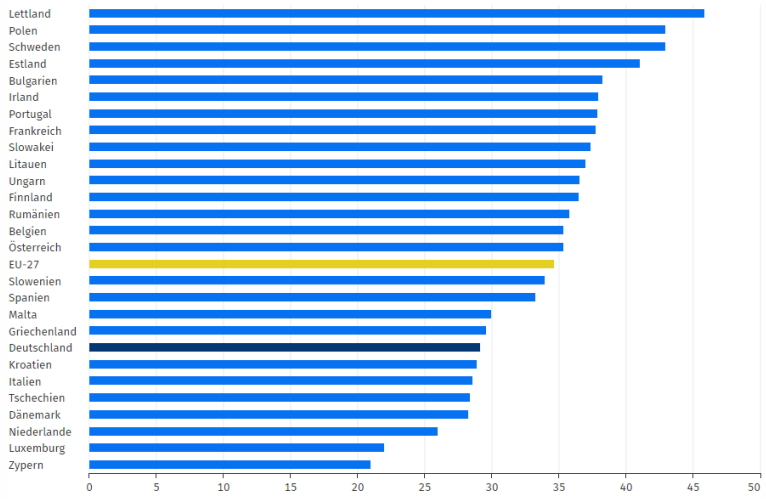

Figure 77: Share of women in leadership positions 2021. [537]

From the supply chain perspective, 62% of supply chain organizations are looking at the dimensions of ethnicity/race as part of their recruitment strategy, while 30% of the full-time supply chain workforce are people of color, but only 9% of supply chain Vice Presidents are people of color. Approximately 41% of supply chain organizations have no plans to improve DEI (Diversity, Equity, and Inclusiveness). Most DEI initiatives in place at supply chain organizations prioritize education and awareness-raising, followed by recruiting and integrated pipeline planning [538].

Various regulations aimed at promoting inclusiveness exist in Europe, such as the EU Charter of Fundamental Rights, the EU Race Equality Directive (2000/43/EC), the EU Gender Equality Strategy 2020-2025, and the EU Disability Strategy 2010-2020. These regulations aim to ensure equal opportunities and treatment for all individuals, regardless of their personal characteristics. However, discrimination remains a significant problem in Europe, with almost one in five people in the EU experiencing discrimination based on their race, ethnicity, religion, or other personal characteristics. The employment rate for people with disabilities in the EU was 50.8%, compared to 74.8% for people without disabilities, highlighting the need for greater inclusiveness in the workplace [539].

In conclusion, inclusiveness regulations are a crucial trend in Europe and will remain relevant for supply chains. The underrepresentation of certain groups, such as women, people of color, and people with disabilities, highlights the need for greater inclusiveness and diversity in the workplace. Companies must prioritize initiatives to promote inclusiveness, equity, and diversity to create a more inclusive workplace culture and promote representation of all individuals.

4.6.3.3 Emissions control regulations

In recent years, the awareness of the harmful effects of greenhouse gas emissions on the environment and human health has increased. This has led to the introduction of strict emission control regulations in Europe aimed at reducing emissions from various sectors such as transport

and energy production. The motivation behind these regulations is to mitigate the negative effects of climate change and improve air quality, both critical social and environmental issues. This trend towards emissions control regulations is expected to continue in the coming years as countries strive to meet their commitments under the Paris Agreement and work towards a more sustainable future.

Emissions control regulations represent a significant and ongoing trend in Europe. For instance, the EU Commission submitted a draft in February 2022 that obligates larger companies to be sustainable. Companies with sales of over €150 million must show efforts to transform in line with the Paris Climate Agreement and recognize their own negative environmental impacts. As a result, companies must adjust their collaborations with cooperation partners, and supply chains must be transparently presented, as the entire supply chain is covered by the law. Small and medium-sized companies can benefit from this directive by positioning themselves early on [540].

In addition, companies are under increasing pressure to reduce their carbon footprint in order to meet EU sustainability targets. The European Union has also introduced several emissions control regulations that affect supply chains. The EU Emissions Trading System (EU ETS), for instance, is a cap-and-trade system that sets a limit on the total amount of greenhouse gas emissions that can be released by certain sectors, such as power generation and aviation. Companies in these sectors must purchase permits to emit greenhouse gases, creating a financial incentive to reduce emissions [541], [542], [543].

In the third quarter of 2022, shown in Figure 78, GDP in the EU grew by 3%, while greenhouse gas (GHG) emissions increased by 2%. This indicates a slight decoupling of economic growth from emissions. Furthermore, emissions increased in 16 out of 27 EU Member States, indicating a recovery from the pandemic [544].

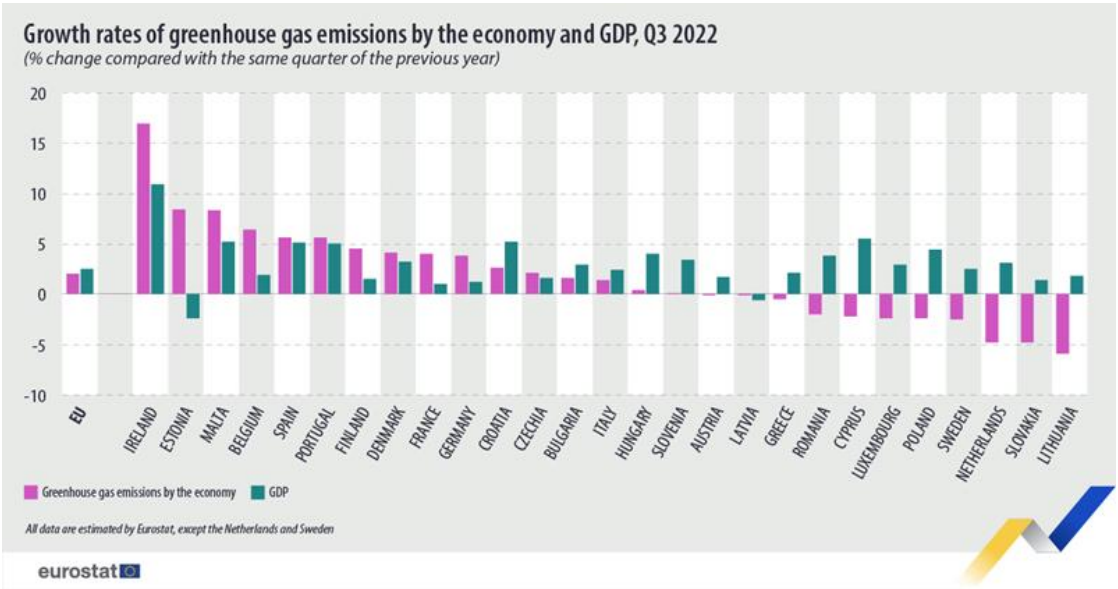

Figure 78: Growth rates of greenhouse gas emissions by the economy and GDP, 2022. [544]

Finally, the EU has introduced regulations to reduce emissions from vehicles, such as the Euro 6 emissions standards for cars and light commercial vehicles. These regulations have had a significant impact on the automotive industry and supply chains. Companies must invest in new technologies and processes to meet the standards [545].

In conclusion, emissions control regulations are an important trend in Europe that affects supply chains. Companies must adapt to these regulations and strive to reduce their carbon footprint to meet their sustainability goals. As the world moves towards a more sustainable future, it is essential for companies to embrace emissions control regulations as a critical aspect of their operations.

4.6.3.4 Waste and resources management regulations

The management of waste and resources is a crucial issue in today's society due to increasing concerns about environmental sustainability. The European Union has introduced various regulations and policies to address this issue, with the aim of promoting a circular economy that minimises waste and maximises resource efficiency. These regulations focus not only on environmental impacts, but also on the social aspects of waste management, such as fair treatment of waste workers. This trend in waste and resource management regulations in Europe reflects a growing awareness of the need to prioritise sustainability in business practices and create a more sustainable future for all.

The trend of urbanization will continue in the coming decades, so that by 2050, about 50% of the world's population will live in cities. Cities are already responsible for about 70% of GHG emissions and about 50% of solid waste. The circular economy will be an essential factor in tackling the problem [546]. Already today, the average European produces 5 tonnes of waste each year, with only 38% of waste being recycled in the EU. Over 60% of household waste is still sent to landfill in some EU countries [547].

Through a circular economy, companies need to change the structure of existing supply chains and redesign them. The new supply chain design includes an optimization of supply chain facilities in order to optimize logistical processes and to be able to use recycled material. A greater willingness to cooperate is necessary along the entire supply chain in order to successfully establish the Circular Economy system. A prominent example is the long-awaited common charger for mobile devices, which will finally become reality in 2024 [548], [549].

Figure 79 illustrates the EU's situation, which so far still has room for improvement. The circular material use rate in the EU is around 11 per cent, with some countries making a significant leap in the right direction over the past decade [550].

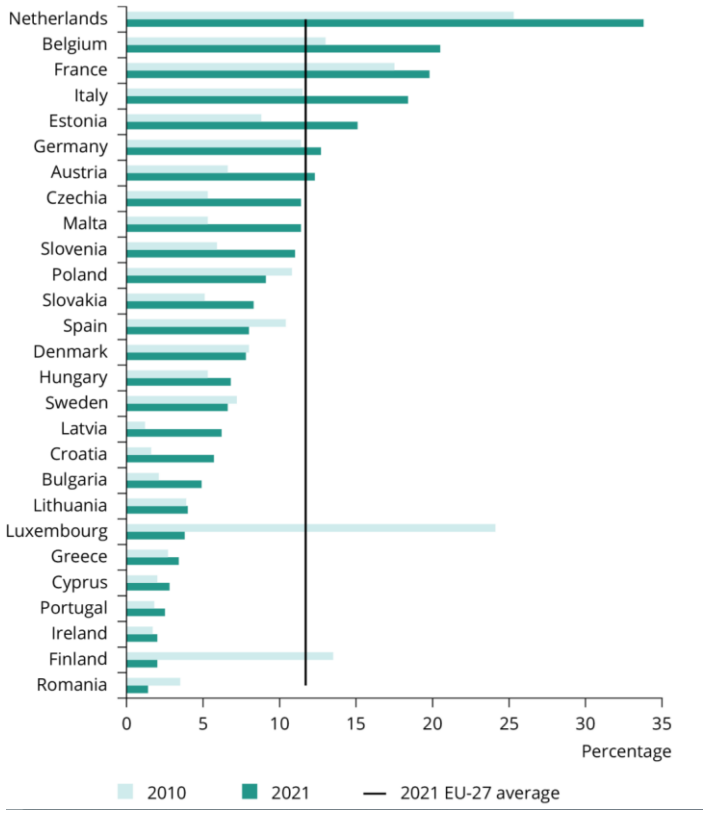

Figure 79: Circular material use rate by EU country, 2010 and 2021. [550]

4.6.3.5 Risks for supply chains from social and environmental regulations

There are some risks for European supply chains arising from social and environmental regulations. These can be divided into economic, environmental and social dimensions of sustainability. First, the economic risks are listed.

- *Greenwashing:* With the increasing popularity of corporate social responsibility (CSR), there is growing concern that some companies are focusing on promoting and highlighting highly visible CSR activities while neglecting the less visible ones. This selective approach to CSR can be seen as a marketing ploy that creates the impression of environmental and social responsibility without taking significant action or achieving impact [551], [552].
- *Increased costs and efforts*: Implementing social and environmental regulations, such as human rights compliance in supply chains, requires companies to be transparent and disclose data. This process can be resource intensive and require significant cost, effort, and time. Companies may need to invest in systems, personnel and processes to effectively monitor and manage their supply chains, driving up their operating costs [553]. In addition, the ban on fossil fuel vehicles from 2040, which is currently under discussion, would also lead to a switch and investment in new infrastructure [554].
- *Obsolete business models*: Existing business models are at risk of becoming obsolete as governments and policy makers introduce new laws and regulations to support social and environmental responsibility. These policies may make current business models incompatible or inefficient with the required standards. Companies may find it difficult to adapt and comply with the new regulations, leading to potential challenges in their business operations. This may lead to business closures or forced divestments, especially if companies are unable to meet the stringent standards imposed. [555]

In addition to the economic aspects, the risks affecting the environment mainly concern the infrastructure with regard to waste management. The main risks have been grouped as follows:

- *Inadequate waste management infrastructure*: The transition to a circular economy that aims to minimize waste and maximize resource efficiency often requires extensive infrastructure and logistical support. Implementing regulations related to waste and resource management can require investments in personnel, facilities, energy, and time. The lack of adequate waste treatment infrastructure can hinder the effective implementation of circular economy principles and present supply chains with challenges in managing their environmental impacts [556].
- *Lack of recycling technologies:* Sustainable waste management depends on effective recycling technologies. However, the lack or limited availability of advanced recycling technologies can hinder the ability of supply chains to efficiently recycle materials and products. This limitation can hinder the achievement of sustainability goals and increase reliance on traditional disposal methods, contributing to environmental degradation [556].

Finally, here is the largest risk to the social dimension, labor health and corporate responsibility:

- *Labour standards and responsible business conduct*: Governments and policymakers are increasingly emphasizing labour standards and responsible business practices in their trade policies and investment treaties. This includes expecting companies to ensure ethical labour practices, fair treatment of workers, and compliance with human rights standards. Failure to meet these standards can lead to reputational damage, legal consequences and supply chain disruption [557], [558].

According to the experts' assessments and the comments collected during the workshop, most of the risks of social and environmental regulation to the supply chain are considered to have a moderate probability of occurrence and moderate impact on supply chains. However, the risks such as increasing costs and efforts due to the Act on Corporate Due Diligence Obligations in Supply Chains were rated as likely by the experts and have a potentially strong impact on supply chains.

4.7 ENVIRONMENTAL DIMENSION

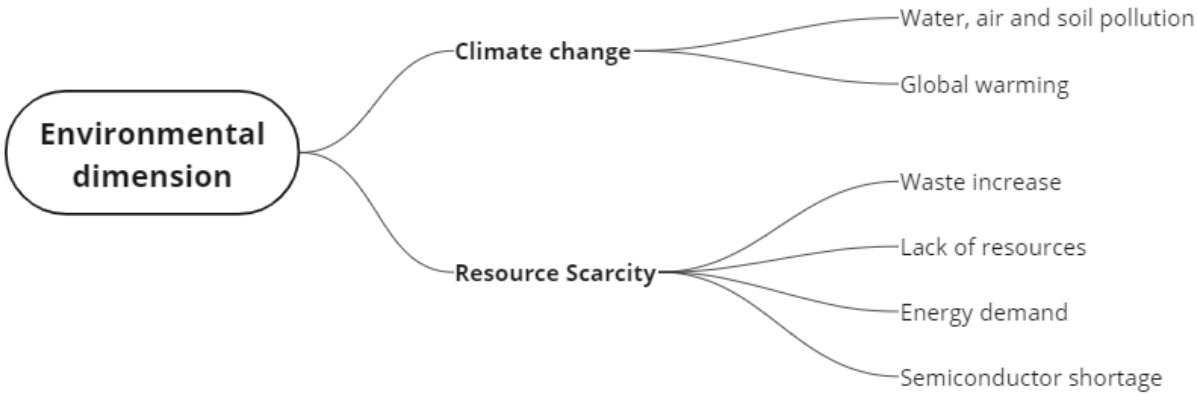

Figure 80: Overview of the trends in the environmental dimension.

4.7.1 Climate change

Climate change is long since impacting economic developments and demands for climate protection activities. Businesses and particularly supply chain partners are increasingly focusing on its consequences as a major risk that - in the context of regulation - requests from regulators and other stakeholders. Climate change is characterized by global warming and fluctuating weather conditions as well as accompanied by sub-trends that are also having an impact on the supply chains, such as air and water pollution.

4.7.1.1 Water, air and soil pollution

Pollution of water, air and soil is an increasingly alarming trend in Europe. Human activities such as industry, agriculture and transport release pollutants into the environment that can affect both human health and ecosystems. According to the European Environment Agency, air pollution is still the largest environmental health risk in Europe and significantly impacts the health of the European population, particularly in urban areas. Also, water resources remain under pressure as large amounts of surface water bodies in the European Union are in poor ecological conditions.

Pollution of water, air and soil is not insignificant in Europe and has a major impact on the environment and health. Water is a valuable resource in Europe and is comprised of 75% of the total water abstraction from rivers and reservoirs and 25% from groundwater. With only 40% of surface water bodies being in good ecological status and 38% in good chemical status, significant risks are posed to European citizens [559]. The gap between global water supply and demand is projected to reach 40% by 2030 if current practices continue. In many places, demand is already exceeding sustainable supply, and in others, water scarcity is hindering economic growth [560]. Without altering current levels of water consumption and pollution, almost half of the world's population will suffer severe water stress by 2030 [561].

Besides the pollution of the essential resource of water, air pollution is a major health risk in Europe. While emissions of key air pollutants and their concentrations in ambient air have fallen, air quality remains poor in many areas. With regard to current statistics, air pollution affects 96% of the urban population that is exposed to levels of particulate matter above the health-based guideline set by the World Health Organization (WHO) [562]. The recommended annual mean value of the WHO is 10 µg/m3. Figure 81 below clearly shows that the EU-wide annual mean value is above the WHO recommended value, even though this varies from country to country. The hotspots are mainly in Bulgaria, Poland, Romania and Croatia [563]. As a consequence, nearly 300,000 Europeans die prematurely each year. New rules that were proposed by the European Commission in October 2022 could reduce deaths resulting from levels of the main pollutants by more than 75% in ten years [564]. The described particulate matter and ground-level ozone are projected to become the top cause of environmentally related death causes worldwide [565].

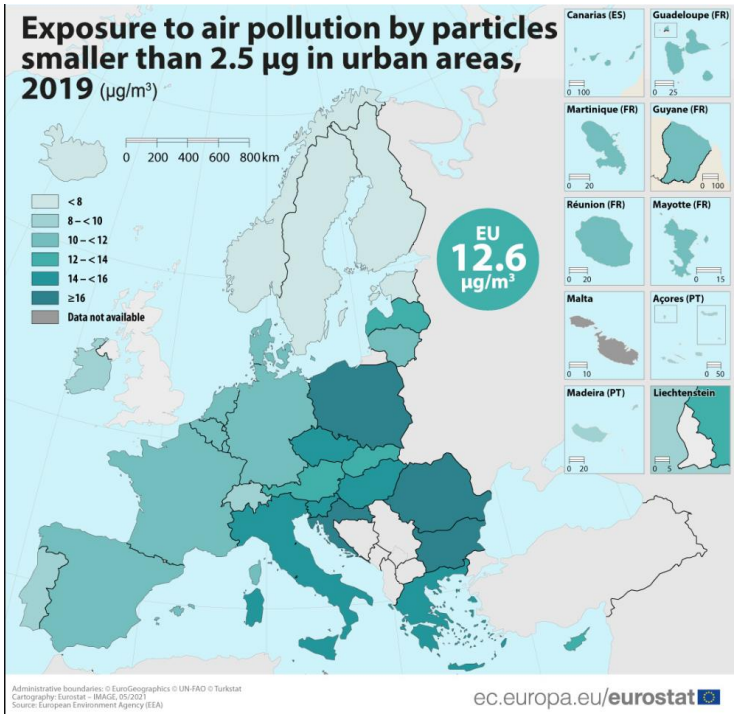

Figure 81: Air pollution by particles smaller than 2.5 in µg/m3 in European countries. [563].

The third elementary factor to be mentioned here is also soil pollution. According to the European Environment Agency (EEA), around 2.8 million sites in Europe are contaminated with soil pollution, including former industrial sites, landfills and agricultural land. Industrial activities and waste disposal are the main causes of pollution, with soil degradation costing the EU more than €50 billion per year. The most common contamination and pollution of European soils occur through mineral oil and heavy metals. 17% of the agricultural land surveyed in Europe is contaminated with high concentrations of heavy metals [566].

4.7.1.2 Global warming

Global warming is an issue of great concern in Europe and around the world. The release of greenhouse gases from human activities such as the burning of fossil fuels, land use and deforestation, is accelerating global warming. This warming is already having a noticeable impact on the climate and environment in Europe, such as heat waves, droughts and floods. The health, economic and environmental impacts are significant and require urgent action to reduce greenhouse gas emissions and limit global warming. In this regard, European countries have set ambitious

climate targets and are striving to take the necessary steps to reduce greenhouse gas emissions and ensure a sustainable future.

The trend of global warming is a significant challenge facing Europe and its effects are already being felt around the world and in Europe. Since 1880 temperature anomalies that represent the difference from an average or baseline temperature have been observed and show a significant increase over time (see Figure 82). Since the 1980s, annual temperature departure from the 20th century has been consistently positive. In 2021, the land and ocean surface temperature anomaly stood at 0.84 degrees Celsius [567].

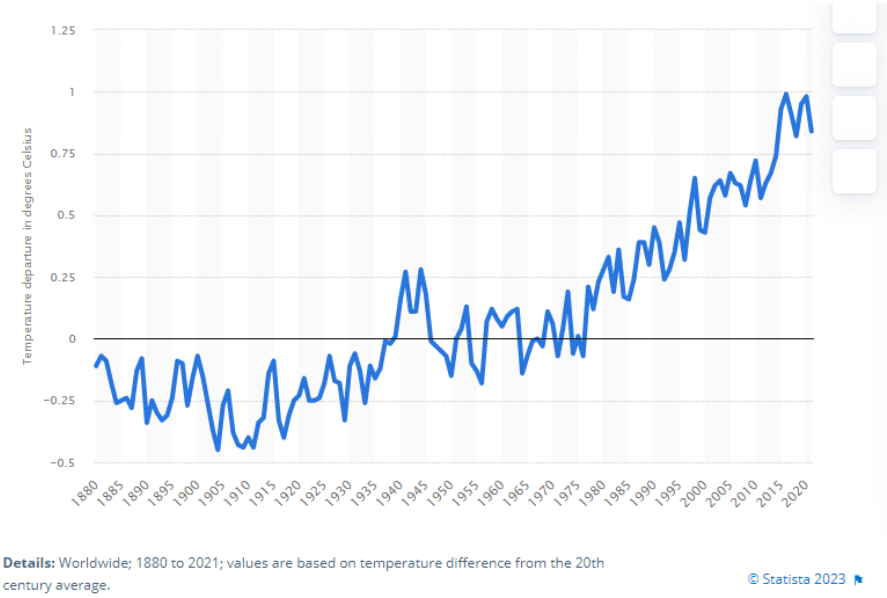

Figure 82: Average annual global temperature variation from 1850 to 2021 (in degrees Celsius). [567]

The year 2020 was the second hottest year on record and all five hottest years on record have occurred since 2015. According to climate researchers, global warming may exceed 1.5 degrees Celsius in the coming decade compared to pre-industrial times [568]. The development of global warming brings different effects such as the general rise in sea level, floods, heat waves and droughts. The rise in mean global sea level serves as an example. This has risen by about 20 cm since 1900, and the process has accelerated in recent decades. Model simulations predict a rise of 28-98 cm in the 21st century, depending on the emissions scenario, although higher rises are not excluded [569].

4.7.1.3 Risks for supply chains from climate change

Supply chains today are exposed to a number of risks related to climate change. The trends associated with climate change are air and water pollution and global warming. The five largest risk categories of climate change on supply chains are presented in more detail below.

Drawing on the insights from literature and validated by experts during the workshop, the subsequent risks emerge as influential factors directly affecting the economic sustainability of the supply chain:

- *Decreasing of labour availability and productivity:* The risks associated with decreasing labour availability and productivity due to climate change are twofold. First, longer lead times in production and longer delivery times in logistics can lead to lower productivity due to resource scarcity, extreme weather events and changes in the supplier base. Furthermore, the tendency to avoid air freight also leads to an extension of lead times. Second, productivity

itself may decline if workers become ill or have to work in difficult conditions. These factors can lead to a decline in the efficiency and effectiveness of supply chains [570]–[572].

- *Escalating costs:* Climate change poses significant financial risks to the supply chain, including risks to build capital, costs along the supply chain, commodity prices and price volatility. Built-up capital is at risk from extreme weather events causing damage to machinery, transport infrastructure, power grids and telecommunications. In addition, supply chain costs are likely to increase due to higher transport and insurance costs and higher commodity prices. Price volatility also poses a risk to the supply chain as it leads to price uncertainty and affects the profitability of the supply chain [572]–[574].
- *Deterioration of storage conditions:* Climate change has worsened storage conditions, leading to reduced shelf life, storage security and quality of produce along the supply chain. This has led to increased post-harvest losses on farms, with significant implications for food safety and supply chain profitability. The reduced quality of storage facilities is due to extreme weather events that cause damage to storage infrastructure and lead to adverse environmental conditions that affect the quality of stored produce [572].

The largest risk that affects environmental sustainability concerns the decrease in the efficiency of logistics and emissions:

- *Decrease in logistics efficiency*: Extreme weather events such as hurricanes, floods and heat waves pose significant risks to the supply chain. The impact of these events includes disruption of transport routes, an increase in transhipment frequency and emissions, delays in shipments leading to higher logistics costs, and reduced operational performance of suppliers and their customers. Adapting the supply chain to extreme weather events is challenging as they can only be predicted over a short period of time. In addition, supply chain actors may lack the resources to adapt to these events, leading to supply chain disruptions and increased risks [574], [575].

The final element is the risk to social sustainability. Here, the health of the workers and the working conditions also pose the greatest risk:

- *Health conditions*: The risks associated with climate change have led to poor worker health and further deterioration of working conditions. This is due to various factors, such as exposure to extreme weather events, air pollution and water contamination, which lead to respiratory and cardiovascular diseases and heat stress. The impact of these health risks also extends to the supply chain, where affected workers are less productive and supply chain costs increase due to medical expenses and insurance [571].

According to the experts' validations and the comments collected during the workshop, most of the climate change risks to the supply chain are considered to have a moderate probability of occurrence while having high to very high impacts on the supply chains. The risk of suffering from extreme weather events that trigger supply chain disruptions was ranked as the risk with the highest potential impact on supply chains by the experts. In contrast, the risks with lower supply chain impact but relatively high probability of occurrence are potential panic reactions of the society and workforce as well as other climate change related changes in health conditions. The highest probability of occurrence is associated with a deterioration of storage conditions.

4.7.2 Resource scarcity

Besides climate change, the scarcity of resources is one of the biggest megatrends in the environmental field. The scarcity of resources has various causes, such as climate change, the type of value creation and also geological conditions. Resources from all sectors may become scarce in the future, including water, land, energy, food, rare earth and semiconductors. The scarcity of these resources poses major challenges for supply chains in the future. The sub-trends below take a closer look at the scarcity of resources and their impact on supply chain risks.

4.7.2.1 Lack of resources such as water, land, energy, food and rare earth elements

The trend of resource scarcity, particularly with regard to water, land, food, energy, and rare earth elements, poses a significant risk to supply chains in Europe. The expanding global population and escalating industrialization have precipitated a surge in resource demand, while simultaneously, their availability remains constrained. Water, as a supremely valuable resource, is increasingly becoming scarce owing to persistent droughts and escalating pollution levels. Moreover, the availability of land is limited, yet indispensable for both agricultural purposes and urban development. The escalating demand for food and meat further exacerbates land overexploitation and consequent decline in agricultural productivity. Additionally, the prevalent dependence on fossil fuels and conventional energy sources exacerbates the situation, compounding the scarcity issue. This is further compounded by a shortage of rare earth elements, which find extensive application in cutting-edge technologies such as smartphones and electric vehicles.

Europe has limited natural resources, which are further diminishing due to economic development. Already today, in some regions of Europe, there are already experiencing shortages of water, land, energy, food and rare earths. In terms of freshwater resources, Europe has abundant amounts compared to many other parts of the world. However, the fact that freshwater resources are not evenly distributed across the continent, and therefore parts of Europe are exposed to water stress [576].

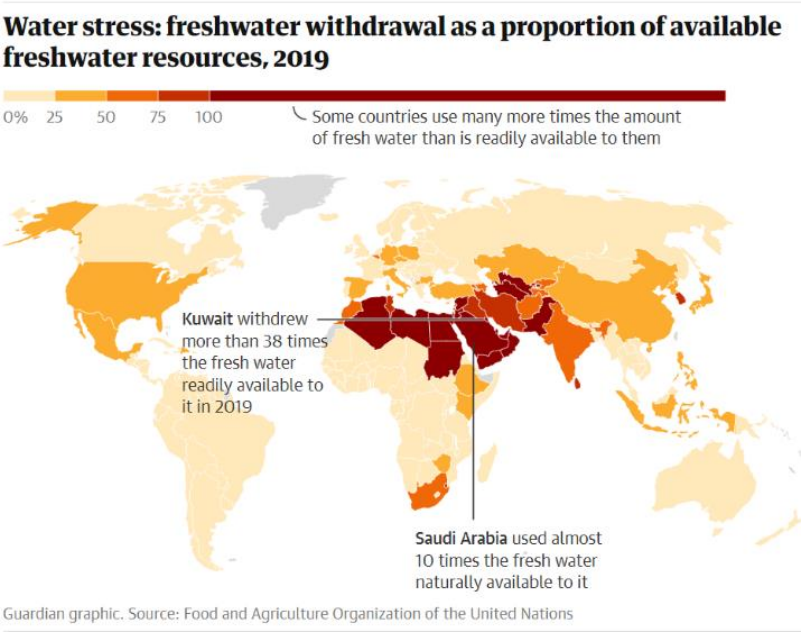

Figure 83: Water stress: freshwater withdrawal as a proportion of available freshwater resources. [577]

Globally, the demand for water and food will increase significantly in the future. By 2050, the demand for food will increase by 60% and demand for water by 20-30% [578]. In addition, Europe is highly dependent on imports of rare earths, which are needed for the production of high-tech products such as mobile phones and wind turbines. In addition, the EU has currently classified 30 raw materials or groups of raw materials as critical and the availability of rare earths may be affected by geopolitical tensions and trade restrictions [579].

4.7.2.2 Waste increase

The trend of increasing waste is a global phenomenon due to several factors, including economic growth, population increase and consumer behaviour. Increased waste of resources also leads to

increased amounts of waste. The cost of waste disposal can be significant for businesses and governments. Increasing amounts of waste require larger landfills and recycling facilities, which require large investments. Waste disposal can also have a significant impact on the environment, including the release of greenhouse gases and pollution of air, water and soil.

The consumption and waste of resources in today's supply chains cannot be ignored. Especially in the area of food, 50% of the harvest is wasted on the transport route from farmer to end consumer. Approx. 24% of this is lost during harvesting, for example. Private persons in the EU throw away approx. 158-298 kg of food per year. Sustainable supply chain management is one way to counteract the waste of resources and the associated increase in waste [580].

According to the European Commission, plastic waste of around 25.8 million tonnes is generated in Europe every year. Of this, less than 30 per cent is currently collected for recycling [581]. Although the total per capita waste generation in the EU decreased by 4.2% between 2010 and 2020, the observation is only visible since 2018. The latest development can be attributed to the slowdown of the EU economy due to the COVID-19 pandemic and the EU is setting big targets to significantly reduce total waste generation by 2030 [582]. Although Figure 84 shows that the recycling rate in Europe is already close to or above 50% in various waste streams, the positive trend since the 2000s has been rather weak.

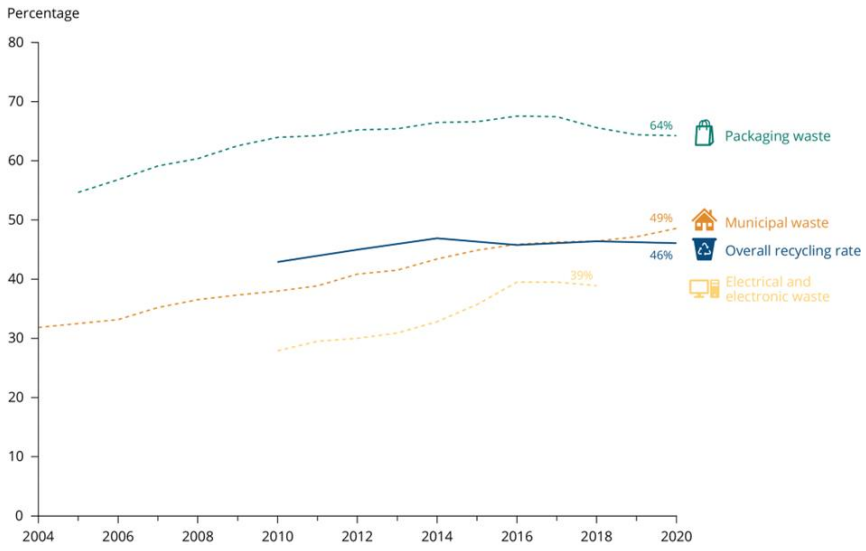

Figure 84: Recycling rates in Europe by waste stream (EU-27). [583]

4.7.2.3 Energy demand

The trend of increasing energy demand is a worldwide phenomenon and is caused by increasing industrialisation, economic growth and the rising world population. Energy is needed to fulfil the needs of the growing world population and the demands of modern industry. However, the increasing energy demand also has a negative impact on the environment, especially through the consumption of fossil fuels, which contribute to the release of greenhouse gases and air pollution. The use of renewable energies such as solar, wind and hydropower, as well as improving energy efficiency, are therefore important measures to meet the growing demand for energy while promoting environmental protection.

Between 2005 and 2020, total energy consumption decreased in 24 EU countries, while it increased in three countries - Lithuania, Poland and Malta. This increase is due to the strong growth in transport demand. Globally, however, energy demand is expected to increase by 25% by 2040, while it is likely to decrease slightly in the EU. In contrast, energy demand in developing countries is expected

to increase by 65% by 2040 due to industrial development and global population growth. These developments and forecasts are clearly illustrated in Figure 85 [584].

Despite efforts to increase the use of renewable energy sources, fossil fuels still dominate energy production worldwide. However, energy efficiency in Europe has improved over the years, with energy intensity (energy consumption per unit of GDP) falling by almost 20% since 2005 [585]. Renewable energy is becoming increasingly important in Europe: in 2020, 34.6% of the EU's gross final energy consumption is expected to come from renewable sources. Germany is the world leader in the use of renewable energies and will obtain 45.3 % of its electricity from renewable sources in 2020 [586], [587]. On the other hand, the share of nuclear energy in the energy mix is declining worldwide. In 2020, only 10.3 % of the electricity generated worldwide will come from nuclear energy, compared to 17.5 % in 2000 [588].

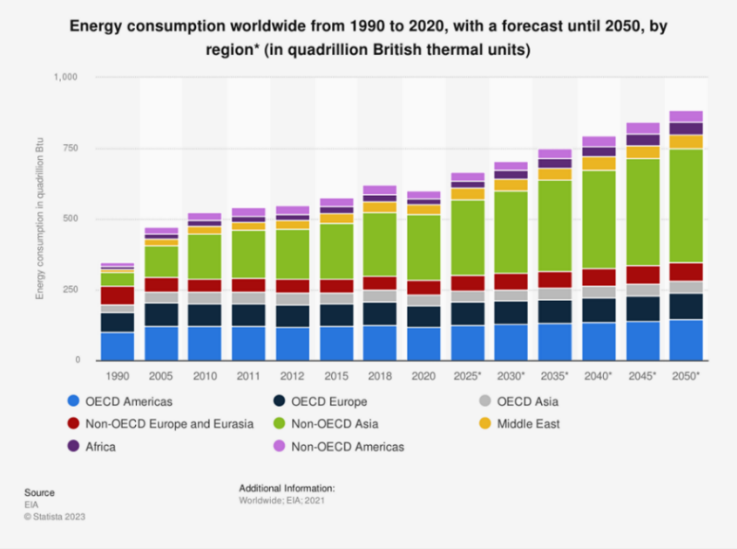

Figure 85: Energy consumption worldwide from 1990 to 2020, with a forecast until 2050, by region* (in quadrillion British thermal units. [589]

4.7.2.4 Semiconductor shortage

Semiconductors are currently part of almost every electronic product we use. As a result of the Corona pandemic and the declining sales of the automobile industry, the demand for semiconductors in the automobile industry also declined, so semiconductors were produced for electrical appliances. Now that the economy and industry have recovered after the pandemic, there is a shortage of semiconductors. Shortages of semiconductors often lead to production cuts in the manufacturing sector, for example, vehicle production fell by 1.3 million vehicles in the first quarter of 2021 due to supply shortages.

The global shortage of semiconductor chips continues to wreak havoc across all industries. Many popular electronic devices, from smartphones to cars, rely on semiconductors that now have lead times of up to a year (see Figure 86) [590]. The pandemic has exacerbated the shortage, which is expected to last well into 2023, according to a KPMG study [591]. The automotive industry has been particularly hard hit, and some forecasts suggest that the shortage could last until 2026 [438]. Despite the challenges, the automotive semiconductor market is expected to grow by more than 9 % annually until 2030 [438]. The future of semiconductors remains uncertain, but it is clear that their importance to our daily lives will continue to grow.

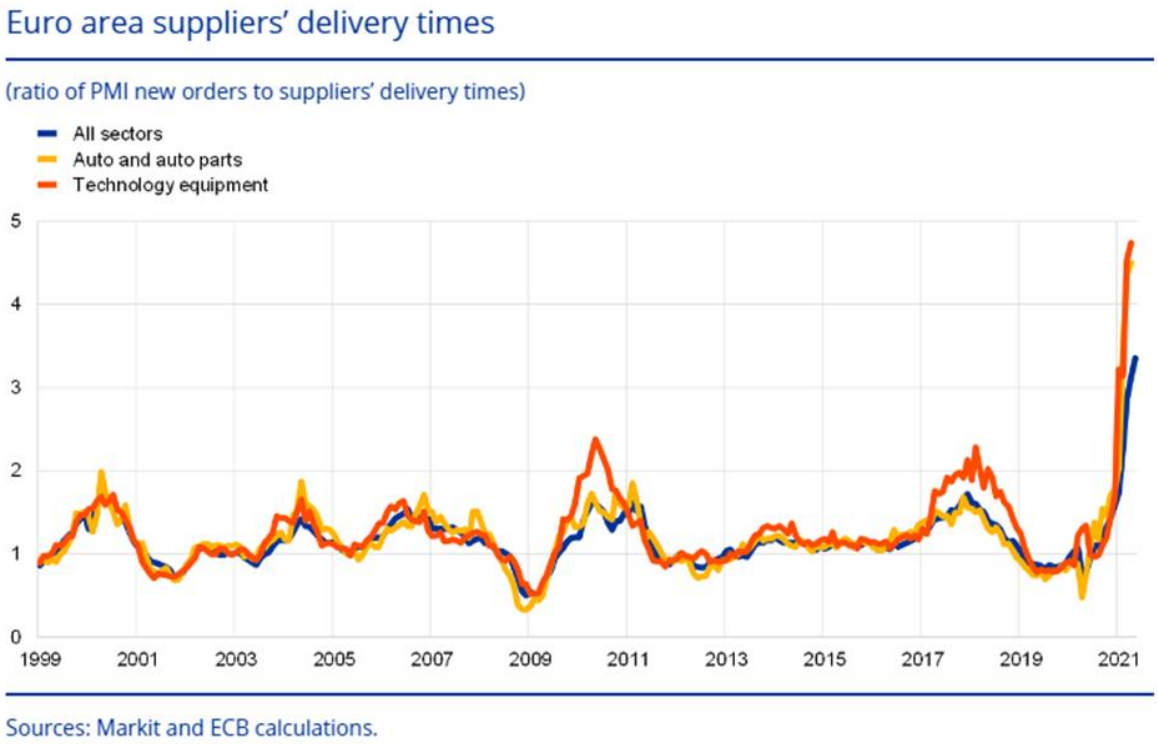

Figure 86: Euro area suppliers' delivery times for semiconductors. [590]

4.7.2.5 Risks from Resource scarcity

Supply chains today are exposed to a number of risks related to the scarcity of resources. The trends associated with resource scarcity are the lack of resources, waste increase, energy demand and scarcity of semiconductors. The largest risk categories based on this megatrend for supply chains are presented in more detail below.

The following risks, identified through extensive literature review and validated by experts during the workshop, directly impact the economic sustainability of the supply chain:

- *High dependency on third-party suppliers:* Companies' increasing reliance on third-party suppliers for key resources raises concerns about price volatility and supply disruptions that can negatively impact supply chain operations and profitability. In addition, dependence on China and Asian markets for renewable energy technologies poses potential political risks and supply chain vulnerabilities. It is critical for companies to diversify their supply chains, invest in alternative sources of key resources and build long-term relationships with reliable suppliers [592], [593].
- *Availability of resources:* The risk of resource unavailability poses significant challenges to supply chains, potentially leading to severe consequences. When key resources become inaccessible, production processes may come to a halt, causing substantial financial losses, reputation damage, and customer dissatisfaction. The unavailability of key resources disrupts the smooth flow of operations, resulting in delayed deliveries, reduced output, and compromised product quality. These disruptions can have a cascading effect, impacting downstream partners and customers, further exacerbating the negative impact on business performance. [594], [595]
- *Increasing costs:* The risk of increasing costs presents significant financial implications for companies operating within supply chains. Rising costs associated with waste disposal, containerization, logistics, and key resources can erode profit margins and strain overall financial performance. Moreover, market volatility and fluctuations in the prices of critical

resources further amplify the financial risks faced by businesses. The escalating costs of waste disposal necessitate companies to allocate substantial financial resources for proper waste management, including recycling and environmentally friendly disposal methods. Failure to address this risk can result in escalated expenses and potential regulatory non-compliance penalties. Fluctuating fuel prices, fees, and charges imposed by shipping and transportation providers can also significantly impact supply chain costs, affecting profitability and competitiveness. [593], [594]

- *Investing and using the wrong technology:* The risk of utilizing the wrong technology in European supply chains poses significant challenges and uncertainties. As technology rapidly evolves, there is a constant possibility of investing in and adopting a technology that may eventually become outdated or outperformed by alternative solutions. This risk stems from the uncertainty surrounding the emergence and adoption of superior technologies within the industry. The utilization of outdated or less efficient technologies can lead to several adverse consequences for supply chains. Firstly, it can result in decreased operational efficiency, hindering the ability to meet customer demands and deliver products in a timely manner. This can lead to increased costs, missed opportunities, and reduced competitiveness in the market. Additionally, investing in the wrong technology can have severe financial implications for European supply chains. Allocating significant resources to a technology that fails to meet industry standards or becomes obsolete can result in wasted investments and financial losses [596], [597].

In addition to the economic aspects, the other risks that have an environmental and social impact relate primarily to resource requirements and health. The main risks were clustered as follows:

- *Labour and health conditions:* The extraction of rare earth minerals in certain countries poses a substantial risk due to associated labour and health conditions. The mining operations in these regions may involve unethical practices, including worker exploitation, human rights abuses, and environmental degradation. Such conditions can lead to reputational damage, legal consequences, and operational disruptions for companies involved in these supply chains [598], [599].
- *Balancing energy demand and environmental harm:* The rising energy demand poses a significant risk for companies as they face the challenge of balancing energy needs while minimizing environmental harm. Increasing reliance on fossil fuels to meet energy requirements can result in elevated carbon emissions, exacerbating climate change impacts and contributing to environmental degradation. The consequences of this risk include reputational damage, regulatory non-compliance, and potential legal ramifications for companies associated with high carbon emissions. Moreover, the adverse effects of climate change, such as extreme weather events and resource scarcity, can disrupt supply chains, leading to production delays, increased costs, and compromised customer satisfaction [600].
- *Difficulties in meeting food demand:* As demand for food continues to rise, the limited availability of resources, such as land and water, exacerbates the challenge of sustainable food production and distribution. Factors such as inefficient agricultural practices, inadequate infrastructure, and poor storage and transportation systems contribute to food loss along the supply chain. Additionally, diverting agricultural resources for biofuel production further strains the availability of food resources [601], [602],[603].

Drawing on the assessments of experts and the feedback collected during the workshop, it is evident that most of the risks associated with resource scarcity in the supply chain are characterized by a moderate likelihood of occurrence and moderate impacts. Nevertheless, experts highlighted the risk of insufficient access to critical production materials as the most probable scenario, potentially exerting a significant impact on supply chains. In addition, further risks were identified together with the experts, which are included in the above list of risk categories.

5. CONCLUSIONS

The aim of this deliverable is to provide an overview of the key megatrends, associated trends, and emerging risks that have the potential to impact the manufacturing, process manufacturing, logistics, and supply chain management of European enterprises.

Guided by a PESTLE analysis, this deliverable has identified 19 megatrends and 70 associated trends, which are categorized under six dimensions: political, economic, social, technological, legal, and environmental. Identifying megatrends and their associated trends is crucial in generating innovative supply chain models, which is the objective of the second ReSChape work package. The overview in Figure 87. has been created based on an extensive literature review that has been conducted with the support of all ReSChape partners and included both scientific literature as well as governmental reports, strategic roadmaps, and sectoral studies. The analysis has been supported and validated by industry expert workshops, where additional findings or more detailed descriptions of the trends have been collected.

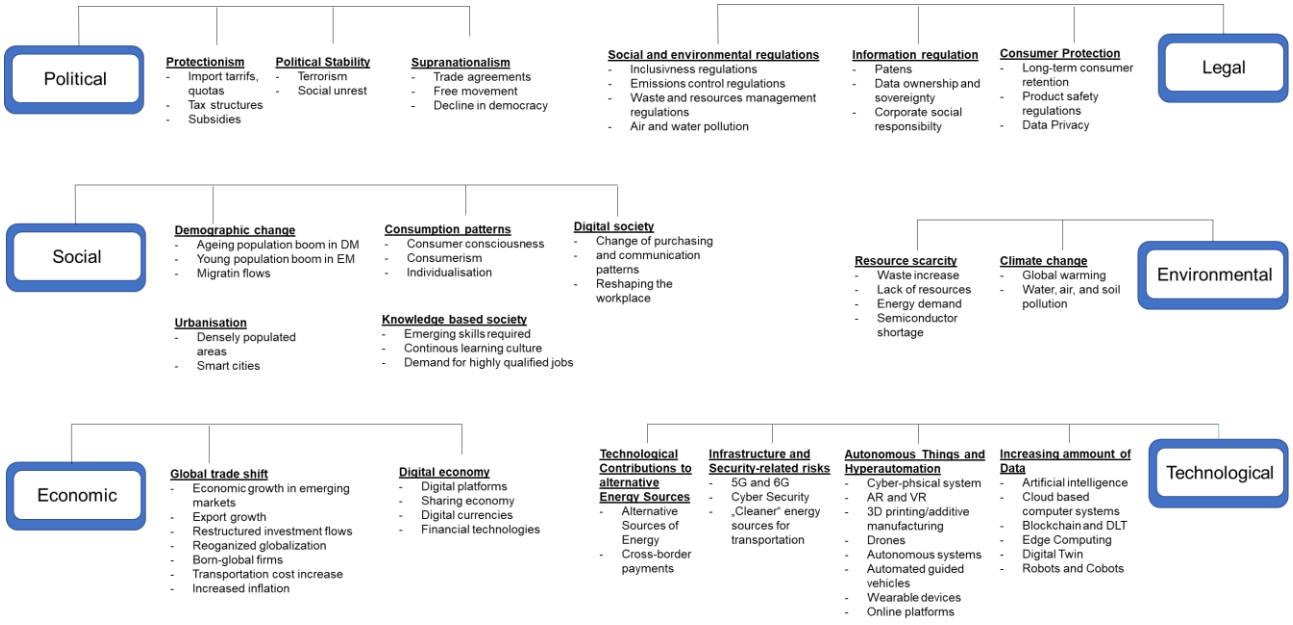

Figure 87: Overview of the PESTLE analysis.

For what concerns the identification of the supply chain risks, the 6 PESTLE dimensions have been analysed from the point of view of the impact that the related different megatrend and related trends can have on the supply chain in terms of sustainability (economic, social and environmental). Grounding on literature review, in T2.2 supply chain risks have been identified as challenges that have the potential to disrupt the information, material and production flows along the supply chain.

The analysis developed regarding the **political dimension** highlighted Protectionism, Political instability, and Supranationalism as megatrends because of their significant impact on global supply chains. Protectionism has increased because of the worsening of geopolitical tensions worldwide, among other issues due to tensions in trade relations between the USA and China, the conflict in Ukraine, and tensions about sovereignty in Taiwan. The analysis conducted confirms that import tariffs, the different tax structures, and subsidies impose limitations and conditions on international

trade and, therefore, affect global supply chains. Concerning the Political instability megatrend, the analysis remarks on its impact on the economic, social and environmental sustainability through the evolution of three global trends such as terrorism, conflicts and corruption, social unrest, and decline in democracy. Regarding Supranationalism megatrend, it has been stated that its impact comes from the potential changes in regulatory frameworks and standardization measures, due to the shift from global to regional and bilateral trade agreements.

The risks derived from the political dimension for global supply chains range from aspects more oriented to the economic perspective (related to both demand and supply sides and also with competitiveness and investors' intention…) and social perspective (loss of jobs, changes in workers' rights, purchasing power of families…) to environmental issues (disincentivizing to the adoption of environmental standards, backtracking on environmental practices…). The interplay and recurrence of the three megatrends and their identified risks underline the inherent complexity of managing global supply chains. These interdependencies give rise to, and multiply the effect of some important risks such as regulatory uncertainties, supply disruptions, raw material scarcity, imbalances of power in the supply chain, social anxiety, and the modification of workers' rights.

The analysis in the **economic dimension** has successfully examined and consolidated two prominent megatrends: the global trade shift and the digital economy. Trends in the global trade shift, such as rising inflation and transportation costs, have been substantiated, as well as a notable reorganization in the long-standing pattern of globalization. Furthermore, post-Covid-19 crisis and the war in Ukraine, among other factors, have contributed to slowing down the export growth (now in recovery), the economic expansion in emerging countries, and rearranging investment flows. The digitalization megatrend continues to flourish, evident in the growing adoption of digital platforms, digital payments facilitated by financial technologies, and the surge in the sharing economy.

When assessing the risks associated with the global trade shift, several significant challenges come to the forefront. These include capacity constraints and supply chain shortages, which have exerted a considerable impact on supply chains in recent years. Additionally, changes in consumption patterns and purchasing partners, coupled with a decline in customer trust due to recent events, have led to societal shifts that necessitate careful consideration. In terms of the digital economy, security concerns pose the most pressing risks that must be addressed to ensure a successful implementation. The issue of data sharing required for certain digital applications further highlights the lack of integration and collaboration among supply chain stakeholders. Lastly, the rapid evolution of digitalization within the market creates a challenge for companies to adapt quickly, potentially placing them at a disadvantage compared to more agile competitors.

Concerning the **social dimension,** the analysis confirmed well-known megatrends such as demographic change, and in particular the related trend of the population ageing, with an increase in the migration trend, especially in Europe during the last year due to the conflict in Ukraine. The relevance of the Urbanisation megatrend has also been validated, with an acceleration of the Smart City trend according to the growth of related supporting digital technologies. The megatrend of Consumption patterns has emerged as one of the most impacted by the recent global scenario due to the even more increasing consciousness in terms of both environmental and social sustainability of consumer choices, the advent of the digital economy and, recently, the rise in inflation. Moreover, the trends of reshaping of the workplace and change of communication patterns further confirmed under the megatrend Digital society due to Covid-19 pandemic disruption of traditional working habits. COVID-19 and digitalisation changed both the purchasing and communication patterns of consumers with the drive towards more online purchasing and communication based on social

media, digital platforms e.g., Zoom. This new way of working should also be supported with emerging skills and a continuous learning culture as mentioned in Knowledge-based society megatrend.

Considering risks across this dimension, one of the most recurring issues is related to knowledge loss, lack of training and skills gap mainly towards digital technologies. While the risks associated with knowledge loss and skill gap impact on economic and social sustainability, social sustainability is jeopardized also by risks related to poor working conditions, workers' rights and unemployment. Organisations should realise that younger generations have more eco-anxiety which can drastically affect what they buy and where they work. Moreover, as highlighted in different megatrends, there are organisational risks relevant to integrating supply chains to be able to provide an omnichannel experience. Finally, Consumption patterns, Urbanisation and Digital society generates common risks that, on the one hand, affect data security, information sharing and traceability; on the other hand, they contribute to the increase of pollution mainly due to deliveries that put at risks environmental sustainability.

The analysis revealed the existence of four megatrends related to the **technological dimension**: increasing amount of data, autonomous things and hyperautomation, infrastructure and security-related risks and contributions of technologies to alternative energy sources. The increasing amount of data is a consequence of the complexity of today's business environments and has enormous consequences for SC management. Technologies such as big data and analytics, distributed ledger and artificial intelligence play a fundamental role in providing data, increasing SC collaboration and, mainly, in allowing managers to use data to make better and more informed decisions. On the other hand, when poorly managed technologies can further increase complexity and lead to poor decision making. The increasingly common application of autonomous things and the hyperautomation of processes represent a major change in operations, productivity and the relationship between humans and machines. Robots and cobots, 3D printers, drones and wearable devices are some of the technologies whose use promises to increase in the coming years with potential positive effects on sustainability and resilience. On the other hand, more actions are needed to ensure that the human factor remains at the centre of companies' strategic choices. Risks related to infrastructure and security can be considered a transversal megatrend whose effects go beyond the technological aspects. Technologies such as online platforms and 5G and 6G will enable the reduction of distance between SC partners, increasing collaboration and visibility, while cybersecurity is already a prerequisite for building trusting relationships with all SC partners, including final consumers. Finally, technologies can make a great contribution to the development of alternative energy sources. As far as SCs are concerned, these alternative energies have great application in both transport and production.

Regarding the **legal dimension**, the analysis has corroborated well-known megatrends such as the need for consumer protection, notably emphasizing the associated trend of increasing product safety regulations. The relevance of the megatrend information regulation has also been affirmed, with an increasing significance placed on data privacy, ownership, and sovereignty due to the rapid proliferation of data volumes and digitalization efforts, including sensor data and machine-to-machine connectivity. The megatrend of social and environmental regulation has emerged as one of the most profoundly impacted trends by recent global developments, as consumer awareness regarding the environmental and social sustainability of their choices continues to escalate.

When considering the risks within this dimension, one of the most prevalent recurring themes pertains to the costs associated with implementing new regulations and laws, along with the potential risks incurred from non-compliance. These risks predominantly encompass financial penalties and

reputational damage stemming from customer trust erosion. Furthermore, there exists the danger of current business models becoming obsolete due to regulations that are incongruent with future requirements. Lastly, the inadequate infrastructure concerning the mounting waste volumes and insufficient recycling technologies pose potential threats to European supply chains, as both are crucial for establishing a circular economy.

Regarding the **environmental dimension**, the analysis has provided confirmation of well-established megatrends such as climate change, highlighting the related trends of global warming and pollution. The significance of the second megatrend, resource scarcity, has also been substantiated, with a notable intensification of the semiconductor shortage trend attributable to the impact of the Covid-19 pandemic. The pandemic-induced surge in demand for electronic devices reliant on semiconductors coincided with the temporary closure or limited operation of numerous factories and production facilities worldwide as a result of lockdowns and other measures implemented to mitigate the spread of the virus. Furthermore, the trend towards escalating energy demand continued to strengthen last year due to the ongoing conflict in Ukraine, especially in Europe.

When examining the risks within this dimension, a prominent recurring theme revolves around escalating costs, employee well-being, and availability, as well as extensive reliance on external suppliers. The environmental ramifications and repercussions of climate change introduce the risk of necessitating the redevelopment of supplier networks, entailing substantial costs. Additionally, there exists the peril of investing in unsuitable emerging technologies, given the rapid advancements witnessed in today's technological landscape. Moreover, future resource availability poses a significant risk that could potentially result in production disruptions and necessitate adjustments to business models.

The literature review has also shown the growing attention of practitioners and researchers towards social sustainability risks and the importance for SCs to carefully identify them in order to properly face them. Thanks to the validation with experts during the workshop, it was possible to confirm the list of identified risks and some others where added after the discussion. The workshop gave also the possibility to start the discussion related to the vulnerability generated by each group of risks on supply chain. The risks were discussed and compared based on a probability of occurrence and on the expected impact on SC processes. Supply chain risks can be considered as challenges that exist, whether they are managed or not and a supply chain always displays a certain degree of vulnerability that becomes manifest if a disruptive event occurs. Therefore, as a latent condition, vulnerability was here analysed as resulting impact of global trends on supply chain processes. The outcome is a heatmap facilitating the identification of the most important impactful risks to be taken into consideration and related probability (see example for the social dimension).

Megatrend	SC Risks	Sustainability dimension	Workshop	
			Probability	Impact
Demographic change	Decreasing of ageing workers' functional capacities	Economic		
	Knowledge loss	Economic		
	Lack of skills and few training opportunities	Social		
	Weak or missing control over workers' rights	Social		
	Poor workplace ergonomics	Social		
Urbanisation	Lack of ad-hoc regulation	Economic		
	Increasing network complexity	Economic		
	Security and privacy issues	Economic		
	Reliance on non-skilled/semi-skilled labour	Economic		
	Technology implementation limitations	Economic		
	Poor working conditions	Social		
	Increase pollution and poor energy efficiency	Environmental		
Consumption patterns	Risks related to supply chain network configuration	Economic		
	Lack of information sharing and traceability	Economic		
	Lack of stakeholder involvement	Economic		
	Demand variability	Economic		
	Lack of interest in working conditions	Social		
	Social sustainability-introduction related risks	Social		
	Environmental sustainability-introduction related risks	Environmental		

Figure 88: Example of the Heatmap for 3 megatrends of the Social dimension

Another interesting way to analyse the identified risks is related to their occurrency across different megatrends and/or PESTLE dimensions. VOSviewer allows to identify most important keywords with a text search in multiple documents and with text mining functionality to construct and visualize co-occurrence networks of important terms extracted from a body of scientific literature.
In this kind of representation, the size of the node corresponds to how recurrent is a keyword and the thickness of the connecting lines how strong is the connection between two keywords.
This methodology was applied to the text with the description of the risks and the creation of the network was based on those keywords with at least 5 occurrences along the text, generating a chart as in figure 89.

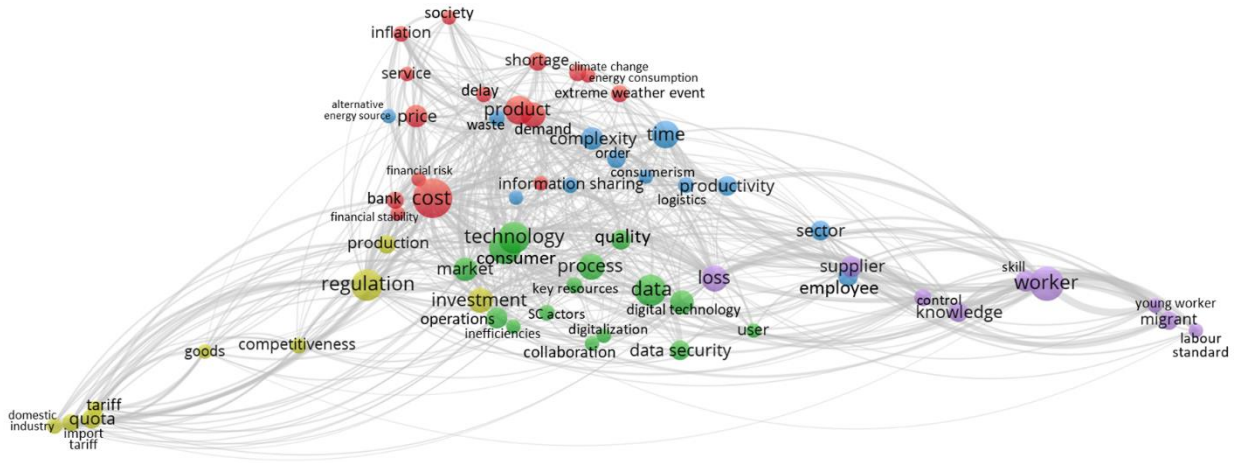

Figure 89: VOSviewer for the risks analysis

The resulting graph shows 5 clusters (coloured in the chart), each with keywords highly interconnected. It is possible to notice that in each of the cluster, there are keywords related to risks from more than one of the PESTLE dimensions showing some relationship between them. Some of the most reccurent keywords along the risks descriptions are: cost, worker, technology, consumer, data, regulation, product, time.
Summarizing the results per cluster, in the yellow one, keywords for risks related to political (i.e. quota, import tariff) and legal dimensions (i.e. regulation) are grouped with keywords derived from economic dimensions (i.e. investment, competitiveness).
The green cluster includes mainly keywords from technological dimensions (i.e. data, data security, digital technologies) as well as from economic dimension (i.e. quality, process, inefficiencies). The cluster with red nodes includes keywords recalling to economic dimension (i.e. demand, cost, financial risk, capital) and to the environmental dimension (shortage, extreme weather event, energy. The blue cluster includes social related keywords (i.e. consumerism, employee), economic related (i.e. productivity and time) as well as technology related (i.e. information sharing, transparency). Also environmental keywords are part of this cluster (i.e. alternative energy source, waste). The purple cluster is mainly related to keywords for risks connected to social dimension (workers, migrant, labour standards, knowledge).

In conclusion, the findings of this deliverable provide valuable insights into the ever-changing landscape within which European companies operate. The dynamic nature of the environment not only introduces new trends but also risks for supply chains. The results clearly emphasize the importance of adopting approaches and strategies that enhance the resilience of supply chains in a sustainable and purposeful manner. Moreover, the findings serve as a solid groundwork for the ongoing conceptual endeavors of the ReSChape project, where essential approaches and strategies will be developed and validated (T2.3 and T2.4). As we move forward, a proactive and resilient approach to supply chain management is imperative to navigate the evolving business landscape and ensure sustainable success also with support of adeguate policies.

6. REFERENCES

[1] D. J. Closs and T. P. Stank, "(PDF) Ten Mega-Trends That Will Revolutionize Supply Chain Logistics," 2000. https://www.researchgate.net/publication/248649433_Ten_Mega-Trends_That_Will_Revolutionize_Supply_Chain_Logistics (accessed May 25, 2023).

[2] D. Kalaitzi *et al.*, "Megatrends and Trends Shaping Supply Chain Innovation," pp. 3–34, 2021, doi: 10.1007/978-3-030-63505-3_1.

[3] Y. Krykavskyy and N. Mashchak, "Sustainable Supply Chain in Forming Environmental Macro Responsibility," pp. 3–17, 2017, doi: 10.1007/978-3-319-46451-0_1.

[4] G. Erboz, H. Abbas, and S. Nosratabadi, "Investigating supply chain research trends amid Covid-19: a bibliometric analysis," *Management Research Review*, vol. 46, no. 3, pp. 413–436, Feb. 2023, doi: 10.1108/MRR-05-2021-0408/FULL/XML.

[5] H. Peck, "Reconciling supply chain vulnerability, risk and supply chain management," *International journal of logistics: Research and applications*, vol. 9, no. 2, pp. 127–142, 2006.

[6] Correia and M. Salome, "Sustainability: An Overview of the Triple Bottom Line and Sustainability Implementation," *https://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/IJoSE.2019010103*, pp. 29–38, Jan. 2019, doi: 10.4018/IJOSE.2019010103.

[7] M. A. Carpenter and W. G. Sanders, "Strategic management : a dynamic perspective : concepts and cases," p. 861, 2009, Accessed: May 25, 2023. [Online]. Available: https://books.google.com/books/about/Strategic_Management.html?hl=de&id=w4aSQgAACAAJ

[8] A. Ziout, A. Azab, and M. Atwan, "A holistic approach for decision on selection of end-of-life products recovery options," *J Clean Prod*, vol. 65, pp. 497–516, Feb. 2014, doi: 10.1016/J.JCLEPRO.2013.10.001.

[9] T. Janet, "The PESTEL Environment and Its Impact on the Value Created," *INTERNATIONAL JOURNAL OF MANAGEMENT & INFORMATION TECHNOLOGY*, vol. 6, no. 2, pp. 805–816, Oct. 2013, doi: 10.24297/ijmit.v6i2.738.

[10] E. Iacovidou, J. Busch, J. N. Hahladakis, H. Baxter, K. S. Ng, and B. M. J. Herbert, "A Parameter Selection Framework for Sustainability Assessment," *Sustainability 2017, Vol. 9, Page 1497*, vol. 9, no. 9, p. 1497, Aug. 2017, doi: 10.3390/SU9091497.

[11] D. Tranfield, D. Denyer, and P. Smart, "Towards a methodology for developing evidence-informed management knowledge by means of systematic review," *British journal of management*, vol. 14, no. 3, pp. 207–222, 2003.

[12] S. Y. Ponomarov and M. C. Holcomb, "Understanding the concept of supply chain resilience," *The international journal of logistics management*, vol. 20, no. 1, pp. 124–143, 2009.

[13] T. J. Pettit, J. Fiksel, and K. L. Croxton, "Ensuring supply chain resilience: development of a conceptual framework," *Journal of business logistics*, vol. 31, no. 1, pp. 1–21, 2010.

[14] C. R. Carter and D. S. Rogers, "A framework of sustainable supply chain management: moving toward new theory," *International journal of physical distribution & logistics management*, 2008.

[15] M. Christopher and H. Peck, "Building the resilient supply chain.," 2004.

[16] C. G. Kochan and D. R. Nowicki, “Supply chain resilience: a systematic literature review and typological framework,” *International Journal of Physical Distribution & Logistics Management*, 2018.

[17] A. Ashby, M. Leat, and M. Hudson-Smith, “Making connections: a review of supply chain management and sustainability literature,” *Supply chain management: an international journal*, vol. 17, no. 5, pp. 497–516, 2012.

[18] P. Lewandowski, R. Keister, W. Hardy, and S. Górka, “Ageing of routine jobs in Europe,” *Economic Systems*, vol. 44, no. 4, p. 100816, 2020.

[19] F. Kwabena Donkor *et al.*, “Attitudinal changes towards agriculture through the generational lens and impact on engagement in related activities: Case study from a mountainous area,” *Food Security and Land Use Change under Conditions of Climatic Variability: A Multidimensional Perspective*, pp. 165–179, 2020.

[20] R. Shepherd, L. Lorente, M. Vignoli, K. Nielsen, and J. M. Peiró, “Challenges influencing the safety of migrant workers in the construction industry: A qualitative study in Italy, Spain, and the UK,” *Saf Sci*, vol. 142, p. 105388, 2021.

[21] K. L. Christ and C. V Helliar, “Blockchain technology and modern slavery: Reducing deceptive recruitment in migrant worker populations,” *J Bus Res*, vol. 131, pp. 112–120, 2021.

[22] J. J. Wang, “The labour surplus and COVID-19: the outlook for Chinese migrant low-skilled workers,” *Accounting & Finance*, vol. 62, no. 1, pp. 577–596, 2022.

[23] C. Gimenez, V. Sierra, and J. Rodon, “Sustainable operations: Their impact on the triple bottom line,” *Int J Prod Econ*, vol. 140, no. 1, pp. 149–159, 2012.

[24] J. Elkington, *Cannibals with forks: The Triple Bottom Line of 21st Century Business*. Oxford, UK: Capstone, 1997.

[25] D. Bogataj, D. Battini, M. Calzavara, and A. Persona, “The ageing workforce challenge: Investments in collaborative robots or contribution to pension schemes, from the multi-echelon perspective,” *Int J Prod Econ*, vol. 210, pp. 97–106, 2019.

[26] D. Bogataj and M. Bogataj, “Age management of transportation workers in global supply chains,” *IFAC-PapersOnLine*, vol. 51, no. 11, pp. 844–849, 2018.

[27] M. S. Aiyar and M. C. H. Ebeke, *The impact of workforce aging on European productivity*. International Monetary Fund, 2016.

[28] D. Bogataj, D. Battini, M. Calzavara, and A. Persona, “The response latency in global production and logistics: a trade-off between robotization and globalization of a chain,” *Procedia Manuf*, vol. 39, pp. 1428–1437, 2019.

[29] Y. Sheffi and J. B. Rice Jr, “A supply chain view of the resilient enterprise,” *MIT Sloan Manag Rev*, 2005.

[30] J.-H. Thun and D. Hoenig, “An empirical analysis of supply chain risk management in the German automotive industry,” *Int J Prod Econ*, vol. 131, no. 1, pp. 242–249, 2011.

[31] P. Fajgelbaum, P. Goldberg, P. Kennedy, A. Khandelwal, and D. Taglioni, “The US-China Trade War and Global Reallocations,” Cambridge, MA, Dec. 2021. doi: 10.3386/w29562.

[32] R. Piazza, J. Eugster, M. MacDonald, and F. Jaumotte, “The Effect of Tariffs in Global Value Chains,” *IMF Working Papers*, vol. 2022, no. 040, pp. 1–33, 2022, doi: 10.5089/9798400201158.001.

[33] G. Gereffi, H.-C. Lim, and J. Lee, “Trade policies, firm strategies, and adaptive reconfigurations of global value chains,” *Journal of International Business Policy*, vol. 4, no. 4, pp. 506–522, Dec. 2021, doi: 10.1057/s42214-021-00102-z.

[34] World Trade Organization, “Trade Facilitation Agreement has increased trade by over US$ 230 billion, new study finds,” Mar. 22, 2023.

[35] G. Gereffi, H.-C. Lim, and J. Lee, “Trade policies, firm strategies, and adaptive reconfigurations of global value chains,” *Journal of International Business Policy*, vol. 4, no. 4, pp. 506–522, Dec. 2021, doi: 10.1057/s42214-021-00102-z.

[36] The Economist Intelligence Unit, “The cost of de-globalising world trade Economic scenarios for the world’s turn inwards,” 2021.

[37] OECD, “Corporate Tax Statistics,” 2022.

[38] R. Piazza, J. Eugster, M. MacDonald, and F. Jaumotte, “The Effect of Tariffs in Global Value Chains,” *IMF Working Papers*, vol. 2022, no. 040, pp. 1–33, 2022, doi: 10.5089/9798400201158.001.

[39] The Economist Intelligence Unit, “The cost of de-globalising world trade Economic scenarios for the world’s turn inwards,” 2021.

[40] Roland Berger, “The Seventh Disruption to the Global Polymer Industry,” Nov. 2022.

[41] L. Dong and P. Kouvelis, “Impact of Tariffs on Global Supply Chain Network Configuration: Models, Predictions, and Future Research,” *Manufacturing & Service Operations Management*, vol. 22, no. 1, pp. 25–35, Jan. 2020, doi: 10.1287/msom.2019.0802.

[42] European Commission, “2022 Report on Energy Subsidies in the EU,” Brussels, Nov. 2022.

[43] P. Feng, X. Zhou, D. Zhang, Z. Chen, and S. Wang, “The impact of trade policy on global supply chain network equilibrium: A new perspective of product-market chain competition,” *Omega (Westport)*, vol. 109, p. 102612, Jun. 2022, doi: 10.1016/j.omega.2022.102612.

[44] B. Laker, “Why Collaboration Needs to Win Over Protectionism,” in *A New World Post COVID-19*, Venice: Fondazione Università Ca’ Foscari, 2020. doi: 10.30687/978-88-6969-442-4/029.

[45] P. Kouvelis and M. J. Rosenblatt, “A Mathematical Programming Model for Global Supply Chain Management: Conceptual Approach and Managerial Insights,” in *Supply Chain Management: Models, Applications, and Research Directions*, Boston: Kluwer Academic Publishers, pp. 245–277. doi: 10.1007/0-306-48172-3_10.

[46] A. Nagurney, D. Besik, and D. Li, “Strict quotas or tariffs? Implications for product quality and consumer welfare in differentiated product supply chains,” *Transp Res E Logist Transp Rev*, vol. 129, pp. 136–161, Sep. 2019, doi: 10.1016/j.tre.2019.07.008.

[47] M. Goh, J. Y. S. Lim, and F. Meng, “A stochastic model for risk management in global supply chain networks,” *Eur J Oper Res*, vol. 182, no. 1, pp. 164–173, Oct. 2007, doi: 10.1016/j.ejor.2006.08.028.

[48] D. Mu, H. Ren, and C. Wang, “A Literature Review of Taxes in Cross-Border Supply Chain Modeling: Themes, Tax Types and New Trade-Offs,” *Journal of Theoretical and Applied Electronic Commerce Research*, vol. 17, no. 1, pp. 20–46, Dec. 2021, doi: 10.3390/jtaer17010002.

[49] A. Esfahbodi, Y. Zhang, G. Watson, and T. Zhang, “Governance pressures and performance outcomes of sustainable supply chain management – An empirical analysis of UK manufacturing industry,” *J Clean Prod*, vol. 155, pp. 66–78, Jul. 2017, doi: 10.1016/j.jclepro.2016.07.098.

[50] A. Barman, R. Das, P. K. De, and S. S. Sana, “Optimal Pricing and Greening Strategy in a Competitive Green Supply Chain: Impact of Government Subsidy and Tax Policy,” *Sustainability*, vol. 13, no. 16, p. 9178, Aug. 2021, doi: 10.3390/su13169178.

[51] J. Manyika, S. Smit, and J. Woetzel, “Risk, resilience, and rebalancing in global value chains,” Aug. 2020.

[52] Institute for Economics and Peace, “Global Terrorism Index 2023,” *https://www.economicsandpeace.org/wp-content/uploads/2023/03/GTI-2023-web-170423.pdf*, 2023.

[53] S. Kumar and R. R. Mallipeddi, “Impact of cybersecurity on operations and supply chain management: Emerging trends and future research directions,” *Prod Oper Manag*, vol. 31, no. 12, pp. 4488–4500, Dec. 2022, doi: 10.1111/poms.13859.

[54] A. Fleck, “Cybercrime Expected To Skyrocket in Coming Years,” *https://www.statista.com/chart/28878/expected-cost-of-cybercrime-until-2027/*, Dec. 02, 2022.

[55] European Commission, “The Cybersecurity Strategy,” *https://digital-strategy.ec.europa.eu/en/policies/cybersecurity-strategy*, Jun. 07, 2022.

[56] Stockholm International Peace Research Institute, “World military expenditure passes $2 trillion for first time,” *https://www.sipri.org/media/press-release/2022/world-military-expenditure-passes-2-trillion-first-time*, Apr. 2022.

[57] Transparency International, “Corruption Perceptions Index,” *https://www.transparency.org/en/cpi/2022*, 2022.

[58] World Economic Forum, “Corruption is costing the global economy $3.6 trillion dollars every year,” *https://www.weforum.org/agenda/2018/12/the-global-economy-loses-3-6-trillion-tocorruption-each-year-says-u-n*, Dec. 2018.

[59] World Economic Forum, “How to prepare for a new economic reality and protect the most vulnerable,” *https://www.weforum.org/agenda/2022/09/4-experts-explain-how-to-prepare-for-a-new-economic-reality-and-protect-the-most-vulnerable*, Sep. 30, 2022.

[60] M. Hribernik and T. Campbell, “Emerging markets face unparalleled civil unrest,” Jul. 2020.

[61] P. Barrett, “Social Unrest is Rising, Adding to Risks for Global Economy,” *International Monetary Fund*, May 2022.

[62] Institute for Democracy and Electoral Assistance, “Global Democracy Weakens in 2022 ,” *https://www.idea.int/news-media/news/global-democracy-weakens-2022*, Nov. 30, 2022.

[63] V. A. Boese, M. Lundstedt, K. Morrison, Y. Sato, and S. I. Lindberg, “State of the world 2021: autocratization changing its nature?,” *Democratization*, vol. 29, no. 6, pp. 983–1013, Aug. 2022, doi: 10.1080/13510347.2022.2069751.

[64] T. A. Hassan, S. Hollander, L. van Lent, and A. Tahoun, “Firm-Level Political Risk: Measurement and Effects*,” *Q J Econ*, vol. 134, no. 4, pp. 2135–2202, Nov. 2019, doi: 10.1093/qje/qjz021.

[65] F. Birol and P. Canfin, “Why the European Union needs bold and broad strategies for critical minerals,” *https://www.iea.org/commentaries/why-the-european-union-needs-bold-and-broad-strategies-for-critical-minerals?language=en*, Mar. 07, 2023.

[66] B. Bader, G. Suder, and R. Grosse, “Terrorism as an external threat factor in global value chains,” *Thunderbird International Business Review*, vol. 62, no. 2, pp. 135–148, Mar. 2020, doi: 10.1002/tie.22118.

[67] G. Chua, K. F. Yuen, X. Wang, and Y. D. Wong, “The Determinants of Panic Buying during COVID-19,” *Int J Environ Res Public Health*, vol. 18, no. 6, p. 3247, Mar. 2021, doi: 10.3390/ijerph18063247.

[68] N. Jadallah and F. Bhatti, “Political instability and sustainable green supply chain management,” *Management Science Letters*, pp. 1169–1178, 2020, doi: 10.5267/j.msl.2019.12.001.

[69] T. Sawik, “A linear model for optimal cybersecurity investment in Industry 4.0 supply chains,” *Int J Prod Res*, vol. 60, no. 4, pp. 1368–1385, Feb. 2022, doi: 10.1080/00207543.2020.1856442.

[70] S. Kim and S. M. Wagner, “Examining the Stock Price Effect of Corruption Risk in the Supply Chain,” *Decision Sciences*, vol. 52, no. 4, pp. 833–865, Aug. 2021, doi: 10.1111/deci.12487.

[71] F. Lumineau and N. Oliveira, “Reinvigorating the Study of Opportunism in Supply Chain Management,” *Journal of Supply Chain Management*, vol. 56, no. 1, pp. 73–87, Jan. 2020, doi: 10.1111/jscm.12215.

[72] A. T. B. Duong, V. X. Vo, M. Do Sameiro Carvalho, P. Sampaio, and H. Q. Truong, “Risks and supply chain performance: globalization and COVID-19 perspectives,” *International Journal of Productivity and Performance Management*, Mar. 2022, doi: 10.1108/IJPPM-03-2021-0179.

[73] A. Alfaqiri *et al.*, “A systemic approach for disruption risk assessment in oil and gas supply chains,” *International Journal of Critical Infrastructures*, vol. 15, no. 3, p. 230, 2019, doi: 10.1504/IJCIS.2019.100428.

[74] C.-H. Hsu, A.-Y. Chang, T.-Y. Zhang, W.-D. Lin, and W.-L. Liu, “Deploying Resilience Enablers to Mitigate Risks in Sustainable Fashion Supply Chains,” *Sustainability*, vol. 13, no. 5, p. 2943, Mar. 2021, doi: 10.3390/su13052943.

[75] M. S. Manger and M. A. Pickup, “The Coevolution of Trade Agreement Networks and Democracy,” *Journal of Conflict Resolution*, vol. 60, no. 1, pp. 164–191, Feb. 2016, doi: 10.1177/0022002714535431.

[76] J. Yang, H. Xie, G. Yu, and M. Liu, “Antecedents and consequences of supply chain risk management capabilities: an investigation in the post-coronavirus crisis,” *Int J Prod Res*, vol. 59, no. 5, pp. 1573–1585, Mar. 2021, doi: 10.1080/00207543.2020.1856958.

[77] I. Manikas, B. Sundarakani, F. Anastasiadis, and B. Ali, “A Framework for Food Security via Resilient Agri-Food Supply Chains: The Case of UAE,” *Sustainability*, vol. 14, no. 10, p. 6375, May 2022, doi: 10.3390/su14106375.

[78] S. Li, Y. Wang, G. M. L. Tacken, Y. Liu, and S. J. Sijtsema, “Consumer trust in the dairy value chain in China: The role of trustworthiness, the melamine scandal, and the media,” *J Dairy Sci*, vol. 104, no. 8, pp. 8554–8567, Aug. 2021, doi: 10.3168/jds.2020-19733.

[79] Q. T. Tran, “Corruption and corporate risk-taking: evidence from emerging markets,” *International Journal of Emerging Markets*, vol. 17, no. 5, pp. 1238–1255, May 2022, doi: 10.1108/IJOEM-08-2019-0602.

[80] L. I. Shelley, “Illicit Trade and Terrorism,” *Perpectives on Terrorism*, vol. 14, no. 4, pp. 7–20, Aug. 2020.

[81] S. Mithun Ali *et al.*, “Modelling of supply chain disruption analytics using an integrated approach: An emerging economy example,” *Expert Syst Appl*, vol. 173, p. 114690, Jul. 2021, doi: 10.1016/j.eswa.2021.114690.

[82] R. Handfield, H. Sun, and L. Rothenberg, “Assessing supply chain risk for apparel production in low cost countries using newsfeed analysis,” *Supply Chain Management: An International Journal*, vol. 25, no. 6, pp. 803–821, Jun. 2020, doi: 10.1108/SCM-11-2019-0423.

[83] Y. Fernando, M.-L. Tseng, I. S. Wahyuni-Td, A. B. L. de Sousa Jabbour, C. J. Chiappetta Jabbour, and C. Foropon, “Cyber supply chain risk management and performance in industry 4.0 era: information system security practices in Malaysia,” *Journal of Industrial and Production Engineering*, vol. 40, no. 2, pp. 102–116, Feb. 2023, doi: 10.1080/21681015.2022.2116495.

[84] A. Ghadge, M. Weiß, N. D. Caldwell, and R. Wilding, “Managing cyber risk in supply chains: a review and research agenda,” *Supply Chain Management: An International Journal*, vol. 25, no. 2, pp. 223–240, Nov. 2019, doi: 10.1108/SCM-10-2018-0357.

[85] B. Debnath, A. Das, S. Das, and A. Das, “Studies on Security Threats in Waste Mobile Phone Recycling Supply Chain in India,” in *2020 IEEE Calcutta Conference (CALCON)*, IEEE, Feb. 2020, pp. 431–434. doi: 10.1109/CALCON49167.2020.9106531.

[86] E. Joseph and D. M. M., “Role of Digitalization Post-Pandemic for Development of SMEs,” in *Research Anthology on Business Continuity and Navigating Times of Crisis*, IGI Global, 2022, pp. 727–747. doi: 10.4018/978-1-6684-4503-7.ch036.

[87] M.-X. Xu, S. Li, L.-L. Rao, and L. Zheng, “The Relationship between Distance and Risk Perception in Multi-Tier Supply Chain: The Psychological Typhoon Eye Effect,” *Sustainability*, vol. 15, no. 9, p. 7507, May 2023, doi: 10.3390/su15097507.

[88] A. V. Itten, *Overcoming social division: conflict resolution in times of polarization and democratic disconnection*. New York: Routledge, 2019.

[89] M. E. Bildirici, S. Lousada, and S. Yılmaz Genç, “Terrorism, Freshwater, and Environmental Pollution: Evidence of Afghanistan, Burkina Faso, Iraq, Arab Republic of Egypt, Cameroon, Mali, Mozambique, Niger, Nigeria, Somalia, Syrian Arab Republic, and Pakistan,” *Water (Basel)*, vol. 14, no. 17, p. 2684, Aug. 2022, doi: 10.3390/w14172684.

[90] B. Ward and A. Bowen, “An analysis of the Trump Administration’s economic and policy arguments for withdrawal of the United States from the Paris Agreement on climate change,” London, Aug. 2020.

[91] K. Hopewell, “Trump & Trade: The Crisis in the Multilateral Trading System,” *New Political Economy*, vol. 26, no. 2, pp. 271–282, Mar. 2021, doi: 10.1080/13563467.2020.1841135.

[92] L. Kinzius, A. Sandkamp, and E. Yalcin, “Trade protection and the role of non-tariff barriers,” *Review of World Economics*, vol. 155, no. 4, pp. 603–643, Nov. 2019, doi: 10.1007/s10290-019-00341-6.

[93] United Nations, “Key statistics and trends in trade policy 2022,” *https://unctad.org/publication/key-statistics-and-trends-trade-policy-2022*, Mar. 17, 2023.

[94] E. Laget, A. Osnago, N. Rocha, and M. Ruta, “Deep Trade Agreements and Global Value Chains,” Washington, DC., 8491, 2018.

[95] European Commission, “Towards a green, digital and resilient economy: our European Growth Model,” *https://ec.europa.eu/commission/presscorner/detail/en/IP_22_1467*, Mar. 02, 2022.

[96] Y. Sheffi and J. B. Rice, “A supply chain view of the resilient enterprise,” *MITSloan Management Review*, Oct. 15, 2005.

[97] World Economic Forum, “Supply chain resilience: How are pandemic-related disruptions reshaping managerial thinking?,” *https://www.weforum.org/agenda/2021/12/supply-chain-resilience-lessons-from-covid-19/*, Dec. 22, 2021.

[98] M. Grazia, M. Balatti, M. Mancini, and L. Metelli, “Supply chain disruptions and the effects on the global economy,” *ECB Economic Bulletin*, 2021.

[99] K. Zeng, Y. Lu, and Y. Li, “Trade agreements and Global Value Chain (GVC) participation: Evidence from Chinese industries,” *Economics & Politics*, vol. 33, no. 3, pp. 533–582, Nov. 2021, doi: 10.1111/ecpo.12185.

[100] A. Razin, *Globalization, Migration, and Welfare State*. Cham: Springer International Publishing, 2021. doi: 10.1007/978-3-030-64392-8.

[101] V. Koval, G. Duginets, O. Plekhanova, A. Antonov, and M. Petrova, “On the supranational and national level of global value chain management,” *Entrepreneurship and Sustainability Issues*, vol. 6, no. 4, pp. 1922–1937, Jun. 2019, doi: 10.9770/jesi.2019.6.4(27).

[102] A. Posthuma and A. Rossi, “Coordinated governance in global value chains: supranational dynamics and the role of the International Labour Organization,” *New Political Economy*, vol. 22, no. 2, pp. 186–202, Mar. 2017, doi: 10.1080/13563467.2016.1273342.

[103] M. Ford, M. Gillan, and H. H. Thein, “Calling multinational enterprises to account: CSOs, supranational institutions and business practices in the global south,” *Global Networks*, Feb. 2023, doi: 10.1111/glob.12438.

[104] R. Obayi and S. N. Ebrahimi, “A neo-institutional view of the transaction cost drivers of construction supply chain risk management,” *Supply Chain Management: An International Journal*, vol. 26, no. 5, pp. 592–609, Jul. 2021, doi: 10.1108/SCM-09-2019-0350.

[105] A. Koukiadaki, “Global Supply Chains and Labour Standards: From a Patchwork of Rules to a Web of Rules?,” *Protecting the Future of Work: New Institutional Arrangements for Safeguarding Labour Standards*. Emerald Publishing Limited, pp. 127–140, 2023.

[106] H. Vanthournhout, “The rise of outward direct investments by Chinese multinationals in the German automotive sector, a Global Production Network analysis,” Université catholique de Louvain, Louvain, 2019.

[107] A. Smith, J. Harrison, L. Campling, B. Richardson, and M. Barbu, *Free Trade Agreements and Global Labour Governance The European Union’s Trade-Labour Linkage in a Value Chain World*. Routledge, 2020.

[108] A. Bongardt and F. Torres, “EU Governance and trade dynamics in the context of globalization challenges,” in *Globalization and EU trade policy at the time of crises: Gobernance and sustainability challenges*, Coimbra: Almedina, 2023.

[109] H. CHEN and Y. ZHANG, “Influencing Factors and Future Trends of Global Climate Governance Pattern and China’s Responsive Measures,” *Chinese Journal of Urban and Environmental Studies*, vol. 09, no. 02, p. 2150008, Jun. 2021, doi: 10.1142/S2345748121500081.

[110] the McKinsey Global Institute, “Outperformers: High-growth emerging economies and the companies that propel them,” Sep. 2018. Accessed: Apr. 18, 2023. [Online]. Available: https://www.mckinsey.com/featured-insights/innovation-and-growth/outperformers-high-growth-emerging-economies-and-the-companies-that-propel-them

[111] EIU Viewpoint, “Emerging markets: will the economic catch-up continue?,” 2022.

[112] S. Wu and Q. Pan, “Economic Growth in Emerging Market Countries,” *Global Journal of Emerging Market Economies*, vol. 13, no. 2, pp. 192–215, May 2021, doi: 10.1177/09749101211004405.

[113] “Emerging markets must balance overcoming the pandemic, returning to more normal policies, and rebuilding their economies,” *FINANCE & DEVELOPMENT*, Jun. 2021.

[114] European Central Bank, “Economic, financial and monetary developments,” *ECB Economic Bulletin, Issue 6*, 2021.

[115] Economic Central Bank, “Economic, financial and monetary developments,” *ECB Economic Bulletin, Issue 2*, 2023.

[116] “Euro Area Manufacturing PMI - April 2023 Data - 2007-2022 Historical - May Forecast,” *Trading Econmics*, 2023.

[117] S. Cigna, V. Gunnella, and L. Quaglietti, “Global Value Chains: Measurement, Trends and Drivers,” *SSRN Electronic Journal*, 2022, doi: 10.2139/ssrn.4007756.

[118] S. Ellerbeck, “What’s the difference between ‘friendshoring’ and other global trade buzzwords?,” *Centre for Regions, Trade and Geopolitics, Wold Economic Forum*, Feb. 17, 2023.

[119] United Nations Conference On Trade And Development - UNCTAD, “World Investment Report 2022 - International tax reforms and sustainable investment,” Jun. 2022.

[120] “Investment Trends Monitor, United Nations Conference on Trade and Development ,” *UNCTAD*, no. 40, 2021.

[121] “Investment Trends Monitor, United Nations Conference on Trade and Development ,” *UNCTAD*, no. 44, 2023.

[122] “Investment Trends Monitor, United Nations Conference on Trade and Development ,” *UNCTAD*, no. 43, 2022.

[123] C. Song, Y. Zhuang, Z. Liu, H. Zhang, and Y. Ding, “Emerging trend on international capital flows and global value chains reconstruction under post COVID-19: a review,” *Transnational Corporations Review*, vol. 14, no. 3, pp. 271–285, Jul. 2022, doi: 10.1080/19186444.2021.2019551.

[124] A. Sachs, C. Funke, P. Kreuzer, and J. Weiss, “Globalization Report 2020 Protectionism is the wrong answer to Corona - Globalization increases prosperity,” Aug. 2020.

[125] B. Baschuk, “Globalization 2.0 Will Realign Trade and Make Things More Expensive,” *Supply Lines Newsletter - Bloomberg*, May 19, 2022.

[126] “Globalization X.0 & Supply Chain in the New World - A Perspective: Part 2,” *Transport Intelligence*, 2022.

[127] T. Holmes, “What will the next era of supply chain globalisation look like? ,” *Supply Chain*, Aug. 19, 2022.

[128] Economist Impact, “Trade in Transition,” 2022.

[129] H. Gong, R. Hassink, C. Foster, M. Hess, and H. Garretsen, “Globalisation in reverse? Reconfiguring the geographies of value chains and production networks,” *Cambridge Journal of Regions, Economy and Society*, vol. 15, no. 2, pp. 165–181, Jun. 2022, doi: 10.1093/cjres/rsac012.

[130] Startup Genome and the Global Entrepreneurship Network (GEN), “Global Startup Ecosystem Report (GSER),” 2022.

[131] N. McCarthy, “How Covid-19 Has Impacted The Global Startup Scene,” *Statista*, Jun. 2020.

[132] “Shaping the Future of Digital Economy and New Value Creation - Platform,” *World Economic Forum*.

[133] E. Quick and P. Danielsson, “Rapid Internationalization During a Global Pandemic : Swedish Born Global Perspective (Dissertation),” Linnaeus University, 2022.

[134] H. Etemad, “The evolutionary trends of international entrepreneurship in the past two decades: The state of the field in the face of COVID-19’s global crisis,” *Journal of International Entrepreneurship*, vol. 19, no. 2, pp. 149–163, Jun. 2021, doi: 10.1007/s10843-021-00299-3.

[135] Bureau of Transportation Statistics’ (BTS’), “Record Breaking Increases in Motor Fuel Prices in 2022,” *U.S. DEPARTMENT OF TRANSPORTATION Bureau of Transportation Statistics*, Aug. 18, 2022.

[136] M. Arroyo, “How much will road transport prices rise in 2022? ,” *Trucksters*, Aug. 18, 2022.

[137] W. Philips, “Logistics firms ‘unable to absorb surging costs,’” *Supply Management*, May 13, 2022.

[138] J. Wolff, “Freight rates continue to rise dramatically in 2022,” *saloodo!blog*, Feb. 16, 2022.

[139] “European Union CPI Transportation - April 2023 Data - 1996-2022 Historical,” *Trading Economics*, Apr. 2023.

[140] “The Impact Rising Fuel Costs Have on Transport Logistics,” *On Logistics*, 2022.

[141] L. Young, “Companies Face Rising Supply-Chain Costs Amid Inventory Challenges,” Jul. 2022.

[142] McKinsey & Company, “The 2021 McKinsey Global Payments Report,” Oct. 2021.

[143] “] Macroeconomic projections March 2023,” *European Central Bank (ECB) Eurosystem*.

[144] “Inflation in the euro area. Data from April 2023. Extracted on 2 May 2023. Next planned article update: 17 May 2023.,” *EUROSTAT*.

[145] Kinaxis Blog, “ The sharing economy: An effective model for supply chain management?,” 2022.

[146] S. Jomthanachai, W.-P. Wong, K.-L. Soh, and C.-P. Lim, “A global trade supply chain vulnerability in COVID-19 pandemic: An assessment metric of risk and resilience-based efficiency of CoDEA method,” *Research in Transportation Economics*, vol. 93, p. 101166, Jun. 2022, doi: 10.1016/j.retrec.2021.101166.

[147] J. Hoffmann, “What supply chain disruptions mean for developing countries ,” *IPS Journal - Economy and Ecology*, Jun. 2022.

[148] G. Maihold and F. Mühlhöfer, “Supply Chain Instability Threatens Security of Supplies ,” *SWP Comment*, vol. 60, Dec. 2021.

[149] World Bank, “Global Economic Prospects, January 2023,” 2023.

[150] N. Ahuchogu, “How does inflation impact the Supply Chain?,” *ZURICH*, 2022.

[151] F. Stocker and G. Abib, “Risk Management in Born Globals: the Case of Brazilian Craft Breweries,” *BBR. Brazilian Business Review, Fucape Business School*, vol. 16, no. 4, pp. 334–349, 2019.

[152] A. C. González Calzadilla, M. Segovia Villarreal, J. M. Ramón Jerónimo, and R. Flórez López, “Risk Management in the Internationalization of Small and Medium-Sized Spanish

Companies," *Journal of Risk and Financial Management*, vol. 15, no. 8, p. 361, Aug. 2022, doi: 10.3390/jrfm15080361.

[153] A. Kerriou, "Inflation is invading the entire supply chain," *Upply*, Mar. 25, 2022.

[154] F. Suárez Ricaurte, "Understanding Supply Chain Disruptions During the COVID-19 Pandemic ," *McGill Business Law Platform*, Feb. 22, 2022.

[155] R. Baldwin and R. Freeman, "Risks and global supply chains: What we know and what we need to know," Cambridge, MA, Oct. 2021. doi: 10.3386/w29444.

[156] R. B. Handfield, G. Graham, and L. Burns, "Corona virus, tariffs, trade wars and supply chain evolutionary design," *International Journal of Operations & Production Management*, vol. 40, no. 10, pp. 1649–1660, Jul. 2020, doi: 10.1108/IJOPM-03-2020-0171.

[157] J. Sekliuckiene and S. Maciulskaite, "Internationalization Decision of a Born Global: the Case of Information Technology Companies," *Soc Sci*, vol. 80, no. 2, Aug. 2013, doi: 10.5755/j01.ss.80.2.4644.

[158] K. Sreelakshmi, "Supply chain challenges in 2023 that need your immediate attention," *GoComet*, Jan. 16, 2023.

[159] B. Bay, "The impact of labor shortage in the transportation and logistics industry," *LGI Blog (Logistics Group International)*.

[160] V. L. Miller, K. E. Wegrzyn, L. R. Imbrogno, and E. Wang, "Going the Distance: Managing Freight Costs and Delivery Delays in 2022," *FOLEY (FOLEY & LARDMER LLP) Bureau of Transportation Statistics, U.S. Department of Transportation, Freight Transportation Services Index*, Jun. 23, 2022.

[161] G. O'Meara, "Supply Chain Disruption – the Risk to Global Economic Recovery," *FTI CONSULTING*, Sep. 01, 2022.

[162] Deloitte, "Central Bank Digital Currencies Reality of realty in the tpost-COVID-19 world Central Bank Digital Currencies | Building Block of the Future of Value Transfer," 2022.

[163] R. Richardson, G. Quinet, and U. Kitajima, "Supply Chain Risk as a Barrier to Trade: A Concise Exploration," *International Management Review*, vol. 17, no. 2, pp. 48–53, 2021.

[164] P. Ibáñez, R. González Rugamas, S. Kohli, and E. Kuehl, "How to deal with price increases in this inflationary market," *McKinsey & Company*, Jan. 13, 2022.

[165] J. Jürgens, "What is a Digital Supply Chain Platform? ," *TOPO*, May 16, 2022.

[166] "Global Supply Chain Readiness Report," *Jabil and IndustryWeek's 2022* .

[167] "Digital experience platform revenue worldwide 2019-2025," *Statista*, 2023.

[168] Platform Revolution, "The State of the Platform Revolution 2021 - How the platform economy is reshaping global trade," 2021.

[169] J. Wu, J. Xu, Y. Zhou, and X. Zhu, "The Current Situation and Future Trend of the Platform Economy," Proceedings of the 2021 3rd International Conference on Economic Management and Cultural Industry (ICEMCI 2021), 2021. doi: 10.2991/assehr.k.211209.027.

[170] R. Watts, "Investing In The Shared Economy," *Forbes*, Feb. 25, 2022.

[171] "Value of the global sharing economy 2021," *Statista*, 2023.

[172] "From Disruptors to Disrupted by COVID-19: Rethinking The Future of Sharing Economy," *Cissoko & Company*, May 23, 2020.

[173] BIS Committee on Payments and Market Infrastructures (CPMI), “Covid-19 accelerated the digitalisation of payments,” Dec. 2021.

[174] “PWC Navigating the payments matrix Charting a course amid evolution and revolution. THE FUTURE OF FINANCIAL SERVICES - PAYMENTS 2025 & BEYOND.”

[175] “The Global Findex Database 2021: Financial Inclusion, Digital Payments, and Resilience in the Age of COVID-19,” 2021.

[176] “Progress on the investigation phase of a digital euro,” 2022.

[177] “Behind the Scenes of Central Bank Digital Currency Emerging Trends, Insights, and Policy Lessons,” *FINTECH NOTE*, 2022.

[178] L. P. Foo, C. L. Lai, D. B. Y. Ooi, and Z. Y. Khoo, “Towards an Ultimate Cashless Society and Potential Collaboration Between Blockchain and E-Payments,” 2022, pp. 176–195. doi: 10.4018/978-1-7998-9035-5.ch011.

[179] N. Grosse, T. Gürpinar, and M. Henke, “Blockchain-Enabled Trust in Intercompany Networks Applying the Agency Theory,” in *2021 3rd Blockchain and Internet of Things Conference*, New York, NY, USA: ACM, Jul. 2021, pp. 8–14. doi: 10.1145/3475992.3475994.

[180] J. D Reses, M. B. Gilroy, and S. Ojha, “The fintech revolution,” 2021.

[181] E. Feyen, J. Frost, L. Gambacorta, H. Natarajan, and M. Saal, “Fintech and the digital transformation of financial services: implications for market structure and public policy,” *The Bank for International Settlements and the World Bank Group*, vol. BIS Papers No 117, Jul. 2021.

[182] “Fintech | On the brink of further disruption,” *Deloitte Financial Advisory Netherlands*, Dec. 2020.

[183] AMR (Allied Market Research), “FinTech Lending Market to Reach $4,957.16 Billion, Globally, By 2030 at 27.4% CAGR: Allied Market Research ,” *PRNewswire news release*, Nov. 15, 2021.

[184] “BigTech – implications for the financial sector,” Feb. 2022.

[185] M. Anifa, S. Ramakrishnan, S. Joghee, S. Kabiraj, and M. M. Bishnoi, “Fintech Innovations in the Financial Service Industry,” *Journal of Risk and Financial Management*, vol. 15, no. 7, p. 287, Jun. 2022, doi: 10.3390/jrfm15070287.

[186] V. Murinde, E. Rizopoulos, and M. Zachariadis, “The impact of the FinTech revolution on the future of banking: Opportunities and risks,” *International Review of Financial Analysis*, vol. 81, p. 102103, May 2022, doi: 10.1016/j.irfa.2022.102103.

[187] A. Nathan, “Top Benefits And Challenges Of A Digital Supply Chain ,” *TECHTREND - Supply Chain Management*, Feb. 04, 2023.

[188] M. Rahman, I. Ismail, S. Bahri, and M. K. Rahman, “An Empirical Analysis of Cashless Payment Systems for Business Transactions,” *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 8, no. 4, p. 213, Dec. 2022, doi: 10.3390/joitmc8040213.

[189] “ CBDCs in emerging market economies, Monetary and Economic Department,” *BIS Papers N^{o} 123*, Apr. 14, 2022.

[190] B. Jaekel, “Is FinTech the Future of Supply Chain?,” *SDC Supply & Demand Chain Executive*, May 13, 2020.

[191] “The challenges of building a digital platform,” *CONCENTRIC*, Mar. 21, 2022.

[192] R. Handfield, “Sorting out Risk in FinTech Source Chains,” *Supply Chain Resource Cooperative. NC State University*, Jan. 27, 2018.

[193] S. Furber, “Wirecard debacle exposes vulnerabilities in fintech, payments value chain ,” *S&P Global - Market Intelligence*, Jul. 01, 2020.

[194] “Technology exposes banks’ vulnerabilities (Speech by Pentti Hakkarainen),” *European Central Bank*, Sep. 17, 2020.

[195] M. Anifa, S. Ramakrishnan, S. Joghee, S. Kabiraj, and M. M. Bishnoi, “Fintech Innovations in the Financial Service Industry,” *Journal of Risk and Financial Management*, vol. 15, no. 7, p. 287, Jun. 2022, doi: 10.3390/jrfm15070287.

[196] E. Princes, “Facing Disruptive Challenges in Supply Chain 4.0,” *International Journal of Supply Chain Management*, vol. 9, no. 4, pp. 52–57, 2020.

[197] F. McKay, “Supply Chain Technology Stack: A Digital Roadmap to Resilience,” *JABIL* , 2022.

[198] A. Hein *et al.*, “Digital platform ecosystems,” *Electronic Markets*, vol. 30, no. 1, pp. 87–98, Mar. 2020, doi: 10.1007/s12525-019-00377-4.

[199] X. Wen and T. Siqin, “How do product quality uncertainties affect the sharing economy platforms with risk considerations? A mean-variance analysis,” *Int J Prod Econ*, vol. 224, p. 107544, Jun. 2020, doi: 10.1016/j.ijpe.2019.107544.

[200] C. Viñuela, J. Sapena, and G. Wandosell, “The Future of Money and the Central Bank Digital Currency Dilemma,” *Sustainability*, vol. 12, no. 22, p. 9697, Nov. 2020, doi: 10.3390/su12229697.

[201] D. Moreira-Santos, M. Au-Yong-Oliveira, and A. Palma-Moreira, “Fintech Services and the Drivers of Their Implementation in Small and Medium Enterprises,” *Information*, vol. 13, no. 9, p. 409, Aug. 2022, doi: 10.3390/info13090409.

[202] S. Peng, “Sharing economy and sustainable supply chain perspective the role of environmental, economic and social pillar of supply chain in customer intention and sustainable development,” *Journal of Innovation & Knowledge*, vol. 8, no. 1, p. 100316, Jan. 2023, doi: 10.1016/j.jik.2023.100316.

[203] R. Estripeau *et al.*, “What an Accelerating Secondhand Market Means for Fashion Brands and Retailers,” *Bolton Counsulting Group BCG*, Oct. 05, 2022.

[204] L. Zhou and S. M. Gupta, “Value depreciation factors for new and remanufactured high-technology products: a case study on iPhones and iPads,” *Int J Prod Res*, vol. 58, no. 23, pp. 7218–7249, Dec. 2020, doi: 10.1080/00207543.2020.1722327.

[205] C. Krys and D. Born, “Trend compendium 2050, Mega trend 1 People and society,” *Roland Berger*, 2021. https://www.rolandberger.com/en/Insights/Publications/Roland-Berger-Trend-Compendium-2050-Population-and-Society.html

[206] “Ageing and health,” *WHO*, 2022. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

[207] “Population structure and ageing,” *Eurostat*, 2023. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Population_structure_and_ageing

[208] D. E. Bloom and L. M. Zucker, “Aging is the real population bomb,” *International Monetary Fund, 2023*, 2023. https://www.imf.org/en/Publications/fandd/issues/Series/Analytical-Series/aging-is-the-real-population-bomb-bloom-zucker

[209] “Ageing and demographic change,” *OECD*, 2019. https://www.oecd.org/economy/ageing-inclusive-growth/ (accessed Apr. 20, 2023).

[210] W. Fengler, “The silver economy is coming of age: A look at the growing spending power of seniors,” *Brookings*, 2021. brookings.edu/blog/future-development/2021/01/14/the-silver-economy-is-coming-of-age-a-look-at-the-growing-spending-power-of-seniors/#:~:text=Until 2030%2C the silver economy,wealthy than the current average.

[211] “World Population Day: Population trends up to 2100,” *Eurostat*, 2020. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/EDN-20200711-1

[212] “Youth and Empowerment,” *Unesco*, 2023. https://www.unesco.org/en/youth-and-empowerment

[213] “Young People’s Potential, the Key to Africa’s Sustainable Development,” *United Nations*, 2021. un.org/ohrlls/news/young-people’s-potential-key-africa’s-sustainable-development

[214] “World Population Prospects 2022,” *United Nations*, 2022. https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf

[215] J. Wilmoth, C. Menozzi, and L. Bassarsky, “Why population growth matters for sustainable development,” *United Nations Department of Economic and Social Affairs*, 2022.

[216] M. Saleh, “Population of Africa 2021, by age group,” *Statista*, 2022.

[217] “Global Trends 2040: Demographics and Human Development,” *Office of the Direction of National Intelligence*, 2021.

[218] “19 of the world’s 20 youngest countries are in Africa,” *World Economic Forum*, 2019. https://www.weforum.org/agenda/2019/08/youngest-populations-africa/

[219] “Increasing significance of migration,” *European Commission*, 2023. https://knowledge4policy.ec.europa.eu/increasing-significance-migration_en

[220] “World Migration Report 2022: Chapter 2 - Migration and Migrants: A Global Overview,” *UN International Organization for Migration*, 2021. https://publications.iom.int/books/world-migration-report-2022-chapter-2

[221] “Migration,” *United Nations*. https://www.un.org/en/global-issues/migration (accessed Apr. 20, 2023).

[222] “Global Trends 2040: The future of Migration,” *Office of the Direction of National Intelligence*, 2021. https://www.dni.gov/index.php/gt2040-home/gt2040-deeper-looks/future-of-migration

[223] V. Boutenko, J. Harnoss, and N. Lang, “5 key predictions for the future of talent migration,” *World Economic Forum*, 2022. https://www.weforum.org/agenda/2022/11/5-key-predictions-for-the-future-of-talent-migration/#:~:text=Migration will accelerate&text=Yet only 280 million people,more than 350 million people

[224] “A complex nexus,” *UN International Organization for Migration*, 2019. https://www.iom.int/complex-nexus

[225] “Climate Change Could Force 216 Million People to Migrate Within Their Own Countries by 2050,” *The World Bank*, 2021. https://www.worldbank.org/en/news/press-release/2021/09/13/climate-change-could-force-216-million-people-to-migrate-within-their-own-countries-by-2050

[226] “International Migration Outlook 2022,” *OECD*, 2022. https://www.oecd-ilibrary.org/sites/30fe16d2-en/index.html?itemId=/content/publication/30fe16d2-en

[227] A. Natarajan, M. Moslimani, and M. H. Lopez, “Key facts about recent trends in global migration,” *Pew Research Center*, 2022. https://www.pewresearch.org/fact-tank/2022/12/16/key-facts-about-recent-trends-in-global-migration/

[228] D. Battini, M. Calzavara, F. Sgarbossa, and A. Persona, “MRP Theory supporting trade-off between investments in collaborative robots and production in foreign countries for a water pumps supply chains,” *SOR ‘17 proceedings*, pp. 229–234, 2017.

[229] D. Bogataj and M. Bogataj, “Age management of human resources,” *SOR ‘17 proceedings*, pp. 235–241, 2017.

[230] M. Calzavara, D. Battini, D. Bogataj, F. Sgarbossa, and I. Zennaro, “Ageing workforce management in manufacturing systems: state of the art and future research agenda,” *Int J Prod Res*, vol. 58, no. 3, pp. 729–747, 2020.

[231] K. Simpson, N. Murtagh, and A. M. Owen, “Domestic retrofit: understanding capabilities of micro enterprise building practitioners,” *Buildings and cities*, vol. 2, no. 1, pp. 449–466, 2021.

[232] S. Jin *et al.*, “Identifying barriers to sustainable apple production: A stakeholder perspective,” *J Environ Manage*, vol. 302, p. 114082, 2022.

[233] V. Cox and J. A. Overbey, “Generational knowledge transfer and retention strategies,” *Development and Learning in Organizations: An International Journal*, no. ahead-of-print, 2022.

[234] A. Burmeister and J. Deller, “Knowledge retention from older and retiring workers: What do we know, and where do we go from here?,” *Work Aging Retire*, vol. 2, no. 2, pp. 87–104, 2016.

[235] D. Ropes, “Intergenerational learning in organizations. An effective way to stimulate older employee learning and development,” *Development and Learning in Organizations*, vol. 28, no. 2, pp. 7–9, 2014.

[236] L. Rubin and G. M. Sparzo, “An aging work force that will not retire,” *Strategic HR Review*, 2020.

[237] D. van den Broek, C. F. Wright, J. Howe, and A. Reilly, “Pro-market governance, migration status and worker vulnerability: The case of Australian horticulture,” *Economic and Industrial Democracy*, vol. 42, no. 4, pp. 1305–1325, 2021.

[238] A. Zuntz *et al.*, “Syrian refugee labour and food insecurity in Middle Eastern agriculture during the early COVID-19 pandemic,” *Int Labour Rev*, vol. 161, no. 2, pp. 245–266, 2022.

[239] R. Cole, N. Al-Ma’aitah, and R. Al Hasan, “Integrating Syrian refugee workers in global supply chains: creating opportunities for stable trade,” *Journal of humanitarian logistics and supply chain management*, 2022.

[240] S. Chanani, H. Spector, S. Restrepo Alvarez, N. Chowdhury, and P. Ma, “Challenges to increasing visibility and support for children in Bangladesh’s informal ready-made garment factories,” *Business Strategy & Development*, vol. 5, no. 4, pp. 361–374, 2022.

[241] S.-H. Cho, X. Fang, S. Tayur, and Y. Xu, “Combating child labor: Incentives and information disclosure in global supply chains,” *Manufacturing & Service Operations Management*, vol. 21, no. 3, pp. 692–711, 2019.

[242] R. Cole and Z. Shirgholami, “The outlook for modern slavery in the apparel sector in a post-lockdown economy,” *Supply Chain Management: An International Journal*, vol. 27, no. 4, pp. 526–537, 2022.

[243] A. Fabry, G. Van den Broeck, and M. Maertens, “Decent work in global food value chains: Evidence from Senegal,” *World Dev*, vol. 152, p. 105790, 2022.

[244] “Urban Development,” *The World Bank*, 2022. https://www.worldbank.org/en/topic/urbandevelopment/overview

[245] “68% of the world population projected to live in urban areas by 2050, says UN,” *United Nations Department of Economic and Social Affairs*, 2018. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

[246] “World Cities Report 2022: Envisaging the Future of Cities,” *United Nations Human Settlements Programme*, 2022. https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf

[247] A. Fleck, “The World’s Next Megacities,” *Statista*, 2023. https://www.statista.com/chart/29152/the-worlds-next-megacities/

[248] “Ecological Threat Report 2022: Analysing Ecological Threats, Resilience & Peace,” *Institute for Economic and Peace*, 2022.

[249] “World Cities Report 2022: Envisaging the Future of Cities,” *United Nations Human Settlements Programme*, 2022. https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf

[250] “Shaping the Trends of Our Time,” *United Nations*, 2020. https://www.un.org/development/desa/publications/wp-content/uploads/sites/10/2020/09/20-124-UNEN-75Report-2-1.pdf

[251] “Global Trends to 2030: Challenges and Choices for Europe,” *ESPAS European Strategy and Policy Analysis System*, 2019.

[252] B. Venditti, “This chart shows the impact rising urbanization will have on the world,” *World Economic Forum*, 2022. https://www.weforum.org/agenda/2022/04/global-urbanization-material-consumption/

[253] B. Thormundsson, “Smart cities market revenues worldwide 2019-2030,” *Statista*, Mar. 03, 2023. https://www.statista.com/statistics/1256262/worldwide-smart-city-market-revenues/#statisticContainer (accessed May 03, 2023).

[254] M. E. Antunes, J. G. Barroca, and D. Guerreiro de Oliveira, “Urban Future With a Purpose: 12 trends shaping the future of cities by 2030,” *Deloitte*, 2021. file:///C:/Users/bettfri51805/Downloads/deloitte-urban-future-with-a-purpose-study-set2021.pdf (accessed May 03, 2023).

[255] “Infrastructure technologies: Challenges and solutions for smart mobility in urban areas,” *McKinsey & Company*, Mar. 28, 2023. https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/infrastructure-technologies-challenges-and-solutions-for-smart-mobility-in-urban-areas#/ (accessed May 03, 2023).

[256] “‘Fit for the Future’ Cities: How technology can accelerate sustainable change,” *Vodafone*, Sep. 2022. https://www.vodafone.com/sites/default/files/2022-09/vodafone-fit-for-the-future-cities-report-final.pdf (accessed May 03, 2023).

[257] “Commission launches EU missions to tackle major challenges,” *European Commission*, Sep. 29, 2021. https://ec.europa.eu/commission/presscorner/detail/en/ip_21_4747 (accessed May 03, 2023).

[258] “EU Mission: 100 climate-neutral and smart cities,” *European Commission*, Apr. 28, 2022. https://op.europa.eu/en/publication-detail/-/publication/822ee360-c9bf-11ec-b6f4-01aa75ed71a1/language-en/format-PDF/source-256649647 (accessed May 03, 2023).

[259] B. Bhushan, A. Khamparia, K. M. Sagayam, S. K. Sharma, M. A. Ahad, and N. C. Debnath, “Blockchain for smart cities: A review of architectures, integration trends and future research directions,” *Sustain Cities Soc*, vol. 61, p. 102360, 2020.

[260] J. Xie *et al.*, “A survey of blockchain technology applied to smart cities: Research issues and challenges,” *IEEE communications surveys & tutorials*, vol. 21, no. 3, pp. 2794–2830, 2019.

[261] F. Borghetti, C. Caballini, A. Carboni, G. Grossato, R. Maja, and B. Barabino, “The use of drones for last-mile delivery: A numerical case study in Milan, Italy,” *Sustainability*, vol. 14, no. 3, p. 1766, 2022.

[262] H. B. Rai *et al.*, “‘Proximity logistics’: Characterizing the development of logistics facilities in dense, mixed-use urban areas around the world,” *Transp Res Part A Policy Pract*, vol. 166, pp. 41–61, 2022.

[263] V. Gružauskas, E. Gimžauskienė, and V. Navickas, “Forecasting accuracy influence on logistics clusters activities: The case of the food industry,” *J Clean Prod*, vol. 240, p. 118225, 2019.

[264] F. Fernqvist and C. Göransson, “Future and recent developments in the retail vegetable category–a value chain and food systems approach,” *International Food and Agribusiness Management Review*, vol. 24, no. 1, pp. 27–49, 2021.

[265] B. Kin, S. Verlinde, and C. Macharis, “Sustainable urban freight transport in megacities in emerging markets,” *Sustain Cities Soc*, vol. 32, pp. 31–41, 2017.

[266] A. Deja, T. Dzhuguryan, L. Dzhuguryan, O. Konradi, and R. Ulewicz, “Smart sustainable city manufacturing and logistics: A framework for city logistics node 4.0 operations,” *Energies (Basel)*, vol. 14, no. 24, p. 8380, 2021.

[267] J. G. V. Vieira, J. C. Fransoo, and C. D. Carvalho, “Freight distribution in megacities: perspectives of shippers, logistics service providers and carriers,” *J Transp Geogr*, vol. 46, pp. 46–54, 2015.

[268] J. A. Orjuela-Castro, J. P. Orejuela-Cabrera, and W. Adarme-Jaimes, “Last mile logistics in mega-cities for perishable fruits,” *Journal of Industrial Engineering and Management*, vol. 12, no. 2, pp. 318–327, 2019.

[269] M. D’Ostuni, L. Zaffi, E. Appolloni, and F. Orsini, “Understanding the complexities of Building-Integrated Agriculture. Can food shape the future built environment?,” *Futures*, vol. 144, p. 103061, 2022.

[270] E. Thiesset and I. Vlachos, “Supply chain resilience in city-region food systems: The case of Paris-Rungis market during the pandemic,” in *2022 IEEE 6th International Conference on Logistics Operations Management (GOL)*, IEEE, 2022, pp. 1–10.

[271] J. Gómez-Maturano and B. Sánchez-Lara, “Sociodemographic Analysis of the Location of MSW Collection Centers in Mexico City,” *Technological and Industrial Applications Associated With Industry 4.0*, pp. 315–330, 2022.

[272] G. Mirabelli and V. Solina, “Blockchain and agricultural supply chains traceability: Research trends and future challenges,” *Procedia Manuf*, vol. 42, pp. 414–421, 2020.

[273] C. Ma, “Smart city and cyber-security; technologies used, leading challenges and future recommendations,” *Energy Reports*, vol. 7, pp. 7999–8012, 2021.

[274] P. K. Sharma, N. Kumar, and J. H. Park, “Blockchain-based distributed framework for automotive industry in a smart city,” *IEEE Trans Industr Inform*, vol. 15, no. 7, pp. 4197–4205, 2018.

[275] K. Salah, N. Nizamuddin, R. Jayaraman, and M. Omar, “Blockchain-based soybean traceability in agricultural supply chain,” *Ieee Access*, vol. 7, pp. 73295–73305, 2019.

[276] P. Zhang *et al.*, “Understanding the tele-coupling mechanism of urban food-energy-water nexus: critical sources, nodes, and supply chains,” *J Clean Prod*, vol. 235, pp. 297–307, 2019.

[277] J. G. V. Vieira and J. C. Fransoo, “How logistics performance of freight operators is affected by urban freight distribution issues,” *Transp Policy (Oxf)*, vol. 44, pp. 37–47, 2015.

[278] A. A. Abdalla, Y. A. Abdalla, A. M. Haddad, G. Bhavani, and E. Zabalawi, “Connections between Big Data and Smart Cities from the Supply Chain Perspective: Understanding the Impact of Big Data,” *Sustainability*, vol. 14, no. 23, p. 16161, 2022.

[279] F. Longo, L. Nicoletti, A. Padovano, G. d’Atri, and M. Forte, “Blockchain-enabled supply chain: An experimental study,” *Comput Ind Eng*, vol. 136, pp. 57–69, 2019.

[280] “Search for Sustainable Goods Grows by 71% As ‘Eco-Wakening’ Grips the Globe,” *WWF*, May 17, 2021. https://www.worldwildlife.org/press-releases/search-for-sustainable-goods-grows-by-71-as-eco-wakening-grips-the-globe (accessed May 09, 2023).

[281] K. McCann, “Conscious consumerism is transforming industries,” *The consumer goods forum*, Oct. 04, 2021. https://www.theconsumergoodsforum.com/blog/2021/10/04/conscious-consumerism-is-transforming-industries/ (accessed May 09, 2023).

[282] K. Alldredge, T. Charm, E. Falardeau, and K. Robinson, “How US consumers are feeling, shopping, and spending—and what it means for companies,” *McKinsey & Company*, May 04, 2022. https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/how-us-consumers-are-feeling-shopping-and-spending-and-what-it-means-for-companies (accessed May 09, 2023).

[283] “Conscious Consumerism: Understanding the dilemmas of today’s consumer,” *Deloitte*, 2023. https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/deloitte-nl-consumer-conscious-consumerism-report-finaal.pdf (accessed May 09, 2023).

[284] A. Emmert, “The rise of the eco-friendly consumer,” *PwC*, Jul. 08, 2021. https://www.strategy-business.com/article/The-rise-of-the-eco-friendly-consumer (accessed May 09, 2023).

[285] L. Pieters, D. R. Novak, D. Pankratz, and S. Rogers, “The cost of buying green,” *Deloitte*, Jun. 17, 2022. https://www2.deloitte.com/xe/en/insights/industry/retail-distribution/consumer-behavior-trends-state-of-the-consumer-tracker/sustainable-products-and-practices-for-green-living.html (accessed May 09, 2023).

[286] “How to Be a More Conscious Consumer, Even If You’re on a Budget,” *New York Times*, 2019. Accessed: May 09, 2023. [Online]. Available: https://www.nytimes.com/2019/10/01/smarter-living/sustainabile-shopping-conscious-consumer.html#:~:text=Conscious%20consumption%20is%20an%20umbrella,way%20to%20consume%20more%20consciously

[287] “The State of Fashion 2022,” *McKinsey & Company*, 2022. https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/state%20of%20fashion/2022/the-state-of-fashion-2022.pdf (accessed May 09, 2023).

[288] “Global Consumer Insights Pulse Survey,” *PwC*, Jun. 2021. https://www.pwc.com/gx/en/consumer-markets/consumer-insights-survey/2021/gcis-june-2021.pdf (accessed May 09, 2023).

[289] McKinsey & Company, “European consumer pessimism intensifies in the face of rising prices,” *McKinsey & Company*, Oct. 27, 2022. https://www.mckinsey.com/capabilities/growth-

marketing-and-sales/our-insights/survey-european-consumer-sentiment-during-the-coronavirus-crisis (accessed May 17, 2023).

[290] M. Butkovská, “PwC Consumer Insights Survey,” *PwC*, Feb. 28, 2023. https://www.pwc.com/sk/en/current-press-releases/pwc-consumer-insights-survey.html (accessed May 15, 2023).

[291] “The State of Fashion 2023: Holding onto growth as global clouds gather,” *McKinsey & Company*, Nov. 29, 2022. https://www.mckinsey.com/industries/retail/our-insights/state-of-fashion (accessed May 15, 2023).

[292] I. Gerretsen and I. Kottasová, “The world is paying a high price for cheap clothes,” *CNN Business*, May 06, 2020. https://edition.cnn.com/2020/05/03/business/cheap-clothing-fast-fashion-climate-change-intl/index.html (accessed May 15, 2023).

[293] Z. Mahmood, “Ultra-fast fashion is taking over – and using every trick in the book to get us addicted,” *The Guardian*, Apr. 18, 2022. https://www.theguardian.com/commentisfree/2022/apr/18/ultra-fast-fashion-retail-sites-shein (accessed May 15, 2023).

[294] B. Einhorn, “Shein’s $100 Billion Value Would Top H&M and Zara Combined,” *Bloomberg*, Apr. 04, 2022. https://www.bloomberg.com/news/articles/2022-04-04/shein-s-100-billion-valuation-would-top-h-m-and-zara-combined?in_source=embedded-checkout-banner&leadSource=uverify%20wall (accessed May 17, 2023).

[295] Z. Yang and W. Chen, “Fast, Cheap, and Out of Control: Inside Shein’s Sudden Rise,” *Wired*, Jun. 2022. https://www.wired.com/story/fast-cheap-out-of-control-inside-rise-of-shein/ (accessed May 17, 2023).

[296] “How Innovation and Collaboration Can Accelerate Sustainability in Fashion,” *Boston Consulting Group*, Jul. 14, 2017. https://www.bcg.com/publications/2017/retail-how-innovation-collaboration-accelerate-sustainability-fashion (accessed May 17, 2023).

[297] “Growing consumption,” *European Commission*, Feb. 16, 2023. https://knowledge4policy.ec.europa.eu/growing-consumerism_en (accessed May 17, 2023).

[298] “Fast fashion market value forecast worldwide from 2022 to 2027,” *Statista*, Feb. 2023. https://www.statista.com/statistics/1008241/fast-fashion-market-value-forecast-worldwide/ (accessed May 17, 2023).

[299] J. Kuhl and D. Krause, “Strategies for customer satisfaction and customer requirement fulfillment within the trend of individualization,” *Procedia CIRP*, vol. 84, pp. 130–135, 2019.

[300] E. Lindecrantz, M. Tjon, P. Gi, and S. Zerbi, “Personalizing the customer experience: Driving differentiation in retail,” *McKinsey & Company*, Apr. 28, 2020. https://www.mckinsey.com/industries/retail/our-insights/personalizing-the-customer-experience-driving-differentiation-in-retail (accessed May 17, 2023).

[301] “2021 Top picks: From recovery to growth,” *McKinsey & Company*, Dec. 2021. https://www.mckinsey.com/~/media/mckinsey/business%20functions/marketing%20and%20sales/our%20insights/2021%20top%20picks%20from%20recovery%20to%20growth/2021-top-picks-from-recovery-to-growth.pdf (accessed May 17, 2023).

[302] J. Gleisberg and O. Knapp, “#OPERA 2030 - The future of Operations - Adapting operations to an uncertain future,” *Roland Berger*, 2023. https://www.rolandberger.com/en/Insights/Global-Topics/Opera-2030/ (accessed May 15, 2023).

[303] K. Rogers and A. Cosgrove, “Five ways to win the consumer of 2030, now,” *EY*, Jun. 07, 2019. https://www.ey.com/en_gl/consumer-products-retail/five-ways-to-win-the-consumer-of-2030-now (accessed May 17, 2023).

[304] F. Shariff, M. Ahuja, N. Dalmia, S. Dulay, S. Ivic, and S. Ebrahim, “Connecting with meaning: Hyper-personalizing the customer experience using data, analytics, and AI,” *Deloitte* , 2020. https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/deloitte-analytics/ca-en-omnia-ai-marketing-pov-fin-jun24-aoda.pdf (accessed May 15, 2023).

[305] “Increased Competitiveness and Resiliency through Next Generation Manufacturing,” *Roland Berger and Manufacturers Alliance*, Apr. 12, 2023. https://www.rolandberger.com/en/Insights/Publications/U.S.-manufacturers-disrupting-themselves.html (accessed May 17, 2023).

[306] G. Poulton, “How reading data can lead to insights of what lies ahead in the coming decades,” *Roland Berger*, Apr. 13, 2023. https://www.rolandberger.com/en/Insights/Publications/Future-reports.html (accessed May 17, 2023).

[307] S. Bali, A. Gunasekaran, S. Aggarwal, B. Tyagi, and V. Bali, “A strategic decision-making framework for sustainable reverse operations,” *J Clean Prod*, vol. 381, p. 135058, 2022.

[308] S. Sarkar and A. Bhadouriya, “Manufacturer competition and collusion in a two-echelon green supply chain with production trade-off between non-green and green quality,” *J Clean Prod*, vol. 253, p. 119904, 2020.

[309] P. Sinha, M. Sharma, and R. Agrawal, “A systematic review and future research agenda for sustainable fashion in the apparel industry,” *Benchmarking: An International Journal*, no. ahead-of-print, 2022.

[310] T. Moysiadis *et al.*, “AgriFood supply chain traceability: data sharing in a farm-to-fork case,” *Benchmarking: An International Journal*, no. ahead-of-print, 2022.

[311] T. Brydges, “Closing the loop on take, make, waste: Investigating circular economy practices in the Swedish fashion industry,” *J Clean Prod*, vol. 293, p. 126245, 2021.

[312] E. Jacobs and C. Mafini, “Transactional leadership, supply chain quality and business performance in the fast-moving consumer goods industry,” *Journal of Transport and Supply Chain Management*, vol. 13, no. 1, pp. 1–13, 2019.

[313] A. Galkin, I. Yemchenko, S. Lysa, M. Tarasiuk, Y. Chortok, and Y. Khvesyk, “Exploring the relationships between demand attitudes and the supply amount in consumer-driven supply chain for FMCG,” *Acta Logistica*, vol. 9, no. 1, pp. 1–12, 2022.

[314] S. Ebrahim, W. Niemann, and T. Kotzé, “Sustainable supply chain integration: An exploration of South African fast-moving consumer goods manufacturers,” *South African Journal of Economic and Management Sciences*, vol. 25, no. 1, pp. 1–14, 2022.

[315] L. R. Camargo, S. C. F. Pereira, and M. R. S. Scarpin, “Fast and ultra-fast fashion supply chain management: an exploratory research,” *International Journal of Retail & Distribution Management*, vol. 48, no. 6, pp. 537–553, 2020.

[316] F. Gimeno-Arias and J. M. Santos-Jaén, “Using PLS-SEM for assessing negative impact and cooperation as antecedents of gray market in FMCG supply chains: an analysis on Spanish wholesale distributors,” *International Journal of Physical Distribution & Logistics Management*, no. ahead-of-print, 2022.

[317] J. Yao, H. Shi, and C. Liu, “Optimising the configuration of green supply chains under mass personalisation,” *Int J Prod Res*, vol. 58, no. 24, pp. 7420–7438, 2020.

[318] S. Harper and R. Pal, “Small-series supply network configuration priorities and challenges in the EU textile and apparel industry,” *Journal of Fashion Marketing and Management: An International Journal*, no. ahead-of-print, 2022.

[319] G. Wang, X. Hu, X. Li, Y. Zhang, S. Feng, and A. Yang, “Multiobjective decisions for provider selection and order allocation considering the position of the CODP in a logistics service supply chain,” *Comput Ind Eng*, vol. 140, p. 106216, 2020.

[320] L. Guo, S. Chen, J. K. Allen, and F. Mistree, “A Framework for Designing the Customer-Order Decoupling Point to Facilitate Mass Customization,” *Journal of Mechanical Design*, vol. 143, no. 2, 2021.

[321] J. Wang, H. Jiang, and M. Yu, “Pricing decisions in a dual-channel green supply chain with product customization,” *J Clean Prod*, vol. 247, p. 119101, 2020.

[322] H. Cao, X. Yang, and R. Deng, “Ontology-based holonic event-driven architecture for autonomous networked manufacturing systems,” *IEEE Transactions on Automation Science and Engineering*, vol. 18, no. 1, pp. 205–215, 2020.

[323] H. Katoozian and M. K. Zanjani, “Supply network design for mass personalization in Industry 4.0 era,” *Int J Prod Econ*, vol. 244, p. 108349, 2022.

[324] M. Gong, Y. Gao, L. Koh, C. Sutcliffe, and J. Cullen, “The role of customer awareness in promoting firm sustainability and sustainable supply chain management,” *Int J Prod Econ*, vol. 217, pp. 88–96, 2019.

[325] Y. Yan, S. Gupta, T. C. Licsandru, and K. Schoefer, “Integrating machine learning, modularity and supply chain integration for Branding 4.0,” *Industrial Marketing Management*, vol. 104, pp. 136–149, 2022.

[326] G. Ji, S. Zhou, K.-H. Lai, K. H. Tan, and A. Kumar, “Timing of blockchain adoption in a supply chain with competing manufacturers,” *Int J Prod Econ*, vol. 247, p. 108430, 2022.

[327] J. Fan, H. Teng, and Y. Wang, “Research on Recycling Strategies for New Energy Vehicle Waste Power Batteries Based on Consumer Responsibility Awareness,” *Sustainability*, vol. 14, no. 16, p. 10016, 2022.

[328] J. P. Loaiza-Ramírez, C. E. Moreno-Mantilla, and T. Reimer, “Do consumers care about companies’ efforts in greening supply chains? Analyzing the role of protected values and the halo effect in product evaluation,” *Cleaner Logistics and Supply Chain*, vol. 3, p. 100027, 2022.

[329] S. Alonso-Muñoz, R. González-Sánchez, C. Siligardi, and F. E. García-Muiña, “Analysis of the Textile Supply Chain from a Circularity Perspective: A Case Study,” in *Eurasian Business and Economics Perspectives: Proceedings of the 34th Eurasia Business and Economics Society Conference*, Springer, 2022, pp. 213–234.

[330] R. Zanjirani Farahani, N. Asgari, and L. N. Van Wassenhove, “Fast fashion, charities, and the circular economy: challenges for operations management,” *Prod Oper Manag*, vol. 31, no. 3, pp. 1089–1114, 2022.

[331] Z. Mosanna, J. Heydari, S. A. Torabi, and M. A. Ülkü, “Donating to a good cause: Optimal coordination design of a dyadic supply chain with socially aware consumers,” *Comput Ind Eng*, vol. 169, p. 108243, 2022.

[332] H. Sheng, T. Feng, L. Chen, and D. Chu, “Operational coordination and mass customization capability: the double-edged sword effect of customer need diversity,” *The international journal of logistics management*, vol. 33, no. 1, pp. 289–310, 2022.

[333] M. Ben-Jebara and S. B. Modi, “Product personalization and firm performance: An empirical analysis of the pharmaceutical industry,” *Journal of Operations Management*, vol. 67, no. 1, pp. 82–104, 2021.

[334] S. Guo, T.-M. Choi, and S.-H. Chung, “Self-design fun: Should 3D printing be employed in mass customization operations?,” *Eur J Oper Res*, vol. 299, no. 3, pp. 883–897, 2022.

[335] S. Guo, T.-M. Choi, B. Shen, and S. Jung, “Inventory management in mass customization operations: A review,” *IEEE Trans Eng Manag*, vol. 66, no. 3, pp. 412–428, 2018.

[336] T. Stringer, A. R. Payne, and G. Mortimer, “As cheap as humanly possible: why consumers care less about worker welfare,” *Journal of Fashion Marketing and Management: An International Journal*, vol. 26, no. 4, pp. 717–737, 2022.

[337] D. Reike, M. P. Hekkert, and S. O. Negro, “Understanding circular economy transitions: The case of circular textiles,” *Bus Strategy Environ*, vol. 32, no. 3, pp. 1032–1058, 2023.

[338] L. Guo, H. Yin, X. Zhao, and Q. Zhu, “Managing your own low-tier suppliers via donation to NGOs: Why do multi-national corporations bother?,” *Int J Prod Econ*, vol. 250, p. 108670, 2022.

[339] F. Ye, S. Jiang, Y. Li, K. H. Tan, and A. Kumar, “The Value and Pitfall of CM’s Sustainability Signal Considering OEM’s Greenwash,” *IEEE Trans Eng Manag*, 2022.

[340] M. A. Achabou, “The effect of perceived CSR effort on consumer brand preference in the clothing and footwear sector,” *European Business Review*, vol. 32, no. 2, pp. 317–347, 2020.

[341] S. Jin *et al.*, “Identifying barriers to sustainable apple production: A stakeholder perspective,” *J Environ Manage*, vol. 302, p. 114082, 2022.

[342] K. S. Abdallah and M. M. El-Beheiry, “The effect of planning horizon and information sharing on the optimisation of the distribution network of a fast-moving consumer goods supply chain,” *Journal of Transport and Supply Chain Management*, vol. 16, no. 0, p. 788, 2022.

[343] B. Xie, W. Li, D. Zhao, and P. Jiang, “Effects of network externalities and recycling channels on closed-loop supply chain operation incorporating consumers’ dual preferences,” *Math Probl Eng*, vol. 2022, 2022.

[344] M. Prensky, “Digital natives, digital immigrants part 2: Do they really think differently?,” *On the horizon*, 2001.

[345] H. Tao, X. Sun, X. Liu, J. Tian, and D. Zhang, “The impact of consumer purchase behavior changes on the business model design of consumer services companies over the course of COVID-19,” *Front Psychol*, vol. 13, 2022.

[346] V. Ali Taha, T. Pencarelli, V. Škerháková, R. Fedorko, and M. Košíková, “The use of social media and its impact on shopping behavior of Slovak and Italian consumers during COVID-19 pandemic,” *Sustainability*, vol. 13, no. 4, p. 1710, 2021.

[347] “E-commerce statistics for individuals,” *Eurostat*, 2023. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=E-commerce_statistics_for_individuals#E-shopping:_largest_increase_among_young_internet_users

[348] K. Sitarska, “5 trends of the future in B2B purchasing that will affect sales - conclusions from the Gartner report. Part 1/2,” 2021.

[349] C. Wulff, “New trends are shaping shopping behaviour,” *PwC*, 2019. https://www.pwc.de/en/retail-and-consumer/digitisation-is-transforming-shopping.html

[350] M. Guta, “73% of All Small Business Teams Will Have Remote Workers by 2028,” *Small Business Trends*, 2019. https://smallbiztrends.com/2019/03/remote-workforce-trends.html

[351] S. Kauffeld, D. Tartler, H. Gräfe, A.-K. Windmann, and N. C. Sauer, “What will mobile and virtual work look like in the future?—Results of a Delphi-based study,” *Gruppe. Interaktion. Organisation. Zeitschrift für Angewandte Organisationspsychologie (GIO)*, vol. 53, no. 2, pp. 189–214, 2022.

[352] Statista, “Leading online communication services used on a regular basis worldwide as of March 2021,” 2021. https://www.statista.com/statistics/1246368/communication-services-usage/

[353] FutureIoT, “Gartner: 25% of people to spend 1 hour daily in the metaverse by 2026,” 2022. https://futureiot.tech/gartner-25-of-people-to-spend-1-hour-daily-in-the-metaverse-by-2026/#:~:text=“By 2026%2C 30%25 of,and services ready for metaverse.”&text=The adoption of metaverse technologies,heavily in a specific metaverse

[354] J. Moss, “What Exactly is the Metaverse?,” *International Banker*, 2022. https://internationalbanker.com/technology/what-exactly-is-the-metaverse/

[355] F. Zandt, “Will the metaverse lead to metawork?,” *Statista*, 2022. https://www.weforum.org/agenda/2022/03/will-the-metaverse-lead-to-metawork/

[356] K.-Y. Kwahk and B. Kim, “Effects of social media on consumers’ purchase decisions: evidence from Taobao,” *Service Business*, vol. 11, no. 4, pp. 803–829, Dec. 2017, doi: 10.1007/s11628-016-0331-4.

[357] C. Beer, “Social Browsers Engage with Brands,” *Global Web Index*, 2018. https://blog.gwi.com/chart-of-the-day/social-browsers-brand/

[358] R. Kowalewicz, “How Social Media Impacts Consumer Buying,” *Forbes*, 2022. https://www.forbes.com/sites/forbesagencycouncil/2022/04/28/how-social-media-impacts-consumer-buying/?sh=52e7133c337d

[359] S. Lund, Susan; Madgavkar, Anu; Manyika, James; Smit, “What’s next for remote work: An analysis of 2,000 tasks, 800 jobs, and nine countries,” *McKinsey & Company*, 2020. https://www.mckinsey.com/featured-insights/future-of-work/whats-next-for-remote-work-an-analysis-of-2000-tasks-800-jobs-and-nine-countries

[360] L. Williams, “The rise of digital nomads could change FDI as we know it,” *Investment Monitor*, 2021. https://www.investmentmonitor.ai/features/rise-digital-nomads-impact-investors/

[361] Zetes, “Five supply chain trends to follow in 2022,” 2022. https://www.zetes.com/en/supply-chain-visibility/supply-chain-visibility-software/five-supply-chain-trends-to-follow-in-2022

[362] Cat Lift Trucks, “E-commerce Growth: How Can Supply Chains Prepare for the Future?,” 2021. https://www.catlifttruck.com/blog/e-commerce-growth-how-can-supply-chains-prepare-future

[363] K. Bohmeyer, “The Impact of New E-Commerce Shopping Behaviors,” *Supply Chain Brain*, 2021. https://www.supplychainbrain.com/blogs/1-think-tank/post/32668-the-impact-of-new-e-commerce-shopping-behaviors

[364] H. Resnick, Nathan; Ho, “Top Omnichannel Logistics and Supply Chain Challenges in Ecommerce,” *Shopify*, 2020. https://www.shopify.com/enterprise/top-omni-channel-logistics-supply-chain-challenges-ecommerce-founders-must-face

[365] M. Hooper, Kate; Benton, “The Future of Remote Work,” 2022. [Online]. Available: https://www.migrationpolicy.org/sites/default/files/publications/mpi-remote-work-2022_final.pdf

[366] F. Tungande, A. Meyer, and W. Niemann, “Opportunities and challenges of social media in supply chain management: A study in the South African FMCG retail industry,” 2020.

[367] H. Al Mashalah, E. Hassini, A. Gunasekaran, and D. Bhatt, “The impact of digital transformation on supply chains through e-commerce: Literature review and a conceptual framework,” *Transp Res E Logist Transp Rev*, vol. 165, p. 102837, 2022.

[368] “STARTLING REMOTE WORK BURNOUT STATISTICS,” *Apollo Technical*, 2023. https://www.apollotechnical.com/remote-work-burnout-statistics/

[369] D. Roe, “Is Remote Working Really Impeding Collaboration and Communication?,” *Reworked*, 2021. https://www.reworked.co/digital-workplace/is-remote-working-really-impeding-collaboration-and-communication/

[370] “How to Attract and Retain Talent in the Logistics & Supply Chain Industry,” *Adecco Group*, 2022. https://www.adeccogroup.com/future-of-work/latest-insights/how-to-attract-and-retain-talent-in-the-logistics-and-supply-chain-industry/

[371] I. Cárdenas, J. Beckers, and T. Vanelslander, “E-commerce last-mile in Belgium: Developing an external cost delivery index,” *Research in transportation business & management*, vol. 24, pp. 123–129, 2017.

[372] J. Sarkis, L. M. Meade, and S. Talluri, “E-logistics and the natural environment,” *Supply Chain Management: An International Journal*, vol. 9, no. 4, pp. 303–312, 2004.

[373] H. Pålsson, F. Pettersson, and L. W. Hiselius, “Energy consumption in e-commerce versus conventional trade channels-Insights into packaging, the last mile, unsold products and product returns,” *J Clean Prod*, vol. 164, pp. 765–778, 2017.

[374] B. K. Chae, R. McHaney, and C. Sheu, “Exploring social media use in B2B supply chain operations,” *Bus Horiz*, vol. 63, no. 1, pp. 73–84, 2020.

[375] “The Future of Workforce and Talent in the Logistics & Supply Chain Industry,” 2022. [Online]. Available: https://www.adecco-jobs.com/-/media/project/adeccogroup/pdf-files/2022-october/logistics-whitepaper-tag-2022-final.pdf/

[376] J. Rowsell, “How has geopolitics changed the skills needed by supply chain execs?,” *CIPS*, 2023. https://www.cips.org/supply-management/news/2023/january/how-has-geopolitics-changed-the-skills-needed-by-supply-chain-execs/

[377] K. Valaskova, P. Durana, and P. Adamko, “Changes in consumers’ purchase patterns as a consequence of the COVID-19 pandemic,” *Mathematics*, vol. 9, no. 15, p. 1788, 2021.

[378] “Port congestion - drivers and impacts on international freight forwarding,” *DB Group*, 2021. https://www.dbgroup.net/en/news/port-congestion-drivers-and-impacts-international-freight-forwarding

[379] R. McIvor, P. Humphreys, and L. McCurry, “Electronic commerce: supporting collaboration in the supply chain?,” *J Mater Process Technol*, vol. 139, no. 1–3, pp. 147–152, 2003.

[380] J. A. Scott, “The most interesting remote work statistics to examine just how popular this phenomenon has become!,” 2021. https://www.linkedin.com/pulse/most-interesting-remote-work-statistics-examine-just-how-scott/

[381] L. Yang *et al.*, “The effects of remote work on collaboration among information workers,” *Nat Hum Behav*, vol. 6, no. 1, pp. 43–54, 2022.

[382] “Talent risks are supply chain risks,” *KPMG*, 2022. https://kpmg.com/ca/en/home/insights/2022/02/talent-risks-are-supply-chain-risks.html

[383] M. Purdy, “How the Metaverse Could Change Work,” *Harvard Business Review*, 2022. https://hbr.org/2022/04/how-the-metaverse-could-change-work

[384] “Supply Chain and Logistics HR Trends Report.” [Online]. Available: https://occupop.s3-eu-west-1.amazonaws.com/Supply-Chain-and-Logistics-HR-Trends-Report-Occupop.pdf

[385] “Supply Chain: skills for the Digital Era,” 2019. [Online]. Available: https://assets.ey.com/content/dam/ey-sites/ey-com/en_uk/topics/advisory/ey-supply-chain-skills-for-the-digital-era.pdf

[386] “New skills, higher pay,” *Amazon*. https://www.aboutamazon.com/workplace/upskilling-commitments#:~:text=Amazon is investing more than,paying%2C in-demand roles.

[387] M. Knut, Alicke; Dumitrescu, Elena; Protopappa-Sieke, “Transforming supply chains: Do you have the skills to accelerate your capabilities?,” *McKinsey & Company*, 2022. https://www.mckinsey.com/capabilities/operations/our-insights/transforming-supply-chains-do-you-have-the-skills-to-accelerate-your-capabilities

[388] S. Knut, Alicke; Hoberg, Kai; Fischer, Julian; Welter, “The future of work in supply chain,” *Supply Chain Quarterly*, 2022. https://www.supplychainquarterly.com/articles/6233-the-future-of-work-in-supply-chain

[389] L. Cecere, “Are you building next-generation supply chain talent?,” *Supply Chain Quarterly*, 2016. https://www.supplychainquarterly.com/articles/1224-are-you-building-next-generation-supply-chain-talent

[390] B. Thomas, “Why Continuous Learning is Attractive to Gen Z and Millennials,” *Market Scale*, 2020. https://marketscale.com/industries/education-technology/continuous-learning-gen-z-millennials/

[391] C. Ro, “How climate change is re-shaping the way Gen Z works,” *BBC*, 2022. https://www.bbc.com/worklife/article/20220225-how-climate-change-is-re-shaping-the-way-gen-z-works

[392] “Logistics skills gap still cause for concern,” *Supply Chain Digital*, 2020. https://supplychaindigital.com/logistics/study-logistics-skills-gap-still-cause-concern

[393] G. Nwafor, “Addressing skills gap in supply chain,” *The Guardian*, 2022. https://guardian.ng/appointments/addressing-skills-gap-in-supply-chain/

[394] R. Sanders, “What enterprises can do to help solve the supply chain talent gap,” *EY*, 2021. https://www.ey.com/en_gr/consulting/what-enterprises-can-do-to-help-solve-the-supply-chain-talent-gap

[395] Y. Rogier, “the Logistics sector is hindered by an image problem: here’s how to fix it,” *Workforce Insights*, 2016. https://workforceinsights.randstad.com/hr-insights/the-logistics-sector-is-hindered-by-an-image-problem-heres-how-to-fix-it

[396] “Maintaining and developing skills of a multigenerational workforce,” *OECD*. https://www.oecd-ilibrary.org/sites/b642f807-en/index.html?itemId=/content/component/b642f807-en#chapter-d1e14233

[397] K. Fowler, “Five Reasons Labor Shortages Are Impacting Supply Chains,” *Forbes*, 2021. https://www.forbes.com/sites/forbeshumanresourcescouncil/2021/10/19/five-reasons-labor-shortages-are-impacting-supply-chains/?sh=73b5b4615b94

[398] N. Martindale, “What are the benefits of life-long learning and continuous development?,” *CIPS*, 2022. https://www.cips.org/supply-management/analysis/2022/december/what-are-the-benefits-of-life-long-learning-and-continuous-development/

[399] “4 Ways That the Pandemic is Changing B2B Buying Behavior,” *Elevation Marketing*, 2021. https://elevationb2b.com/blog/4-ways-that-the-pandemic-is-changing-b2b-buying-behavior/

[400] T. Ciarli, M. Kenney, S. Massini, and L. Piscitello, “Digital technologies, innovation, and skills: Emerging trajectories and challenges,” *Res Policy*, vol. 50, no. 7, p. 104289, 2021.

[401] L. Li, “Education supply chain in the era of Industry 4.0,” *Syst Res Behav Sci*, vol. 37, no. 4, pp. 579–592, 2020.

[402] M. Koot, M. R. K. Mes, and M. E. Iacob, “A systematic literature review of supply chain decision making supported by the Internet of Things and Big Data Analytics,” *Comput Ind Eng*, vol. 154, p. 107076, Apr. 2021, doi: 10.1016/J.CIE.2020.107076.

[403] S. Maheshwari, P. Gautam, and C. K. Jaggi, “Role of Big Data Analytics in supply chain management: current trends and future perspectives,” *https://doi.org/10.1080/00207543.2020.1793011*, vol. 59, no. 6, pp. 1875–1900, 2020, doi: 10.1080/00207543.2020.1793011.

[404] R. Y. Zhong, S. T. Newman, G. Q. Huang, and S. Lan, “Big Data for supply chain management in the service and manufacturing sectors: Challenges, opportunities, and future perspectives,” *Comput Ind Eng*, vol. 101, pp. 572–591, Nov. 2016, doi: 10.1016/J.CIE.2016.07.013.

[405] “The European market potential for big data services | CBI.” https://www.cbi.eu/market-information/outsourcing-itobpo/big-data/market-potential (accessed May 10, 2023).

[406] “Final Report on Big Data and Advanced Analytics.pdf | European Banking Authority.” https://www.eba.europa.eu/file/609786/ (accessed May 09, 2023).

[407] “Big data - statistics & facts | Statista.” https://www.statista.com/topics/1464/big-data/#topicOverview (accessed Jun. 01, 2023).

[408] S. Modgil, R. K. Singh, and C. Hannibal, “Artificial intelligence for supply chain resilience: learning from Covid-19,” *International Journal of Logistics Management*, vol. 33, no. 4, pp. 1246–1268, Oct. 2022, doi: 10.1108/IJLM-02-2021-0094/FULL/XML.

[409] “Advanced Technologies for Industry-EU Report,” 2020, doi: 10.2826/239658.

[410] “Artificial Intelligence Market Size and Share | Analysis - 2030.” https://www.nextmsc.com/report/artificial-intelligence-market (accessed Jun. 01, 2023).

[411] C. G. Cegielski, L. Allison Jones-Farmer, Y. wu, and B. T. Hazen, “Adoption of cloud computing technologies in supply chains: An organizational information processing theory approach,” *The International Journal of Logistics Management*, vol. 23, no. 2, pp. 184–211, Aug. 2012, doi: 10.1108/09574091211265350/FULL/XML.

[412] “Cloud computing used by 42% of enterprises - Products Eurostat News - Eurostat.” https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20211209-2 (accessed May 10, 2023).

[413] T. Gürpinar, G. Guadiana, P. Ioannidis, and N. Straub, “The Current State of Blockchain Applications in Supply Chain Management,” in *International Conference on Blockchain Technology (ICBCT 2021)*, Shanghai, 2021.

[414] T. Gürpinar *et al.*, “Blockchain Technology in Supply Chain Management – A Discussion of Current and Future Research Topics,” in *European Alliance for Innovation - Smart City 360*, Braga, Portugal, 2022.

[415] T. Gürpinar, S. Harre, M. Henke, and Farah Saleh, " Blockchain technology – integration in supply chain processes," in *Hamburg International Conference of Logistics (HICL)*, Hamburg, 2020.

[416] M. Kouhizadeh, S. Saberi, and J. Sarkis, "Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers," *Int J Prod Econ*, vol. 231, p. 107831, Jan. 2021, doi: 10.1016/J.IJPE.2020.107831.

[417] M. Schwarzer, T. Gürpinar, and M. Henke, "To join or not to join?–A framework for the evaluation of enterprise blockchain consortia," *Frontiers in Blockchain*, vol. 5, Aug. 2022, doi: 10.3389/fbloc.2022.935346.

[418] "Blockchain technology market size worldwide 2030 | Statista." https://www.statista.com/statistics/1319369/global-blockchain-technology-market-size/ (accessed Jun. 01, 2023).

[419] "Overview of EU-funded blockchain-related projects | Shaping Europe's digital future." https://digital-strategy.ec.europa.eu/en/news/overview-eu-funded-blockchain-related-projects (accessed May 15, 2023).

[420] S. Hu, S. Huang, J. Huang, and J. Su, "Blockchain and edge computing technology enabling organic agricultural supply chain: A framework solution to trust crisis," *Comput Ind Eng*, vol. 153, p. 107079, Mar. 2021, doi: 10.1016/J.CIE.2020.107079.

[421] "From Cloud to Edge to Internet of Things for European Data | Shaping Europe's digital future." https://digital-strategy.ec.europa.eu/en/library/cloud-edge-internet-things-european-data (accessed May 10, 2023).

[422] T. Nguyen, Q. H. Duong, T. Van Nguyen, Y. Zhu, and L. Zhou, "Knowledge mapping of digital twin and physical internet in Supply Chain Management: A systematic literature review," *Int J Prod Econ*, vol. 244, p. 108381, Feb. 2022, doi: 10.1016/J.IJPE.2021.108381.

[423] "Digital Twin Market worth $73.5 billion by 2027 - Exclusive Report by MarketsandMarkets™ - Bloomberg." https://www.bloomberg.com/press-releases/2022-07-01/digital-twin-market-worth-73-5-billion-by-2027-exclusive-report-by-marketsandmarkets (accessed May 10, 2023).

[424] I. Mezgár and U. Rauschecker, "The challenge of networked enterprises for cloud computing interoperability," *Comput Ind*, vol. 65, no. 4, pp. 657–674, May 2014, doi: 10.1016/J.COMPIND.2014.01.017.

[425] Y. K. Dwivedi *et al.*, "Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy," *Int J Inf Manage*, vol. 57, p. 101994, Apr. 2021, doi: 10.1016/J.IJINFOMGT.2019.08.002.

[426] H. Cui, "Research on Agricultural Supply Chain Architecture Based on Edge Computing and Efficiency Optimization," *IEEE Access*, vol. 10, pp. 4896–4906, 2022, doi: 10.1109/ACCESS.2021.3113723.

[427] D. Horváth and R. Z. Szabó, "Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?," *Technol Forecast Soc Change*, vol. 146, pp. 119–132, Sep. 2019, doi: 10.1016/J.TECHFORE.2019.05.021.

[428] M. Giannakis, K. Spanaki, and R. Dubey, "A cloud-based supply chain management system: effects on supply chain responsiveness," *Journal of Enterprise Information Management*, vol. 32, no. 4, pp. 585–607, Jun. 2019, doi: 10.1108/JEIM-05-2018-0106/FULL/XML.

[429] M. Schwarzer, T. Gürpinar, and M. Henke, “To join or not to join?–A framework for the evaluation of enterprise blockchain consortia,” *Frontiers in Blockchain*, vol. 5, Aug. 2022, doi: 10.3389/fbloc.2022.935346.

[430] M. Asante, G. Epiphaniou, C. Maple, H. Al-Khateeb, M. Bottarelli, and K. Z. Ghafoor, “Distributed Ledger Technologies in Supply Chain Security Management: A Comprehensive Survey,” *IEEE Trans Eng Manag*, vol. 70, no. 2, pp. 713–739, Feb. 2023, doi: 10.1109/TEM.2021.3053655.

[431] A. Correia Simões, A. Lucas Soares, and A. C. Barros, “Factors influencing the intention of managers to adopt collaborative robots (cobots) in manufacturing organizations,” *Journal of Engineering and Technology Management*, vol. 57, p. 101574, Jul. 2020, doi: 10.1016/J.JENGTECMAN.2020.101574.

[432] V. Casamayor-Pujol, M. Morenza-Cinos, B. Gastón, and R. Pous, “Autonomous stock counting based on a stigmergic algorithm for multi-robot systems,” *Comput Ind*, vol. 122, p. 103259, Nov. 2020, doi: 10.1016/J.COMPIND.2020.103259.

[433] “RTD - World Robotics Report 2020 by International Federation of Robots.” https://ec.europa.eu/newsroom/rtd/items/700621/en (accessed May 10, 2023).

[434] “How Supply Chain Technology Will Evolve in the Future.” https://www.gartner.com/smarterwithgartner/gartner-predicts-the-future-of-supply-chain-technology (accessed May 10, 2023).

[435] “Robotics - Worldwide | Statista Market Forecast.” https://www.statista.com/outlook/tmo/robotics/worldwide (accessed May 15, 2023).

[436] “EU Report - Technological trends and policies | Advanced Technologies for Industry.” https://ati.ec.europa.eu/reports/eu-reports/eu-report-technological-trends-and-policies (accessed May 10, 2023).

[437] M. Ben-Daya, E. Hassini, and Z. Bahroun, “Internet of things and supply chain management: a literature review,” *https://doi.org/10.1080/00207543.2017.1402140*, vol. 57, no. 15–16, pp. 4719–4742, 2017, doi: 10.1080/00207543.2017.1402140.

[438] A. Aakash *et al.*, “Examining the Automotive Semiconductor Shortage | BCG,” 2022. https://www.bcg.com/publications/2022/tracking-next-phase-automotive-semiconductor-shortage (accessed May 16, 2023).

[439] Transforma Insights, “IoT connected devices worldwide 2019-2030 | Statista,” 2022. https://www.statista.com/statistics/1183457/iot-connected-devices-worldwide/ (accessed May 16, 2023).

[440] A. Rejeb, J. G. Keogh, S. F. Wamba, and H. Treiblmaier, “The potentials of augmented reality in supply chain management: a state-of-the-art review,” *Management Review Quarterly 2020 71:4*, vol. 71, no. 4, pp. 819–856, Oct. 2020, doi: 10.1007/S11301-020-00201-W.

[441] “REALITY VIRTUAL AND ITS POTENTIAL FOR EUROPE - European Commission.” https://www.readkong.com/page/reality-virtual-8465176 (accessed May 10, 2023).

[442] “AR & VR - Worldwide | Statista Market Forecast.” https://www.statista.com/outlook/amo/ar-vr/worldwide (accessed May 15, 2023).

[443] M. E. Arbabian and M. R. Wagner, “The impact of 3D printing on manufacturer–retailer supply chains,” *Eur J Oper Res*, vol. 285, no. 2, pp. 538–552, Sep. 2020, doi: 10.1016/J.EJOR.2020.01.063.

[444] A. Beltagui, S. Gold, N. Kunz, and G. Reiner, “Special Issue: Rethinking operations and supply chain management in light of the 3D printing revolution,” *Int J Prod Econ*, vol. 255, p. 108677, Jan. 2023, doi: 10.1016/J.IJPE.2022.108677.

[445] “3D Printing Market Size, Growth | Global Research Report [2029].” https://www.fortunebusinessinsights.com/industry-reports/3d-printing-market-101902 (accessed May 10, 2023).

[446] T. Bányai, “Impact of the Integration of First-Mile and Last-Mile Drone-Based Operations from Trucks on Energy Efficiency and the Environment,” *Drones*, vol. 6, no. 9, Sep. 2022, doi: 10.3390/DRONES6090249.

[447] A. Rejeb, K. Rejeb, S. J. Simske, and H. Treiblmaier, “Drones for supply chain management and logistics: a review and research agenda,” *https://doi.org/10.1080/13675567.2021.1981273*, 2021, doi: 10.1080/13675567.2021.1981273.

[448] “EUROPEAN COMMISSION DIRECTORATE-GENERAL FOR MOBILITY AND TRANSPORT Report of the Drone Leaders’ Group in support of the preparation of ‘A Drone Strategy 2.0 for a Smart and Sustainable Unmanned Aircraft Eco-System in Europe’”.

[449] D. Li and X. Wang, “Dynamic supply chain decisions based on networked sensor data: an application in the chilled food retail chain,” *https://doi.org/10.1080/00207543.2015.1047976*, vol. 55, no. 17, pp. 5127–5141, Sep. 2015, doi: 10.1080/00207543.2015.1047976.

[450] L. Wu, X. Yue, A. Jin, and D. C. Yen, “Smart supply chain management: A review and implications for future research,” *International Journal of Logistics Management*, vol. 27, no. 2, pp. 395–417, Aug. 2016, doi: 10.1108/IJLM-02-2014-0035/FULL/PDF.

[451] “Sensors are rapidly changing the way of farming in Europe. Product watch : sensors for farm management of livestock value chain | CDE Almería - Centro de Documentación Europea - Universidad de Almería.” https://www.cde.ual.es/ficha/sensors-are-rapidly-changing-the-way-of-farming-in-europe-product-watch-sensors-for-farm-management-of-livestock-value-chain/ (accessed May 10, 2023).

[452] N. E. Bezai, B. Medjdoub, A. Al-Habaibeh, M. L. Chalal, and F. Fadli, “Future cities and autonomous vehicles: analysis of the barriers to full adoption,” *Energy and Built Environment*, vol. 2, no. 1, pp. 65–81, Jan. 2021, doi: 10.1016/J.ENBENV.2020.05.002.

[453] A. Alam, J. Mårtensson, and K. H. Johansson, “Experimental evaluation of decentralized cooperative cruise control for heavy-duty vehicle platooning,” *Control Eng Pract*, vol. 38, pp. 11–25, May 2015, doi: 10.1016/J.CONENGPRAC.2014.12.009.

[454] “Advanced Technologies for Industry-Sectoral Watch Technological trends of the automotive industry-European Commission EUROPEAN COMMISSION,” 2020, doi: 10.2826/4434.

[455] “Europe Automated Guided Vehicle Market Size & Share Analysis - Industry Research Report - Growth Trends.” https://www.mordorintelligence.com/industry-reports/europe-automated-guided-vehicles-market (accessed May 15, 2023).

[456] “Autonomous Vehicle Market Worth $2,161.79 Billion by 2030.” https://www.alliedmarketresearch.com/press-release/autonomous-vehicle-market.html (accessed May 15, 2023).

[457] M. N. Shafique, M. M. Khurshid, H. Rahman, A. Khanna, D. Gupta, and J. J. P. C. Rodrigues, “The Role of Wearable Technologies in Supply Chain Collaboration: A Case of Pharmaceutical Industry,” *IEEE Access*, vol. 7, pp. 49014–49026, 2019, doi: 10.1109/ACCESS.2019.2909400.

[458] "IEEE Xplore Full-Text PDF:" https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8681451&tag=1 (accessed May 10, 2023).

[459] T. De Vass, H. Shee, and S. J. Miah, "IoT in Supply Chain Management: Opportunities and Challenges for Businesses in Early Industry 4.0 Context," *Operations and Supply Chain Management: An International Journal*, vol. 14, no. 2, pp. 148–161, Jan. 2021, doi: 10.31387/OSCM0450293.

[460] C. Gkartzonikas and K. Gkritza, "What have we learned? A review of stated preference and choice studies on autonomous vehicles," *Transp Res Part C Emerg Technol*, vol. 98, pp. 323–337, Jan. 2019, doi: 10.1016/J.TRC.2018.12.003.

[461] L. Viale and D. Zouari, "Impact of digitalization on procurement: the case of robotic process automation," *https://doi.org/10.1080/16258312.2020.1776089*, vol. 21, no. 3, pp. 185–195, Jul. 2020, doi: 10.1080/16258312.2020.1776089.

[462] Y. Liu, X. Ma, L. Shu, G. P. Hancke, and A. M. Abu-Mahfouz, "From Industry 4.0 to Agriculture 4.0: Current Status, Enabling Technologies, and Research Challenges," *IEEE Trans Industr Inform*, vol. 17, no. 6, pp. 4322–4334, Jun. 2021, doi: 10.1109/TII.2020.3003910.

[463] M. S. Tareq, T. Rahman, M. Hossain, and P. Dorrington, "Additive manufacturing and the COVID-19 challenges: An in-depth study," *J Manuf Syst*, vol. 60, pp. 787–798, Jul. 2021, doi: 10.1016/J.JMSY.2020.12.021.

[464] X. Xu and T. M. Choi, "Supply chain operations with online platforms under the cap-and-trade regulation: Impacts of using blockchain technology," *Transp Res E Logist Transp Rev*, vol. 155, p. 102491, Nov. 2021, doi: 10.1016/J.TRE.2021.102491.

[465] "Digital economy and society statistics - enterprises - Statistics Explained." https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Digital_economy_and_society_statistics_-_enterprises#E-business_integration (accessed May 10, 2023).

[466] A. Dolgui and D. Ivanov, "5G in digital supply chain and operations management: fostering flexibility, end-to-end connectivity and real-time visibility through internet-of-everything," *https://doi.org/10.1080/00207543.2021.2002969*, vol. 60, no. 2, pp. 442–451, 2021, doi: 10.1080/00207543.2021.2002969.

[467] X. Xu and T. M. Choi, "Supply chain operations with online platforms under the cap-and-trade regulation: Impacts of using blockchain technology," *Transp Res E Logist Transp Rev*, vol. 155, p. 102491, Nov. 2021, doi: 10.1016/J.TRE.2021.102491.

[468] "Europe launches the second phase of its 6G Research and Innovation Programme | Shaping Europe's digital future." https://digital-strategy.ec.europa.eu/en/news/europe-launches-second-phase-its-6g-research-and-innovation-programme (accessed May 10, 2023).

[469] K. F. Cheung, M. G. H. Bell, and J. Bhattacharjya, "Cybersecurity in logistics and supply chain management: An overview and future research directions," *Transp Res E Logist Transp Rev*, vol. 146, p. 102217, Feb. 2021, doi: 10.1016/J.TRE.2020.102217.

[470] C. Meath, J. Karlovšek, C. Navarrete, M. Eales, and P. Hastings, "Co-designing a multi-level platform for industry level transition to circular economy principles: A case study of the infrastructure CoLab," *J Clean Prod*, vol. 347, p. 131080, May 2022, doi: 10.1016/J.JCLEPRO.2022.131080.

[471] Y. Tolcha *et al.*, "Towards interoperability of entity-based and event-based IoT platforms: The case of NGSI and EPCIS standards," *IEEE Access*, vol. 9, pp. 49868–49880, 2021, doi: 10.1109/ACCESS.2021.3069194.

[472] G. Culot, F. Fattori, M. Podrecca, and M. Sartor, “Addressing Industry 4.0 Cybersecurity Challenges,” *IEEE Engineering Management Review*, vol. 47, no. 3, pp. 79–86, Jul. 2019, doi: 10.1109/EMR.2019.2927559.

[473] A. A. Ganin *et al.*, “Multicriteria Decision Framework for Cybersecurity Risk Assessment and Management,” *Risk Anal*, vol. 40, no. 1, pp. 183–199, Jan. 2020, doi: 10.1111/RISA.12891.

[474] L. J. R. Nunes, T. P. Causer, and D. Ciolkosz, “Biomass for energy: A review on supply chain management models,” *Renewable and Sustainable Energy Reviews*, vol. 120, p. 109658, Mar. 2020, doi: 10.1016/J.RSER.2019.109658.

[475] “New registrations of electric vehicles in Europe.” https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles (accessed May 10, 2023).

[476] S. I. Martínez-Guido, J. F. García-Trejo, C. Gutiérrez-Antonio, A. Domínguez-González, F. I. Gómez-Castro, and J. M. Ponce-Ortega, “The integration of pelletized agricultural residues into electricity grid: Perspectives from the human, environmental and economic aspects,” *J Clean Prod*, vol. 321, p. 128932, Oct. 2021, doi: 10.1016/J.JCLEPRO.2021.128932.

[477] “EUR-Lex - 52020DC0066 - EN - EUR-Lex.” https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066 (accessed May 10, 2023).

[478] “Renewable energy statistics - Statistics Explained.” https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics#Share_of_renewable_energy_more_than_doubled_between_2004_and_2021 (accessed Jun. 01, 2023).

[479] A. Kulanov, A. Issakhova, O. Koshkina, P. Issakhova, and A. Karshalova, “Venture financing and the fuel and energy complex: Investing in alternative energy,” *International Journal of Energy Economics and Policy*, vol. 10, no. 5, pp. 531–538, 2020, doi: 10.32479/IJEEP.9963.

[480] M. L. Tseng, V. Ardaniah, R. Y. Sujanto, M. Fujii, and M. K. Lim, “Multicriteria assessment of renewable energy sources under uncertainty: Barriers to adoption,” *Technol Forecast Soc Change*, vol. 171, p. 120937, Oct. 2021, doi: 10.1016/J.TECHFORE.2021.120937.

[481] “Euro area international trade in goods surplus €4,6 bn,” 2023.

[482] “Intra-EU trade in goods - main features - Statistics Explained.” https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=452727#Intra-EU_trade_in_goods_compared_with_extra-EU_trade_in_goods (accessed May 15, 2023).

[483] “International trade in goods - Statistics Explained.” https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_trade_in_goods#United_States_largest_partner_for_exports.2C_China_for_imports (accessed May 15, 2023).

[484] EY Global, “How new entrants are redefining cross-border payments | EY Finland,” 2021. https://www.ey.com/en_fi/banking-capital-markets/how-new-entrants-are-redefining-cross-border-payments (accessed May 16, 2023).

[485] “Cross-border payments by type 2022 | Statista.” https://www.statista.com/statistics/609723/value-of-cross-border-payments-by-type/ (accessed May 15, 2023).

[486] Marketing Skaleet, “Global Cross-Border Payments: Market Developments,” 2022. https://skaleet.com/en/blog/global-cross-border-payments-market-developments/ (accessed May 16, 2023).

[487] European Union, “REGULATION (EU) 2021/1230 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 July 2021 on cross-border payments in the Union ,” *Official Journal of the European Union*, 2021.

[488] Havard Business Review, “The Value of Keeping the Right Customers,” 2014. https://hbr.org/2014/10/the-value-of-keeping-the-right-customers (accessed May 15, 2023).

[489] IBM, “What is customer rentention? | IBM,” 2021. https://www.ibm.com/topics/customer-retention (accessed May 15, 2023).

[490] F. Reichheld, “Prescription for cutting costs,” 2001.

[491] Statista, “Customer satisfaction: retention rates by industry worldwide 2018 | Statista,” 2018. https://www.statista.com/statistics/1041645/customer-retention-rates-by-industry-worldwide/ (accessed May 15, 2023).

[492] Apps run the world, “Global CRM software market 2015-2025 | Statista,” 2021. https://www.statista.com/statistics/605933/worldwide-customer-relationship-management-market-forecast/ (accessed May 15, 2023).

[493] P. C. Patel, C. Baldauf, S. Karlsson, and P. Oghazi, “The impact of free returns on online purchase behavior: Evidence from an intervention at an online retailer,” *Journal of Operations Management*, vol. 67, no. 4, pp. 511–555, Jun. 2021, doi: 10.1002/JOOM.1135.

[494] “Global shoppers more likely to purchase online 2022 | Statista.” https://www.statista.com/statistics/1343029/share-online-shoppers-likely-purchase-delivery-options/ (accessed May 09, 2023).

[495] U.S. Food & Drug Administration, “UPDATE: Certain Philips Respironics Ventilators, BiPAP Machines, and CPAP Machines Recalled Due to Potential Health Risks: FDA Safety Communication | FDA,” 2023. https://www.fda.gov/medical-devices/safety-communications/update-certain-philips-respironics-ventilators-bipap-machines-and-cpap-machines-recalled-due (accessed May 23, 2023).

[496] European Commission, “Daily News 29 / 11 / 2022,” 2022. https://ec.europa.eu/commission/presscorner/detail/en/MEX_22_7275 (accessed May 23, 2023).

[497] K. Blind, S. S. Petersen, and C. A. F. Riillo, “The impact of standards and regulation on innovation in uncertain markets,” *Res Policy*, vol. 46, no. 1, pp. 249–264, Feb. 2017, doi: 10.1016/J.RESPOL.2016.11.003.

[498] “SAFER PRODUCTS FOR ALL 2022 RESULTS DG Justice and Consumers”, doi: 10.2838/174316.

[499] “THE THREE MOST COMMON PRODUCT CATEGORIES NOTIFIED THE THREE MOST COMMON RISKS NOTIFIED”, Accessed: May 15, 2023. [Online]. Available: www.youtube.com/user/EUJustice

[500] “BAuA - Tödliche Arbeitsunfälle - Bundesanstalt für Arbeitsschutz und Arbeitsmedizin.” https://www.baua.de/DE/Themen/Arbeitswelt-und-Arbeitsschutz-im-Wandel/Arbeitsweltberichterstattung/Toedliche-Arbeitsunfaelle/Toedliche-Arbeitsunfaelle_node.html (accessed May 15, 2023).

[501] “Produktsicherheit | IHK München.” https://www.ihk-muenchen.de/de/Service/Produktsicherheit/Allgemeine-Produktsicherheit/ (accessed May 15, 2023).

[502] L. Qian and W. Yanna, “Prospect and Challenges of Cross-border Payment Posed by Digital Currency-From the Perspective of Blockchain Coalition”, doi: 10.1051/e3sconf/202021804001.

[503] “The Risks to Society of Central Bank Digital Currencies.” https://www.finextra.com/blogposting/21584/the-risks-to-society-of-central-bank-digital-currencies (accessed May 15, 2023).

[504] J. Wu, N. Jiang, Z. Wu, and H. Jiang, “Early warning of risks in cross-border mobile payments,” *Procedia Comput Sci*, vol. 183, pp. 724–732, Jan. 2021, doi: 10.1016/J.PROCS.2021.02.121.

[505] European Commission - Press release, “European Commission-Press release Consumer protection: Commission revises EU rules on product safety and consumer credit,” 2021.

[506] “amplus | Deutsche Bundesbank.” https://www.bundesbank.de/en/tasks/payment-systems/publications/amplus/amplus-859690 (accessed May 15, 2023).

[507] U. Bindseil and G. Pantelopoulos, “Working Paper Series Towards the holy grail of cross-border payments”, doi: 10.2866/333725.

[508] Cpmi, “Exploring multilateral platforms for cross-border payments,” 2023, Accessed: May 15, 2023. [Online]. Available: www.bis.org

[509] “Committee on Payments and Market Infrastructures Improving access to payment systems for cross-border payments: best practices for self-assessments,” 2022, Accessed: May 15, 2023. [Online]. Available: www.bis.org

[510] G. Khusainova, “There Is No Such Thing As A Free Return,” 2019. https://www.forbes.com/sites/gulnazkhusainova/2019/03/28/there-is-no-such-thing-as-a-free-return/?sh=4b0c13a47135 (accessed May 23, 2023).

[511] “10 Key Marketing Trends for 2017 and Ideas for Exceeding Customer Expectations,” *IBM Marketing Cloud* , 2017.

[512] M. Szczepański, “BRIEFING EPRS | European Parliamentary Research Service”.

[513] Eprs, “Recent cyber-attacks and the EU’s cybersecurity strategy for the digital decade,” 2021, Accessed: May 15, 2023. [Online]. Available: http://www.europarl.europa.eu/thinktank

[514] “Global Digital Trust Insights Survey 2021.”

[515] IDC, “Daten - Volumen der weltweit generierten Daten 2025 | Statista,” 2021. https://de.statista.com/statistik/daten/studie/267974/umfrage/prognose-zum-weltweit-generierten-datenvolumen/ (accessed May 16, 2023).

[516] K. Kwon, S. Jun, Y. J. Lee, S. Choi, and C. Lee, “Logistics Technology Forecasting Framework Using Patent Analysis for Technology Roadmap,” *Sustainability 2022, Vol. 14, Page 5430*, vol. 14, no. 9, p. 5430, Apr. 2022, doi: 10.3390/SU14095430.

[517] M. Grimaldi, M. Greco, and L. Cricelli, “A framework of intellectual property protection strategies and open innovation,” *J Bus Res*, vol. 123, pp. 156–164, Feb. 2021, doi: 10.1016/J.JBUSRES.2020.09.043.

[518] “Number of patent applications worldwide 2021 | Statista.” https://www.statista.com/statistics/257610/number-of-patent-applications-worldwide/ (accessed May 15, 2023).

[519] Statista, “Künstliche Intelligenz | Statista,” 2022. https://de.statista.com/statistik/studie/id/116984/dokument/kuenstliche-intelligenz/ (accessed May 16, 2023).

[520] “Global last mile delivery market size 2020-2027 | Statista.” https://www.statista.com/statistics/1286612/last-mile-delivery-market-size-worldwide/ (accessed May 15, 2023).

[521] “Last mile delivery: startup funding by region | Statista.” https://www.statista.com/statistics/1088797/last-mile-startup-investment-worldwide/ (accessed May 15, 2023).

[522] J. Asswad and J. M. Gómez, “Data Ownership: A Survey,” *Information 2021, Vol. 12, Page 465*, vol. 12, no. 11, p. 465, Nov. 2021, doi: 10.3390/INFO12110465.

[523] D.-I. Günther Schuh Dr-Ing Volker Stich Max-Ferdinand Stroh *et al.*, “BMWK_KI_2022,” 2022, Accessed: May 16, 2023. [Online]. Available: www.bmwk.de

[524] Cisco, “Privacy’s Growing Importance and Impact C I S CO 2 0 2 3 DA TA P R I VA CY B E N C H M A R K ST U DY,” 2023. [Online]. Available: https://www.cisco.

[525] N. J. Ogbuke, Y. Y. Yusuf, K. Dharma, and B. A. Mercangoz, “Big data supply chain analytics: ethical, privacy and security challenges posed to business, industries and society,” *Production Planning & Control*, vol. 33, no. 2–3, pp. 123–137, 2020, doi: 10.1080/09537287.2020.1810764.

[526] McKinsey & Company, “Data localization and new competitive opportunities,” 2022. https://www.mckinsey.com/capabilities/risk-and-resilience/our-insights/localization-of-data-privacy-regulations-creates-competitive-opportunities (accessed May 17, 2023).

[527] R. Janßen, R. Kesler, M. E. Kummer, J. Waldfogel, M. E. Kummer EFRY, and J. R. Waldfogel Frederick Kappel Chair, “GDPR and the Lost Generation of Innovative Apps,” 2022, Accessed: May 17, 2023. [Online]. Available: www.nytimes.com/2019/12/29/technology/california-privacy-law.html.

[528] K. Blind, C. Niebel, and C. Rammer, “The Impact of the EU General Data Protection Regulation on Innovation in Firms,” *SSRN Electronic Journal*, Oct. 2022, doi: 10.2139/SSRN.4257740.

[529] CMS, “GDPR Enforcement Tracker Report | Executive Summary,” 2022.

[530] Statista Research Department, “Nachhaltigkeit in Unternehmen - Statistiken rund um CSR | Statista,” 2022. https://de.statista.com/themen/7808/nachhaltigkeit-in-unternehmen/#topicOverview (accessed May 17, 2023).

[531] Edelman, “Edelman Trust Barometer 2021,” 2021. https://www.edelman.com/sites/g/files/aatuss191/files/2021-03/2021%20Edelman%20Trust%20Barometer.pdf (accessed May 17, 2023).

[532] United Nations, “THE 17 GOALS / Sustainable Development .” https://sdgs.un.org/goals (accessed May 17, 2023).

[533] “Europe Sustainable Development Report 2022.” https://eu-dashboards.sdgindex.org/map (accessed May 09, 2023).

[534] “Global Gender Gap Report 2022 | World Economic Forum,” 2022. https://www.weforum.org/reports/global-gender-gap-report-2022/digest/ (accessed May 15, 2023).

[535] McKinsey, “Ten facts about gender equality | McKinsey,” 2020. https://www.mckinsey.com/featured-insights/diversity-and-inclusion/ten-things-to-know-about-gender-equality (accessed May 15, 2023).

[536] D. Born and C. Krys, “Trend Compendium 2050 Six megatrends that willshape the world,” 2020. Accessed: May 17, 2023. [Online]. Available: https://www.rolandberger.com/de/Insights/Global-Topics/Trend-Compendium/

[537] Statistisches Bundesamt, “Frauen in Führungspositionen in der EU - Statistisches Bundesamt,” 2022. https://www.destatis.de/Europa/DE/Thema/Bevoelkerung-Arbeit-Soziales/Arbeitsmarkt/Qualitaet-der-Arbeit/_dimension-1/08_frauen-fuehrungspositionen.html (accessed May 15, 2023).

[538] S. Hippold, “Supply Chain Diversity: 3 Learnings From the Gartner/ASCM DEI Survey,” 2022. https://www.gartner.com/smarterwithgartner/3-learnings-for-more-supply-chain-diversity-equity-inclusion (accessed May 15, 2023).

[539] F. – European Union Agency for Fundamental Rights, “EU-MIDIS II Second European Union Minorities and Discrimination Survey Main results,” 2017, doi: 10.2811/902610.

[540] European Commission, “OECD Guidelines for Multinational Enterprises,” *OECD Guidelines for Multinational Enterprises, 2011 Edition*, Sep. 2022, doi: 10.1787/9789264115415-EN.

[541] European Commission, “2030 Climate Target Plan,” 2021. https://climate.ec.europa.eu/eu-action/european-green-deal/2030-climate-target-plan_en (accessed May 17, 2023).

[542] European Commission, “EU-Emissionshandelssystem (EU-EHS).” https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_de (accessed May 17, 2023).

[543] News Euorpean Parliament, “Reducing carbon emissions: EU targets and policies | News | European Parliament,” 2023. https://www.europarl.europa.eu/news/en/headlines/society/20180305STO99003/reducing-carbon-emissions-eu-targets-and-policies (accessed May 17, 2023).

[544] “EU economy greenhouse gas emissions in Q3 2022 - Products Eurostat News - Eurostat.” https://ec.europa.eu/eurostat/web/products-eurostat-news/w/DDN-20230215-1 (accessed May 09, 2023).

[545] EUR-Lex, “EUR-Lex - mi0029 - EN - EUR-Lex,” 2022. https://eur-lex.europa.eu/DE/legal-content/summary/emissions-from-heavy-duty-vehicles-euro-vi-certification-rules.html (accessed May 17, 2023).

[546] OECD, “Towards a more resource-efficient and circular economy The role of the G20,” 2021.

[547] European Commission, “Waste and recycling.” https://environment.ec.europa.eu/topics/waste-and-recycling_en (accessed May 17, 2023).

[548] European Commission, “Circular economy action plan.” https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en (accessed May 17, 2023).

[549] News European Parliament, “Long-awaited common charger for mobile devices will be a reality in 2024,” 2022. https://www.europarl.europa.eu/news/en/press-room/20220930IPR41928/long-awaited-common-charger-for-mobile-devices-will-be-a-reality-in-2024 (accessed May 17, 2023).

[550] “Circular material use rate in Europe (8th EAP).” https://www.eea.europa.eu/ims/circular-material-use-rate-in-europe (accessed May 09, 2023).

[551] Y. Wu, K. Zhang, and J. Xie, “Bad Greenwashing, Good Greenwashing: Corporate Social Responsibility and Information Transparency,” *https://doi.org/10.1287/mnsc.2019.3340*, vol. 66, no. 7, pp. 3095–3112, Jan. 2020, doi: 10.1287/MNSC.2019.3340.

[552] S. Kim, G. Lee, and H. G. Kang, “Risk management and corporate social responsibility,” *Strategic Management Journal*, vol. 42, no. 1, pp. 202–230, Jan. 2021, doi: 10.1002/SMJ.3224.

[553] I. unicef OECD, “Ending child labour, forced labour and human trafficking in global supply chains EXECUTIVE SUMMARY,” 2019.

[554] European Commission, “2030 zero-emissions target for new buses and trucks,” 2023. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_762 (accessed May 17, 2023).

[555] TVP World, “Netherlands to buy up and close down 3,000 farms to comply with EU rules | TVP World,” 2022. https://tvpworld.com/64801898/netherlands-to-buy-up-and-close-down-3000-farms-to-comply-with-eu-rules (accessed May 17, 2023).

[556] A. Bahraini, “The 5 Common Obstacles in Implementing Circular Economy - Waste4Change,” 2021. https://waste4change.com/blog/the-5-common-obstacles-in-implementing-circular-economy/ (accessed May 17, 2023).

[557] Bundesministerium für Arbeit und Soziales, “CSR - Fragen und Antworten zum Lieferkettengesetz,” 2023. https://www.csr-in-deutschland.de/DE/Wirtschaft-Menschenrechte/Gesetz-ueber-die-unternehmerischen-Sorgfaltspflichten-in-Lieferketten/FAQ/faq.html#doc977f9a9d-bfdd-4d31-9e31-efab307ceee6bodyText15 (accessed May 17, 2023).

[558] M. Tamvada, “Corporate social responsibility and accountability: a new theoretical foundation for regulating CSR,” *International Journal of Corporate Social Responsibility 2020 5:1*, vol. 5, no. 1, pp. 1–14, Apr. 2020, doi: 10.1186/S40991-019-0045-8.

[559] European environment agency, “Ecological status of surface waters in Europe,” 2021. https://www.eea.europa.eu/ims/ecological-status-of-surface-waters (accessed May 15, 2023).

[560] World economic forum, “Ensuring sustainable water management for all by 2030 | World Economic Forum,” 2022. https://www.weforum.org/impact/sustainable-water-management/ (accessed May 15, 2023).

[561] UN Environment programme, “Half the World to Face Severe Water Stress by 2030 unless Water Use is ‘Decoupled’ from Economic Growth, Says International Resource Panel,” 2016. https://www.unep.org/news-and-stories/press-release/half-world-face-severe-water-stress-2030-unless-water-use-decoupled (accessed May 15, 2023).

[562] European Environmental Agency (EEA), “Air quality in Europe 2022. Report no. 05/2022.,” 2022.

[563] Eurostat, “How polluted is the air in urban areas? - Products Eurostat News - Eurostat,” 2021. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20210603-1 (accessed May 15, 2023).

[564] European Commission, “Commission proposes rules for cleaner air and water,” 2022. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6278 (accessed May 15, 2023).

[565] “ENVIRONMENTAL OUTLOOK TO 2050: The consequences of Inaction Key Findings on Health and Environment,” 2012.

[566] European Environment Agency, “Soil,” 2023. https://www.eea.europa.eu/en/topics/in-depth/soil (accessed May 15, 2023).

[567] Met Office, “Klima: Durchschnittliche Temperaturschwankungen 1850-2021 | Statista,” 2021. https://de.statista.com/statistik/daten/studie/1073559/umfrage/durchschnittliche-temperaturschwankungen-land-meer/ (accessed May 16, 2023).

[568] W. J. Ripple *et al.*, “World Scientists’ Warning of a Climate Emergency 2021,” *Bioscience*, vol. 71, no. 9, pp. 894–898, Sep. 2021, doi: 10.1093/BIOSCI/BIAB079.

[569] European Environment Agency, “The european environment - state and outlook 2020,” 2019.

[570] N. Pestel, “MATTHEW NEIDELL Air pollution and worker productivity,” 2023, doi: 10.15185/izawol.363.v2.

[571] World Economic Forum, “Air pollution hits worker productivity and decision-making | World Economic Forum,” 2022. https://www.weforum.org/agenda/2022/07/damage-from-air-pollutants-you-won-t-hear-about-from-your-doctor/ (accessed May 17, 2023).

[572] C. M. Godde, D. Mason-D’Croz, D. E. Mayberry, P. K. Thornton, and M. Herrero, “Impacts of climate change on the livestock food supply chain; a review of the evidence,” *Glob Food Sec*, vol. 28, p. 100488, Mar. 2021, doi: 10.1016/J.GFS.2020.100488.

[573] A. Ghadge, H. Wurtmann, and S. Seuring, “Managing climate change risks in global supply chains: a review and research agenda,” *https://doi.org/10.1080/00207543.2019.1629670*, vol. 58, no. 1, pp. 44–64, Jan. 2019, doi: 10.1080/00207543.2019.1629670.

[574] N. M. C. Pankratz and C. Schiller, “Climate Change and Adaptation in Global Supply-Chain Networks,” *SSRN Electronic Journal*, Jun. 2021, doi: 10.2139/SSRN.3475416.

[575] Yale Environment, “How Climate Change Is Disrupting the Global Supply Chain - Yale E360,” 2022. https://e360.yale.edu/features/how-climate-change-is-disrupting-the-global-supply-chain (accessed May 17, 2023).

[576] European Environment Agency, “Water,” 2023. https://www.eea.europa.eu/en/topics/in-depth/water (accessed May 16, 2023).

[577] “Global fresh water demand will outstrip supply by 40% by 2030, say experts | Water | The Guardian,” 2023. https://www.theguardian.com/environment/2023/mar/17/global-fresh-water-demand-outstrip-supply-by-2030 (accessed May 16, 2023).

[578] A. Boretti and L. Rosa, “Reassessing the projections of the World Water Development Report,” *npj Clean Water 2019 2:1*, vol. 2, no. 1, pp. 1–6, Jul. 2019, doi: 10.1038/s41545-019-0039-9.

[579] “EUR-Lex - 52019DC0014 - EN - EUR-Lex,” 2019. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0014 (accessed May 16, 2023).

[580] Y. Tan, F. Hai, J. Popp, and J. Oláh, “Minimizing Waste in the Food Supply Chain: Role of Information System, Supply Chain Strategy, and Network Design,” *Sustainability 2022, Vol. 14, Page 11515*, vol. 14, no. 18, p. 11515, Sep. 2022, doi: 10.3390/SU141811515.

[581] U. E. M. I. und T. Bundesministerium Klimaschutz, “EU-Kunststoffstrategie,” 2023. https://www.bmk.gv.at/themen/klima_umwelt/kunststoffe/europ_kunststoffstrategie.html (accessed May 16, 2023).

[582] “Waste generation in Europe (8th EAP),” 2022. https://www.eea.europa.eu/ims/waste-generation-and-decoupling-in-europe (accessed May 16, 2023).

[583] “Recycling rates in Europe by waste stream (EU-27) — European Environment Agency.” https://www.eea.europa.eu/data-and-maps/figures/recycling-rates-in-europe-by-1 (accessed May 09, 2023).

[584] “World Energy Outlook 2020 – Analysis - IEA,” 2020. https://www.iea.org/reports/world-energy-outlook-2020 (accessed May 16, 2023).

[585] “Trends and projections in Europe reports — European Environment Agency.” https://www.eea.europa.eu/themes/climate/trends-and-projections-in-europe (accessed May 16, 2023).

[586] I. Herausgeber, “Erneuerbare Energien in Zahlen 2021,” 2021, Accessed: May 16, 2023. [Online]. Available: www.bmwk.de

[587] European Commission, “Energy,” 2023. https://energy.ec.europa.eu/index_de (accessed May 16, 2023).

[588] “Energy Technology Perspectives 2020 – Analysis - IEA,” 2020. https://www.iea.org/reports/energy-technology-perspectives-2020 (accessed May 16, 2023).

[589] “Global energy consumption by region 2050 | Statista.” https://www.statista.com/statistics/268297/world-energy-consumption-outlook/ (accessed May 09, 2023).

[590] B. Vakil and T. Linton, “Why We’re in the Midst of a Global Semiconductor Shortage,” 2021. https://hbr.org/2021/02/why-were-in-the-midst-of-a-global-semiconductor-shortage (accessed May 17, 2023).

[591] KPMG, “Global semiconductor idustry outlook 2022,” 2022.

[592] G. Naumann, E. Schropp, and M. Gaderer, “Life Cycle Assessment of an Air-Source Heat Pump and a Condensing Gas Boiler Using an Attributional and a Consequential Approach,” *Procedia CIRP*, vol. 105, pp. 351–356, 2022, doi: 10.1016/j.procir.2022.02.058.

[593] A. Ntaradimou, “Ed’s note: Is Europe’s semiconductor supply at risk? | Smart Energy International,” 2022. https://www.smart-energy.com/features-analysis/is-europes-semiconductor-supply-at-risk/ (accessed May 23, 2023).

[594] A. Hinrichsen, “Challenges in building a Circular Supply Chain,” 2020. https://digitallead.dk/viden/digital-knowledge-panel/challenges-in-building-a-circular-supply-chain/ (accessed May 23, 2023).

[595] R. Huggins, “The Future of Europe’s Semiconductor Industry: Innovation, Clusters and Deep Tech,” 2022.

[596] S. Hao and B. Yu, “The Impact of Technology Selection on Innovation Success and Organizational Performance,” *iBusiness*, vol. 03, no. 04, pp. 366–371, 2011, doi: 10.4236/IB.2011.34049.

[597] Ö. Özkanlisoy and E. Akkartal, “Risk Assessment in Digital Supply Chains,” 2020. https://www.researchgate.net/publication/343350364_Risk_Assessment_in_Digital_Supply_Chains (accessed May 26, 2023).

[598] K. T. Rim, “Effects of rare earth elements on the environment and human health: A literature review,” *Toxicol Environ Health Sci*, vol. 8, no. 3, pp. 189–200, Sep. 2016, doi: 10.1007/S13530-016-0276-Y/METRICS.

[599] V. Balaram, “Rare earth elements: A review of applications, occurrence, exploration, analysis, recycling, and environmental impact,” *Geoscience Frontiers*, vol. 10, no. 4, pp. 1285–1303, Jul. 2019, doi: 10.1016/J.GSF.2018.12.005.

[600] V. Nemov, I. Filimonova, A. Komarova, and M. Mishenin, “Jointly organized by AMIR Technical Services LLC,” 2020, doi: 10.21467/abstracts.93.

[601] A. R. Mahmood, M. R. Abdullah, and H. S. Khalaf, “Biofuel Production and Its Impact on Global Food Security: A Review Article,” *Iraqi Journal of Industrial Research*, vol. 9, no. 1, pp. 75–83, Jun. 2022, doi: 10.53523/IJOIRVOL9I1ID149.

[602] T. Koizumi, “Biofuels and food security,” *Renewable and Sustainable Energy Reviews*, vol. 52, pp. 829–841, Aug. 2015, doi: 10.1016/J.RSER.2015.06.041.

[603] P. K. Ozili and E. Ozen, “Global Energy Crisis: Impact on the Global Economy,” *SSRN Electronic Journal*, Jan. 2023, doi: 10.2139/SSRN.4309828.