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Towards more Sustainable Global Value Chains: The Role of Blockchain and Allied Technologies

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Introduction

The advent of the globalization phenomenon, in the 20th century, included the development of complex and globally interconnected networks of value-adding activities, referred to as Global Value Chains (GVCs) by academics and practitioners. Most often, within these networks, the activities perpetrated follow a repetitive geographical pattern: that is, low value added activities are located in developing countries and high value added activities in developed countries.
However, the upsurge of global sustainability issues has put these networks under scrutiny: with respect to environmental, social and economic challenges, are GVCs 'agents of chaos' or are they potential 'agents of change'? Are they, most likely, both?
To shed light on the topic, this thesis ventures in a cross-section of sustainability, power dynamics and technology. In particular, it aims to explore the dynamics of sustainability-related decisions along GVCs and the potential applicability of a specific emerging technology, blockchain, in fostering sustainability along GVCs. The ensuing analysis culminates in the determination that, while this emerging technology certainly holds potential as a 'sus-tech' - i.e., a technology suited to drive sustainable development - with widespread applicability, on the other hand, it must be acknowledged that its role is necessarily that of a *supporting* tool. Thus, I observe that blockchain cannot be expected to be a panacea for global sustainability issues and, in the quest for sustainable development, it needs to be paired with other tools, technologies, policies and, most of all, good will and cooperation, to be truly impactful. Hence, this dissertation can be of interest for academics, policy-makers and business actors seeking to understand the potential impacts of blockchain on the sustainability and power dynamics of their value chain.

The structure of this thesis is organized as follows: the first chapter provides an overview of the history and functioning of GVCs, as well as of the power dynamics inherently present within these networks. The second chapter follows by providing a

systematic review of the literature on the three dimensions of sustainability and upgrading within GVCs, ultimately stressing the pressing nature of sustainability issues, their interdependence and, often, their aggregation in the related publications.
The third chapter, with the help of two objective literature reviews, provides insights on which drivers and barriers have the most relevance for companies deciding to integrate sustainability in their business activities. Finally, the fourth and fifth chapter delve into the technological domain and, in particular, they explore how the adoption industry 4.0 technologies can impact GVCs, their geographies and their sustainability. More specifically, the fourth chapter discusses the impact of industry 4.0 technologies aggregately, while the fifth and last chapter focuses on one of such technological advancements, i.e. blockchain. First, it provides an overview of its historical development, functioning and the evolution of the related scholarly interest. Subsequently, it investigates how this technology can help address sustainability issues as well as what dangers it may hide. Finally, it explores the status of its adoption, the counter-arguments to its potential as catalyst for positive change and it elaborates some considerations on its potential impact on the traditional geographies of GVCs.

Chapter 1

A world of Global Value Chains

1.1 What are Global Value Chains?

The concept of Global Value Chain is an extension to the original notion of value chain. This captures - in terms of value added - all the activities perpetrated, across the various stages and the various participant of the chain, to design, produce, market, deliver and support products and services to the end user (Porter, 1985).

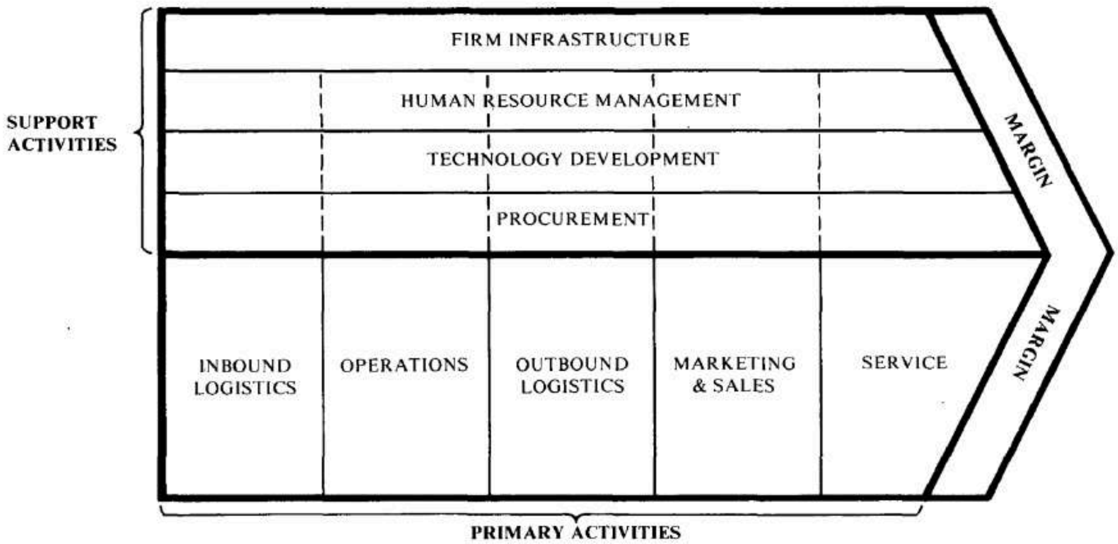

FIGURE 1.1: COMPONENTS OF A VALUE CHAIN
SOURCE: PORTER, 1985.

But such business activities are not always perpetrated in-house nor in the same geographical area. Actually, the decision on where to locate them is most often not easy and is object of careful planning by managers, as the abundance of scientific papers on the 'manufacturing location decision' testifies (McIvor, 2013).

In a *Global* Value Chain, these functions are scattered among many firms from different places all over the world and with several types of control mechanisms, ranging from arm's length transactions to equity participation (TUAC, 2004).

The famous American retailer *Nike* is a good example of how fragmented and complex a value chain can be. Their products are manufactured through a system of 930 subcontractors located across 50 countries - largely in China, Indonesia and Vietnam -, with over one million workers involved, while Nike directly employs only around 70.000 of them (Locke, 2013; Distelhorst et al., 2017).

1.2 The rise of GVCs: a new paradigm of value creation

The importance of GVCs trade itself has risen, in the latter decades, to a point where they account for half of world's trade (World Bank, 2020) and they have been defined 'the world economy's backbone and central nervous system' (Cattaneo et al., 2010).
But *how* and *why* did we get to this point? In ancient times, the supply/value chain of almost every good was local and, in many cases such as for food and textile products, even limited to the household: almost everything that the inhabitants of the household consumed, was also grown and produced there. Until the 19th century, the local farm kept its role of fundamental economic and social pillar, as between 80 and 90% of the population lived in a farm and off agricultural activities (Paulsson, 2007).
The following key aspects of such production and distribution paradigm can be identified:

- it evolved around the need to minimize transportation distances, as the available technologies (horses, 'small' boats) presented high unitary transportation costs; because of this, a limited number of long-distance supply chain actually existed, but only high-value goods were traded on such routes: for example, in Roman times, olive oil was produced in North Africa and shipped to Rome and other imperial territories and fine fabrics and spices were traded along the Silk Road;
- the 'proximity' of the supply chain enabled a smooth exchange of information and, in the many cases in which the producer and the consumer were the same person,

eliminated the problems of information asymmetries and lack of trust inherently present in transactions (Gössling, 2004);

- Storing was deemed necessary to: a) survive the winter in the farm/household and b) lower the risk of not being able to satisfy demand: having inventory was therefore looked at as a risk mitigation tool and with an asset-, rather than a cost-, perspective;
- it was, to a fair extent, 'green', or 'environmentally sustainable'.

The transition from the aforementioned local production/distribution system to today's all-pervasive *Global* value chains happened, according to Thomas Friedman, through 3 main eras: between 1492 - when Columbus set sails - and 1800, 'Globalization 1.0' was led by nation-states and powered by the blowing wind. Later on, between 1800 and 2000, the agents of change for 'Globalization 2.0' were those companies that, thanks to Watt's steam engine and to the spread of railroads, which significantly cut transportation costs, and telegraphs, which reduced telecommunications costs, managed to establish a global presence, thus becoming 'multinationals' or MNEs (Baldwin, 2013); at this stage, vertically integrated industries were the normal, with Fordist manufacturing lines and standardized mass production taking over.

Finally, 'Globalization 3.0' saw individuals as the leading actors, thanks to the power of the internet, of software tools and of social networks, which enabled people, teams, business units and even companies to get in touch and collaborate at large distances (Friedman, 2005).

In specie, in the latter 'era', two main effects can be noticed: first, the advent of the internet enabled the expansion of outsourcing and offshoring, previously most often limited to manufacturing and accounting, to IT, services and administrative activities (Low, 2013; Gereffi et al., 2010); second, for in-house functions, the rapid adoption of software tools - namely ERPs - at large scale provided enterprises the technology to make informed decisions based on real-time data analytics from all over the world and to manage increasing complexity, fragmentation and spatial dispersion of business activities and cross-functional projects in a global playfield (Dicken, 2015).

In these circumstances of arbitrage strategies pressures - mainly related to lower labour costs, followed by cost of energy, land and capital (Kinkel & Maloca, 2009) -, the decline in barriers to the free flow of goods, people and services and the possibility brought by geographical expansion of activities to access new markets (Sarin & Kumar, 2019), organizations were able to streamline their operations, reduce costs and increase efficiency, ultimately triggering the decisive shift towards an all-pervasive 'global' value chain archetype.

Lean Production and Just-in-time philosophies, introduced in the same years in Japan and quickly embraced by many manufacturers all over the world, shifted the viewpoint of holding inventory from an asset perspective to a cost perspective, causing business activities to be dependent on continuous replenishment and further reinforcing trends of rising complexity, frequency of trade and need for real-time sharing of information (Schonberger, 1982).

This pattern follows the obvious rule, observed also empirically (Jacks et al., 2011), that global trade flows and production fragmentation increase when communication, transportation and trade costs decrease (Costinot et al., 2013; Amador & Cabral, 2016). Drivers for such cost reduction can be institutional - e.g., the birth of WTO or the creation of free trade areas -, technological - e.g., ICTs -, organizational - e.g., containerization - or of other kind.

Additionally, MNEs seeked to minimize their productive capital investments and inventory through global outsourcing and thus disaggregating production processes (Froud et al., 2000; Engelen, 2008) but also disaggregating themselves legally and fiscally - in order to optimize their tax expenditure - by placing controlled entities in tax haven jurisdictions and allocating a portion of the profits there through tax-avoidance strategies such as intellectual property licensing or transfer pricing (Christensen & Murphy, 2004; Blair-Stanek, 2015).

Looking at Figure 1.2, which compares GVC networks in 1995 with 2015, we can appreciate this rising interconnectedness in world trade, as more emerging economies in Asia, Latin America and Eastern Europe have been engaging in regional value chains. In addition, it is also evident from the graph how GVCs organize around a ‘hub and spoke’ structure, with US, Germany and China - which dethroned Japan - playing a pivotal role for the respective regions.

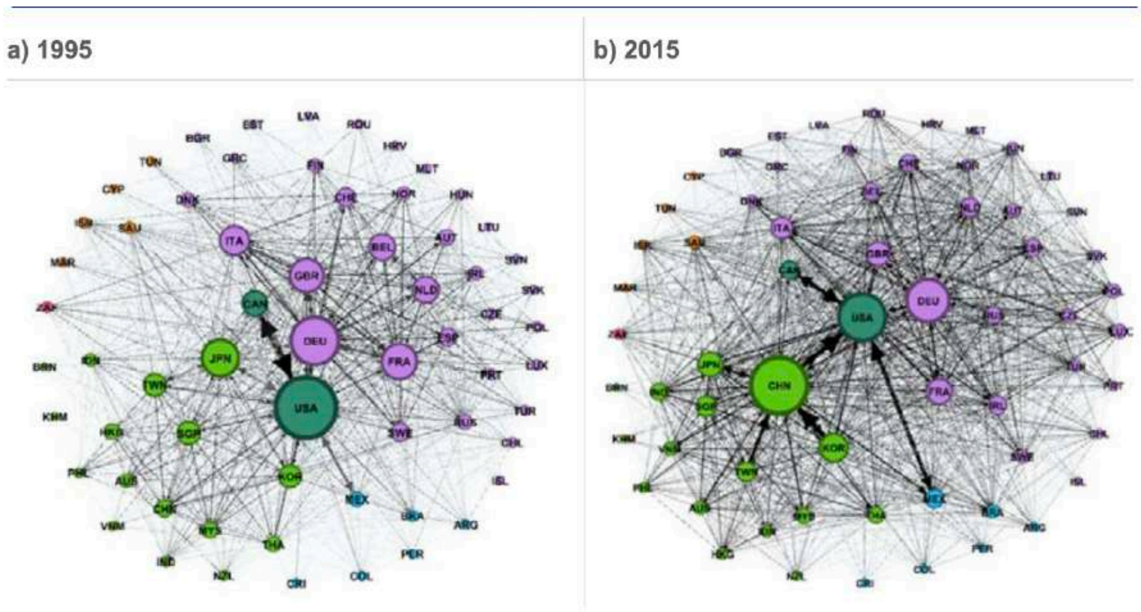

FIGURE 1.2: GVC NETWORKS - 1995 AND 2015
SOURCE: EUROPEAN CENTRAL BANK

1.3 Coming back home?

However, in the last two decades, certain events started to question the offshored production paradigm. Among all, the significant inflation in the price of raw materials, oil and other commodities, that followed the 2008 financial crisis, increased transportation costs and, as a consequence, further reduced profit margins that were already shrinking due to the reduction of consumers' spending capabilities. To add on this, many companies with global subsidiaries reported to have met difficulties in dealing with cultural clashes within their branches' heterogeneous workforce (Manning, 2014).

Finally, some macroeconomic drivers for offshoring - such as labour cost - that at first fueled globalization, changed.

For instance, as we can see in figures 1.1 and 1.2, wages in emerging economies showed a higher growth rate than their western counterparts in the period between 2006 and 2013, thus reducing a significant part of the cost advantages associated with these strategies.

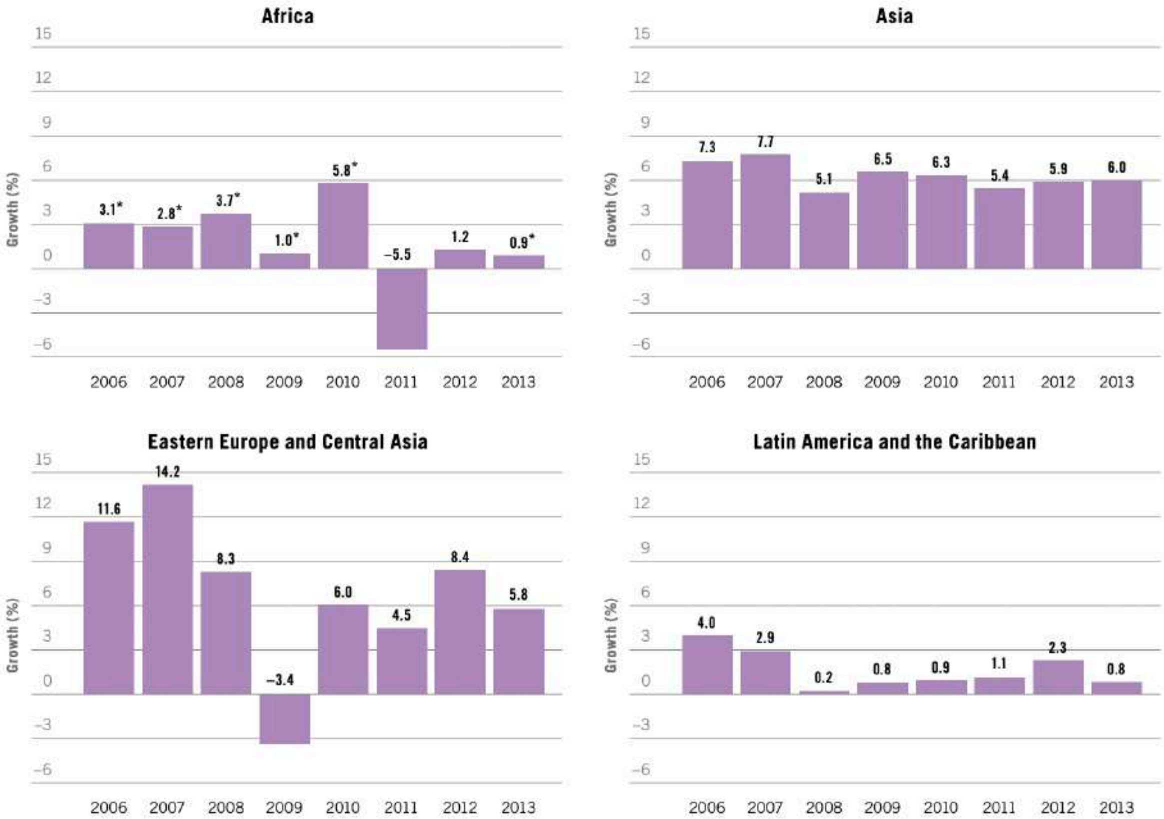

FIGURE 1.3 - ANNUAL AVERAGE REAL WAGE GROWTH IN DEVELOPED ECONOMIES, 2006-2013
SOURCE: GLOBAL WAGE REPORT 2014/15, INTERNATIONAL LABOUR ORGANIZATION.

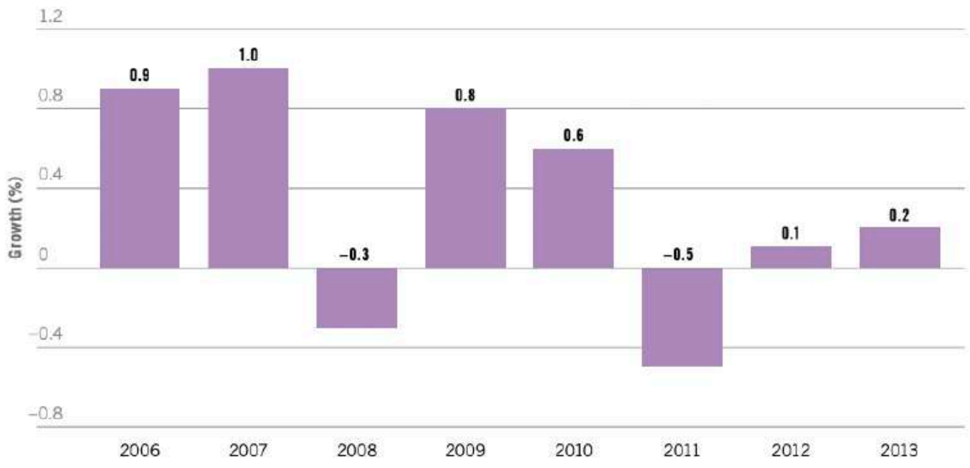

FIGURE 1.4 - ANNUAL AVERAGE WAGE GROWTH IN EMERGING AND DEVELOPING ECONOMIES BY REGION, 2006-2013

SOURCE: GLOBAL WAGE REPORT 2014/15, INTERNATIONAL LABOUR ORGANIZATION.

As a result, a number of companies have begun to 'backshore' or 'reshore' several of their global operations; that is, to move their previously offshored activities back to their countries of origin (Kinkel & Maloca, 2009). The terms encompass relocating from either offshore integrally owned facilities or offshore suppliers, to either own home facilities or home suppliers (Arlbjørn & Mikkelsen, 2014; Fratocchi et al., 2014).

A key role in the rise of this trend was also played by the made-in effect, by recent nationalism pressures (e.g. Brexit, Trump and Bolsonaro presidencies) and trade wars and by the rise of industry 4.0 technologies (Baldwin, 2016; Rehnberg & Ponte, 2017; Fratocchi & Di Stefano, 2020), which allowed companies to automate many tasks, ultimately reducing the significance of an access to cheap human labour.

Still, despite the countless resounding headlines published quite recently in several economic newspapers (The Washington Post, June 25th 2016; The Guardian, November 9th 2016; The Economist, June 28th 2019; Foreign Affairs, March 17th 2022), it is not possible to state that globalization is in 'retreat': it is indeed slowing, but as we can see in the following graph, showing the ratio of Exports to World GDP, it has not gone into reverse.

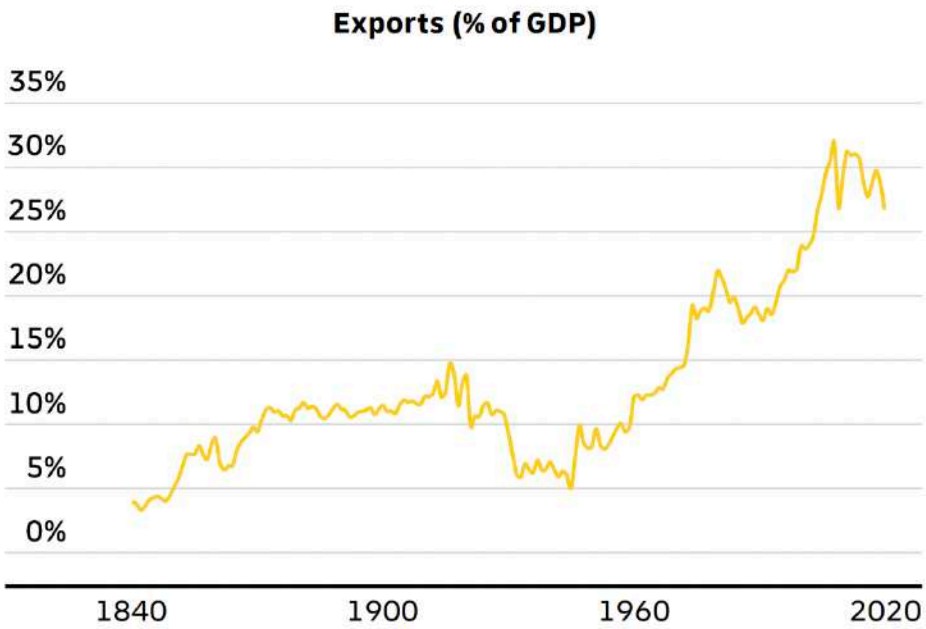

FIGURE 1.5 - WORLD EXPORTS AS % OF WORLD GDP, 1840-2020
SOURCE: DHL GLOBAL CONNECTEDNESS INDEX - 2021 UPDATE.

With this regard, globalization has become 'Slowbalization' (Morgan Stanley, 2022) in contrast to the era of 'hyperglobalization' characterizing the latter decades of the 20th century and the early 2000s (Subramanian & Kessler, 2013).

Nevertheless, GVCs' regionalization trends we witnessed in the latter years are certainly not enough to make them sufficiently more 'green' and socially sustainable: even though this phenomenon is not negligible, it hasn't brought a real shift in the geography of supply chains: as we can see in Figure 1.4, the average distance travelled by merchandise trade has been flattening in the latter years, but it hasn't decreased.

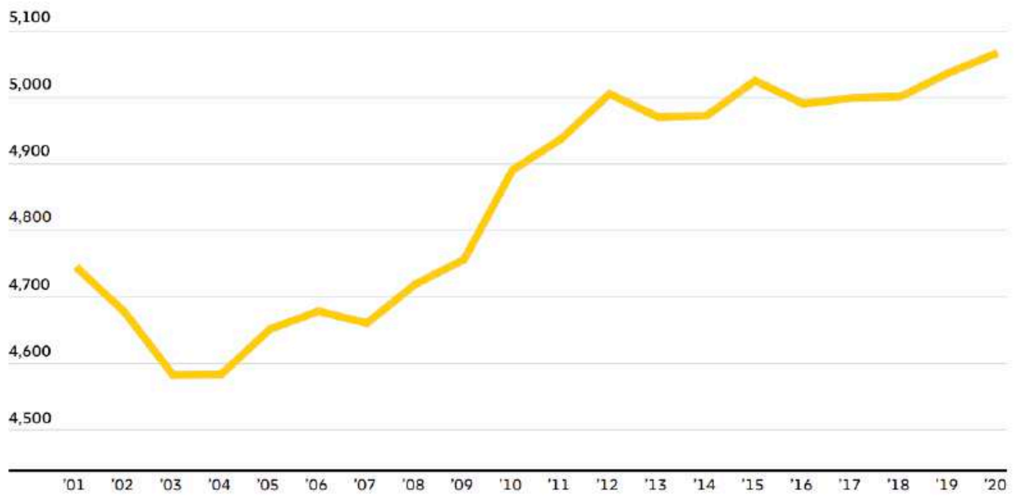

FIGURE 1.6 - AVERAGE DISTANCE TRAVERSED BY MERCHANDISE TRADE (IN KILOMETERS), 2001-2020
SOURCE: DHL GLOBAL CONNECTEDNESS INDEX - 2021 UPDATE.

The Wall Street Journal effectively sums up how the truth actually lies in the middle: 'Globalization isn't dead. But it's changing.' (WSJ, January 16th 2023). In fact, companies are not willing anymore to trade the advantage of a labour cost gap - which is shrinking, as we just saw - for disadvantages such as increase in uncertainty, increase in the risk of disruptions at a certain stage of the supply chain, increase in coordination costs (Larsen et al., 2013) and weaker environmental and social performance (Eriksson & Svensson, 2016), and are thus reconsidering the design of their supply chains (Tate et al., 2014). Other issues have also been detected: in particular, capital being tied up in inventory during the longer transportation routes (The Economist, 2013), Intellectual Property theft (Forbes, 2009; Kazmer, 2014; Tate, 2014), instability in exchange rates, risk of losing supplier/technical capabilities (Ellram et al., 2013; Becker & Zirpoli, 2011 & 2017).

Furthermore, all of these considerations were magnified by the Covid-19 pandemic: in the first months of 2020, 94% of Fortune 1000 companies were dealing with some degree of value chain disruption such as delays in supplier procurements and rising freight rates (Sherman, 2020). Since Covid-19 pandemic was the first one to hit modern GVCs in their full complexity, the propagation of the effects has been more disruptive than ever before, rapidly spreading among interconnected firms and functions (Strange, 2020; Pinna & Lodi, 2021; Moosavi et al., 2022).

Thus, the original main motive for offshoring, i.e. cheap labour to inflate the bottom line, has been mitigated, lately, by the necessity to maintain a sound competitive advantage, to mitigate risk and potential exposure to *black swans*, to increase brand reputation and, in general, to durably perform well across a wider range of dimensions, namely economic, social and environmental. Lead firms, hence, are not seeking to simply minimize costs anymore. Instead, they increase their value extraction and capital accumulation by aiming at reducing the cost/capability ratios in selecting their suppliers (Coe & Yeung, 2015).
In this context of trade-offs, the term 'right-shoring' was coined: that is, 'the placement of a business' components and processes in localities and countries that provide the best combination of cost and efficiency' (Investopedia, 2023). Countries such as India and China, for instance, have become popular destinations for companies seeking access to a plethora of low-cost, indeed, but also highly skilled workers (Manning et al., 2008; Lewin et al., 2009; Javalgi et al., 2009; Andersson & Pederson, 2010; Canham & Hamilton, 2013; Papanastassiou et al., 2020).

1.4 The governance of GVCs

Here the concept of GVC governance is introduced, which is widely acknowledged as one of the most determinant factors influencing economic, social and environmental performance and upgrading (Humphrey & Schmitz, 2002; Gereffi & Lee, 2016; Niesten et al., 2017; Golini et al., 2018; Ponte, 2020; Hochachka, 2023). Governance is defined as 'authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain' (Gereffi, 1994). GVCs are often *governed* centrally, more or less explicitly, by a set of powerful *lead firms* that have the capability to shape the GVCs which they participate in (Kaplinsky, 2005; Bair, 2009; Cattaneo et al., 2010; Ponte & Sturgeon, 2014; Coe & Yeung, 2015). They do so by selecting suppliers and sub-suppliers, setting prices, entry requirements, standards and protocols and coordinating the activities perpetrated in the chain according to their needs (Gereffi, 1994; Humphrey & Schmitz, 2001; Gibbon & Ponte, 2005), to the extent that they have been compared to *keystone species*, a term used in ecology to identify those species that have a disproportionate influence on the ecosystem they inhabit (Österblom et al., 2015). Thus, the sustainable leadership of these prominent actors and the standards and protocol requirements they set for their suppliers and distributors can make a determinant impact in improving the overall sustainability performance of their value chains.

In the GVC literature, a set of five governance typologies has been identified to more precisely describe the intrinsic complexity of their power dynamics (Gereffi et al., 2005), them, in turn, being determined by three variables: 1) the complexity of transactions, 2) the ability to codify information involved in such transactions and 3) the level of supplier capabilities. This taxonomy considers:

- *Market* governance: transactions between two participants in a market-type GVC are relatively simple, and the information involved easily codifiable. Capabilities in the supply base are technical and quite specific, thus the input from buyers for product development is generally minimal. The dominant coordination mechanism is price and switching costs are very low.

- *Modular*: here, transactions are complex but codifying information is still relatively easy. As for market GVCs, suppliers are very capable and take full responsibility for competencies concerning process technology, using generic machinery and equipment that can be used across a wide customer base, thus limiting transaction specificity of investments. Products are made according to customers' specifications, so information technology and standards are key to codifying information and making modular GVCs function smoothly.

- *Relational*: interactions in this kind of networks are complex and codifying information is not simple. This implies frequent interactions and information sharing, so suppliers and buyers develop high levels of mutual dependence and asset-specificity. In relational GVCs, reputation and social and geographical proximity are key to running smooth relationships. Furthermore, since relational kinds of linkages take time to be built, switching costs are high for both buyers and suppliers. Nevertheless, lead firms still exert a certain amount of power over suppliers, specifying what they need and having the last word on standards adopted.
- *Captive*: these show high levels of power asymmetry between one or a few buyers - the lead firm(s) - and a multitude of small suppliers. Switching costs are very low for the lead firm and very high for suppliers, as they are required to undertake high buyer-specific sunk costs and to operate under conditions and standards explicitly specified by the lead firm. In particular, buyers typically demand high efficiency from their supply base and suppliers' margins are generally low. As a consequence, ethical leadership is focal to ensure that fair treatment and a fair share of value added are granted to suppliers and their workforce. Also, the upstream parts of such value chains may end up being located in places with weak environmental and labour regulations (Soundararajan et al., 2019; World Bank, 2020), leading to higher environmental degradation and labor exploitation for the sake of efficiency. However, data on this supposition - called *Pollution Haven Hypothesis* - are ambiguous and do not fully confirm the significance of environmental regulation as a driver for production location decisions (see Levinson & Taylor, 2008).
- *Hierarchy*: this form of vertical integration occurs when lead firms set controlled subsidiaries in foreign countries. Here, the production process is entirely run in-house, for example, to manage operations smoothly in presence of complex transactions and difficulties in codifying information, together with struggles in finding competent suppliers. Information stream is always downward, with the headquarters of the firm making the strategic decisions and then translating them into instructions for the subsidiaries. Environmental and social performances of the

chain are therefore entirely dependent on the decisions taken by the organization's c-suite.

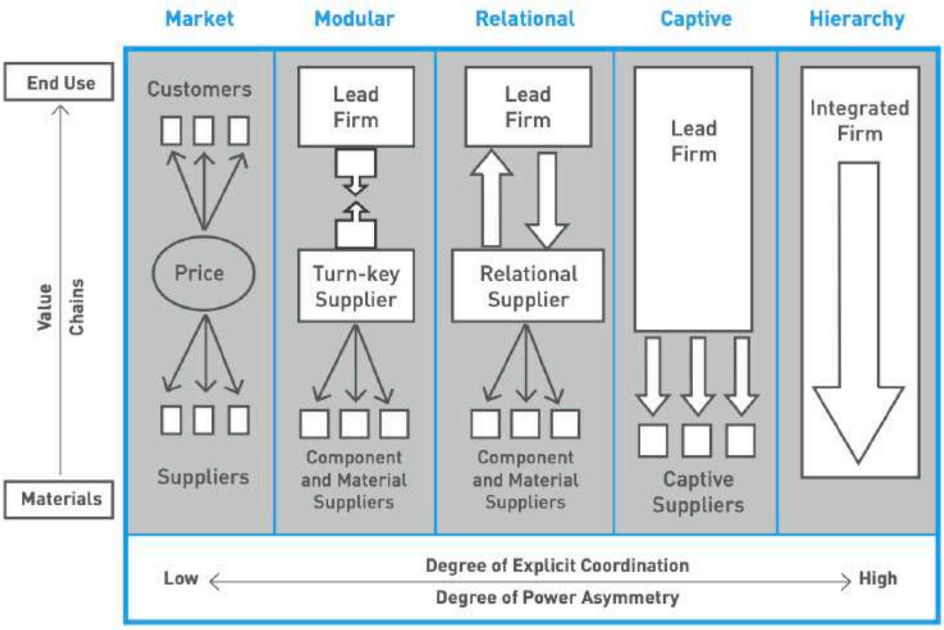

FIGURE 1.7 - FIVE TYPES OF GVC GOVERNANCE.
SOURCE: GEREFFI ET AL., 2005.

1.5 Global Sustainability challenges

The rising entropy in world trade didn't come without costs: in 1987, the United Nations' World Commission on Environment and Development (WCED) published the Brundtland Report, also known as Our Common Future: in this paper they raised red flags on climate change and emphasized the significance of making Development *Sustainable*, that is, 'meeting the needs of the present without compromising the ability of future generations to meet their own' (Brundtland, 1987). The report sought to promote multilateralism and interdependence of nations as the key for the pursuit of a sustainable development path, elements that are quintessential in the main topic of this thesis on Global Value Chains.

Although sustainability has been and is currently extensively discussed among both media and scholars, to the point where it has been regarded as a distinct branch of science (Kates et al., 2001; Schoolman et al., 2012), it still remains a vague concept (Phillis & Andriantiatsaholiniaina, 2001). The mainstream interpretations, however, follow the TBL - Triple Bottom Line concept (Elkington, 1994; Trianni et al., 2017) encompassing a blend of economic, environmental and social dimensions (also called *pillars* of sustainability).

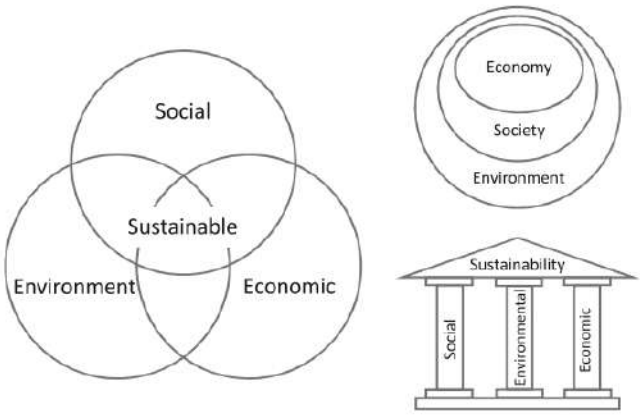

FIGURE 1.8 - THE THREE MOST USED REPRESENTATIONS OF THE DIMENSIONS OF SUSTAINABILITY
SOURCE: PURVIS ET AL., 2018.

The organization of value creation along GVCs - other than bringing the already mentioned firm-level improvements - has certainly improved certain macro-economic indicators as well; examples are: an overall increase in trade process efficiency (Gereffi & Lee, 2012), global economic growth (Iamsiraroj & Ulubaşoğlu, 2015) and increases in wages, labour productivity and capital intensity of firms participating in value chains (Choi et al., 2021).

But past economic and productivity growth has often come at the expense of the environment, to the point that scholars have introduced a new geological era to reflect the impact that human activity is having on planet Earth: the *Anthropocene* (Crutzen & Stoermer, 2000). In turn, challenges surrounding this dimension affect - by extension - social and economic welfare as well (Gaziulusoy, 2010), for example releasing negative externalities such as polluted air, thus harming society and its long-term well-being. These issues, against which GVCs can be both the origin of the problem and part of the solution, are broad in range and include several hot topics that need to be addressed by individuals, organizations and policy makers. Among these, are:

- Climate change: it's the most discussed topic and it refers to the long-term shift in temperatures and weather patterns (United Nations, 2023). Although this naturally happens, for example, due to variations in the solar cycle, in the last two centuries human activities have been the main catalyst of climate change (Jacob et al., 2014; Trenberth, 2018; Ge et al., 2021), mainly because of the intensive use of fossil fuels - like oil, gas and coal -, but also other harmful activities such as deforestation (Li et al., 2022). This pressing threat has forced the scientific community in unanimously call for an immediate reduction in carbon emissions, in order to stabilize global warming at 1.5° C above pre-industrial levels (Park et al., 2015; Hoegh-Guldberg et al., 2019; Haines & Ebi, 2019).
- Ocean acidification: this is related to the first topic, as the oceans' ability to intake of CO2 helps moderate climate change. However, the hydrolysis of CO2 in seawater, increases the hydrogen ion concentration, thus reducing ocean pH and triggering a vicious cycle that reduces its capacity to intake CO2 and that poses a serious threat to the majority of species inhabiting our waters (Orr et al., 2005);
- Soil degradation: it refers to the progressive loss of soil fertility, biodiversity and degradation, resulting in the inability of lands to be cultivated and to provide nutrients (Maximillian et al., 2019). Humans get 95% of the food they consume from soils, yet an alarming 90% of them are set to be degraded by 2050, if we don't improve our industrial and agricultural practices soon enough (FAO, 2022);
- Air pollution: it has been estimated that 99% of people are currently breathing polluted air - that is, air that exceeds the WHO guideline limits in the levels of pollutants -, which exponentially increases the risk of respiratory illnesses (WHO, 2023);
- Freshwater shortage: 1.1 billion people lack an accessible source of water and between 2.7 and 4 billion face water scarcity at least for one month of the year (Mekonnen & Hoekstra, 2016; WWF, 2023);

- Overpopulation and waste management: in the last two centuries, world population increased sevenfold and is set to grow from around 8 billion today to 10.4 billion in 2100 (Lee, 2011; United Nations, 2022). This implies a parallel increase in natural resources consumption but, since a large part of the natural resources used by mankind is exhaustible and non-renewable, this constitutes a natural barrier to economic growth (Skawińska & Zalewski, 2018). As a result, the 'take-make-dispose' model is no longer feasible, and an urgent need to make production, use, recovery and recycling more efficient, or to find alternative resources, arises.

The extent to which sustainability issues are critical today also for GVCs is well depicted by the 2020 AXA Future Risks Report, which includes 'Climate change', 'Natural Resources and Biodiversity Risks' and 'Pollution' among the top 10 global emerging risks for the next five to ten year period (AXA, 2020).
More specifically, the Business Continuity Institute identifies Climate change as the most threatening risk to business continuity in the current century (Deloitte, 2020).

To address this, the supply chain has been identified as the most critical business area to focus on, as it is the source of more than 50% of the carbon emissions of any corporation (Carbon Disclosure Project, 2011), with supply chains of particular sectors - such as agriculture and food & beverage - producing up to 90% of its participants' $CO2$ emissions. Further, Peters et al. (2011) have estimated that around one-quarter of global carbon emissions is associated with international trade.
In addition to its predominance in environmental impacts, focusing on the value chain becomes crucial also in light of its role as a pathway for shocks propagation: in the current geography of deeply interconnected and widespread value chains, a climate change-related disruption - such as a tropical storm or a drought period - may quickly propagate its effects to both upstream and downstream actors of the network (Ivanov, 2018a; Li et al., 2021).
In recent years, the concept of value chain *resilience* has thus gained rapidly growing and significant attention by scholars (Figure 1.9). In its *climate* connotation, it is

defined as the capability of a value chain, on the one hand, to minimize its environmental impact and, on the other, to cope successfully with climate-related hazardous events, including disrupted supply chains, unavailability of raw materials, disrupted transportation, and other impactful events (Norton et al., 2015).
Thus, resilience at the company level is achieved by adopting environmentally friendly practices that reduce CO_2 emissions and by building adaptive capacity, for example by investing in risk mitigation strategies or by diversifying supply chain routes.

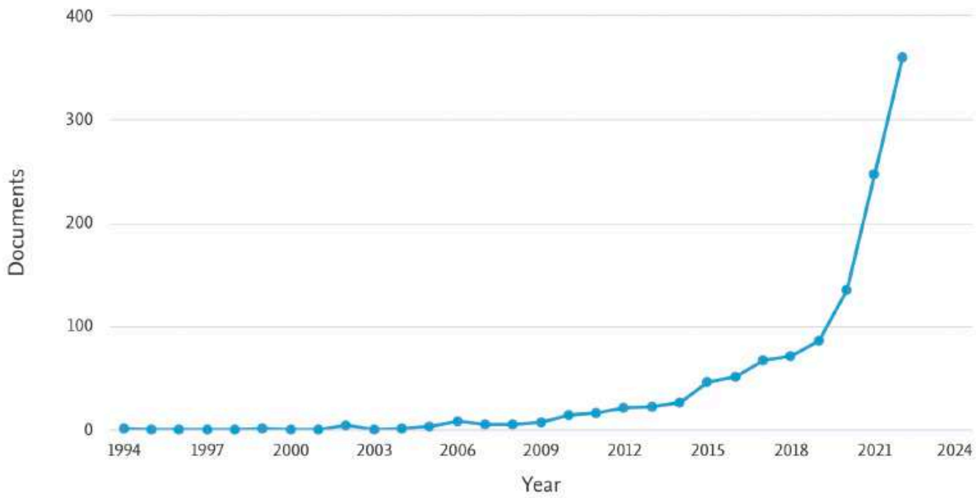

FIGURE 1.9 - PUBLICATIONS ON 'VALUE CHAIN RESILIENCE' (IN EITHER THE TITLE, ABSTRACT OR KEYWORD) IN SCOPUS DATABASE, 1994 - 2022
SOURCE: SCOPUS.COM

The concerns listed above, being deeply interconnected and interdependent between each other, need to be addressed promptly and in an integrated way, cutting the negative effects of one issue or sustainability dimension at their roots and preventing them to spread through every other (Rockström et al., 2009; Cornescu & Adam, 2014).
Several studies have further shown how the pattern of specialization along value chains has direct implications for numerous TBL issues such as: world income distribution (Lopez Gonzalez et al., 2015; de Medeiros & Trebat, 2017), environmental performances (World Bank, 2020; Huang et al., 2022; Li et al., 2022), social impacts (Choi et al., 2021) and, as I have previously highlighted, for how shocks and economic and social trends spread across countries (Gangnes et al., 2012; Gerschel et al., 2020).

In this context, four main attitudes towards CSR and Sustainability have been identified (Van Tulder & van der Zwart, 2006); ordered from the least to the most resource-demanding, they are:

1) Inactive CSR: the one embodied in Friedman's mantra 'the business of business is business': the only responsibility of firms is to generate profits, so they don't have to play particular roles in addressing environmental, social and ethical matters (Friedman, 1970).
2) Reactive CSR: companies don't take initiative, but they pay attention to not make mistakes that can deteriorate company's reputation and they adopt responsible behaviors when forced to do so by activists, civil society organizations, governments and so on.
3) Active CSR: it occurs when the firm's activities are inspired by ethical values and goals are set in accordance.
4) Proactive CSR: here, all stakeholders need to be engaged and constructive dialogues must be established among all parties, consequently setting CSR goals and milestones according to an heterogeneity of needs.

Until the latter years of the twentieth century, corporations were predominantly *reacting* to sustainability campaigns perpetrated by NGOs, activists, consumers and governments. Businesses, rather than taking initiative in tackling environmental and social issues, channeled instead their efforts towards denying accuses moved to them. Companies with a focus on sustainability as their competitive advantage were rare (e.g., Ben & Jerry's, Patagonia) and they targeted niche markets.

But today, with rising awareness about ESG matters and increasing demand for sustainable products (De Marchi et al., 2013; Whelan & Kronthal-Sacco, 2019; McKinsey, 2023), companies cannot turn a blind eye anymore. GVCs actors, hence, need to develop a wider view of value creation today, one that embraces the idea that their managers' priority should be the long-term performance and health of the company, rather than quarterly reports, and that this is related not only to the returns that it can give to its shareholders but, more broadly, on the benefits they are able to distribute to a multitude of stakeholders: customers, suppliers, employees, creditors, governments, society (Norman & MacDonald, 2004; Business Roundtable, 2019). Three drivers are essential for the implementation of such *shared value* (Kramer & Porter, 2011): 1) reconceiving products and markets, 2) redefining productivity along the value chain and 3) enabling local cluster development. I will recall these in the next chapter.

The wave of sustainability initiatives undertaken recently by many multinational corporations (Bregman, 2017) are the result of the expectations that these, together with the development of trusting relationships with key stakeholders (Andriof & Waddock, 2002; MacMillan et al., 2004), will generate additional value and enhance image and reputation (Fombrun, 2005; Hillenbrand & Money, 2007; Pfau et al., 2008; Melo & Garrido-Morgado, 2011; Martinez & del Bosque, 2014; Alon & Vidovic, 2015).
Managing successfully these two intangible assets becomes thus of particular significance in light of their influence in directing the overall performance of the organization (Miles & Covin, 2000; Dedrick & Kraemer, 2017) and of the predominance, seen in the past years, of investments in intangibles compared to tangibles (Figures 1.9 and 1.10).

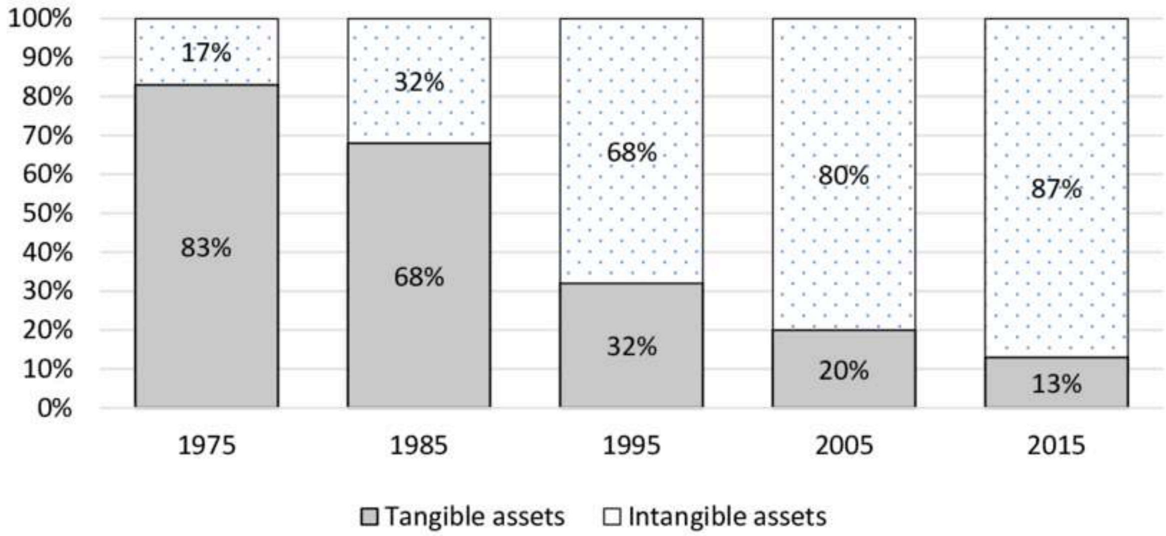

FIGURE 1.10 - COMPONENTS OF S&P 500 MARKET VALUE
SOURCE: ADAPTED FROM OCEAN TOMO (2015).

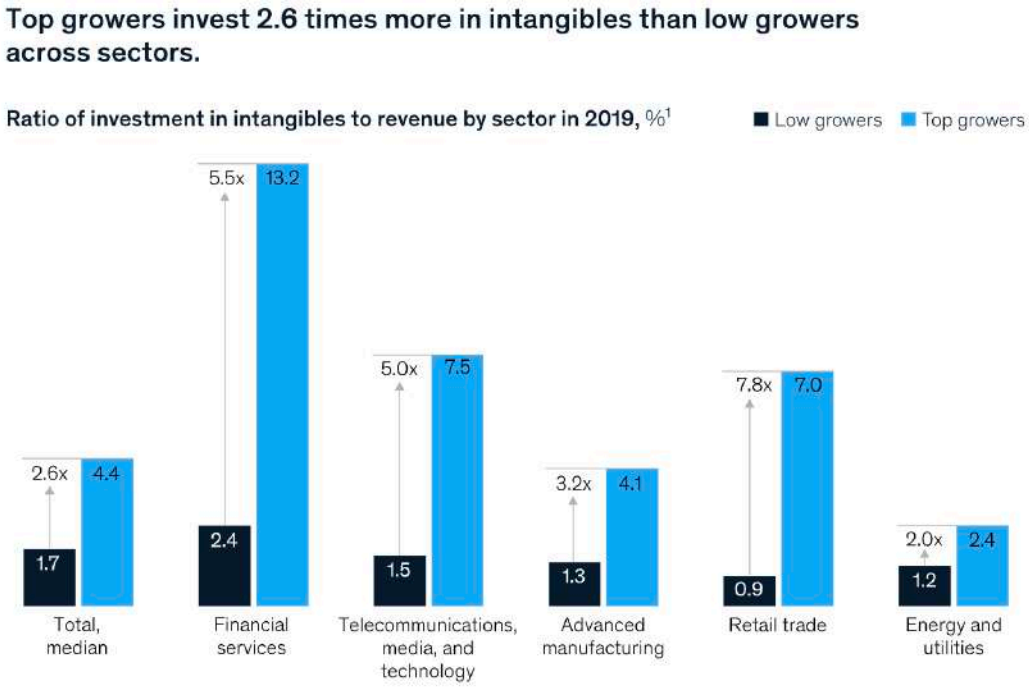

FIGURE 1.11 - INVESTMENTS IN INTANGIBLES: TOP GROWERS VS LOW GROWERS

SOURCE: MCKINSEY.COM

Firms, hence, are seeking new competitive advantages based on the 'going green' paradigm, and they do so by developing eco-friendly products, processes and practices (Orsato, 2006; Kramer & Porter, 2006) and communicating their commitments effectively to the key stakeholders (Herremans et al., 2016; Genç, 2017).

This is a focal point, since a gap between the actual behavior of an organization and the reputation it creates through sustainability communications may unlock some criticalities: in particular, if the company has a high sustainability reputation among the public but some hidden practices it undertakes don't reflect such commitment, then eventually the company may face a sudden and steep decline in reputation when such behaviors are exposed. On the opposite, if communication strategies don't fully convey the obligations the company committed to, then a part of its efforts are wasted and the company leaves a portion of value unseized.

Sustainability has thus become a mainstream pivot of business strategy decisions (Humes, 2011; Dauvergne & Lister, 2013), being in itself able to direct the economic performance of an organization, rather than just representing an effort springing from spontaneous ethical concerns of the top management.

In light of this, and since competition in the business playfield is not among single firms anymore, but rather between value chains (Christopher, 1992; Li et al., 2006; Hult et al., 2007), then lead firms need to extend their span of attention and accountability not only to their in-house functions, but they have to reach as far as to the operations of first-tier and second-tier suppliers, in order to avoid reputational risks related to possible degrading practices perpetrated by such actors (Nadvi, 2008; Wahl & Bull, 2014; Nadvi & Raj-Reichert, 2015). Ultimately then, the implementation and assessment of sustainable management practices and cooperation need to be carried out along the value chain as a whole (Miemczyk et al., 2012).

They can do so either by implementing active practices, such as direct supply selection or setting environmental requirements and standards (Jensen & Whitfield, 2022), or by adopting 'hands-off' approaches such as, for example, requiring the suppliers to obtain standard third party certifications (e.g., GRI 308, *Supplier Environmental Assessment* and GRI 414, *Supplier Social Assessment*).

The importance of sustainability as a strategic driver has been confirmed by business executives themselves: in a 2019 survey conducted over 2,600 CEOs from 128 countries, 40% of the participants declared to see sustainability as a driver for revenue growth, while 25% of them associated it with cost-reduction advantages (UN Global Compact & Accenture, 2019). In accordance with this, a 2013 survey, conducted over 1,000 CEOs across 103 countries, had shown that sustainability is a routine matter of discussion in board meetings for 84% of the CEOs interviewed (UN Global Compact & Accenture, 2013). Finally, more than 60% of respondents to a 2011 study surveying 250 executives, revealed how they look at sustainability as an essential element for expansion to emerging markets (Accenture, 2011).

1.6 The geographies of value capture across GVCs

The Global Value Chain paradigm allowed regions to specialize in particular activities of the value chain, thus allowing also less developed countries - which typically have access to reduced financial resources and capabilities bases - to increase their participation in the global economy (World Bank, 2020), without having to build a whole back-to-front value chain from scratch (Kowalski et al., 2015; Gereffi, 2019). Data for the period 2015-2019, provided by the World Trade Statistical Review (WTO, 2020), gives a fair representation of this effect (Figure 1.9): we can see that Merchandise Exports by least-developed countries showed a 4,25% CAGR increase in the 5 years between 2015 and 2019, while Commercial Services Exports rose at 5,44% CAGR in the same time frame.

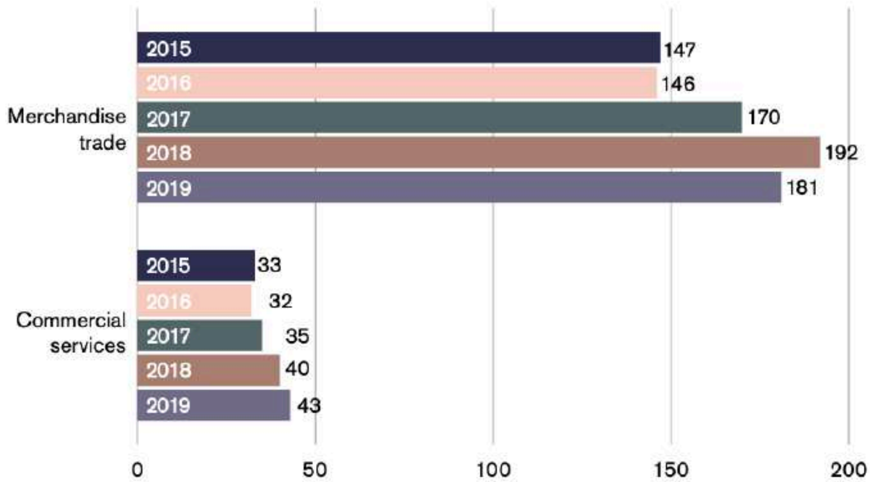

FIGURE 1.12 - WORLD EXPORTS OF LEAST-DEVELOPED COUNTRIES, 2015 - 2019 (US $ BILLIONS)
SOURCE: WORLD TRADE STATISTICAL REVIEW 2020, WTO.

Firms in developing economies and developing countries themselves can take significant advantages by participating in GVCs, as these - especially those with a relational, captive or hierarchical governance - entail durable firm-to-firm relationships (World Bank, 2020) that enhance knowledge spillovers, learning externalities and diffusion of technology (Romer, 1993; Ivarsson & Alvstam, 2010; Pietrobelli & Rabellotti, 2010; Li & Liu, 2014; Tajoli & Felice, 2018).

But, even though GVCs can theoretically have significantly positive effects both at the firm and at the country-region level, it has been shown that value created along the chain is generally not captured equally across regions and firms (Piñero et al., 2020; Stöllinger, 2021). The extent to which a firm is effectively able to reap the benefits associated with its participation largely depends on factors such as its positioning along the chain - which in turn is affected also by the countries' level of economic development and comparative advantage -, on company reputation and, more comprehensively, on its market power, measured as its ability to charge prices above its marginal cost (i.e., *markup*).

In this regard, despite markups having been rising globally since 1980 (De Locker & Eeckhout, 2018), scholars have shown that their growth has been mainly driven by developed economies and by a restricted number of large, powerful and highly profitable firms (Autor et al., 2020) rather than by a more 'fair' allocation of the value created to developing economies, where trends in markup growth are, in fact, ambiguous (Diez et al., 2021). According to some scholars, this happens because lead firms often limit the markup pricing power of suppliers by *leading* them into high mutual competition (Havice & Campling, 2017; Milberg & Winkler, 2013). By doing so, they reduce small suppliers' investment capacity and they prevent them from upgrading their positioning in the value chain, which would endanger lead firms' dominant positions.

The imbalance with which value is captured across different organizations and countries is effectively expressed graphically by the so-called *smile curve* (Figure 1.12). Despite it being an empirical construct - identified in 1996 by the former CEO of Taiwanese IT company Acer, Stan Shih - rather than a strict economic model, it has become widely accepted and tested in business strategy and in the business literature (Mudambi, 2007; Imahashi et al., 2018; Rungi & Del Prete, 2018; Meng et al., 2020; Stöllinger, 2021).

Firms that specialize in production generally show a lower profit margin and lower wages (i.e., generate less value added), while firms focusing on more knowledge- and creativity-intensive activities (upstream and downstream ends of the value chain) are able to reap a higher share of value added (Mudambi, 2007). Most often, developing economies host the first set of activities, while countries in the economic North are behind the second set (see, for example: Yoffie, 1991; Cao, 2002). It has to be noted, furthermore, that the low value-added stages of a value chain are also the most polluting ones (Zhang & Liu, 2023). As a result, the GVC participation of developing countries has a significantly larger negative impact on their embodied carbon emission intensity, compared to developed countries (Liu & Zhao, 2021). Similarly, Jin et al. (2022) found that a deeper participation in GVCs by developed regions significantly reduces their CO_2 intensity, while for developing regions the opposite is true.

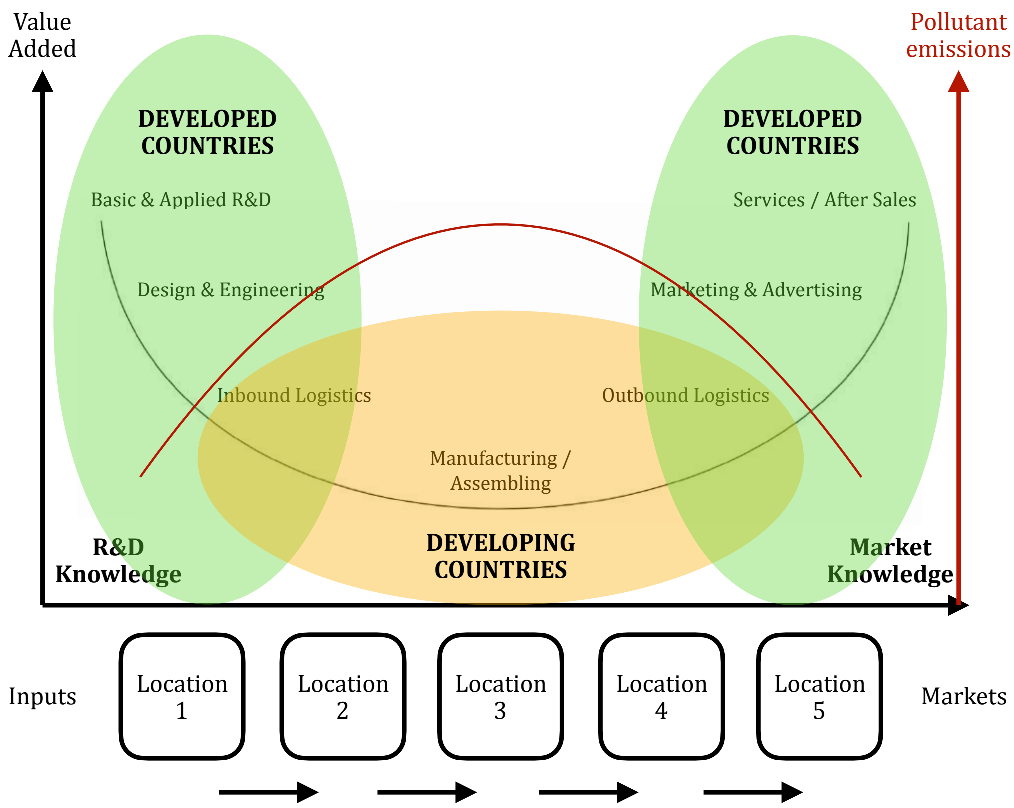

FIGURE 1.13 - STAN SHIH'S SMILE CURVE AND POLLUTING EMISSIONS

SOURCE: OWN ELABORATION BASED ON MUDAMBI, 2007 AND ZHANG & LIU, 2023.

This graphical depiction of value-added distribution has further been strengthened and popularized over time by famous case studies such as the one on Apple's iPod value chain (Dedrick et al. 2010), which reported how the lead firm and its distributors are able to reap a huge proportion of the value added generated along the chain, while small manufacturing contractors - located mostly in east Asian countries in this specific case - are left with an almost insignificant fragment.

This has important repercussions on the ability of SMEs to upgrade their environmental performances, as doing so can require business process reconfigurations and heavy CapEx that are bearable only for firms with plenty of liquidity and steady and secure profit margins.

It has to be noted though, in this regard, that the ability of a firm to capture the value created can change over time: competition, for instance, which has as its primary effect the erosion of margins, can also have a flip side: i.e., nudging firms in distress towards higher value added activities of the value chain - so-called *Economic Upgrading* - thus redesigning the distribution of value across its participants (Dolan & Humphrey, 2004; Gereffi et al., 2009; Gereffi, 2011).

Chapter 2

The dimensions of sustainability in Global Value Chains

A truly sustainable development can be achieved only if measures are taken as soon as possible (Walther et al., 2005; Jacob et al., 2012; Grodach, 2020; Guterres, 2020) and if a thorough blend of Economic, Environmental and Social improvements is taken into consideration simultaneously (Slootweg et al., 2001; Munasinghe, 2011) by firms - when planning their strategies -, by policy makers - when promulging new laws and regulation -, and by other organizations, such as NGOs (Non Governmental Organizations) - when setting up, for example, activism campaigns -.

These three centers of focus have come to be known in literature, respectively, as *Economic* (see Gibbon, 2000; Coe, 2014; Kummritz et al., 2017; Gereffi, 2019; Islam & Polonsky, 2020; Pahl & Timmer, 2020), *Environmental* (see Goger, 2013; De Marchi et al., 2013; Achabou et al., 2017; Khattak & Pinto, 2018; Khan et al., 2020; Hansen et al., 2021) and *Social* (see Lund-Thomsen et al., 2012; Selwyn, 2013; De Oliveira et al., 2014; Godfrey, 2015; Pyke & Lund-Thomsen, 2016; Marslev & Staritz, 2022) *Upgrading*. Thereby, they match the same triplet of objectives of concepts such as the Triple Bottom Line, which I already mentioned in the previous chapter, and the *triple Ps* - 'Profit, People and Planet' - (Kleindorfer et al., 2005; Carter & Rogers, 2008; Seuring & Miller, 2008; Burritt, 2012; Larivière & Smit, 2022).

In particular, Economic upgrading refers to the process by which firms, industries, or economies improve their competitiveness, productivity, and technological capabilities to move towards higher value-added activities and higher income levels. (Gereffi et al., 2005; Pietrobelli & Rabellotti, 2006).
Environmental upgrading, on the other hand, refers to the process by which economic actors move towards a production system that avoids or reduces the environmental damage from their products, processes or managerial systems or, yet, that results in positive environmental outcomes (De Marchi et al., 2013; Krishnan, 2017).
Finally, Social upgrading refers to improvements in the rights and entitlements of workers as social actors, as well as of the well-being of the communities they belong to,

and to the enhancement of the quality of their employment (Barrientos et al., 2011; Rossi, 2011).

The need to act soon along these three dimensions and to scrutinize their strict interdependency in an integrated way is effectively illustrated by the corresponding literature: the scholars' interest towards them has seen, in accordance with the need to address global issues promptly, very fast-paced growth (Figure 2.1) and, in accordance with the need to address them in an integrated way, very similar evolution trajectories (Figure 2.2), with Economic Upgrading (948 publications in 2022) getting the largest share of attention, followed by Environmental Upgrading (696 publications) and Social Upgrading (464 publications).

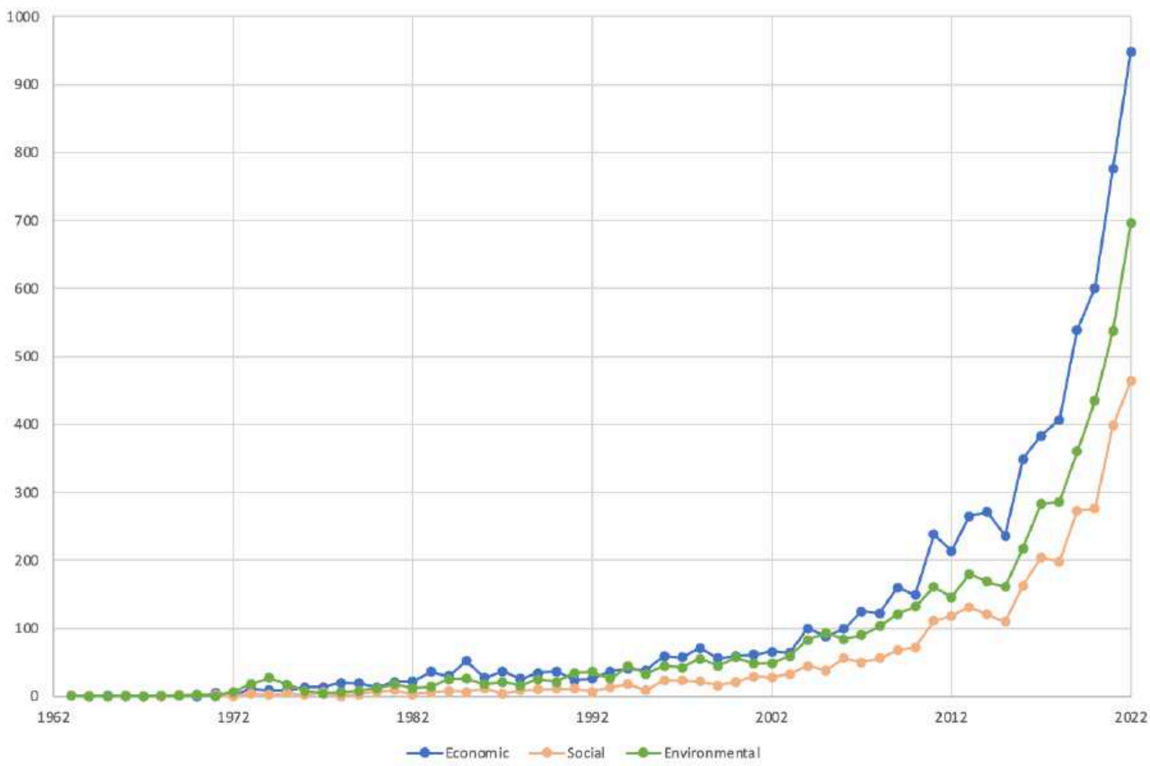

FIGURE 2.1 - PUBLICATIONS ON EACH OF THE THREE DIMENSIONS OF UPGRADING (IN EITHER THE TITLE, ABSTRACT OR KEYWORDS); PERIOD 1962-2022
SOURCE: OWN ELABORATION OF SCOPUS.COM DATABASE QUERY

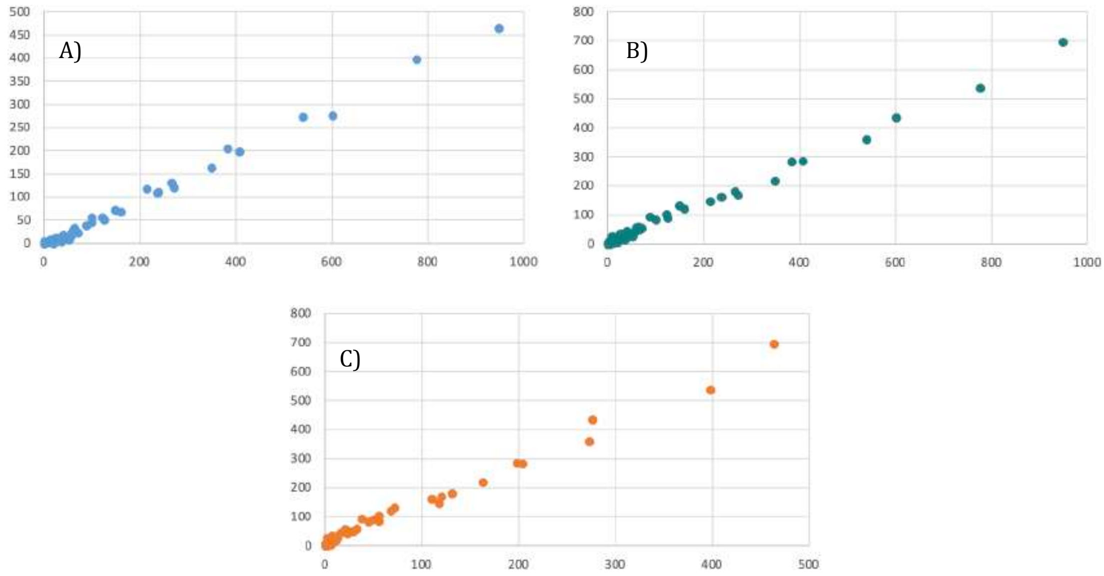

FIGURE 2.2 - CORRELATION (PER YEAR, PERIOD 1962-2022) BETWEEN NUMBER OF PAPERS ON:

A) 'ECONOMIC' AND 'SOCIAL' UPGRADING

B) 'ECONOMIC' AND 'ENVIRONMENTAL' UPGRADING

C) 'ENVIRONMENTAL' AND 'SOCIAL' UPGRADING

SOURCE: OWN ELABORATION OF SCOPUS.COM DATABASE QUERY

Very often, in addition, - and this further proves the relevance of looking at them as mutual and complimentary topics - at least two of them are discussed together in a single paper (see, for example, Perez-Aleman & Sandilands, 2008; Gereffi & Lee, 2016; Golini et al., 2018) or are even studied as interdependent variables (especially the Economic and the Social dimensions: see, for example, Bernhardt & Milberg, 2011; Bernhardt & Pollak, 2016; Marslev, 2019; Wang et al., 2020; see also: Klooster & Mercado-Celis, 2016; Krauss & Krishnan, 2022).

To gain a better overview on how the three upgrading dimensions are currently investigated in scientific literature, I performed a query of Scopus database, which is one of the most extensive abstract and citation databases of peer-reviewed literature (Chadegani et al., 2013). The search was conducted for publications including in their title, abstract or keywords the topics of Economic, Environmental, or Social Upgrading in Global Value Chains [TITLE-ABS-KEY: (Economic OR Environmental OR Social) AND Upgrading AND ((Global AND Value AND Chains) OR GVC OR GVCS)]. The search parameters were set to include all articles published up to the present date. From the initial pool of articles returned by this search, a selection process was undertaken. This involved sorting the articles by the number of citations [CITED BY (HIGHEST)] in order to get the most impactful and relevant papers first. Based on this, the first 50 relevant papers were selected for abstract review and were categorized based on the upgrading theme(s) they focused on (table 2.3):

table 2.3 - categorization of analyzed papers by upgrading theme(s)

Document title	Authors	Year	Source	Cited by	Upgrading themes
Economic and social upgrading in global production networks: A new paradigm for a changing world	Barrientos, S., Gereffi, G., Rossi, A.	2011	International Labour Review 150(3-4), pp. 319-340	538	**Economic & Social**
Economic and Social Upgrading in Global Value Chains and Industrial Clusters: Why Governance Matters	Gereffi, G., Lee, J.	2016	Journal of Business Ethics 133(1), pp. 25-38	343	**Economic & Social**
Why the World Suddenly Cares About Global Supply Chains	Gereffi, G., Lee, J.	2012	Journal of Supply Chain Management 48(3), pp. 24-32	342	**Economic, Social & Environmental**
Environmental Strategies, Upgrading and Competitive Advantage in Global Value Chains	De Marchi, V., Di Maria, E., Micelli, S.	2013	Business Strategy and the Environment 22(1), pp. 62-72	170	**Environmental**
Building value at the top and the bottom of the global supply chain: MNC-NGO partnerships	Perez-Aleman, P., Sandilands, M.	2008	California Management Review 51(1), pp. 24-49+3	155	**Economic, Social & Environmental**
Global value Chains, rising power firms and economic and social upgrading	Lee, J., Gereffi, G.	2015	Critical Perspectives on International Business 11(3-4), pp. 319-339	136	**Economic & Social**
Social upgrading and labour in global production networks: A critique and an alternative conception	Selwyn, B.	2013	Competition and Change 17(1), pp. 75-90	136	**Social**
Integrating poverty and environmental concerns into value-chain analysis: A strategic framework and practical guide	Riisgaard, L., Bolwig, S., Ponte, S., (...), Halberg, N., Matose, F.	2010	Development Policy Review 28(2), pp. 195-216	117	**Social & Environmental**

Economic and social upgrading in global production networks: Problems of theory and measurement	Milberg, W., Winkler, D.	2011	International Labour Review 150(3-4), pp. 341-365	95	**Economic & Social**
Bring In, Go Up, Go West, Go Out: Upgrading, Regionalisation and Delocalisation in China's Apparel Production Networks	Zhu, S., Pickles, J.	2014	Journal of Contemporary Asia 44(1), pp. 36-63	88	**Economic & Social**
Decent work in global production networks: Framing the policy debate	Barrientos, S., Mayer, F., Pickles, J., Posthuma, A.	2011	International Labour Review 150(3-4), pp. 297-317	78	**Economic & Social**
Environmental upgrading in global value chains: The potential and limitations of ports in the greening of maritime transport	Poulsen, R.T., Ponte, S., Sornn-Friese, H.	2018	Geoforum 89, pp. 83-95	74	**Environmental**
Buyer-driven greening? Cargo-owners and environmental upgrading in maritime shipping	Poulsen, R.T., Ponte, S., Lister, J.	2016	Geoforum 68, pp. 57-68	72	**Environmental**
Upgrading for whom? Relationship coffee, value chain interventions and rural development in Indonesia	Vicol, M., Neilson, J., Hartatri, D.F.S., Cooper, P.	2018	World Development 110, pp. 26-37	70	**Economic & Social**
Shifting regional dynamics of global value chains: Implications for economic and social upgrading in African horticulture	Barrientos, S., Knorringa, P., Evers, B., Visser, M., Opondo, M.	2016	Environment and Planning A 48(7), pp. 1266-1283	69	**Economic & Social**
Labour in Global Value Chains: Work Conditions in Football Manufacturing in China, India and Pakistan	Lund-Thomsen, P., Nadvi, K., Chan, A., Khara, N., Xue, H.	2012	Development and Change 43(6), pp. 1211-1237	68	**Economic & Social**
Globlisation, firm upgrading and impacts on labour	Knorringa, P., Pegler, L.	2006	Tijdschrift voor Economische en Sociale Geografie 97(5), pp. 470-479	65	**Economic & Social**
Beyond Upgrading: Gendered Labor and the Restructuring of Firms in the Dominican Republic	Werner, M.	2012	Economic Geography 88(4), pp. 403-422	53	**Economic & Social**
A reconceptualisation of social value creation as social constraint alleviation	Sinkovics, N., Sinkovics, R.R., Hoque, S.F., Czaban, L.	2015	Critical Perspectives on International Business 11(3-4), pp. 340-363	49	**Economic & Social**
Gendered Global Production Networks: Analysis of Cocoa-Chocolate Sourcing | [Les réseaux de production mondiaux sexospécifiques: Une analyse de l'approvisionnement en cacao/ chocolat]	Barrientos, S.	2014	Regional Studies 48(5), pp. 791-803	49	**Economic & Social**

Competitiveness and Technological Upgrading in Global Value Chains: Evidence from the Indonesian Electronics and Garment Sectors	Kadarusman, Y., Nadvi, K.	2013	European Planning Studies 21(7), pp. 1007-1028	49	**Economic**
E-Commerce and Industrial Upgrading in the Chinese Apparel Value Chain	Li, F., Frederick, S., Gereffi, G.	2019	Journal of Contemporary Asia 49(1), pp. 24-53	47	**Economic**
Global inequality chains: integrating mechanisms of value distribution into analyses of global production	Quentin, D., Campling, L.	2018	Global Networks 18(1), pp. 33-56	47	**Economic & Social**
Economic upgrading in global value chains	Gereffi G.	2019	Handbook on Global Value Chains pp. 240-254	43	**Economic**
Decoupling Standards from Practice: The Impact of In-House Certifications on Coffee Farms' Environmental and Social Conduct	Giuliani, E., Ciravegna, L., Vezzulli, A., Kilian, B.	2017	World Development 96, pp. 294-314	42	**Social & Environmental**
CSR in industrial clusters: An overview of the literature	Lund-Thomsen, P., Pillay, R.G.	2012	Corporate Governance (Bingley) 12(4), pp. 568-578	41	**Economic, Social & Environmental**
The making of a 'business case' for environmental upgrading: Sri Lanka's eco-factories	Goger, A.	2013	Geoforum 47, pp. 73-83	40	**Environmental**
Economic and social upgrading dynamics in global manufacturing value chains: A comparative analysis	Bernhardt, T., Pollak, R.	2016	Environment and Planning A 48(7), pp. 1220-1243	39	**Economic & Social**
Environmental Upgrading of Developing Country Firms in Global Value Chains	Achabou, M.A., Dekhili, S., Hamdoun, M.	2017	Business Strategy and the Environment 26(2), pp. 224-238	34	**Environmental**
Global value chain analysis: a primer (second edition) (Book Chapter)	Fernandez-Stark, K., Gereffi, G.	2019	Handbook on Global Value Chains pp. 54-76	31	**Economic & Social**
Which governance structures drive economic, environmental, and social upgrading? A quantitative analysis in the assembly industries	Golini, R., De Marchi, V., Boffelli, A., Kalchschmidt, M.	2018	International Journal of Production Economics 203, pp. 13-23	31	**Economic, Social & Environmental**
Coordinated governance in global value chains: supranational dynamics and the role of the International Labour Organization*	Posthuma, A., Rossi, A.	2017	New Political Economy 22(2), pp. 186-202	31	**Social**
Peasant inclusion in global value chains: economic upgrading but social downgrading in labour processes?	Pegler, L.	2015	Journal of Peasant Studies 42(5), pp. 929-956	28	**Social**
Why the Transatlantic Trade and Investment Partnership is not (so) new, and why it is also not (so) bad	De Bièvre, D., Poletti, A.	2017	Journal of European Public Policy 24(10), pp. 1506-1521	24	**Social & Environmental**

Environmental upgrading and suppliers' agency in the leather global value chain	de Marchi V., di Maria E.	2019	Sustainability 11(23), no. 6530	23	**Environmental**
Upgrading without formal integration in M&A: The role of social integration	Torres de Oliveira, R., Sahasranamam, S., Figueira, S., Paul, J.	2020	Global Strategy Journal 10(3), pp. 619-652	23	**Economic**
Making the connections: Bringing skill formation into global value chain analysis	Ramirez, P., Rainbird, H.	2010	Work, Employment and Society 24(4), pp. 699-710	23	**Economic & Social**
From disposable to empowered: Rearticulating labor in Sri Lankan apparel factories	Goger, A.	2013	Environment and Planning A 45(11), pp. 2628-2645	22	**Economic & Social**
Local means in value chain ends: Dynamics of product and social upgrading in apparel manufacturing in Guatemala and Colombia	Pipkin, S.	2011	World Development 39(12), pp. 2119-2131	21	**Economic & Social**
The dark side of the sun: solar e-waste and environmental upgrading in the off-grid solar PV value chain	Hansen, U.E., Nygaard, I., Dal Maso, M.	2021	Industry and Innovation 28(1), pp. 58-78	19	**Environmental**
State policies and upgrading in global value chains: A systematic literature review	De Marchi, V., Alford, M.	2022	Journal of International Business Policy 5(1), pp. 88-111	17	**Economic, Social & Environmental**
The 'factory manager dilemma': Purchasing practices and environmental upgrading in apparel global value chains	Khan, M.J., Ponte, S., Lund-Thomsen, P.	2020	Environment and Planning A 52(4), pp. 766-789	17	**Economic & Environmental**
Technology generation and international collaboration in the Global Value Chain of Lithium Batteries	Moreno-Brieva, F., Marín, R.	2019	Resources, Conservation and Recycling 146, pp. 232-243	17	**Economic**
A review of inclusive business models and their application in aquaculture development	Kaminski, A.M., Kruijssen, F., Cole, S.M., (...), Rogers, W., Little, D.C.	2020	Reviews in Aquaculture 12(3), pp. 1881-1902	16	**Economic & Social**
Technological Capabilities, Upgrading, and Value Capture in Global Value Chains: Local Apparel and Floriculture Firms in Sub-Saharan Africa	Whitfield, L., Staritz, C., Melese, A.T., Azizi, S.	2020	Economic Geography 96(3), pp. 195-218	16	**Economic & Social**
Primary Sector Value Chains, Poverty Reduction, And Rural Development Challenges In The Philippines	Andriesse, E.	2018	Geographical Review 108(3), pp. 345-366	15	**Social**
The competitive factors of the Bangladeshi garment industry in the post-MFA era	Alam, M.S., Natsuda, K.	2016	Canadian Journal of Development Studies 37(3), pp. 316-336	15	**Social**
Global, regional and domestic apparel value chains in Southern Africa: Social upgrading for some and downgrading for others	Godfrey, S.	2015	Cambridge Journal of Regions, Economy and Society 8(3), pp. 491-504	15	**Social**

Global value chains and social upgrading of clusters: Lessons from two cases of fair trade in the Brazilian Northeast	De Oliveira, J.A.P., De Oliveira Cerqueira Fortes, P.J.	2014	Competition and Change 18(4), pp. 365-381	15	**Economic & Social**
Sustainable Production Networks: Capturing Value for Labour and Nature in a Furniture Production Network in Oaxaca, Mexico	Klooster, D., Mercado-Celis, A.	2016	Regional Studies 50(11), pp. 1889-1902	12	**Social & Environmental**

TABLE 2.3 - CATEGORIZATION IN EITHER ECONOMIC, SOCIAL OR ENVIRONMENTAL UPGRADING OF THE ANALYZED PAPERS

SOURCE: OWN ELABORATION OF SCOPUS.COM DATABASE QUERY

Table 2.3 reveals the following: 22 papers out of 50 could be associated with both 'Economic' & 'Social' Upgrading, 7 papers only with 'Environmental', 6 only with 'Social' Upgrading, 5 only with 'Economic', 5 with all the three of them, 4 with both 'Social' & 'Environmental', 1 with both 'Economic' & 'Environmental' Upgrading. Summing up, only 18 papers out of 50 addressed one of the three topic individually, thereby testifying the significance of studying sustainability dimensions in an integrated way.

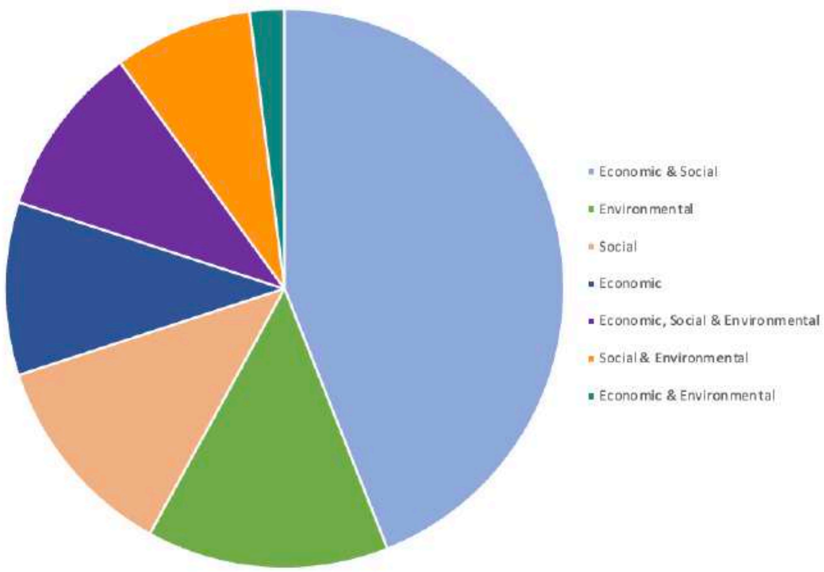

FIGURE 2.2 - CATEGORIZATION OF ANALYZED PAPERS BY THEMES

SOURCE: OWN ELABORATION OF SCOPUS.COM DATABASE QUERY

The most relevant sources were Environment and Planning A (4 publications taken into account), Geoforum (3 publication), International Labour Review (3 publications), World Development (3 publications).
Please also note that, drawing from Gereffi (2019), I catalogued papers treating *Product*, *Process*, *Functional* and *Intersectoral* (or *Chain*) *Upgrading* more broadly into the *Economic Upgrading* category, as well as those concerning technological upgrading, when the clear objective of their study was to examine the related Economic or Value Distribution effects (e.g.: Whitfield et al., 2020).

In light of their strict correlation and interdependence, therefore, these three dimensions will be investigated aggregately under the broader umbrella concept of Sustainability in this work, occasionally referring individually to each of them. In the next chapter, I will examine drivers and barriers for sustainability integration in value chains, with the ultimate aim of suggesting upgrading trajectories supported by Blockchain technology in the subsequent and last chapter.

Chapter 3

Integrating Sustainability in GVCs: drivers and barriers

To truly gain a solid understanding of the dynamics of Sustainability in GVCs, answers to the following questions need to be provided first: Why should GVC participants have an economic interest in adopting sustainable conducts (*Drivers*)? What are the barriers that prevent the implementation of such positive behaviors (*Barriers*)?

In particular, I will turn to the business literature on Sustainable Value and Supply Chains - integrating it with other observations drawn from the broader Sustainability literature - to get a complete overview on these themes, in light of the closeness of the concepts of value chain and supply chain and of the particularly large abundance of publications on the latter. The choice of embedding the Supply Chain literature is then further supported by the fact that, as I concluded earlier, organizations that seek to considerably improve the sustainability of their global affairs need to target the supply chain in a predominant way, in consideration of its weight on the overall negative externalities of a company (see p. 21). Finally, focusing on the supply chain as a sustainability propellent is crucial since this business area is the most likely to have significant and direct impacts on every other business function, as well as on the overall sustainable performance of organizations and on a multitude of value chain partners (Mentzer et al., 2001; Diabat & Govindan, 2011; Aboelmaged, 2012; Jamaluddin & Saibani, 2021).

I hereby briefly introduce the concept of Sustainable Supply Chain Management (SSCM). Several definitions for SSCM have been provided over the years: some of them keep it very simple, by stating that SSCM is the 'integration of sustainable development and supply chain management' (Dyllick & Hockerts, 2002), some put more emphasis on the supply chain as a strategic tool for achieving sustainable development (Carter & Rogers, 2008), others simply appending the need to take ESG matters into consideration when managing the supply chain (Seuring & Miller, 2008; Garcia-Torres et al., 2019).

Reviews of different elements related to supply chain sustainability suggests that SSCM may have a predominant environmental focus when taking ESG matters into account: it can be directly associated, in fact, with eco-friendly practices such as green design, product recovery, reverse logistics, waste management, energy efficiency and emissions reduction (Ramudhin & Chaabane, 2009). In this respect, the locution *Green Supply Chain Management* (*GSCM*) was also coined.

The interest towards Sustainable Supply Chain Management has been growing (Corbett & Klassen, 2006) not only as a lever of managerial decision, but also in literature, as testified by the number of scientific publications on the matter. In particular, with a 21,6% CAGR in the twenty-year period between 2002 and 2022 (Figure 3.1), its growth rate significantly outpaced, for instance, that of papers concerning Supply Chain Management or Sustainability and Sustainable Development (respectively, 10,8% and 15,5% CAGR; source: own elaboration of Scopus database query). Moreover, SSCM has emerged as a relevant topic not only for the Business Management literature, but also for other subject areas, such as Engineering, Environmental Science and Energy (Figure 3.2).

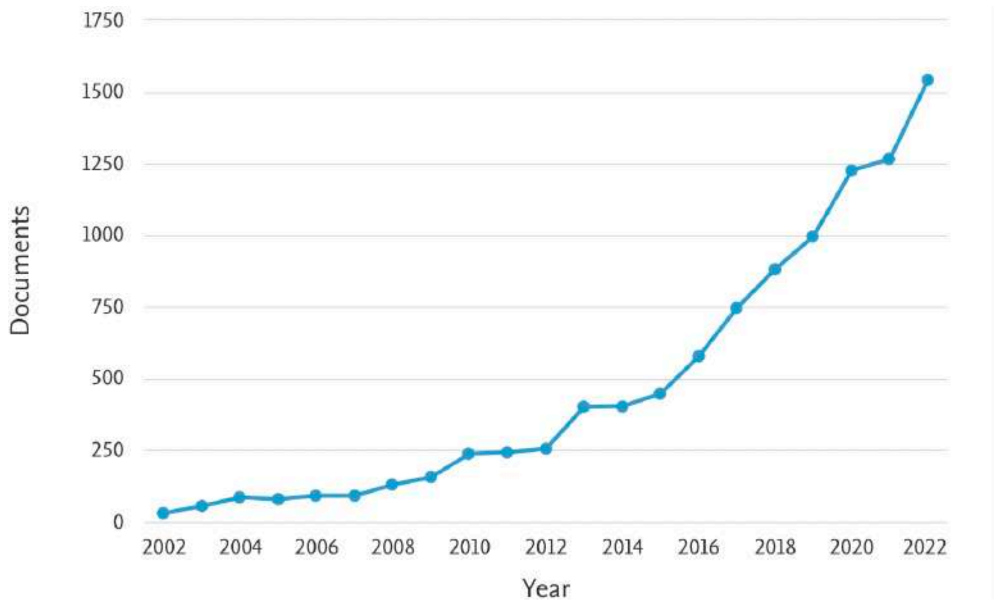

FIGURE 3.1 - PUBLICATIONS ON ‘SUSTAINABLE SUPPLY CHAIN MANAGEMENT’ OR ‘SSCM’ (IN EITHER THE TITLE, ABSTRACT OR KEYWORDS) IN SCOPUS DATABASE.

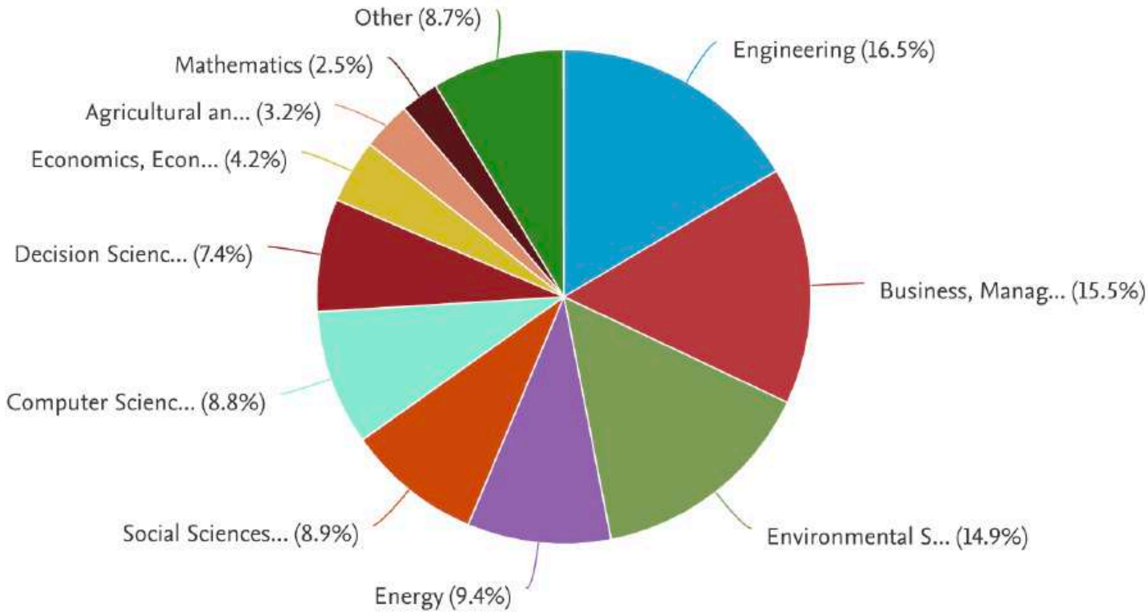

FIGURE 3.2 - RESEARCH AREAS OF PUBLICATIONS ON 'SUSTAINABLE SUPPLY CHAIN MANAGEMENT' OR 'SSCM' (IN EITHER THE TITLE, ABSTRACT OR KEYWORDS) IN SCOPUS DATABASE.
SOURCE: SCOPUS.COM

3.1 Drivers

Before the emerging of trends like *Sustainable Supply Chain Management* (*SSCM*) or *Green Supply Chain Management* (*GSCM*), companies used to worry solely about excesses in production with a cost-perspective, but neglected the impacts of their value chain on society and the environment (Van Hoek, 1999). Towards the end of the 20th century, however, a rapid rise in the popularity of topics like *corporate environmental strategy* (*CES*; Figure 3.3; see, for example, Roome, 1992; Sharma & Vredenburg, 1998; Delmas & Toffel, 2004) and *corporate social responsibility* (*CSR*; Figure 3.4; see, for example, Carroll, 1991; Waddock & Graves, 1997; McWilliams & Siegel, 2001) could be noticed, and thus firms began to integrate these levers in their strategic decisions (Lozano, 2015). But why has this (in part) reassuring trend started to emerge?

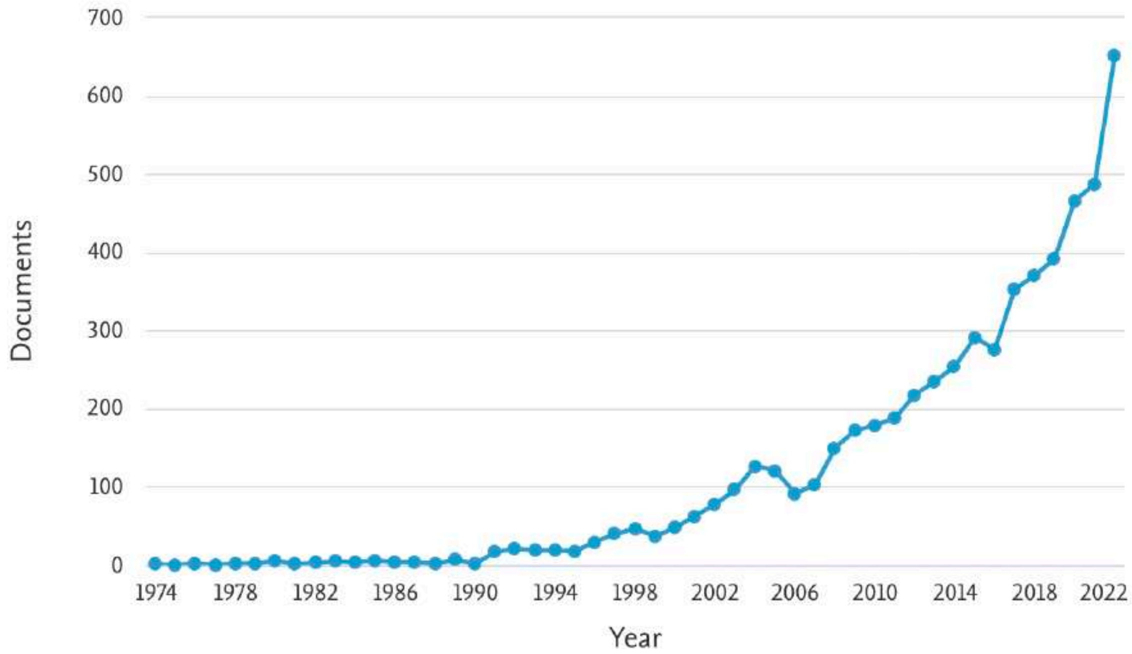

FIGURE 3.3 - PUBLICATIONS ON 'CORPORATE ENVIRONMENTAL STRATEGY' (IN EITHER THE TITLE, ABSTRACT OR KEYWORD) IN SCOPUS DATABASE, 1974 - 2022
SOURCE: SCOPUS.COM

Today, there is wide consensus that the implementation of sustainability along global value chain networks is certainly necessary (see, for example, Hall et al., 2012; Miemczyk et al., 2012). However, this isn't enough for GVC players - whose primary goal remains profitability - to take spontaneous initiative. They do so, instead, if they are forced to or if they see a clear economic convenience in acting sustainable. Thus, motives for going *sustainable* can be of two kinds: *pressures* - when firms are forced to improve their sustainable practices even without a clear economic convenience - and *opportunities* - when firms do so in order to enhance, in some way, their short term or long term profitability -.

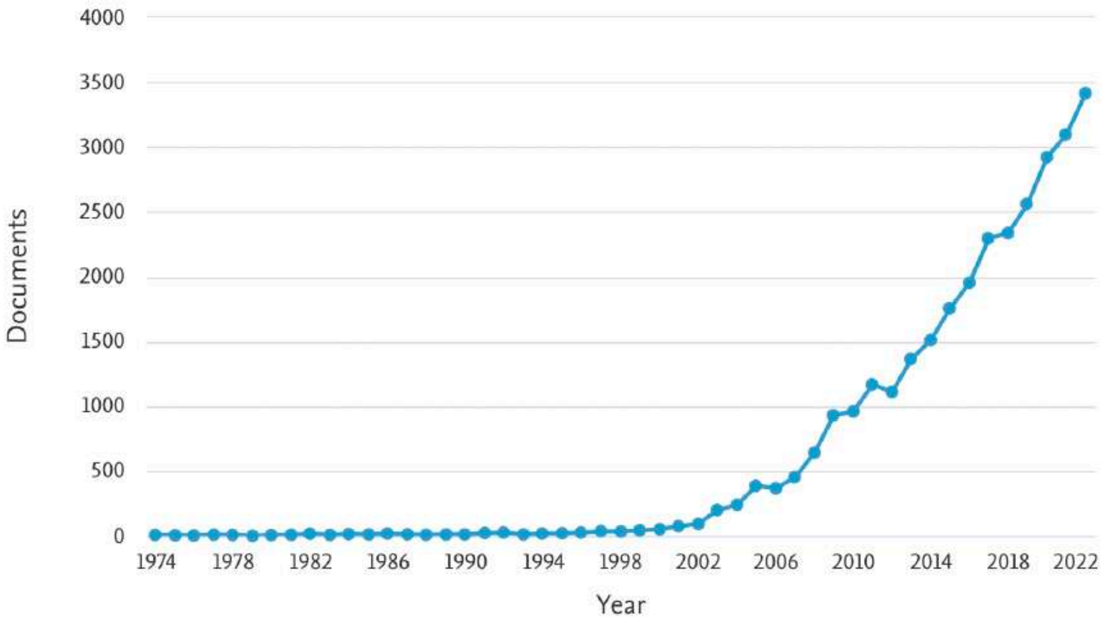

FIGURE 3.4 - PUBLICATIONS ON 'CORPORATE SOCIAL RESPONSIBILITY' (IN EITHER THE TITLE, ABSTRACT OR KEYWORD) IN SCOPUS DATABASE, 1974 - 2022
SOURCE: SCOPUS.COM

3.1.1 Drivers by querying Scopus database

To investigate the most relevant drivers for investing in sustainable value/supply chains, I performed a systematic literature review drawing on Snyder's (2019) suggestions on the methodology. The first step in the process was to perform a query of Scopus database for publications on *pressures* or *drivers* for *sustainable value/supply chains* and sorting them by relevance. The search parameters were set to include all articles published since 2010, in order to get up-to-date information. The complete query was the following:

[TITLE-ABS-KEY ((Pressures OR Drivers) AND Sustainable AND (Supply OR Value) AND Chain) AND (LIMIT-TO (PUBYEAR, 2023) OR LIMIT TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO

(PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011) OR LIMIT-TO (PUBYEAR, 2010))].

From the initial pool of articles returned by the search, the first 20 papers were selected for full-text review. This selection strategy was chosen based on a preliminary assessment of the relevance and quality of the articles. I observed that after the first 20 results, the relevance of the articles to the research purpose began to diminish significantly. Therefore, to maintain the focus and quality of the review, I decided to limit the analysis to these first 20 papers. In particular, this involved reading the full text and extracting the main relevant drivers identified by each paper: the results are noted and categorized in table 3.5. Please also note that, in order to ease the interpretation of the research, some drivers were grouped together: for instance, when ‘reducing cost of energy’ and ‘cost pressures’ were treated as two different drivers, I reported only the more general ‘cost pressures’ driver. Similarly, I grouped together ‘consumer pressures’ with ‘consumer demands’, ‘reputation’, ’media’ and 'public pressure’ with ‘social awareness’ and yet again ‘government regulation’ with ‘government subsidies’, and so on. I also excluded those that can’t be considered drivers, such as *cash availability* or *technology readiness,* but are, in fact, *enablers* of sustainable practices. Finally, one paper was not considered because inaccessible and two papers were not considered because not relevant for the purpose of the research, despite being among the first 20 results.

table 3.5 - Identified drivers from reviewed papers

Document title	Authors	Year	Source	Cited by	Main Drivers identified
Analysis of sustainability drivers among suppliers of Iranian Gas Engineering and Development Company	Mehregan, M.R., Chaghooshi, A.J., Hashemi, S.H.	2014	International Journal of Applied Decision Sciences 7(4), pp. 437-455	8	**Regulation** **Consumer Demands** **Competitive Pressures** **Reputation/Public Pressures/ NGOs**

Sustainable supply chain management in a developing context: An empirical examination of antecedents and consequences	Aboelmaged, M.G.	2012	International Journal of Social Ecology and Sustainable Development	7	/
Drivers of sustainable supply chain management: Identification and classification	Saeed, M.A., Kersten, W.	2019	Sustainability (Switzerland) 11(4),1137	82	**Top Management Commitment** **Consumer Demands** **Regulation** **Competitive Pressures**
An entropy-based approach for assessing operational visibility in sustainable supply chain	Apeji, U.D., Sunmola, F.T.	2020	Procedia Manufacturing 51, pp. 1600-1605	3	**Consumer Demands** **Competitive Pressures**
Carbon neutrality drivers and implications for firm performance and supply chain management	Zhang, A., Tay, H.L., Alvi, M.F., Wang, J.X., Gong, Y.	2022	Business Strategy and the Environment	2	**Consumer Demands** **Top Management Committment** **Regulation** **Competitive Pressures**
A stakeholder perspective of sustainable supply chain management: Evidence from a developing country (Book Chapter)	Aboelmaged, M.G.	2017	Operations and Service Management: Concepts, Methodologies, Tools, and Applications pp. 1560-1589	0	**Regulation** **Consumer Demands** **Supply Chain Pressures** **Reputation/Public Pressures/ NGOs** **Cost pressures (Eco-Efficiency)** **Top Management Commitment**
Drivers and Barriers of Sustainable Supply Chain's Enhancement in Pharmaceutical Industry in Indonesia: A Conceptual Model	Melati, G.I., Ardi, R.	2021	ACM International Conference Proceeding Series pp. 141-148	0	**Regulation** **Competitive Pressures** **Financial Benefits** **Consumer Demands** **Reputation** **Top Management Commitment** **Cost pressures (Eco-Efficiency)** **Innovation**
Analysis of supply chain sustainability with supply chain complexity, inter-relationship study using delphi and interpretive structural modeling for Indian mining and earthmoving machinery industry	Chand, P., Thakkar, J.J., Ghosh, K.K.	2020	Resources Policy 68,101726	19	**Competitive Pressures** **Consumer Demands** **Regulation** **Supply Chain Pressures**

Green drivers and green enablers in pharmaceuticals supply chain: in the context of an emerging economy	Sabat, K.C., Krishnamoorthy, B., Bhattacharyya, S.S.	2022	TQM Journal	1	**Reputation/Public Pressures** **Supply Chain Pressures** **Competitive Pressures**
An Empirical Analysis of the Factors That Support the Drivers of Sustainable Manufacturing	Fargani, H., Cheung, W.M., Hasan, R.	2016	Procedia CIRP 56, pp. 491-495	12	**Competitive Pressures** **Regulation** **Cost Pressures (Eco-Efficiency)** **Top Management Commitment** **Consumer Demands** **Reputation/Public Pressures/ NGOs** **Supply Chain Pressures**
Ranking different enablers/drivers of sustainable supply chain management by using AHP in Indian manufacturing industries	Chaudhari, J.S., Wasu, R., Sarode, A.	2020	International Journal of the Analytic Hierarchy Process 12(2), pp. 272-296	1	**Regulation** **Reputation/Public Pressures/ NGOs** **Competitive Pressures** **Supply Chain Pressures**
Identifying significant drivers for sustainable practices in achieving sustainable food supply chain using modified fuzzy decision-making trial and evaluation laboratory approach	Ocampo, L.A., Villegas, Z.V.A., Carvajal, J.T., Apas, C.-A.A.	2018	International Journal of Advanced Operations Management 10(1), pp. 51-89	19	**Employment Attraction** **Top Management Commitment** **Supply Chain Pressures**
Supply chain stakeholder pressure for the adoption of sustainable supply chain practices: examining the roles of entrepreneurial and sustainability orientations	Vidal, N.G., Spetic, W., Croom, S., Marshall, D.	2023	Supply Chain Management 28(3), pp. 598-618	1	/
Corporate supply chain responsibility: Drivers and barriers for sustainable food retailing	Chkanikova, O., Mont, O.	2015	Corporate Social Responsibility and Environmental Management 22(2), pp. 65-82	119	**Regulation** **Cost Pressures (Eco-Efficiency)** **Reputation/Public Pressures/ NGOs** **Consumer Demands** **Supply Chain Pressures**
Supply chain sustainability drivers for fast-moving consumer goods (FMCG) sector: an Indian perspective	Prashar, A.	2022	International Journal of Productivity and Performance Management	0	**Regulation** **Competitive Pressures** **Innovation**

Sustainable supply chain in food industries: Drivers and strategic sustainability orientation	Emamisaleh, K., Rahmani, K.	2017	Cogent Business and Management 4(1),1345296	31	**Top Management Commitment**
Investigating and analysing the factors affecting the development of sustainable supply chain model in the industrial sectors	Andalib Ardakani, D., Soltanmohammadi, A.	2019	Corporate Social Responsibility and Environmental Management 26(1), pp. 199-212	34	/
A dynamic perspective on the key drivers of innovation-led lean approaches to achieve sustainability in manufacturing supply chain	Orji, I.J., Liu, S.	2020	International Journal of Production Economics 219,107228	55	**Regulation**
Drivers and barriers in sustainable supply chains: The case of the Brazilian coffee industry	Guimarães, Y.M., Eustachio, J.H.P.P., Leal Filho, W., (...), do Valle, M.R., Caldana, A.C.F.	2022	Sustainable Production and Consumption 34, pp. 42-54	3	**Cost Pressures (Eco-Efficiency)** **Reputation/Public Pressures/ NGOs** **Regulation** **Innovation**
Drivers of sustainable supply chain management in South Africa a total interpretive structural method (TISM) based review	Thaba, S.C.	2017	Lecture Notes in Engineering and Computer Science 2, pp. 939-945	0	**Regulation** **Supply Chain Pressures** **Cost Pressures (Eco-Efficiency)** **Top Management Commitment**

TABLE 3.5 - SUSTAINABLE VALUE / SUPPLY CHAIN DRIVERS, IDENTIFIED BY THE FIRST 20 RESULTS, SORTED BY RELEVANCE AND LIMITED TO PAPERS PUBLISHED AFTER 2010, FOR QUERYING 'DRIVERS OR PRESSURES FOR SUSTAINABLE VALUE / SUPPLY CHAIN' (IN EITHER THE TITLE, ABSTRACT OR KEYWORDS), IN SCOPUS DATABASE. SOURCE: OWN ELABORATION OF SCOPUS.COM DATABASE QUERY

As effectively illustrated in Figure 3.6, the most mentioned drivers for sustainable value/supply chains were: regulation (cited in 13 papers), competitive pressures (10 papers), consumer demands (9 papers), followed by Top Management Commitment and Supply Chain Pressures (8 papers each). Additionally, reputation/public pressures/NGOs were recognized as a focal driver by 7 papers and cost pressures by 6 papers, while implementing sustainable practices in order to innovate - for instance, by introducing a green product to the company portfolio - were considered a major theme by 3 papers. Finally, employment attraction and financial benefits were taken into consideration only by 1 paper each.

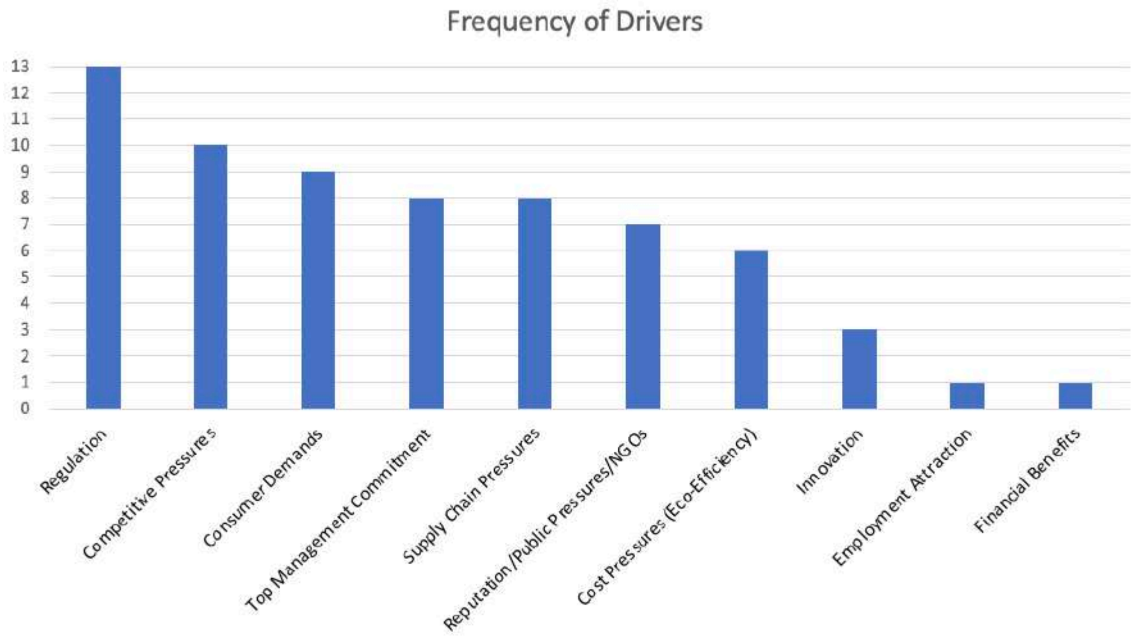

FIGURE 3.6 - ILLUSTRATION OF THE FINDINGS OF TABLE 2.9
SOURCE: OWN ELABORATION OF SCOPUS.COM DATABASE QUERY

3.1.2 A further insight on key drivers

Lubin and Esty (2010) argued that addressing the *megatrend* of Sustainability will be an imperative, sooner or later, for every organization, to the point that their competitiveness, or perhaps even their survival, will depend on their ability to do so.

Unsurprisingly hence, corporations have been shown to engage almost exclusively in sustainable activities that are of strategic importance for their competitiveness - for instance, in the form of improved positioning or, ultimately, of enhanced profitability -, rather than of benefit to the society and the environment (Babiak & Trendafilova, 2011; Bondy et al., 2012). Global brands can thus engage in CES/CSR activities in the Economic South, for instance, in response to a legitimacy crisis, and they do so by implementing practices that tackle certain environmental and social issues (or both). Therewith, they seek to regain public approval (Newell, 2008; Robinson, 2010). This approach, which falls in the definition of *CSR as a business tool*, in contrast with that of *CSR as a development tool* (Newell & Frynas, 2007), seems to fit with Devinney's (2009) provocative verdict: 'the holy grail of CSR – doing well by doing good – is an illusory goal that is noble in spirit but unachievable in practice'. Overall, improving corporate reputation often can be the leitmotiv behind organizations' efforts to act sustainable (Hart & Milstein, 2003; Hemingway & Maclagan, 2004; Branco & Rodrigues, 2006; Esen, 2013; Gomez-Trujillo et al., 2020; Le, 2022; Martos-Perdrero et al., 2022).

Still, the reasons for firms to be more sustainable are obviously not limited to this and many other key drivers have been observed in literature. Among these, an important role is played by customers' preferences (Hall, 2001; Carter & Jennings, 2002; Azevedo et al., 2011): in particular, in a recent survey by McKinsey, 66% of all respondents and 75% of millennial respondents reported to take sustainability into consideration when purchasing a luxury product, while 26% of millennials and 31% of Gen Z respondents stated that they would pay a price premium for products with the least negative environmental impact (McKinsey, 2020). Very similarly, a Nielsen survey conducted over 30,000 consumers found that 66% of them are willing to pay more for sustainable goods, up from 55% in 2014 and 50% in 2013 (Nielsen, 2015). This is in line with the idea that businesses need to 'reconceive products and markets' to address societal and environmental needs (Kramer & Porter, 2011). Furthermore, interest in so-called *ethical consumption* has been on the rise lately (Prothero et al., 2011; Sebastiani et al., 2013), sometimes ending up in *brand avoidance* by customers concerned about social and environmental practices of firms along their value chain (Low & Davenport, 2007; Iyer & Muncy, 2009; Strandvik et al., 2013). Thus, as consumers become more ethically conscious, they prompt companies to adopt sustainable production methods, reduce waste, minimize their carbon footprint and ensure that their value chain partners and employees are treated fairly, either to avoid such negative brand associations or, simply, to target niche markets and charge price premia (Bartley, 2007). In accordance with this driver, 40% of CEOs interviewed in the aforementioned UN Global Compact & Accenture survey (p. 26) declared to see revenue growth as a consequence of acting sustainable. *Eco-branding* strategies have also been found to often entail direct sourcing from the local producers/farmers, thus shortening the length of the value chains, reducing their complexity and increasing transparency and traceability (Chkanikova & Lehner, 2015).

Another reason for acting sustainable, and probably the most convenient one also in the short term, is Eco-efficiency: this locution refers to the possibility for firms to improve their environmental impacts while simultaneously adding to the bottom line by cutting costs (Lovins et al., 1999; Dyllick & Hockerts, 2002; Huppes & Ishikawa, 2009; Orsato, 2009). This can be achieved, for instance, by reengineering business processes to decrease the use of energy, water and other resources or by reducing production waste (DeSimone & Popoff, 1997), in line with the second *shared value* mantra of 'redefining productivity in the value chain' (Kramer & Porter, 2011). The potentialities of Eco-efficiency are also recognized in a ISO standard (ISO 14045). In the UNGC & Accenture survey already taken into consideration, 25% of CEOs emphasized the possibility to cut costs by being sustainable. This percentage, interestingly, fits quite well with the results of the previous literature research, where 5 papers out of 20 recognized eco-efficiency as a key sustainability driver.

Despite underrepresented in the literature research results, financial benefits and employment attraction both deserve a further mention. Notably, acting sustainable has been shown to ease access to finance (Cheng et al., 2014) and to lower the cost of

capital (El Ghoul et al., 2011). Analogous conclusions are also drawn by Dauvergne & Lister (2013), who state that collecting carbon emissions data and other sustainability information facilitates access to equity and debt by allowing investors and creditors to assess in more detail the attractiveness of a company and the ESG risks connected with it.
A further advantage is the capacity to build a stronger employer brand and more committed workforce, in particular for organizations with a young employee base and when implementing *environmentally* sustainable practices. Climate change and environmental issues, in this respect, have been found to be a top concern for Millennials and Generation Z (Deloitte, 2021; Pew Research Centre, 2021): hence unsurprisingly, a study by Cone Communications (2016) found that 76% of millennials consider a firm's social and environmental commitments when evaluating potential employers. Similarly and going more in depth, a study conducted over 1,510 full and part-time employees in the US found that companies are 2.3 times more likely to retain employees when these can establish a strong connection with their employer's purpose. And this is even more impactful for millennials and Generation Z employees: when this condition is satisfied, they are 5.3 times more likely to stay (PwC, 2016).

Among the *pressures* for acting sustainable, on the other hand, regulation seems to be the most relevant (Zhu et al., 2005; Álvarez-Gil et al., 2007; Berns et al., 2009; Mann et al., 2010; Giunipero et al., 2012; Govindan & Hasanagic, 2018; Balon, 2020). In particular, coercive regulation has been found to be more effective in the achievement of environmental sustainability, rather than normative regulation (Dhanda et al., 2022). However, regulating dispersed activities such as those of today's Value Chains is not an easy task for state governments, civil society and supra-national institutions (e.g., WTO, United Nations, IAS, etc.). As a matter of fact, these entities have limited capacity when it comes to setting regulations and standards that can work - in a binding way - in a global playfield over global enterprises (Laufer, 2003; Prieto-Carrón et al., 2006; Cherepanova, 2021).

To fill this gap, many of the these lead firms have proactively started to adopt 'soft law' tools - such as standards or codes of conduct - to govern the sustainability of their operations and of their suppliers (Waddock et al., 2002; Roberts, 2003; Matten & Crane, 2005; Fulponi, 2006; Busch, 2009; Preuss, 2009; Bartley & Egels-Zandén, 2015; van der Ven, 2018), in line with the broader trend of the *privatization* of regulation and global governance (Cutler et al., 1999; Dingwerth, 2008; Cutler, 2012; Büthe & Mattli, 2013; Grabs et al., 2021so). Interestingly, as a collateral effect, the involvement of private organizations into the regulation of sustainability across GVCs seems to also mitigate institutions' demands with respect to environmental practices, thus dispelling the danger of more stringent regulation and policies (Roger et al., 2017; Malhotra et al., 2018; Kolkata et al., 2021).

Although some authors consider the adherence to these to be non-binding and quasi-voluntary (Gilbert & Rasche, 2008; Lund-Thomsen et al., 2012), others have reported the existence of ethical audit mechanisms that can have a 'make it or break it' significance for the participation of a supplier in the value chain (Nadvi, 2008; LeBaron et al., 2017); others yet have found the effectiveness of such standards and codes of conducts to be dependent on the governance type embedded in the value chain, at the same time highlighting manifestations of dishonesty, lack of transparency and even fraud by certain audited suppliers (Jiang, 2009). Finally, some argue that ethical audits can, in some occasions, end up concealing the actual sustainability problems of a value chain or even being counterproductive and eventually destroying social value (LeBaron & Lister, 2015; Sinkovics et al., 2016).

Anyhow, it has to be noted that the success of standards and codes of conduct relies on the willingness and capabilities of suppliers to meet the requests. In this regard, lead firms need to provide support to ensure compliance. This may include offering technical assistance, capacity building, workforce training and financial incentives (Ponte, 2008). In connection with this point, as expected, it has been noted that for suppliers-supported environmental upgrading, the extent of its success remains limited, in absence of adequate support by the lead firms (Achabou et al., 2017).

Also, concerning this privatization of regulation, it has to be underlined that auditing by private firms is, increasingly, employed by legal institutions to assess compliance with environmental- and labour-related 'hard' regulation (International Labour Organization, 2009; MacDonald, 2014). For instance, many institutions in Europe and America have recurred to privately-imposed forest certification audits to complement or even substitute state regulations and enforcements (Dauvergne & Lister, 2011; Gulbrandsen, 2014).

If the vast geographic reach of their operations makes MNEs particularly difficult to be addressed by 'hard' regulation, at the same time it makes them uniquely exposed to a multitude of economic, environmental and social issues. Furthermore, the dispersion of their outsourcing activities among a myriad of small partners can make the monitoring of the various stages very difficult, especially for external stakeholders, thus casting a shadow on the practices implemented within the boundaries of their value chain (Busse et al., 2017; Hatte & Koenig, 2020). Finally, in light of the large scale of their operations and the heterogeneity of affairs they undertake, they happen to interact with a plethora of different private and institutional stakeholders. These peculiarities make them a crucial pivot for sustainable development. Thus, they are increasingly called upon to increase their efforts in global challenges (Kolk & Van Tulder, 2010; Boström et al., 2015) and they have become daily targets of activism campaigns (Wall Street Journal, 2001; Spar & La Mure, 2003; Lenox & Eesley, 2009; Schurman & Munro, 2009; Bair & Palpacuer, 2015; Daubanes & Rochet, 2019).
These social movements follow a consistent pattern: that is, helding big corporations in the Economic North accountable for the whole length of their value chain, especially for its social and environmental externalities in Southern Countries (Rothenberg-Aalami, 2004), thus questioning a logic of global sourcing whereby lead firms are able to control the whole value chain without bearing the burden of a direct ownership and of the consequent legal responsibilities (Hale & Wills, 2007). In this perspective, hence, Northern firms' value chains are transformed into *chains of responsibility* (Barraud de Lagerie, 2016) that force these firms to act on the claims made, if they care to protect

their image and reputation (Hudson & Hudson, 2003; Balsiger, 2014). The 'Behind the Brands' campaign led by Oxfam is an example of how sustained pressure from activists can compel major corporations to improve their environmental and social performance: according to the non profit organization's reports, the campaign resulted in commitments from companies to address land grabs, climate change, and workers' rights (Oxfam, 2021).
The influence of activism campaigns also extends to policy-making. By advocating for stricter regulations, these campaigns can indirectly affect GVCs by increasing the cost of non-compliant behavior (Newell, 2008). For instance, the Clean Clothes Campaign's work has led to more stringent labor laws in countries like Bangladesh (Clean Clothes Campaign, 2013).
However, it has to be noted, although activism campaigns play an important role in enhancing the sustainability of GVCs, they don't always achieve the desired outcomes. Companies may respond to such pressures by *greenwashing* their practices or shifting unsustainable activities to less regulated regions, undermining genuine sustainability efforts (Lyon & Maxwell, 2011).

Furthermore, so-called *multi-stakeholder initiatives* (*MSIs*) have started to emerge as a frequent regulatory mechanism to address pressing global sustainability challenges (Vogel, 2008; Zeyen et al., 2016; Soundararajan, 2019; MacDonald et al., 2022), by combining the expertise, skills and finances of private corporations, governments, public or non-profit organizations and consumer associations (Fransen, 2012; Lambin & Thorlakson, 2018). What distinguishes MSIs from the aforementioned other private regulation mechanisms, such as lead firm-set standards and codes of conducts, is thus their capacity to include an heterogeneous set of stakeholders in steering the direction of the initiative (de Bakker et al., 2019). These collaborative initiatives have been found to be particularly useful inso they provide learning platforms - in the sense that they are effective in linking supply chains to their sustainability context and in rising awareness about specific ESG issues (Brown & Timmer, 2006)-, set common sustainability standards (Daviron & Vagneron, 2011; Ponte & Cheyns, 2013), develop enforcing mechanisms for sustainability and, finally, issue labels and certifications to guaranteeing compliance along value chains (Searcy, 2017).

However, although MSIs rely on the cooperation between diverse players to productively align their efforts towards a common goal (Fowler & Biekart, 2017), significant power dynamics are nevertheless noticeable: in particular, actors involved are ofter trying to assert their dominance over each other and, notably, they seek to establish a decision-making authority on particular environmental or social issues (Cashore, 2002; Fransen, 2012). Hence, the interests of large corporations may end up being over-represented, thereby excluding marginalized actors lacking voice and power - such as local communities - from the decision-making process (Eikelenboom & Long, 2022).

All things considered, while MSIs have certainly helped addressing certain social and environmental issues along GVCs, there are still several improvements to be made, including the need for increased participation, transparency and accountability (Fuchs et al., 2011; Franken & Schütte, 2022)

Some examples of such MSIs, actively regulating global corporate conduct in the respective areas, are the United Nations Global Compact (UNGC), the Roundtable for Sustainable Palm Oil (RSPO), the Marine Stewardship Council (MSC), and the Forest Stewardship Council (FSC) (Fransen & Kolk, 2007; Lambin & Thorlakson, 2018).

3.2 Barriers

The market case for sustainability may seem to be largely established by now: in the already introduced UNGC & Accenture survey, only 28% of the CEOs interviewed included the “absence of market pull” among the barriers preventing businesses to implement sustainability-enhancing practices (UN Global Compact & Accenture, 2019). However, despite the vast and growing demand for sustainable products, there still are many other barriers to improving sustainability in GVCs, including the fact that such market pull does not always translate in an increased willingness to pay.

3.2.1 Barriers by querying Scopus database

To identify the most prominent, I conducted a systematic literature review following the same structure adopted for the research on ‘Drivers’. However, due to a minor availability of relevant papers, I extended the search also to Google Scholar database, to get to a total of 17 relevant papers, which is the same number of articles I analyzed for the drivers. In particular, the query in Google Scholar was made by typing ‘Barriers Sustainable Supply Chain’ and ‘Barriers Sustainable Value Chain’ in the search bar, then skewing the results for papers published from 2010 onwards, while for Scopus database the query was the following:

[Barriers AND Sustainable AND (Supply OR Value) AND Chain AND (LIMIT-TO (PUBYEAR, 2023) OR LIMIT TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011) OR LIMIT-TO (PUBYEAR, 2010))].

Please note that the same rationales used for the literature review on ‘Drivers’ were used: thus, for instance, I grouped together barriers such as ‘high implementation costs’, ‘high sunk costs’, ‘high cost for environmentally friendly packaging’ or ’lack of liquidity for investment’ in the more general barrier ‘high costs’. Similarly, ‘lack of information on sustainability’ and ‘lack of reliable data’ were grouped together under ‘lack of reliable information’, and so on.

Finally, barriers identified in only one paper were not reported, in order to ease the interpretation of relevant results. Papers scrutinized and related findings are reported in Table 3.7.

table 3.7 - Identified barriers from reviewed papers

Document title	Authors	Year	Source	Cited by	Main Barriers Identified
An analysis of barriers affecting implementation of sustainable supply chain management in electronics industry: a Grey-DEMATEL approach	Menon, R.R., Ravi, V.	2022	Journal of Modelling in Management 17(4), pp. 1319-1350	6	Institutional deficiency Complexity in monitoring results
Studies on sustainable supply chain barriers of suppliers to the thermal power heavy industry	Kathirvel, P., Parthiban, P., Amaladhasan, S.	2019	Journal of Scientific and Industrial Research 78(6), pp. 368-372	5	High costs Lack of supporting technologies Institutional deficiency
Drivers and Barriers of Sustainable Supply Chain's Enhancement in Pharmaceutical Industry in Indonesia: A Conceptual Model	Melati, G.I., Ardi, R.	2021	ACM International Conference Proceeding Series pp. 141-148	0	Lack of sustainability education High costs Institutional deficiency Supply Chain partners deficiencies Lack of top-management commitment
Sustainable Supply Chain Management: Motivators and Barriers	Sajjad, A., Eweje, G., Tappin, D.	2015	Business Strategy and the Environment 24(7), pp. 643-655	126	Supply Chain partners deficiencies Institutional deficiency Lack of sustainability education
Analysis of Barriers in Sustainable Supply Chain Management for Indian Automobile Industries	Jamwal, A., Patidar, A., Agrawal, R., Sharma, M., Manupati, V.K.	2022	Lecture Notes in Mechanical Engineering pp. 79-89	0	High costs
Barriers to adoption of industry 4.0 and sustainability: a case study with SMEs	Kumar, S., Raut, R.D., Aktas, E., Narkhede, B.E., Gedam, V.V.	2022	International Journal of Computer Integrated Manufacturing	2	High costs Workforce deficiency

Barriers and enablers for developing sustainable supply chain at traditional Shipyards in East Java, Indonesia	Praharsi, Y., Abu Jami'in, M., Shipbuilding, G.S., Wee, H.-M.	2020	Proceedings of the International Conference on Industrial Engineering and Operations Management 0(March), pp. 1373-1380	2	Lack of reliable information High costs Complexity in monitoring results Workforce deficiency
Barriers to sustainable food consumption and production in China: A fuzzy DEMATEL analysis from a circular economy perspective	Liu, Y., Wood, L.C., Venkatesh, V.G., Zhang, A., Farooque, M.	2021	Sustainable Production and Consumption 28, pp. 1114-1129	36	Institutional deficiency Lack of sustainability education
Corporate supply chain responsibility: Drivers and barriers for sustainable food retailing	Chkanikova, O., Mont, O.	2015	Corporate Social Responsibility and Environmental Management 22(2), pp. 65-82	119	Institutional deficiency Lack of top management commitment High costs Low applicability of price premia
Supply-chain sustainability barriers: An empirical assessment	Movahedipour, M., Zeng, J., Yang, M., Wu, X.	2018	Human Systems Management 37(1), pp. 27-43	3	Lack of supporting technologies
Drivers and barriers in sustainable supply chains: The case of the Brazilian coffee industry	Guimarães, Y.M., Eustachio, J.H.P.P., Leal Filho, W., (...), do Valle, M.R., Caldana, A.C.F.	2022	Sustainable Production and Consumption 34, pp. 42-54	3	High costs Workforce deficiency Lack of top management commitment Institutional deficiency Lack of sustainability education Lack of supporting technologies
Using AHP to evaluate barriers in adopting sustainable consumption and production initiatives in a supply chain	Luthra, S., Mangla, S.K., Xu, L., Diabat, A.	2016	International Journal of Production Economics 181, pp. 342-349	172	Institutional deficiency
Analysis of barriers of sustainable supply chain management in electronics industry: An interpretive structural modelling approach	Menon, R. R., Ravi, V.	2021	Cleaner and Responsible Production 3, 100026	31	Lack of sustainability education Supply Chain partners deficiencies Institutional deficiency

Barriers to sustainable supply chain management implementation in Egyptian industries: an interpretive structural modeling (ISM) approach	Zayed, E. A., Yaseen, E. A.	2021	Management of Environmental Quality: An International Journal 32:6	21	Institutional deficiency High costs Lack of top management commitment Workforce deficiency Lack of sustinability education
Analyzing the interactions among barriers of sustainable supply chain management practices: A case study	Narayanan, A. E., Sridharan, R., Ram Kumar, P. N.	2019	Journal of Manufacturing Technology Management 30: 6, 937-971	43	Institutional deficiency Complexity in monitoring results
Managerial perspectives on drivers for and barriers to sustainable supply chain management implementation: Evidence from New Zealand	Sajjad, A., Eweje, G., Tappin, D.	2020	Business strategy and the environment 29:2, 592-604	99	High costs Institutional deficiency Supply chain partners deficiencies Low applicability of price premia
Analysis of interaction between the barriers for the implementation of sustainable supply chain management	Al Zaabi, S., Al Dhaheri, N., Diabat, A.	2013	International Journal of Advanced Manufacturing Technology	259	Lack of reliable information High costs

TABLE 3.7 - BARRIERS TO SUSTAINABLE VALUE / SUPPLY CHAIN, IDENTIFIED BY SELECTING 17 RELEVANT PAPERS FROM SCOPUS DATABASE AND GOOGLE SCHOLAR, AND LIMITING THE SEARCH TO PAPERS PUBLISHED AFTER 2010
SOURCE: OWN ELABORATION OF SCOPUS.COM DATABASE QUERY AND GOOGLE SCHOLAR SEARCH

As summed up in Figure 3.8, the most frequent factors identified as hindering the transition to sustainable value/supply chains are: institutional deficiency (that is, lack of regulation, lack of government incentives to develop sustainable practices, and absence of control authorities - recognized as a major barrier by 12 of the papers scrutinized), high costs (10 papers), lack of education concerning the need to be more sustainable and the benefits associated with the integration of sustainability into the supply chain (5 papers), supply chain partners' deficiencies (such as unwillingness or unpreparedness to collaborate - 5 papers), workforce deficiency (for example, lack of training, lack of qualified staff, reluctance to change, lack of motivation - 4 papers), complexity monitoring the outcomes of investments in sustainability (3 papers), lack of supporting technologies such as an adequate IT structure (3 papers), lack of top management commitment (3 papers) and, finally, low applicability of price premia for sustainable products (2 papers each).

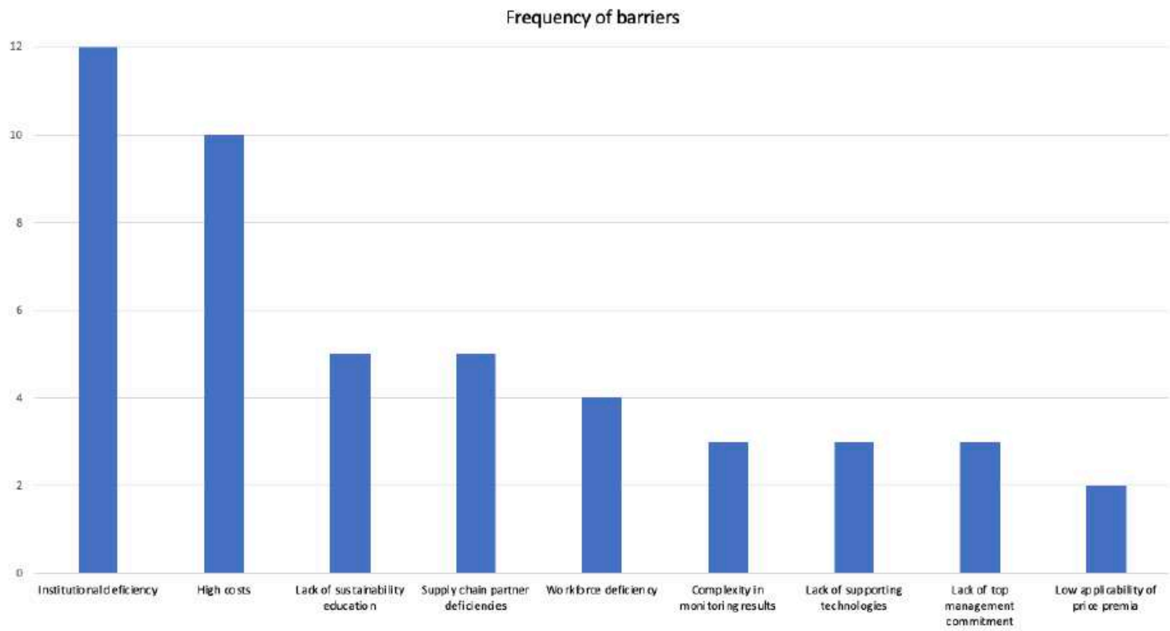

FIGURE 3.8 - ILLUSTRATION OF THE FINDINGS OF TABLE 2.11

SOURCE: OWN ELABORATION OF SCOPUS.COM DATABASE QUERY & GOOGLE SCHOLAR SEARCH

3.2.2 A further insight on key barriers

I hereby briefly discuss the four most important barriers identified: interestingly enough, institutions play a leading role among the *barriers* to integrate sustainability along value/supply chains, just as they did in *driving* it, through regulation (see p. 51). In particular, they can curb sustainable development by avoiding to regulate sustainability-related issues, by omitting to update outdated and inadequate policies,

by designing unenforceable regulations (Kelling et al., 2021) and by avoiding to provide financial incentives for sustainable investments. Also, if regulations vary widely from country to country, lead firms may find it difficult to establish universal ethical practices and standards across a multitude of suppliers along their global value chain (Seuring & Müller, 2008). And sometimes, even when collaboration among governments succeeds in developing international regulation, the industries that need it the most may remain out of their remit: for example, international shipping and aviation, which are among the most polluting industries (Colvile et al., 2001; Gössling et al., 2021), are not covered by the Paris Agreement (Henriksen & Ponte, 2018). Additionally, institutions can become entrenched in established industries and vested interests - especially with regard to those industries and companies providing high employment or high contribution to a country's GDP -, advantaging them through protective regulations, industry subsidies or other means, thereby creating inertia in making the shift towards more sustainable alternatives difficult (Acemoglu et al., 2004). For instance, large fossil fuels companies have been found to exert significant influence over regulatory bodies because of their economic relevance (Mitchell, 2012). Furthermore, as I have previously underlined (see p. 57), multi-stakeholder initiatives are emerging to address sustainability challenges: failure by institutions to collaborate and gain authority within these networks may constitute an hindrance to sustainable development.
Finally, Castaldi et al. (2023) recently theorized that local institutions attitudes can strongly influence suppliers' receptiveness of lead firms' sustainability requests.

Incorporating sustainability into supply chain operations generally entails high upfront costs in the short term (Arseculeratne & Yazdanifard, 2013). This is especially true for Small-Medium Enterprises (Hervani, et al., 2005; Revell et al., 2005). Examples of costs incurred when deploying sustainable strategies are: infrastructure investments, employee training (Delmas & Burbano, 2011), higher procurement costs for sustainable-sourcing, certification costs and short-term productivity losses during the transition to more sustainable processes. However, it's also important to note that while these costs can be significant, the long-term benefits of sustainability are generally thought to outweigh the initial investment (see, for example, Figure 3.9). In this perspective, it becomes critical - for firms that can't bear such upfront costs with available liquidity - to gain better access to finance. We will see, in the next and last chapter, how this - among other things - can be achieved by relying on Blockchain technology.

Another significant barrier to achieving sustainability in value chains is represented by lack of sustainability education, that is, the lack of awareness and appreciation of the urgency of implementing sustainable practices, as well as the non-realization of the benefits that these can bring (Kollmuss & Agyeman, 2002). This lack of comprehension - especially when largely present in society as a whole (Cortese, 2003) or when shown by key decision makers in governments or business organizations (Hopkins & McKeown, 2002; Tilbury, 2011) - can significantly slow the path towards sustainable development.

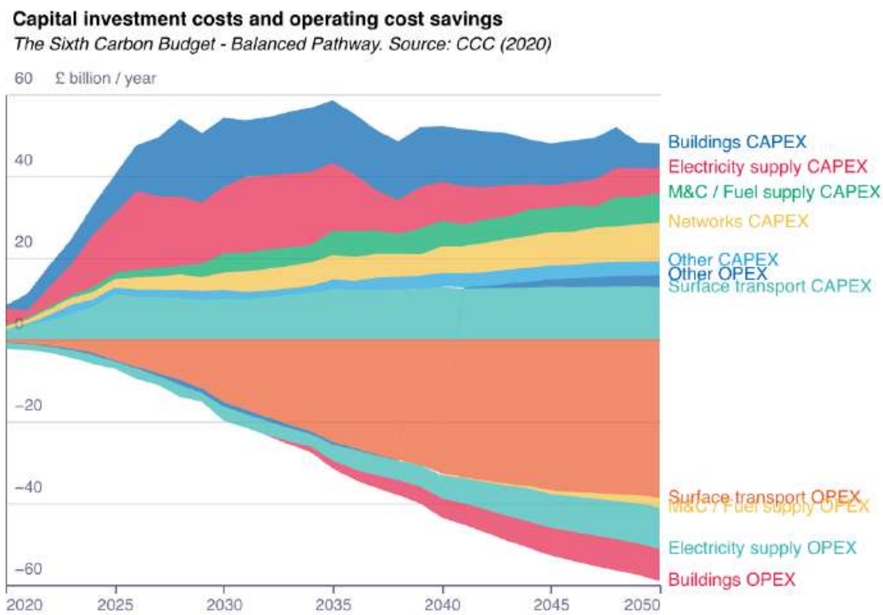

FIGURE 3.9 - LONG-TERM SAVINGS IN OPERATING EXPENDITURES OFFSET THE UPFRONT CAPITAL EXPENDITURES REQUIRED FOR UK'S NET-ZERO TRANSITION.

SOURCE: CLIMATE CHANGE COMMITTEE, SIXTH CARBON BUDGET 2020

Finally, supply chain partners' unpreparedness to participate in the transition towards a more sustainable value chain also represents a determinant barrier. As I have already stressed, in today's world, competition is not among single firms anymore but, rather, among value chains; moreover, lead firms need to extend their span of attention and accountability not only to their in-house functions, but they have to reach as far as to the operations of first-tier and second-tier suppliers, in order to avoid reputational risks related to possible degrading practices perpetrated by such actors (see p. 26). Thus, it is straightforward that one weak link in the chain may spoil the other participants' efforts concerning sustainable practices.

Chapter 4

Tools for sustainability in GVCs: Industry 4.0 technologies

Having delved into the intricacies of current Global Value Chains and of pressing sustainability concerns in the preceding three chapters, this thesis now ventures into a cross-section of technology and sustainability, where potential solutions to some of the challenges identified may reside. Thus, these fourth and fifth chapters will deal with *how* Sustainability can be fostered along GVCs: i.e., on the 'tools' that can aid support to pressing global challenges. The reader, anyhow, must keep in mind that the journey towards global Sustainability is a complex one, with an array of tools available to policy-makers, firms and individuals.

As technology continues to evolve, it wields an increasing influence on sustainability initiatives: these last chapters seek to thoroughly investigate, in particular, the potential of Industry 4.0 technologies and of one specific of such advancements - Blockchain - to act as catalyst for positive change.

Broadly, systematic reviews collect, analyze and synthesize existing research in a more or less systematic way, in order to shed light on a particular research topic (Snyder, 2019).

Following Snyder's (2019) suggestions on the choice of a literature review method, the 4th and 5th chapter will follow a semi-structured approach. Several factors came into consideration for this decision: first of all, this method affords a higher degree of flexibility compared to other review types, such as systematic reviews. This method allowed me to maintain a core guiding research question ('How can Industry 4.0 and blockchains foster sustainability in Global Value Chains'?), while retaining the flexibility to explore emergent themes, ideas, and connections that might not be captured in a strictly structured review. This approach is particularly suited in light of the complex and emerging nature of the research topic. Second, the semi-structured approach allows to include a broader range of literature, including practical case studies, providing a more inclusive and comprehensive perspective. This was deemed important in capturing the full breadth of the topic under study and minimizing the risk of potential bias inherent in excluding certain types of sources.

Third, given the interdisciplinary nature of the research topic, a semi-structured review was more appropriate as it allowed for the inclusion of diverse sources across different fields of study, such as information technology, social sciences or agricultural studies. A more structured approach could have potentially narrowed the focus and overlooked valuable insights from various disciplines.
Finally, this method allowed for ongoing reflection and refinement of the research questions and focus. This is central to robust research practice, and particularly so in areas that are emergent or rapidly evolving (Mauthner & Doucet, 2003), such as that of Industry 4.0 technologies and blockchain.

4.1 A taxonomy of 'tools' for Sustainability

There are manyfold concepts that can be categorized as 'tools' in the fight against global issues such as climate change or social inequality and, hence, it is indeed impossible to give an overview of all the strategies, methods, practices, technologies and policies that are, in some way, suited to improve global sustainability.
The actors that can incentivize or directly resort to such tools, moreover, are themselves of various kind: private organizations, policy-makers, NGOs (non-governmental organizations), MSIs (multi-stakeholder initiatives), and many others.

Thus, depending on the focus of research, level of analysis and background of expertise, many scholars have provided different point of views on the matter.
Some have stressed the importance of relying on new production and consumption paradigms. Skawinska & Zalewski (2018), for example, argued that circular economy (CE; Figure 4.1) may be the most appropriate concept to support Sustainable Development. It addresses problems such as the lack of resources and waste management (p. 20) by reducing the use of virgin materials and increasing, instead, the circulation of resources within value chains (Genovese et al., 2017).

Therefore, CE is certainly a promising approach to enhance the sustainability of GVCs by redefining traditional linear production models. By promoting resource efficiency, waste reduction, and product lifecycle extension, its principles encourage companies to design and manage their GVCs more sustainably (Geissdoerfer et al., 2017). On this matter, the Ellen MacArthur Foundation's Circular Design Guide provides a framework for companies to develop products and services that minimize waste and pollution, maximize the use of renewable resources, and increase the value of products through reuse and recycling (Ellen MacArthur Foundation, 2023).

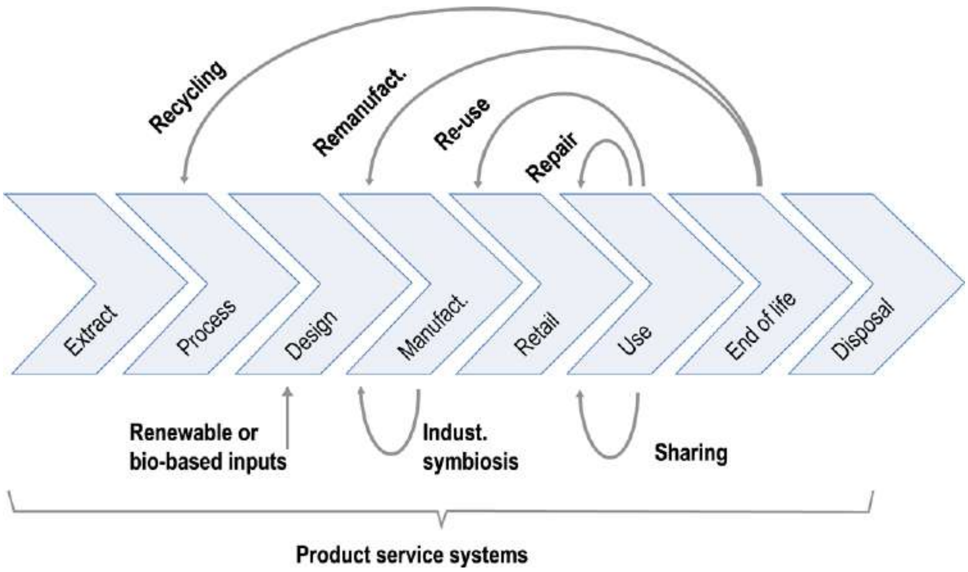

FIGURE 4.1 - CIRCULAR ECONOMY BUSINESS MODEL
SOURCE: OECD.ORG

However, CE has a predominant environmental focus. On the other hand, SD necessarily encompasses all three dimensions of sustainability, as already illustrated in this work (see chapters 1 and 2). This is also testified by the United Nations Sustainable Development Goals (SDGs), themselves considerable as 'tools' for Sustainability and, more exactly, as policy-making tools: part of the 2030 Agenda for Sustainable Development, they are a set of 17 interconnected objectives, conceived as a 'shared blueprint for peace and prosperity for people and the planet' (United Nations, 2015). Among these, as is illustrated by Figure 4.2, all the three dimensions of sustainability are represented and, more precisely, they are somehow even extended to five, i.e, people, planet, prosperity, peace and partnership (Sam, 2016; Tremblay et al., 2020; Urata et al., 2023).

FIGURE 4.2 - THE 2030 AGENDA'S SUSTAINABLE DEVELOPMENT GOALS
SOURCE: UN.ORG

The SDGs have often been adopted in literature as a benchmark for evaluating sustainability impact potential of specific tools, technologies, practices or trends. For example, they have been studied, with this purpose, in association with multi-stakeholder initiatives (Fowler & Biekart, 2017; MacDonald et al., 2018; Eweje et al., 2021), reverse logistics (Braga Jr et al., 2023; Butt et al., 2023), eco-design (Lozano Rivas et al., 2023), 3D printing (Caldona et al., 2022; Alami et al., 2023), artificial intelligence (Vinuesa et al., 2020; Di Vaio et al., 2020; Palomares et al., 2021; Visvizi, 2022), Cloud Computing (Li et al., 2020; Wu et al., 2020), Internet of Things (López-Vargas, 2020; Verdejo Espinosa et al., 2021), and Blockchain (Kewell et al., 2017; Adams et al., 2018; Kim & Huh, 2020; Aysan et al., 2021; Tsolakis et al., 2021; Parmentola et al., 2022; Chandan et al., 2023).

On this very last mentioned technology I will deepen, on the 5th and last chapter of this thesis, evaluating it as a tool to drive sustainability along global value chains, also in light of its applicability to each of the three pillars of SD (Rana et al., 2019; Park & Li, 2021; Munir et al., 2022).

However, before doing so, I will first introduce the concept of the Fourth Industrial Revolution and of related Industry 4.0 technologies - which Blockchain is part of - in this chapter. In particular, I will deepen on how they are are fitted to impact Global Value Chains and Sustainability aspects.

4.2 Brief history of industrial revolutions

Among scholars and practitioners, there is wide consensus that four major shifts can be recognized throughout the history of industrial production, the latter being the ongoing 'Industry 4.0' transformation (Qin et al., 2016), also referred to as 4IR or Fourth Industrial Revolution.

The First Industrial Revolution, which took place from the late 18th century to the early 19th century, was characterized by the transition from manual labor to mechanized manufacturing. Key technologies such as the steam engine, the spinning jenny, and the power loom revolutionized the textile industry, marking a shift from an agrarian economy to an industrial one. This period also saw the emergence of distinct working and middle classes, laying the groundwork for the modern capitalist economy (Hobsbawm, 1962; Hudson, 1992).

The Second Industrial Revolution, spanning the late 19th century to the early 20th century, was marked by the widespread use of electricity and the development of new industries such as steel, oil, and chemicals. Innovations like the telephone, the light bulb, and the internal combustion engine were key during this period. The Second Industrial Revolution also saw the rise of large-scale industrial production and the growth of global markets, facilitated by advancements in transportation and communication technologies (Chandler, 1990).

The Third Industrial Revolution, also known as the Digital Revolution, began in the mid-20th century. This period is characterized by the transition from analog and mechanical devices to digital technology. Developments such as the invention of the transistor, the microprocessor, and the internet revolutionized communication, information processing, and commerce. The Third Industrial Revolution has also brought about significant social and economic changes, with the rise of the information economy, the growth of service industries, the increasing importance of knowledge and information as economic resources, and the dispersion of production activities in scattered Global Value Chains (Castells, 2000; also, see first chapter of this thesis).

4.3 Industry 4.0

It is considered the next phase in the digitization of industrial operations (McKinsey, 2022), set to drastically impact GVCs by improving production flexibility, efficiency and productivity (Rüßmann et al., 2015; Ibarra et al., 2018). Its transformative potential is connected to the deep change in the manufacturing systems connectivity thanks to the integration of ICT, IoT and tangible production assets in cyber-physical systems at the business ecosystem level (Schwab, 2016). In particular, it allows a horizontal and vertical connection among 'smart' factories (Kagermann & Wahlster, 2013). This shift enables collaborative and distributed production, interoperability among devices and machines, decentralized decision-making and the supply of customized products (Hermann et al., 2016; Smit et al., 2016; Wang et al., 2017), ultimately opening to the

possibility of a ‘zero’ marginal cost production paradigm (Brettel et al., 2014; Rifkin, 2015).
Industry 4.0 technologies include, but are not limited to, digital innovations such as internet of things (IoT), additive manufacturing, artificial intelligence (AI), big data, cloud computing, blockchain, augmented / virtual / mixed reality, and cybersecurity, coupled with other physical technological advances such as robotics, smart sensors, RFID technologies and others (Dalenogare et al., 2018; Chun et al., 2019; Peres et al., 2020; Dal Mas et al., 2023).

The locution, later popularized by World Economic Forum chairman Klaus Schwab in 2015, was first introduced in 2011 by a German working group of scientists, appointed by the government to develop a national high-tech manufacturing strategy (Kagermann et al., 2013; Reischauer, 2018). It was coined referring to the potential disruption, made possible by the aforementioned set of emerging technologies, that was comparable in magnitude to that triggered by the introduction of steam-powered mechanization, electricity and information and communication technologies (respectively 1st, 2nd and 3rd Industrial Revolution). The expression has subsequently been borrowed by other EU governments and EU institutions to describe public policies aimed at fostering the digitalization of European SMEs (Probst et al., 2018).

It is interesting to note, as I have highlighted in the first chapter, that the Third Industrial Revolution gave rise to the current geography of dispersed GVCs by supporting organizations in dealing with large distances and high complexity: thus, its main effect on GVCs was the dispersion of business activities. On the contrary, the outcomes of the Fourth Industrial seem to be potentially the opposite: in particular many scholars claim that, by reducing the significance of low labour cost and other arbitrage strategies, it can encourage phenomenons of back-shoring and localization of production (Baldwin, 2016; Fratocchi, 2017; Müller et al., 2017; Rehnberg & Ponte, 2018; Fratocchi & Di Stefano, 2020; Krenz et al., 2021). The relevance of these dynamics has been recognized to the extent that some identify the global value chain as the main focus of the 4IR (Rodrigue, 2020).

In light of the dramatic increase in interest shown by scholars on the matter (Figure 4.3), a clear-cut definition of Industry 4.0 would be expected. However, on the contrary, a large majority of publications omit to explicitly conceptualize the phenomenon (Culot et al., 2020).

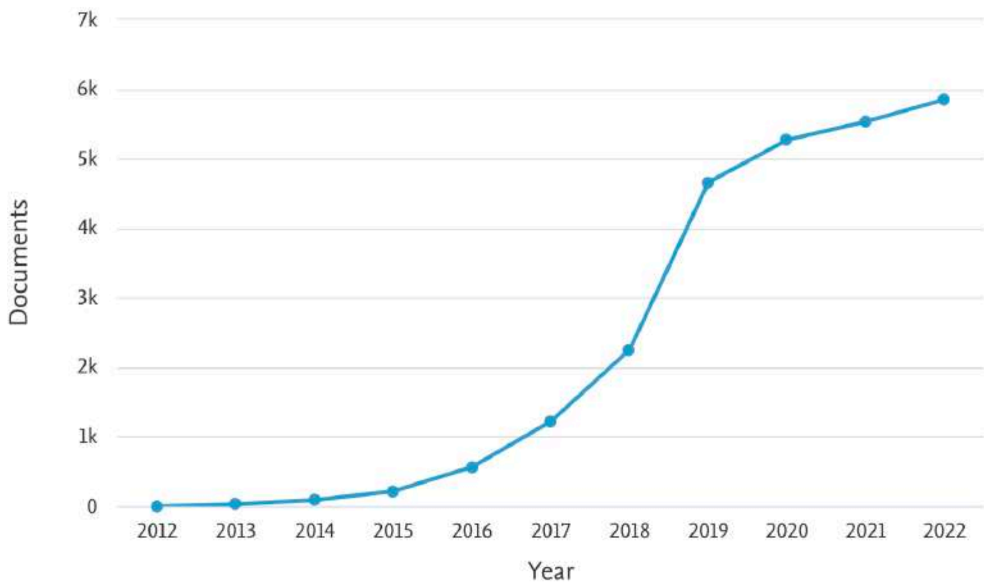

FIGURE 4.3 - PUBLICATIONS ON 'INDUSTRY 4.0' (IN EITHER THE TITLE, ABSTRACT OR KEYWORDS) IN SCOPUS DATABASE, 2012-2022
SOURCE: SCOPUS.COM

Adding uncertainty on the matter, it has to be noted that the concept of Industry 4.0 is also frequently used interchangeably with overlapping ideas such as 'smart manufacturing' (e.g., Radziwon et al., 2014) or 'digital transformation' (e.g., Suleiman et al., 2022).
Finally, there is not universal consensus on which technologies are to be included among the enablers for Industry 4.0 (Figure 4.4).

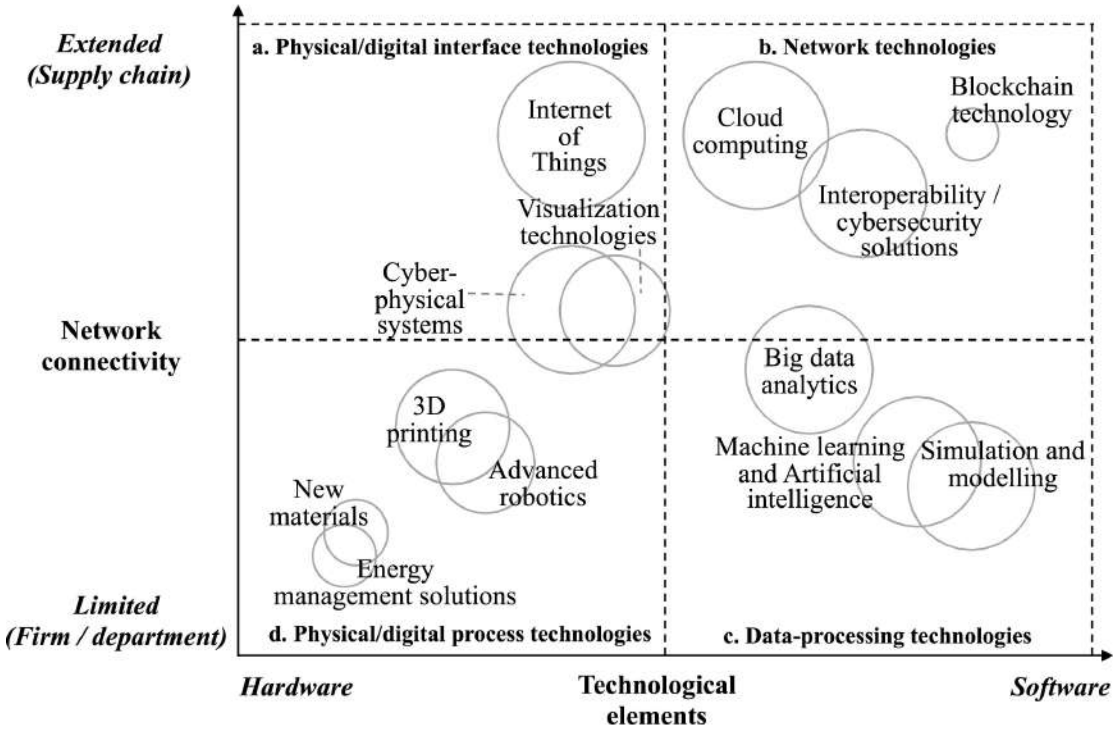

FIGURE 4.4 - KEY ENABLING TECHNOLOGIES (BUBBLE SIZE IS PROPORTIONAL TO THE NUMBER OF OCCURRENCES IN INDUSTRY 4.0-RELATED PUBLICATIONS EXAMINED)
SOURCE: CULOT ET AL., 2020

Although such technologies are still years away from reaching widespread adoption, some of their effects are already tangible. For example, in a period when traditional globalization metrics - i.e., trade and FDI - are trudging (e.g., see p. 13), Greenberg et al. (2017) report that cross-border data flows are, on the other hand, skyrocketing, with growth rates that outpace by fifty times those of the last decade.

4.3.1 Environmental and Social impacts

While the previous three industrial revolutions carried significant improvements in firms' productivity, the dark side that tacked together all the three of them was the ignorance of their social and environmental dimensions.

On the other hand AI, robotics, and other 4.0 technologies have been recognized to hold significant potential to act as catalysts for Sustainable Development by tackling various environmental and social aspects, such as easing the physically strenuous work (Pfeiffer & Suphan, 2015; Stock & Seliger, 2016; Husain, 2017; McAfee & Brynjolfsson, 2017; Morrar et al., 2017; Schwab, 2016; Müller et al., 2018; Bai et al., 2020; Margherita & Braccini, 2021; Hassoun et al., 2022).

Notably, AI and IoT can optimize the use of resources in production processes, reducing waste and minimizing environmental impact. For instance, AI can analyze vast amounts of data to predict demand more accurately, enabling companies to produce exactly what is needed, when it is needed, thereby reducing overproduction and waste. Similarly, IoT devices can monitor and control the use of energy, water, and other resources or possible leakages in real-time, leading to significant efficiency gains (Thoben et al., 2017).

Furthermore, leveraging these technologies can enhance the resilience of GVCs. Advanced robotics and automation can reduce reliance on human labor, making the seamlessness of production processes less vulnerable to disruptions such as those caused by pandemics or natural disasters.

However, the effectiveness of the integration of Industry 4.0 technologies in business operations is not straightforward. It requires, in fact, an organization- or even value chain-wide transformation (Schneider, 2018; Sony & Naik, 2020), that includes the development of new skills across the workforce (Liboni et al., 2019; Pejic-Bach et al., 2020) and new buyers-suppliers collaboration paradigms (Patrucco et al., 2022; Schmidt et al., 2022), often extending as far as to the development of new business models. Most notably, they open up the possibility to offer internet-based services linked to the products sold (so-called 'servitization'; Coreynen et al., 2017; Frank et al., 2019; Marcon et al., 2022).

Servitization, according to some, represent a forced shift in the way value added is generated: since it doesn't require further direct materials to generate additional cash flows, it may be fit to permeate a future that, most probably, will be characterized by a lack of natural material resources (Annarelli et al., 2016; Siagri, 2021). Furthermore, the shift to automation and additive manufacturing and the recirculation of products enabled by circular business models may lead to job losses in traditional manufacturing: in this respect, servitization-generated jobs can compensate for such jobs losses (Mont, 2002; Baines et al., 2007). Still, overall, the fourth industrial revolution is likely to push large groups of 'low-skilled' workers off employment (Hirsch-Kreinsen, 2014; Bonekamp & Sure, 2015): hence, some authors have highlighted the need to introduce some form of basic income provision (Bregman, 2017; Saha, 2022). Furthermore, additional provisions may also be needed due to rising concerns about the privacy of individuals (Strange & Zucchella, 2017).
While posing several works at risk, at the same time, smart manufacturing systems may lead to significant improvements in the health and safety of employees by automating monotonous and arduous operations, thus increasing job quality (Asokan et al., 2022).

The flip side of the coin is that, while production increasingly becomes more capital- and less labor-intensive, the comparative advantage (Ricardo, 1817) of developing countries - i.e., low-skilled, low-cost manufacturing - results threatened because of such technological advancements (Javaid et al., 2022).

As a result, automated manufacturing along with telepresence technologies may enable backshoring dynamics (Baldwin, 2016; Fratocchi, 2017; Müller et al., 2017; Rehnberg & Ponte, 2017; Aqlan et al., 2019; Dachs et al., 2019; Fratocchi & Di Stefano, 2020). One interesting case study is represented by the athletic apparel and footwear colossus Adidas. The german multinational has started moving part of their sneakers production activities back to their home country in 2017, and this was possible mainly thanks to extensive investments in smart manufacturing technologies such as robotics and additive manufacturing (The Economist, 2017).

These possible reshoring dynamics can be particularly impactful on the sustainability of GVCs. In particular, by shortening value chains, they reduce also, by reflex, carbon emissions related to transportation and lead times, which in turn reduces the need for larger inventories and waste due to overproduction.

On a last note, it must be pointed out that firms participating in GVCs are more likely to integrate industry 4.0 technologies in their operations, thus confirming once again the role of GVCs as propellent for industrial and sustainable trends (Delera et al., 2022).

4.3.2 Impacts on value distribution & graphical summing-up

In chapter 1, I highlighted how value gets disproportionally captured by firms engaging in activities at the two ends of the value chain and with high intangible assets intensity. But the adoption of industry 4.0 technologies may bear significant impacts on the dynamics of value capture along the chain, thus potentially reshaping the classical trajectory of the so-called 'smile curve'. In particular, I have underlined in subsection 4.3.1 how it improves manufacturing efficiency and productivity (see, for example, Rüßmann et al., 2015; Ibarra et al., 2018). By doing so, it increases the value added in the production stages of the value chain.

Integrating this observation with those illustrated in paragraph 4.3.1, I build on Figure 1.13 (p. 29) - which I report in the next page to ease the comparison, - to graphically show the potential impacts of industry 4.0 technologies in global value chains (Figure 2.5).

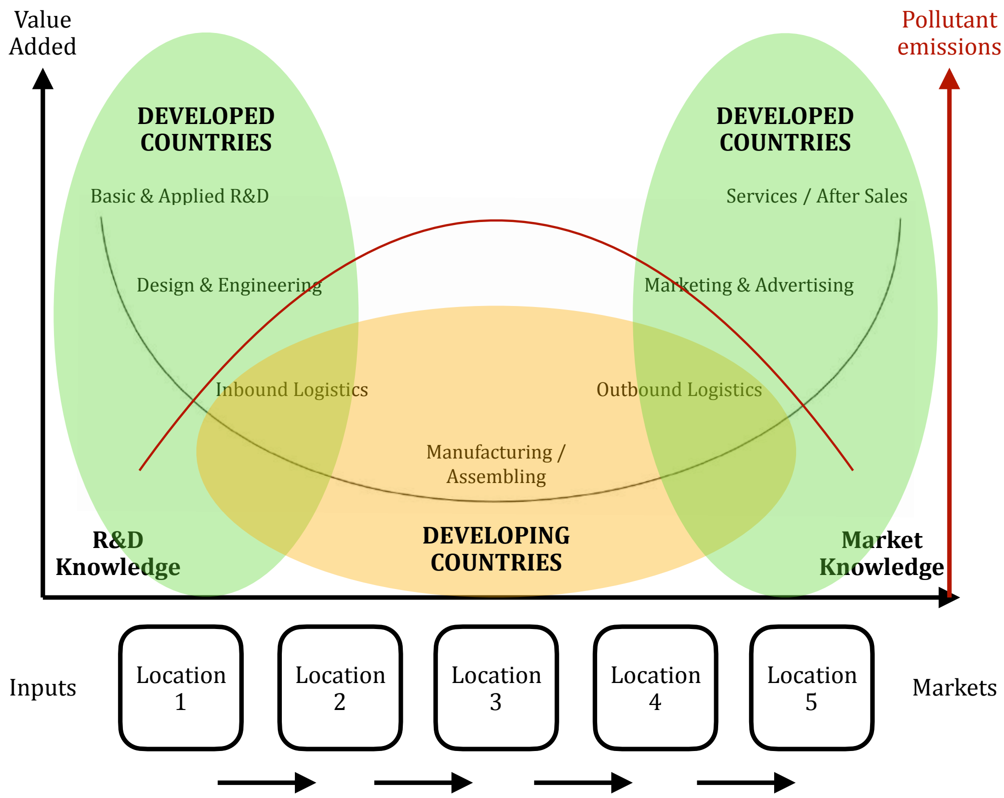

FIGURE 1.13 - STAN SHIH'S SMILE CURVE AND POLLUTING EMISSIONS

SOURCE: OWN ELABORATION BASED ON MUDAMBI, 2007 AND ZHANG & LIU, 2023.

In particular, Figure 2.5 highlights how the curve of value added results flattened in light of the higher value added during the production stage and how the polluting intensity across the various stages flattens as well, thanks to higher productivity, enhanced energy efficiency, reduced overproduction and better waste management during production activities. Also, please note that Figure 2.5, differently from Figure 1.13, doesn't capture the dichotomy between developed and developing countries along the stages of the value chain: this is because the adoption of Industry 4.0 technologies reduces the comparative advantage of developing countries in low-skilled, low-cost labor, and the reshoring dynamics illustrated in the previous subsection may re-localize production in developed countries, thus blurring the geographical boundaries of value capture along the chain; finally, in addition to the flattening of the two curves represented, it illustrates that Industry 4.0 technologies may also 'stretch' the curve of value added by creating new stages of value-add. For example, data generated by smart and connected products may enable new services and business models, adding a new peak to the curve (right-end of the smile curve in Figure 2.5).

Still, it must be kept in mind that these graphical illustrations have the sole objective of presenting the directions of the likely impacts of Industry 4.0 technologies. To more precisely quantify such outcomes, further research is needed.

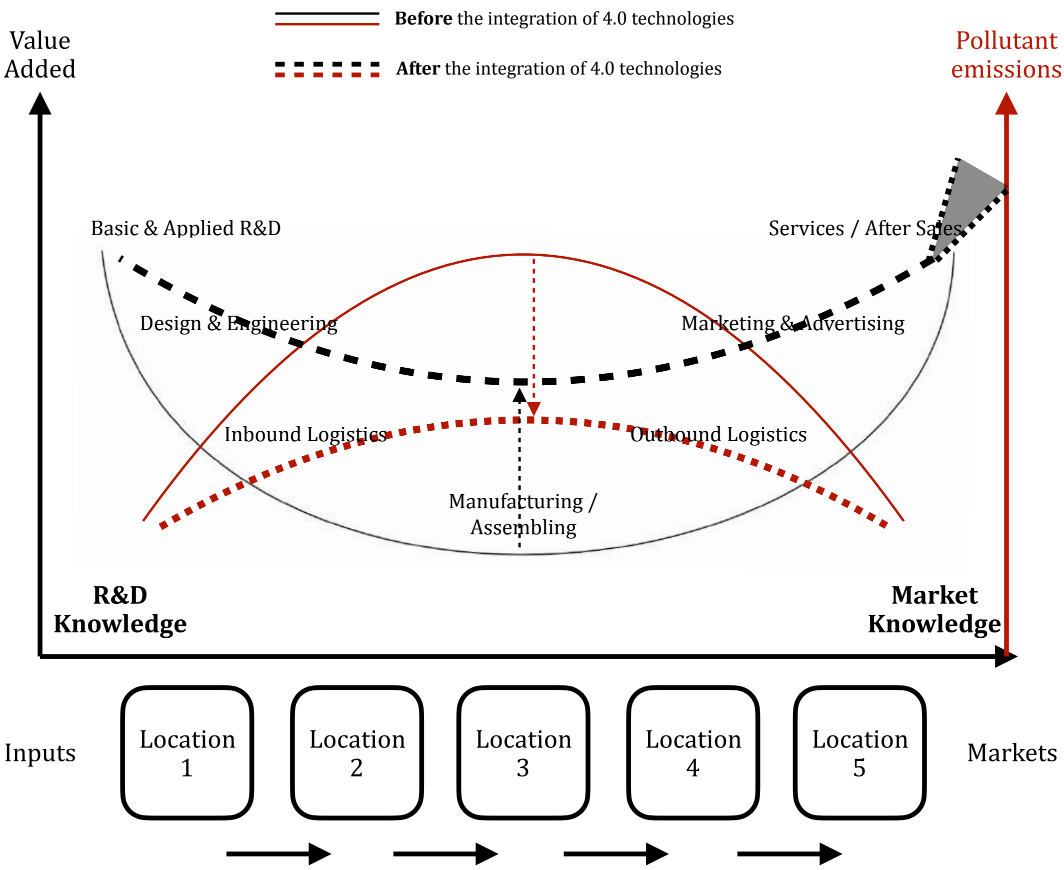

FIGURE 4.5 - THE IMPACT OF INDUSTRY 4.0 TECHNOLOGIES

SOURCE: OWN ELABORATION

As a further consideration, the integration of Industry 4.0 technologies shifts the manufacturing activities from being labour-intensive to capital-intensive, since it reduces the need for human labor but requires large upfront investments. Thus, the cost structure becomes much more skewed towards fixed costs (so-called 'operating leverage'). As shown in Figure 4.6, this entails higher margins when firms are able to reach higher volumes.

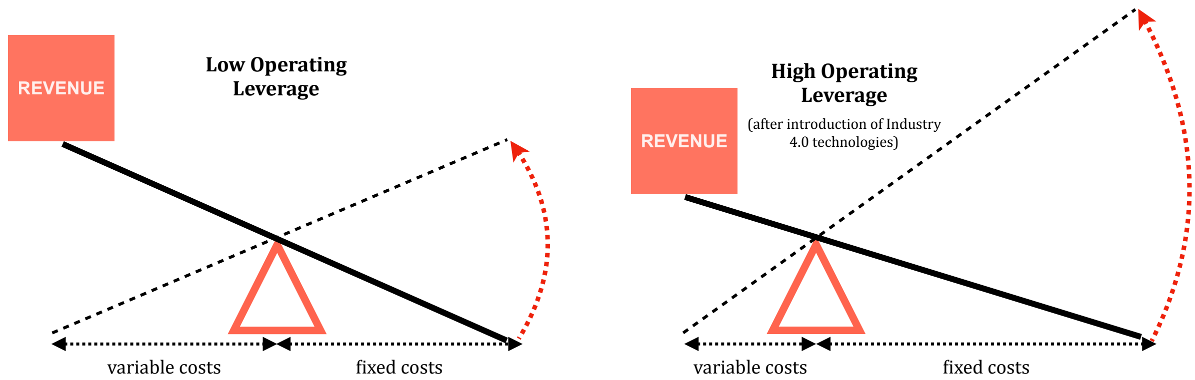

FIGURE 4.6 - INDUSTRY 4.0 TECHNOLOGIES AND OPERATING LEVERAGE

SOURCE: OWN ELABORATION

As a result, I argue that industrial re-organizations may be hypothesized in value chains that intensively adopt Industry 4.0 technologies: in particular, I find two possible scenarios particularly likely:

A) in value chains where lead firms don't have a disproportional power over their suppliers (modular, relational), there may be a consolidation of manyfold manufacture suppliers into bigger 'hub' suppliers (to satisfy the aforementioned economies of scale). In this regard, suppliers that are ready to bear industry 4.0 CapEx sooner than the others may reap very large market shares. This is supported also by the flexibility of production enabled by Industry 4.0 technologies: while human workers have to be trained for specific tasks to improve their efficiency, on the other hand robots and 3D printers can be used for the production of multiple goods without incurring in significant productivity losses, thus enabling digitized suppliers to simultaneously serve multiple value chains to better recover the CapEx incurred;
B) in value chains were lead firms do have disproportionate power (captive value chains), they may be prompted by the opportunities of higher value capture

brought by industry 4.0 technologies in the manufacturing stage, and by worries that suppliers may gain excessive bargaining power, to vertically integrate and englobe such stages of value-add in their in-house activities.

It's important to note, although, that these are just two possible outcomes and that the actual impacts will likely vary across regions, industries, and companies, depending on several factors such as the nature of the product or service, the competitive landscape, the institutional environment, the financial and bargaining strength of firms, and many others.

Seen the potential of Industry 4.0 technologies in general, in the next chapter I will deepen into a specific one of these advancements, i.e. Blockchain, highlighting potential applications of this tool that can help make Global Value Chains more sustainable.

Chapter 5

Fostering positive change through Blockchain technology

Various technological innovations have been mobilized in the quest for Sustainable Development in the recent history, with applications ranging from simple increases in resource efficiency (De Marchi, 2012) to the creation of whole new business models such as the so-called sharing economy and collaborative consumption enabled by platform technologies (Botsman & Rogers, 2010).

One of such technological innovation, Blockchain, holds various applications in support of Sustainable Development Goals (see, for example, Adams et al., 2017; Parmentola et al., 2022; Chandan et al., 2023) and will be the focus of this fifth and last chapter.
Some experts state that its impact may be as disruptive as that of the World Wide Web (Mougayar, 2016; Ito et al., 2017; JPMorgan Chase & Co., 2023).
But before diving deep into how Blockchain can enhance sustainability in GVCs, I will trace a brief overview of its history and introduce the key aspects of this technology.

5.1 Evolution of blockchain and related literature

The concept behind blockchain technology can be traced back as far as to 1991, when two American research scientists described, for the first time, a mechanism to create digital time stamps, in order for them to be impossible to be backdated, postdated or manipulated. In practice, they suggested the first cryptographically secured 'chain of blocks' (Haber & Stornetta, 1991).

Later on, in 2008, this concept was integrated with other computing concepts by a developer (or group of developers), under the pseudonym of Satoshi Nakamoto, to create the first cryptocurrency: Bitcoin (Nakamoto, 2008). In the related white paper, 'Bitcoin: A Peer-to-Peer Electronic Cash System', Haber & Stornetta were the most cited auhors, with three references out of a total of nine (Nakamoto, 2008).

Bitcoin was the first as well as the most well-known cryptocurrency, but today the number of such digital assets have grown exponentially: as of May 2023, according to Coinmarketcap.com, there are 10,144 active cryptocurrencies, with a total market cap of around 1,1 trillion of dollars. To put things in perspective, that is equivalent to Amazon's market capitalization as of May 2023 and bigger than the GDP of countries like Netherlands, Saudi Arabia, Turkey & Switzerland.

Since the introduction of the first cryptocurrencies, the popularity of Blockchain has risen exponentially, as testified also by the trends in related research publications (Figure 5.1).

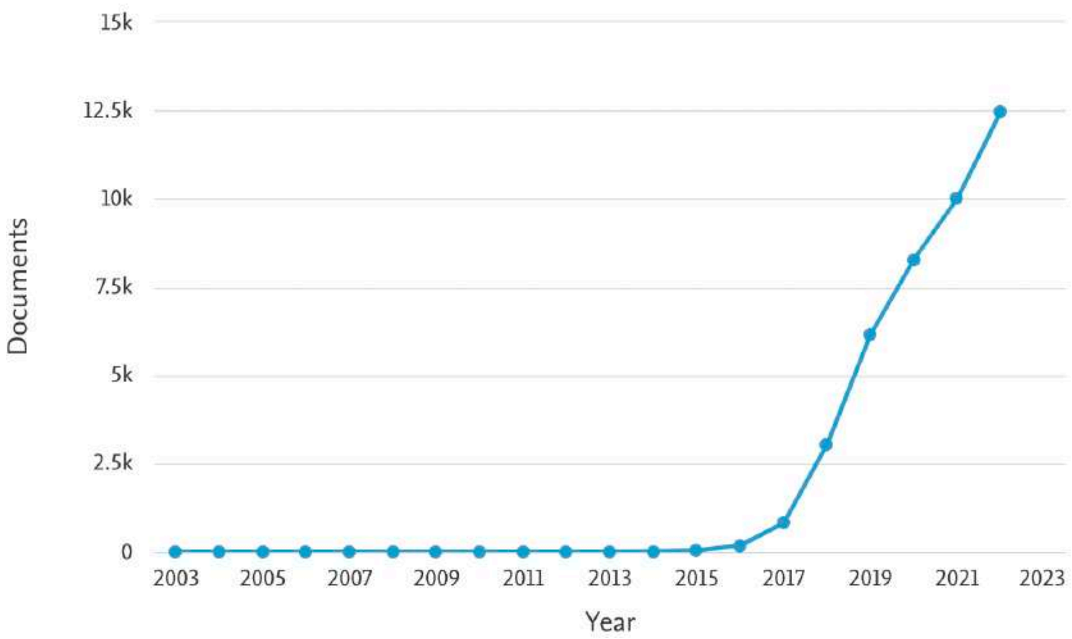

FIGURE 5.1 - PUBLICATIONS ON 'BLOCKCHAIN' (IN EITHER THE TITLE, ABSTRACT OR KEYWORDS) IN SCOPUS DATABASE, 2003-2022
SOURCE: SCOPUS.COM

For the objective of this thesis, which seeks potential applications of Blockchain outside the scope of the 'classical' digital currency exchange, it is crucial to shed light on the evolution of this technology and of its applications. To do so, it is possible to examine the shifts in research themes over time. Thus, an analysis based on an objective literature review of the 1000 oldest and 1000 newest papers concerning blockchain technology, retrieved from the Web of Science database, was performed. By examining the most popular keywords in these two strands of literature, it is possible to can gain insights into how the focus of blockchain research has changed over time.

The objective literature review was conducted using a keyword analysis methodology. This approach involves identifying and analyzing the frequency of keywords in the selected papers to determine the main themes and topics of interest. The keywords serve as a proxy for the main themes and topics that have dominated the blockchain discourse at different points in time.
The analysis was performed in two stages. First, the 1000 oldest papers on blockchain were analyzed to identify the initial themes that characterized the early stages of blockchain research. This was followed by a similar analysis of the 1000 newest papers to identify the current and emerging themes in blockchain research.

This approach provides a lens through which we can observe the maturation of blockchain technology, from its initial conceptualization and technical development to its current and potential applications in various sectors. It also allows us to identify trends and shifts in the focus of blockchain research, providing insights into the trajectory of blockchain technology and its potential future directions.

In Figure 5.2 (1000 oldest papers) and in Figure 5.3 (1000 newest papers), the most recurrent keywords are illustrated. Hereby the key take-aways of this analysis are illustrated.

First of all, Blockchain gained importance as a central topic of research: in the 1000 oldest papers mentioning ‘Blockchain’, only 257 reported it as a keyword; on the most recent 1000, on the other hand, that number grew to 303.

Secondly, Bitcoin has lost its centrality in Blockchain research: it was a keyword in 71 of the oldest papers analyzed, but only in 8 of the most recent. In this regard, research on Blockchain seems to have opened to new and diverse applications diverging from cryptocurrencies: for example, a new strand of literature has focused on potential impacts on the Supply chain, which was a keyword in 31 of the newest papers.

As a third takeaway of this analysis, it was possible to notice that Blockchain technology is often studied in association with other 4.0 advancements, such as IoT (27 times a keyword in oldest papers and 37 times in the newest publications) and Artificial Intelligence (reported 8 times as a keyword in newest papers).

Another interesting aspect to note, within the scope of this thesis, is that in the fifty most frequent keywords in recent papers, many sustainability themes recurred: for example, 'resource management', 'climate change', 'circular economy', 'sharing economy', 'sustainability', and 'energy trading' (2 occurrences each).

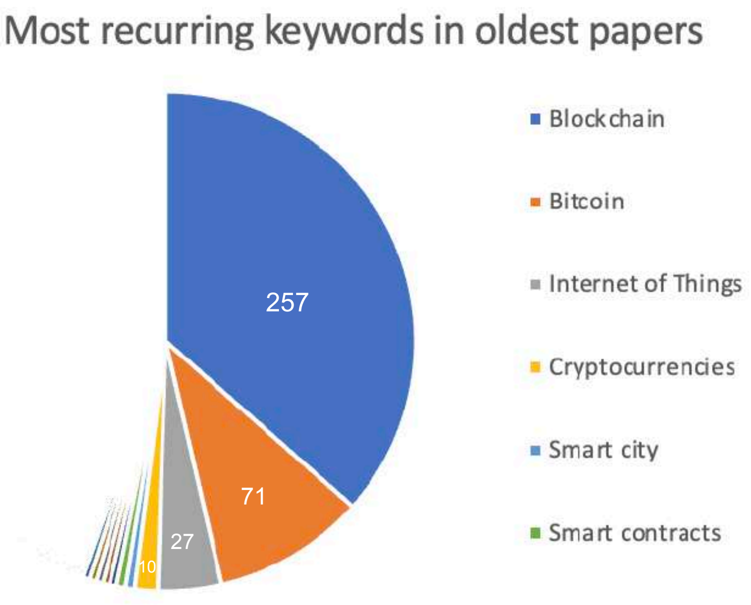

FIGURE 5.2 - MOST RECURRING KEYWORDS IN THE 1000 OLDEST PAPERS MENTIONING 'BLOCKCHAIN'
SOURCE: OWN ELABORATION OF DATA FROM WEBOFSCIENCE.COM

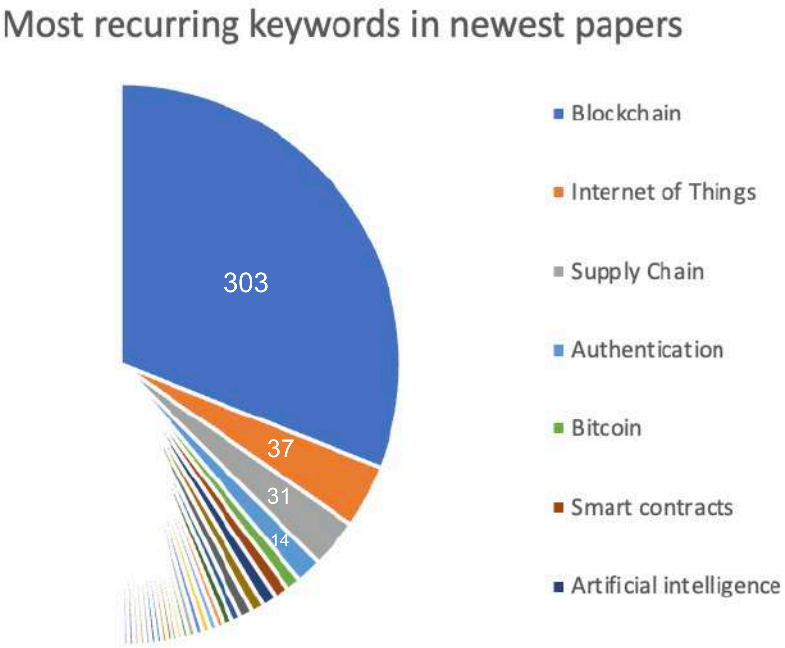

FIGURE 5.3 - MOST RECURRING KEYWORDS IN THE 1000 NEWEST PAPERS MENTIONING 'BLOCKCHAIN'
SOURCE: OWN ELABORATION OF DATA FROM WEBOFSCIENCE.COM

The progressive departure from Bitcoin as the central focus of Blockchain research - and the corresponding opening to other applications - is also confirmed by the generally accepted classification of the history of such technology, which can be divided into three main phases (Swan, 2015; Xu et al., 2019; Hsieh, 2021). In particular, Blockchain 1.0 came with the introduction of Bitcoin and thus regarded currency transfer and digital payments. Later on, the introduction of Ethereum in 2014 (Buterin, 2014) and, with it, the introduction of smart contracts, signs the beginning of Blockchain 2.0: in this phase, the applications of blockchain extend to transfer of various assets other than currency. Finally, Blockchain 3.0 is currently ongoing and enables all the features related to blockchain's trustless decentralization - e.g., absence of intermediaries, transparency, non-manipulability, openness, and accuracy (Xu et al., 2019; Secinaro et al., 2021) -, to be exploited by other systems such as companies, supply chains, and many others. This last phase offers several next-level use case, often with the simultaneous integration of different industry 4.0 technologies. For instance, applications can range from predictive task automation and IP protection as far as to 'personal thinking blockchain', i.e., where a person's thoughts and memories are stored in a blockchain for post-stroke memory restoration (Swan, 2015).

Furthermore, the peculiarities of blockchain have stem research interest from the most disparate backgrounds: for instance, potential applications of Blockchain have been discussed in relation to accounting (e.g., Spanò et al., 2022), agriculture (e.g., Dey & Shekhawat, 2021), art (e.g., Whitaker, 2019), education (e.g., Sousa et al., 2022), healthcare (e.g., Massaro, 2021), voting systems (e.g., Wang et al., 2018) and many other fields.

Figure 5.4 shows the diversity of research areas of papers concerning blockchain in Scopus database.

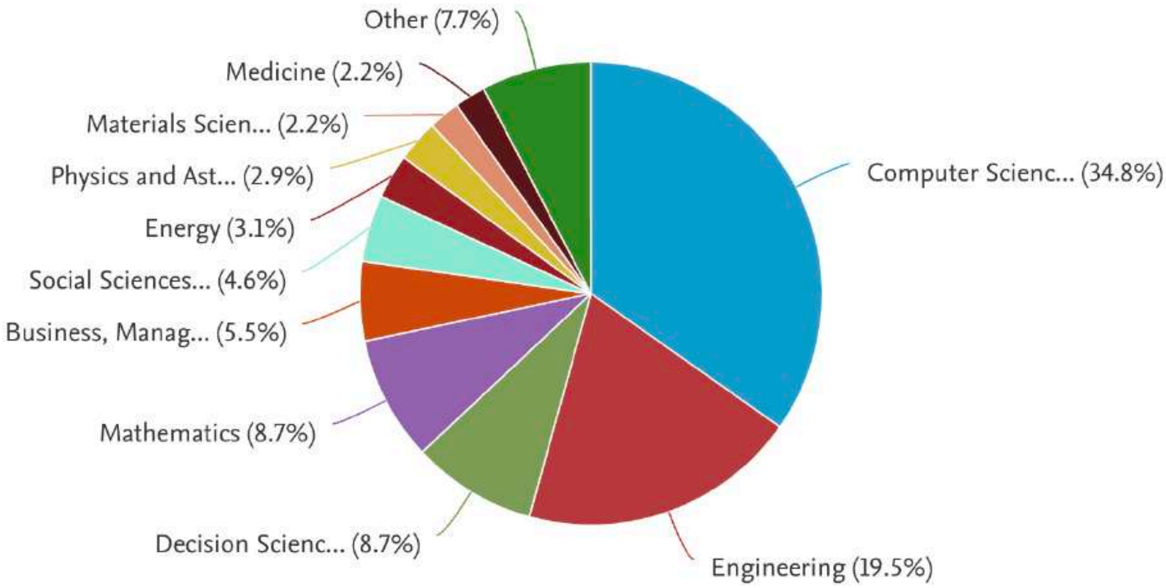

FIGURE 5.4 - RESEARCH AREAS OF PUBLICATIONS ON 'BLOCKCHAIN' (IN EITHER THE TITLE, ABSTRACT OR KEYWORDS) IN SCOPUS DATABASE, 2003-2022
SOURCE: SCOPUS.COM

5.2 Brief overview of the functioning

A Blockchain operates as a decentralized and distributed ledger system, as illustrated in Figure 5.5. It enables peer-to-peer transactions across multiple nodes of a computer network, and records these in a verifiable and permanent way, without the need for third-party involvement (Al-saqaf & Seidler, 2017; Iansity & Lakhani, 2017; Xu et al., 2019; Secinaro et al., 2021). It also allows multiple stakeholders in various locations to access and hold exact copies of the same information (Zheng et al., 2018).

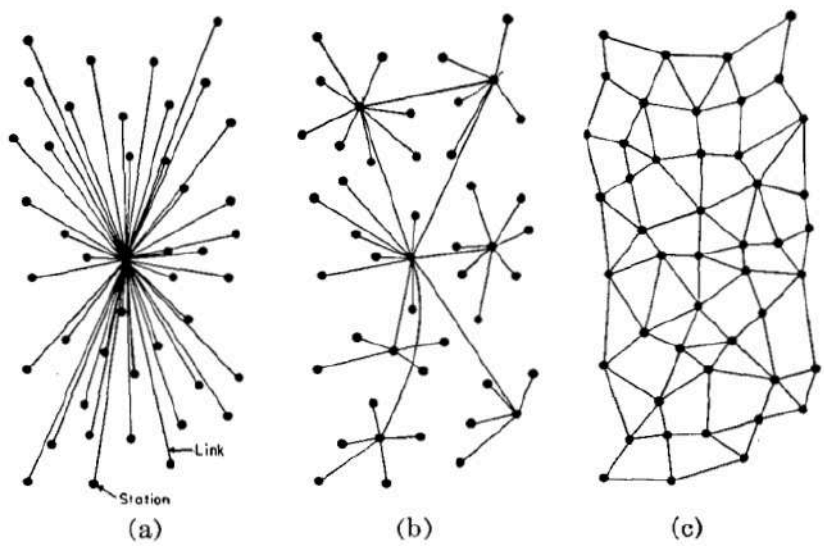

FIGURE 5.5 - TYPES OF NETWORKS: A) CENTRALIZED, B) DECENTRALIZED, C) DISTRIBUTED
SOURCE: ADAPTED FROM BARAN (1964)

When a transaction or data exchange takes place between two peer-to-peer nodes, it is digitally signed using cryptographic keys to ensure security and authenticity. This process results in the creation of a new block that encapsulates information about the transactions, such as the address of the sender and of the receiver, the ID of the transaction, the content of the transaction and a timestamp. This new block is subsequently broadcasted to all the nodes of the network for validation. Authentication is permitted by consensus protocols, the most standard of which is called Proof of Work (PoW). This process is commonly referred to as 'mining' and, in its most traditional form (PoW), it consists in using computational resources to solve complex mathematical problems to validate the block. The miner that first solves the problem shares the solution with the rest of the network and, upon confirmation of the correctness, he is rewarded with cryptocurrency for its effort. At this point, the block is considered verified (Mattila & Seppälä, 2015; Laurence, 2017; Seebacher & Schüritz, 2017; Queiroz & Fosso Wamba, 2019).

Hence, transactions are authenticated without the need for a trusted authority or intermediaries such as banks or PayPal for money transactions, land registers for real estate purchases, eBay for assets trade, etc. (Crosby et al., 2016). Once validated, the new block is appended to the chain - linking it permanently to the previous block through a 'hash key' - thus forming a 'block-chain' (Tillemann et al., 2019). The hash key, a cryptographic representation of the block's data, is virtually impossible to forge: if any data in the block was altered, the hash would also change, indicating tampering.
Every node in the network retains a copy of the blockchain: when a new transaction is appended, they update their copy to include the new block. As a consequence, the blockchain is highly transparent, since every participant has access to all historical transactions of the other nodes, and further secured against tampering (Ganne, 2018).
Thus, in short, Blockchain is nothing but an extremely transparent and immutable linear event log of transactions (Risius & Spohrer, 2017).
Moreover, since every block's hash contains a reference to the previous one, records on the blockchain cannot be altered retroactively without altering all the blocks subsequent to the corrupted one.

These peculiarities make the technology known to be 'immutable', 'tamper-proof', 'non-manipulable' (Monrat et al., 2019; Mercuri et al., 2021; Lavi et al., 2022; Marthews & Tucker, 2023). Therefore, as aptly represented by The Economist, blockchain is suited to become a 'trust machine' (The Economist, October 31st 2015).

While a comprehensive exploration of additional aspects of blockchain technology, including its diverse security models and the dynamics of forks, may indeed be enlightening, such detailed exposition extends beyond the scope of this dissertation. Consequently, for the moment, the principles delineated hitherto should provide a sufficient foundational understanding of the blockchain's technical features and will not be further deepened.

5.3 Potential impacts on GVCs and their sustainability

The introduction of new technologies in GVCs' operations can be considered one of the most important factors determining their evolution trajectories (Gereffi, 2001). This section of the dissertation explores the prospective applications and impacts of one particular technological advancement, Blockchain, on enhancing the sustainability of Global Value Chains. The area of research is visually represented in Figure 5.6.

The analysis culminates in the determination that this technology can be effectively harnessed to enhance traceability, transparency, visibility, and accountability throughout the chain. Moreover, it reveals the potential for Blockchain to contribute to environmental and social sustainability also through enhanced resource efficiency, employment of smart contracts, fraud prevention and trust development, among others (Chapron, 2017; Dai et al., 2017). Therefore, it is a powerful tool to drive 'Corporate Sustainability' (Mercuri et al., 2021). However, some criticalities to an effective integration of Blockchain in GVCs exist, and may limit its potential for widespread adoption.

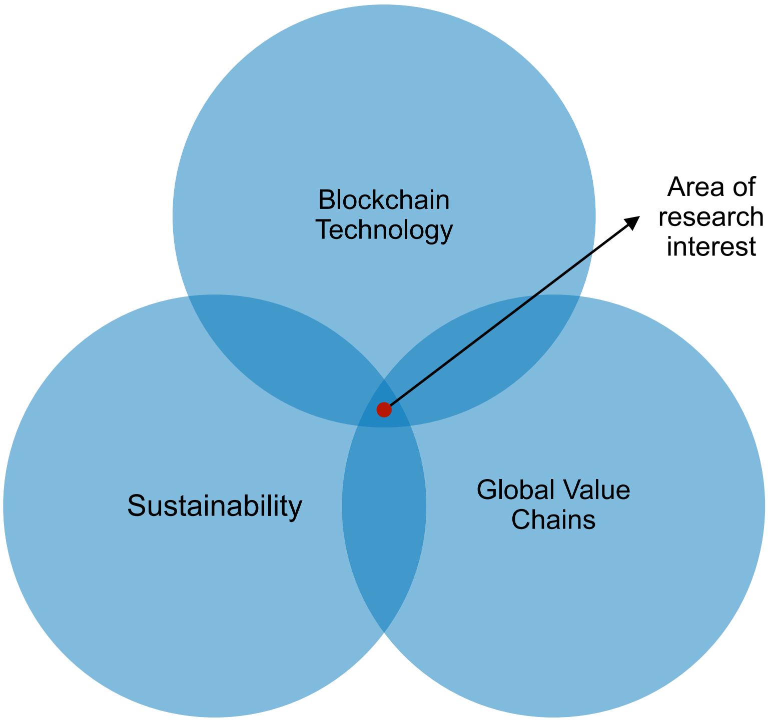

FIGURE 5.6 - AREA OF RESEARCH INTEREST OF THE FOLLOWING SUBSECTIONS

SOURCE: OWN ELABORATION

In the last years, the transparency, auditability and resilience associated with Blockchains led to assessment of their potential in several areas beyond cryptocurrencies (Themistocleous et al., 2020).

In particular, they have been recognized by scholars and practitioners to hold promising application potential in several sectors, including business management (see, for example, Kimani et al., 2020; Ruzza et al., 2020; Yang et al., 2022), as well as in various Sustainable Development areas (e.g., Adams et al., 2018; Kim & Huh, 2020; Parmentola et al., 2022; Chandan et al., 2023).

In the following sections, I will delineate the main benefits that the incorporation of blockchain technology can confer to GVCs.

5.3.1 Trust and accountability

As a powerful enabler of trust and transparency, one of the most promising areas in which blockchain technology can make a significant impact is in the development and maintenance of more sustainable global value chains (Casey & Wong, 2017; Saberi et al., 2019; Kshetri, 2021).
However, before delving into this, it is crucial to understand some terms frequently linked with Blockchain and GVCs, often wrongly used interchangeably (Sodhi & Tang, 2019; Sunny et al., 2020): traceability, transparency and visibility.

Traceability encapsulates the capacity to monitor and record the journey of products, components, and raw materials across the entire value chain. From the origin - be it the farmer who grew the product or the miner who extracted the metal - to the final destination, traceability is about capturing and documenting pertinent information about each stage of production, processing, and distribution. This includes details about the sources, locations, and conditions of each transaction (Sarpong, 2014; Garcia-Torres et al., 2019).
Transparency, on the other hand, refers to the extent to which firms convey such recorded information about their value chains to consumers and other stakeholders, and thus regards the openness with which companies share the operational details of their value chains (Duan & Aloysius, 2019).
Visibility, finally, refers to the extent to which firms within the value chain have access to, or voluntarily share, mutually benefiting information that supports decision making (Apeji & Sunmola, 2022).
Thus, whether or not the firm discloses any of its *traceability* or *visibility* information to the public, is a matter of *transparency* (Sodhi & Tang, 2019).

The first chapter of this dissertation, in the initial pages, painted a picture of how supply chains were structured in the past. It highlighted that, in ancient times, trade

was often conducted directly between individuals, often within the same community. This 'proximity' of the supply chain enabled a smooth exchange of information and reduced the problems of information asymmetries and lack of trust inherently present in transactions. Subsequently, the chapter went on illustrating the historical evolution of this paradigm into today's complex and all-pervasive phenomenon of Global Value Chains. Due to their multi-tiered and geographically dispersed nature, these modern networks are characterized by high complexity (Niforou, 2015; Amador & Cabral, 2016) and, as a consequence, by frequent information asymmetries, lack of trust and, in general, high transaction costs (den Butter, 2012).
For instance, Apple iPhone production is distributed across 785 suppliers from 31 countries (Clarke & Boersma, 2017), Nestlé's supply base consists of around 150,000 direct and indirect partners from 50 different countries (Nestlé, 2020), Walmart can count on a network of 100,000 suppliers all over the world (Humes, 2011), and Nike's sportswear is manufactured by 930 subcontractors located across 50 countries (Locke, 2013; Distelhorst et al., 2017).

This inherent intricacy of GVCs, originally motivated by the quest for natural resources, cost minimization, and efficiency, also makes the monitoring and enforcement of ethical and sustainable practices a resource-intensive task, both in terms of difficulty and time, as well as financial investment (Doorey, 2011; Wilhelm et al., 2016; Busse et al., 2017; Andrews et al., 2018; Fraser et al., 2020).

Chapter 3 showed that, to do so, lead firms often adopt private regulation mechanisms, such as performing ethical audits over their suppliers (Mayer & Gereffi, 2010; Knudsen, 2013; Bartley, 2022). But this process can be particularly cumbersome, as exemplified in Figure 5.7, which graphically illustrates the main steps in the audit process undertaken by German sportswear retailer Puma. In addition, as already stressed previously in this dissertation, supplier audits have shown several limitations, are not infallible and can occasionally hide opportunistic behaviors and even frauds (Jiang, 2009; Boström, 2015; Lebaron et al., 2017; Khalid et al., 2020; Sarfaty, 2021; Asif et al., 2022). Finally, they do not allow for continuous monitoring but, rather, they only entail sporadic checks over suppliers' environmental and social practices (Powell et al., 2013).

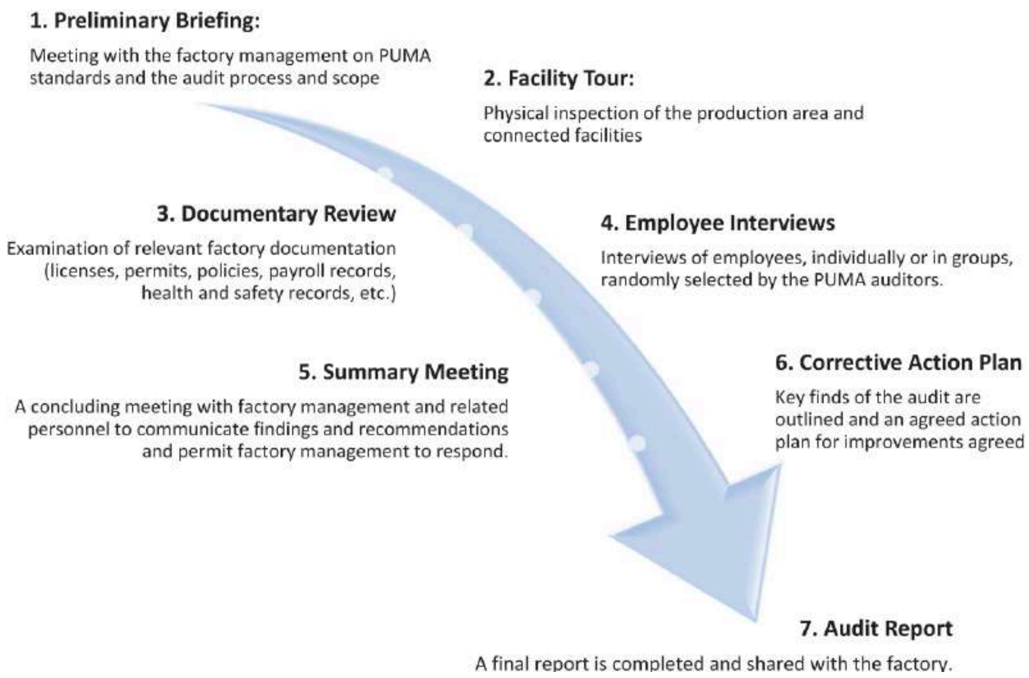

FIGURE 5.7 - GERMAN SPORTSWEAR GIANT PUMA'S AUDIT PROCESS OVER SUPPLIERS
SOURCE: PUMA, 2019

Consequently, in light of the aforementioned complexity of GVCs and fallibility of audits mechanisms, it is particularly challenging to ensure that all actors within the value chain adhere to ethical and sustainable principles, both for consumers and stakeholders, as well as for value chain partners (Boström et al., 2012; Kumar et al., 2022). Challenges arising from such lack of transparency and accountability are manifold and result in negative externalities such as environmental degradation, labor exploitation, and economic inequality, among others (Kaplinsky & Morris, 2001; Khurana & Ricchetti, 2016).

Today, hence, transparency is deemed crucial as a first basic need to create sustainable and resilient supply chains and to establish effective governance mechanisms (McGrath et al., 2021). More specifically, enhancing transparency includes reporting supply chain membership, material provenance and traceability, and ESG indicators such as water usage, energy usage, GHG emissions, waste and recycling levels, working conditions, and living wages (Bendixen & Abratt, 2007; McGrath et al., 2021).

Similarly, transparency has been acknowledged as a paramount condition also to improve the effectiveness of multi-stakeholder initiatives (Tröster & Hiete, 2018; Sauer & Hiete, 2020), a key component of sustainable development. In these kind of networks, as mentioned in chapter 3, certain power dynamics can be recognized, whereby participants are constantly seeking to assert their decision-making authority on sustainability matters over the other actors involved (Brower et al., 2013; Wong, 2014; Gruzd et al., 2018). In such games of power, in absence of adequate transparency and visibility over other players' conduct, opportunistic behaviors may be encouraged and some actors may lie about implementing the stipulated agreements.

Another key component determining the need for increased transparency is the fact that consumers in the end market, often willing to purchase sustainable products, have in fact limited insights on how value is added and on what practices are perpetrated along value chains (Wilhelm et al., 2016; Montecchi et al., 2019). Thus, it is difficult for them to 'reward' those companies that actually make efforts towards sustainability, as they lack reliable data and cannot always trust voluntarily disclosed information.

In parallel, a lack of value chain transparency compromises also policy-makers's ability to design regulation and to determine wether the enforcement of such measures resulted in positive effects or failed to do so. The significance of this issue is greater than it might seem at first glance: as underscored by the research conducted in Chapter 3, in particular, regulations can serve a primary and pivotal role both as a catalyst and an obstacle to sustainable GVCs.

As a result, firms today are increasingly urged to increase transparency along the full-length of their value chains (see chapter 3; Francisco and Swanson, 2018), so that they can be effectively held accountable for their environmental and social practices, as well as those of their suppliers and sub-suppliers (Closs et al., 2011; Tachizawa & Yew Wong, 2014; Busse et al. 2017).

By storing a secure record of transactions in an irreversible manner, Blockchain provides both a visible and transparent source of traceability of physical (e.g., goods, containers) or digital (e.g., invoices, barcodes, orders) assets (Caro et al., 2018; Kim & Laskowski, 2018; Litke et al., 2019; Centobelli et al., 2022; Wittine et al., 2022), from their sourcing as raw materials to finished goods, allowing a precise report of industrial processes (Zhao et al., 2016; Westerkamp et al., 2020), the identification of products' provenance (Toyoda et al., 2017; Kshetri, 2018; Malik et al., 2018; Kumar et al., 2022) and, ultimately, assurance of accountability at every stage of the value chain (Manski, 2017; Kim & Laskowski, 2018; Fernandez et al., 2020).

Furthermore, blockchain technologies can be adopted to significantly improve supplier audit mechanisms and to enable continuous monitoring, especially when coupled with supporting technologies such as IoT, RFID, and Big Data Analytics (Dai & Vasarhelyi, 2016; Richins et al., 2017; Gaur & Gaiha, 2020; Asif et al., 2022). Data thus collected would be characterized by higher veracity and trustworthiness levels, when compared to data supplied by human auditees (Buer et al., 2018), since they are originated by automated systems and directly stored on the blockchain, which prevents subsequent manipulation.

Increased transparency thus plays a pivotal role in ensuring that products are sourced and produced in a sustainable and ethical manner. By enabling companies to be held accountable for their environmental and social impacts at every step of the value chain - from the way they deal with farmers and miners to their distribution and retailing practices -, firms can be forced to adopt higher ESG standards and greater sustainability can be achieved (Moran et al., 2020). Moreover, following trustworthy data provided by blockchains systems, consumers can make more informed choices, selecting products that align with their values and expectations regarding sustainability (Montecchi et al., 2019; Cao et al., 2023; Wang et al., 2023).

In particular, the customer may verify the sustainability credentials of a product, for instance, by framing with his smartphone's camera a QR code that links to information stored on the blockchain, and that could have been previously uploaded by IoT, RFID systems, farmers, producers, processors, transporters, smart vehicles, distributors, retailers or auditors.

Moreover, some of the sustainability-related information may be intrinsically present on the blockchain: for example, the consumer will be able to track the product back to the smallholder who produced it and check on the blockchain's transactions history if she/he was rewarded with a fair compensation. Figure 5.8 shows an example of architecture for blockchain-based traceability.

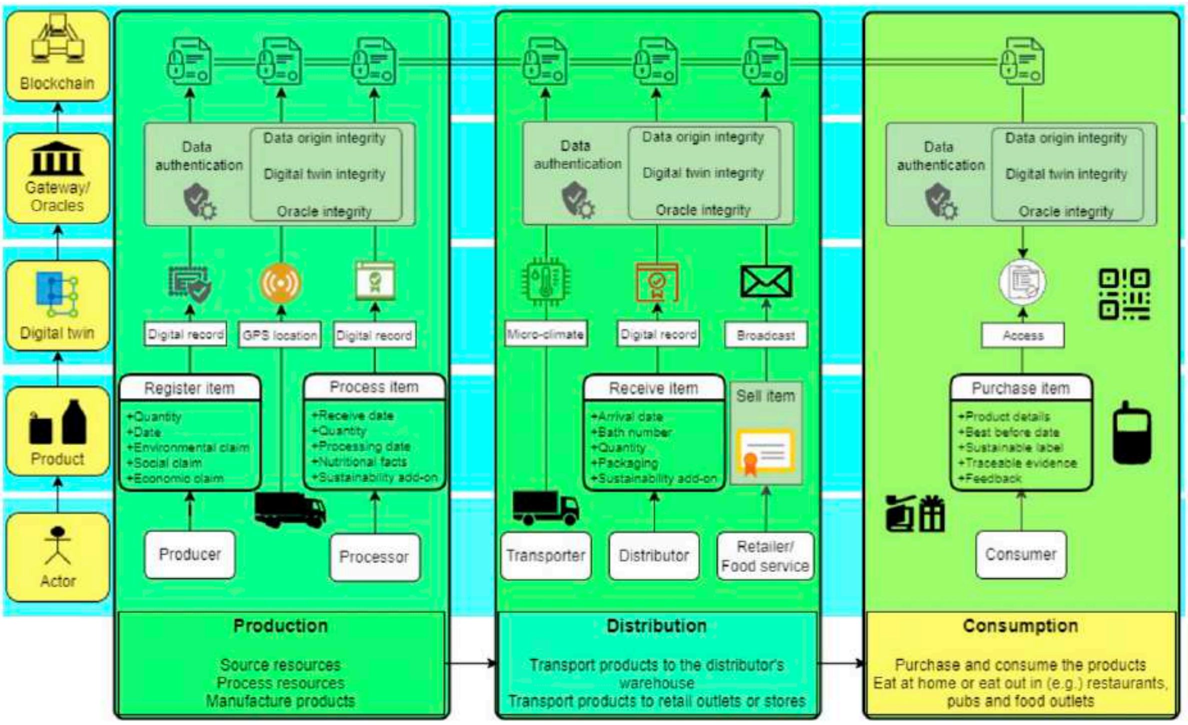

FIGURE 5.8 - BLOCKCHAIN-BASED ARCHITECTURAL FRAMEWORK FOR TRANSPARENCY AND TRACEABILITY

SOURCE: CAO ET AL., 2023

The relevance of these three attributes, i.e. traceability, transparency and visibility, extends to the point that they are often acknowledged, by academics as well as value chain stakeholders, as a *conditio sine qua non* to achieve sustainability (Bastian & Zentes, 2013; Daniel et al., 2017; Fraser et al., 2020; Papú-Carrone, 2020). For instance, in a very recent study conducted on the octopus value chain, fishermen asserted to see product traceability as the most important prerequisite to increase the overall sustainability of their value chain (Ainsworth et al., 2023).

Furthermore, ICTs and Industry 4.0 technologies are adopted in a primary way as catalysts for fast, secure and frictionless collaboration among value chain partners (Li, 2006; Fawcett et al., 2006; Fatorachian & Kazemi, 2021). In this regard, the transparency and visibility enabled by blockchains can improve collaboration and cooperation among different stakeholders (Hellani et al., 2021; Rejeb et al., 2021; Lumineau et al., 2021; Agrawal et al., 2023), which have been widely recognized as a critical prerequisite in the pursuit of sustainability (Lozano, 2007; Blome et al., 2014; Ramanathan, 2014; Varsei et al., 2014; Chen et al., 2017; Sudusinghe & Seuring, 2022; Hochachka, 2023). With this perspective, integrating blockchain within the value chain can enhance visibility, mitigate information asymmetries (Chohan, 2019; Liu et al., 2021), cultivate trust (Barnard, 2017; Centobelli et al., 2022) and reduce transaction costs between value chain partners (Tapscott & Tapscott, 2017; Henten & Windekilde, 2019; Schmidt & Wagner, 2019; Chen et al., 2022). Therefore, by facilitating collaboration and cooperation between participants in value chains, as well as between business actors and public regulators or civil organizations, blockchain offers further potential as a catalyst for sustainability.

However some additional considerations can be made in this respect. While enhanced information sharing can indeed foster collaboration towards sustainability, it may also hide secondary outcomes. Ponte (2020), in particular, argues that extracting sustainability-related information from suppliers may further increase the control lead firms exert over their suppliers, thereby exacerbating existing power imbalances.

More specifically, under the guise of monitoring suppliers' environmental performances - such as energy and resources consumption -, lead firms can accumulate important knowledge about their suppliers, such as - for instance - cost structure, profit margins and so on. This information, while ostensibly gathered for sustainability purposes, can be instead leveraged to gain greater control over partners, extract more value added by further squeezing purchasing prices and shift additional costs and risks upstream (so-called *sustainability-driven suppliers squeeze*).

Therefore, in this regard, the integration of blockchain within global value chains may yield intricate and unpredictable outcomes. On one hand, by providing increased visibility, it may further intensify these power dynamics. On the other, by increasing transparency, it may reduce such imbalances, as consumers and NGOs may held lead firms more accountable for their practices towards suppliers. At the same time, it may be worth noticing that public sentiment may exhibit greater concern for the initial stages of GVCs - i.e., smallholders, peasants, fishermen, etc. - rather than for the profit margins of mid-chain suppliers. Thus, the effects of blockchain technology on power dynamics within GVCs are quite intricate and may vary depending on the stage of production. In this regard, they necessitate further investigation to be untangled.

A final consideration concerns the relevance of transparency, traceability and visibility to drive sustainability along GVCs. While the existing body of blockchain literature considers them as pivotal prerequisites in fostering sustainable practices (e.g., Warasthe et al., 2020; Mercuri et al., 2021; Cao et al., 2023), conversely my investigation in Chapter 3 revealed their absence, in the GVCs literature, among significant drivers or barriers to sustainability. This finding suggests the possibility that the literature on GVCs may be outdated compared to that on blockchain, thus failing to recognize the importance of these emerging variables. Another plausible explanation is that the Blockchain literature may overemphasize their significance. Since the arguments for transparency, traceability and visibility seem to be quite compelling, I am inclined to prepend for the first hypothesis.

To bolster this argument, it is possible to observe the recent accelerated growth of scientific publications (see Figure 5.9) concerning ‘sustainability’ and at least one among ‘transparency’, ‘traceability' and ‘visibility’, which have seen a compound annual growth rate (CAGR) of 21.1% over the past decade. This rate significantly outpaces the 14.4% CAGR observed in the broader collection of publications on 'sustainability' during the same period.

Nevertheless, wether transparency, traceability and visibility should be given priority in the quest for sustainability, also represents a theme that will require future research to be clarified.

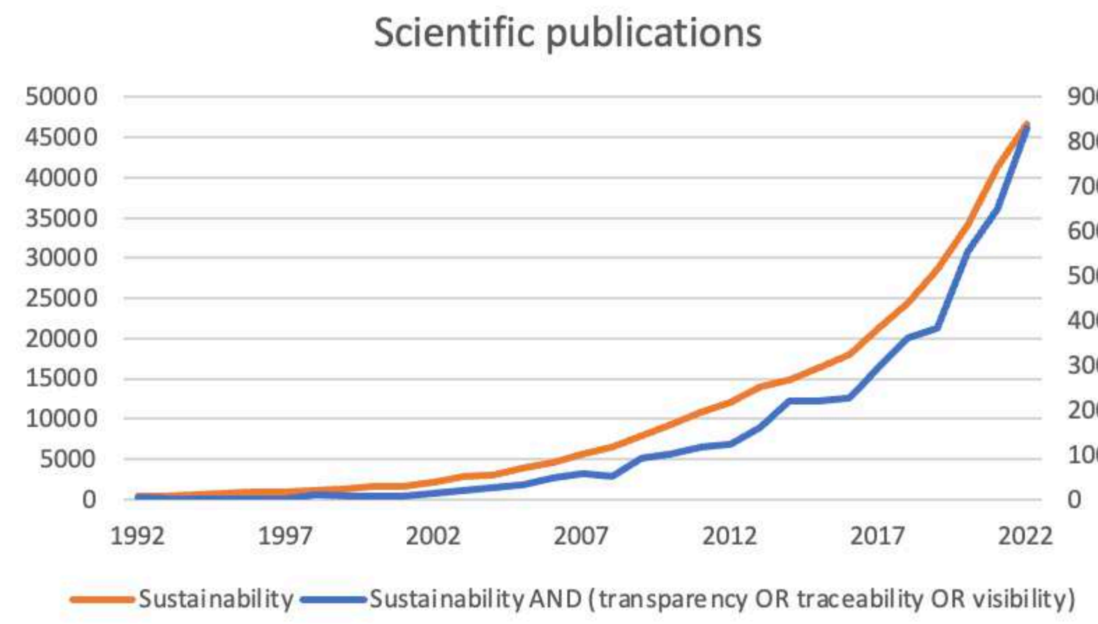

FIGURE 5.9 - NUMBER OF SCIENTIFIC PUBLICATIONS ON ‘SUSTAINABILITY’ VS ‘SUSTAINABILITY’ WITH ‘TRANSPARENCY’, ‘TRACEABILITY’ OR ‘VISIBILITY’

SOURCE: OWN ELABORATION OF SCOPUS DATABASE QUERY

5.3.2 Process, resources and energy efficiency

Other than making more transparent, secure and trustworthy information available, blockchain allows for such information to be gathered much more quickly and efficiently (Ernst & Young, 2017). In 2017, for instance, IBM and Walmart jointly undertook a pilot to determine the efficiency of blockchain in tracing the journey of a package of mangoes, from retail back to the origin. Using existing paper-based records, it took 6 days, 18 hours and 26 minutes to identify a farm in Mexico as the source of the product. The equivalent blockchain search took 2.2 seconds (Forbes, 2017; Walmart, 2018). This can result in several positive backlashes for business organizations: for example, they can more quickly detect disruptions along their value chains, they can promptly identify suppliers that didn't satisfy quality or ESG standards, and so on.

Moreover, blockchain can reduce inefficiencies and waste in GVCs, particularly when combined with other 4.0 tools such as Internet of Things (IoT), Artificial Intelligence (AI), and Big Data Analytics (Tian, 2016; Kshetri, 2018; Reyna et al., 2018; Astill et al., 2019; Tijan et al., 2019; Kamble et al., 2020; Venkatesh et al., 2020; Egwuonwu et al., 2022). The coupling of blockchain with the first technology mentioned, i.e. IoT, in particular, deserves further deepening. While they have vast potential on their own, their symbiotic integration can open up a myriad of further applications and, most notably, it has been noted that the blockchain architecture can empower IoT by minimizing its deficiencies (Buccafurri et al., 2017; Liao et al., 2017), among which data manipulability and security issues related to the centralization of IoT networks (Panarello et al., 2018; Salimitari et al., 2020).

By providing a real-time, accurate record of processes and by enabling faster and more affordable payment and finance options, blockchain and IoT can help identify bottlenecks, reduce errors, and streamline operations, not only in-house but also across value chain partners (Tijan et al., 2019; Rejeb et al., 2020) Goyal et al., 2022).

This leads to reduced production excesses and more sustainable use of resources (Nanayakkara et al., 2019; Saberi et al., 2019).
Also, Arena et al. (2019) proposed a blockchain and IoT-based traceability system - called 'Bruschetta' - to track the value chain of Extra Virgin Olive Oil and preventing fraud, data falsification, and allowing consumers to access tamper-proof and IoT-monitored product history, from plantation to the shop. Simultaneously, the framework includes dynamic auto-tuning mechanisms to optimize the system in case of high loads (Arena et al., 2019). Similar systems have been implemented in the grain value chain (Zhang et al., 2020) and in the cocoa beans value chain (Musah et al., 2019). Most notably, in the latter the adoption of such systems has been found to also enable a reduction in child labor and unethical practices (Musah et al., 2019).
Furthermore, in GVCs characterized by perishable goods, the integration of blockchain, AI and IoT can be used to guarantee maintained quality and reduce waste (see, for example, Haji et al., 2022; Kayikci et al., 2022).

A further key component of blockchain-based value chain efficiency is the possibility to employ so-called *smart contracts* (Yaga et al., 2019; Themistocleous et al., 2020), first theorized in the early 1990s by the American computer scientist, legal scholar and cryptographer Nick Szabo. These are self-executing contracts with the terms of the agreement directly written into lines of code and recorded within a blockchain network (Szabo, 1997). The advent of the cryptocurrency Ethereum has made the practical implementation of smart contracts feasible, thus making scholarly interest towards this concept soar (Figure 5.10).
Ethereum's blockchain is designed to store complex applications, and most notably smart contracts, which automatically execute transactions when predefined conditions are met (Buterin, 2014). Hence, smart contracts not only define the clauses and penalties of an agreement in the same way a traditional contract does, but they also enforce the stipulated obligations automatically (Min, 2019). This automation further reduces the need for intermediaries, thereby reducing costs and increasing efficiency (Kshetri, 2018).

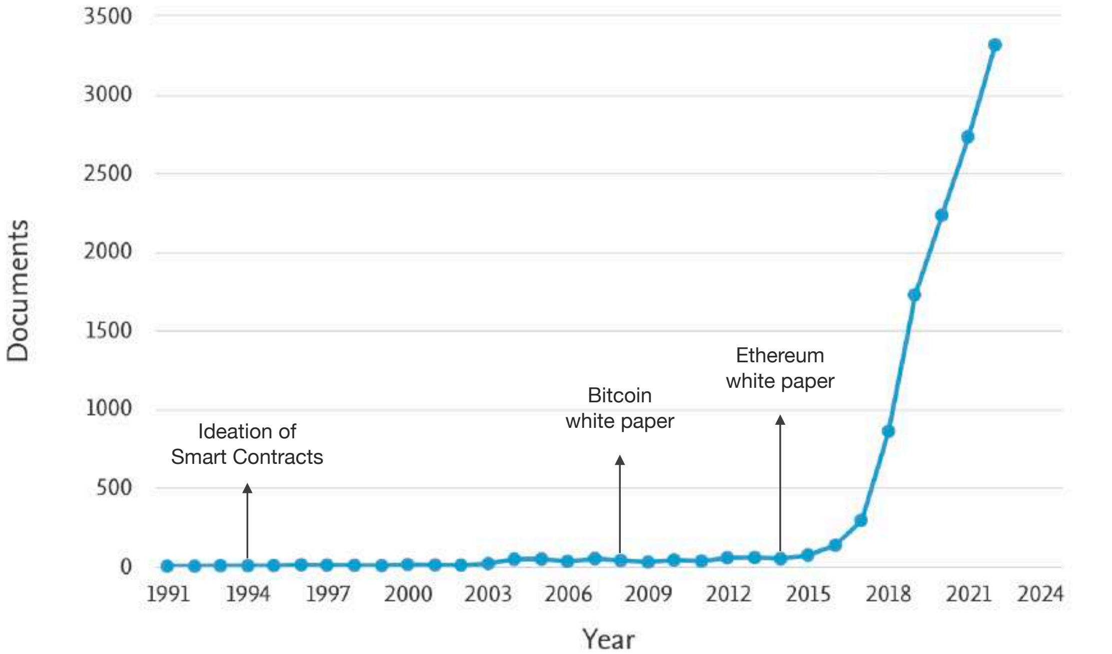

FIGURE 5.10 - EVOLUTION OF SCIENTIFIC PUBLICATIONS ON SMART CONTRACTS

SOURCE: OWN ELABORATION OF SCOPUS DATABASE QUERY

In the context of GVCs, smart contracts can streamline various processes, from procurement to payment, by automating tasks that were traditionally performed manually or required third-party verification (Bhandari, 2018; Babich & Hilary, 2020; Pournader et al., 2020), while increasing process accuracy, security, speed and traceability and reducing overall costs (Dolgui et al., 2020a). For instance, a smart contract could be programmed to automatically release a fair payment to a supplier once a shipment has been received and verified against the contract's terms. This not only speeds up the transaction but also reduces the potential for disputes or fraud (Kshetri, 2018), hence further encouraging collaboration among value chain partners (Bottoni et al., 2020). Additionally, the application of smart contracts can be extended to various domains, such as the automation of compliance verification with respect to sustainability standards. In this context, smart contracts could be employed to automatically award certifications or bonuses based on the adherence to these standards. Moreover, they could serve as an interface for the collection of environmental data through Internet of Things (IoT) devices. Hence, smart contracts could be used to track the environmental footprint of suppliers along the value chain, and specifically, here, they would be programmed to mandate IoT sensors to monitor and detect the emission of pollutants and to securely store on the blockchain the data thus collected, therefore ensuring its integrity and accessibility. This information would be readily available to all network participants, as well as NGOs and consumers.

Yet again, smart contracts are being successfully adopted also to enhance energy efficiency. For instance, they have been utilized to enable more efficient and effective control and consumption of energy (Li et al., 2019; Schletz et al., 2020; Botsaris et al., 2021; Agung & Handayani, 2022) and to enable peer-to-peer energy trading (Han et al., 2020; Masaud et al., 2020; Seven et al., 2020; Vieira & Zhang, 2021; Kirli et al., 2022). Moreover, they can be used also to predetermine that production processes will lower the volumes when the power grid is overcharged or that they cease polluting activities when the quality of the air surrounding the plant is particularly low.

However, despite their potential impact, the legal status of smart contracts is still unclear in many jurisdictions (Patel et al., 2018; Durovich & Lech, 2019), thus limiting their impacts on value chains, hitherto, to a restricted number of applications.

Another application of smart contracts and blockchain is the automatic trading of carbon credits, which are considered a critical policy making tool in the fight against climate change (Kim & Huh, 2020). More specifically, they are permits allowing a country or organization to produce up to a certain amount of carbon emissions. When the full allowance is not exploited, it can be sold to firms or countries that are exceeding their threshold. These permits can be *tokenized* and traded on a blockchain platform, with each token representing a specific amount of carbon credits. Thus, they can be traded more efficiently and transparently (Pan et al., 2019; Al Sadawi et al., 2021; Woo et al., 2021). Smart contracts can also be programmed to monitor compliance automatically, especially if integrated with IoT and sensors: if devices detect that an organization exceeds its carbon emission limits, the smart contract could be set to automatically calculate the corresponding number of tokens needed and, accordingly, to purchase the necessary carbon credits, ensuring adherence to environmental regulations (Hua & Sun, 2019).

A further aspect concerns the fact that GVCs are intrinsically paper-intensive: from trade finance to customs clearance, transportation and logistics, GVCs involve multiple actors and third-parties and thereby require huge piles of paper for bureaucratic compliance (Duval & Hardy, 2021).
Blockchain, in this respect, has been recognized as an interesting tool to improve the efficiency of trade processes and help move towards paperless trade (Civelek & Özalp, 2018; Ganne, 2018; Allen et al., 2019), which in turn will result in significant environmental gains (Tenhunen & Penttinen, 2010; Tijan et al., 2019; Kim et al., 2021). In addition, it may ease the tasks of workers: it has been estimated that generating a paper-based invoice can take up to 13 minutes, while a further 27 minutes are needed for the receiver to open, process, audit and file the document (SITPRO, 2008).
Nonetheless, on this last point, it is important to acknowledge that while reducing paperwork can contribute to curbing polluting emissions, the magnitude of these savings still pales in comparison to the emissions derived from transportation activities within GVCs (Duval & Hardy, 2021). In light of this, the potential reshoring dynamics highlighted in Chapters 1 and 4, leading to a reduction in the distance traveled by goods, appear to hold considerably greater potential for enhancing the environmental performance of GVCs. By bringing production activities closer to each other and to the end consumer, reshoring has the capacity to mitigate the carbon footprint associated with long-distance transportation, thereby yielding more substantial environmental benefits.

Finally, in the first chapter I highlighted how GVCs are particularly susceptible to disruptions and shocks propagation, given the global dimensions of their activities, and today more than ever due to the concurrence of other phenomenons such as the rise in climate-related disasters (Thomas & López, 2015). Furthermore, the rise of trends as the Lean Production and Just-in-time philosophies - focusing on the efficiency of supply chains - reduced the main risk-management tool against the effects of such disruptions, i.e. holding buffer stock in inventories. Today, as a result, GVCs are increasingly vulnerable to disruptions (Kamalahmadi & Parast, 2016; Lund et al., 2018) and the outcomes of such events no longer affect only portions of the supply chain, but tend to spread across the entire global network (so-called *ripple effect*; Ivanov, 2018b; Pavlov et al., 2019; Dolgui et al., 2020b). In this context, the theme of value chain *resilience* has grown to be central in the various discussions around sustainability: it consists in the capability of the network to anticipate, recognize and adopt defensive measures against risks (Hollnagel et al., 2017). This capability unwinds in two aspects: resistance and recovery (Dolgui et al., 2018), the first referring to the ability of the value chain to minimize disruption outcomes, the latter concerning its ability to return to a steady state once a disruption has happened (Melnyk et al., 2014).

With respect to the first aspect, by establishing a real-time and trusted exchange of information, blockchain allows every node of the network to instantaneously acknowledge disruptions and to act immediately, thus enhancing the resilience of the value chain (Priya Datta et al., 2007). In particular, for instance, smart contracts may be programmed to alert the system, once a disruption is detected, and to automatically contact third parties to fulfill the demand that was unaddressed due to the disruption (Manupati et al., 2022). With respect to the second aspect, contingency and recovery plans, too, can be supported by smart contracts, programmed to initiate recovery procedures swiftly and without delays at the occurrence of a disruption (Weber et al., 2016; Lohmer et al., 2020).

5.3.3 Sustainability control & assessments

In evaluating the sustainability performance of a value chain, the use of appropriate performance measures is crucial as they directly impact the effectiveness and usefulness of the practices implemented (Gunasekaran et al., 2004). For the assessment of the sustainability of a value chain, a variety of techniques have been suggested and employed by practitioners. Often, they seek to strike a balance between economic and environmental performance, recognizing the need to find trade-offs between the two (Nagurney and Toyasaki, 2003; Pistikopoulos and Hugo, 2005; Sheu and Chou, 2005; Lu and Wu, 2007; Frota Neto and Bloemhof-Ruwaard, 2008; Guillen-Gosalbez and Grossmann, 2009; Figge & Hahn, 2012; Accorsi et al., 2014; Carvajal et al., 2016).

However, specific measures exist to capture the social dimension of sustainability too, such as the Social Life Cycle Assessment (S-LCA), which considers indicators including, e.g., the number of jobs created. Overall, however, measuring the environmental impacts of a company's operations seems to be much more frequent.

For instance, the Life Cycle Assessment (LCA) is a systematic analysis of the environmental impacts of a product or service throughout its entire life cycle, from raw material extraction to end-of-life disposal (Finnveden et al., 2009). Other measures are also widely adopted. Footprinting, which draws from LCA, consists in gathering, analyzing and reporting information on products' environmental impacts over their 'cradle to grave' journey, with regards to specific matters such as greenhouse gas emissions (Freidberg, 2014).

To address global sustainability issues, several initiatives have been introduced to provide standardized frameworks for measuring, reporting, and communicating sustainability performance, many of these promoted by MSIs, as I have previously mentioned. A prominent example is the Greenhouse Gas Protocol, which developed, in a multi-stakeholder process with 2.300 participants from 55 countries, the Corporate Value Chain (Scope 3) Standard: an accounting and reporting standard that allows companies to assess their value chain emissions impact and to identify where to focus their reduction efforts (Greenhouse Gas Protocol, 2011). Other examples of such initiatives are the Higgs Index, introduced by the Sustainable Apparel Coalition (SAC), and the Global Reporting Initiative (GRI), which introduced important standards such as the GRI 204, assessing the procurement practices of a company, the GRI 308-1 & 308-2, assessing suppliers' environmental performances, and the GRI 414, assessing suppliers' social performances. These frameworks offer companies guidelines and tools to evaluate their sustainability efforts in a consistent and transparent manner, enabling better benchmarking and comparison among value chains.

By utilizing sustainability assessment techniques, companies can enhance their understanding of their own and their suppliers' sustainability performance and compare it with industry peers, as well as communicating their efforts to key stakeholders. Thus, they seek to promote transparency and accountability in supply chain operations, facilitating the identification of areas for improvement, the adoption of best practices and, ultimately, the development of more sustainable value chains (Lambin et al., 2018).

Yet, the reliability of these assessments is meeting new challenges: in particular, the increasing complexity of global production call for increased 'big data' efforts (Cooper et al., 2013), spatial data traceability (Hellweg & Canals, 2014) and for increased transparency to avoid hidden manipulation (International Organization for Standardization, 2006).

In the context of the mentioned criticalities, the integration of blockchain technology, IoT, RFID, sensors and big data analytics softwares can be a game-changer, providing large and secure datasets, traceability and non-manipulability of records (see, e.g., Mercuri et al., 2021).

5.5 Considerations on the adoption of Blockchains

Given the promising effects of increased traceability, transparency, visibility, safety, collaboration, efficiency, and increased stakeholder involvement, among others, applications of blockchain technology in the field of GVCs have raised notable interest from academics, practitioners and business organizations, particularly in the last five years. To sum up what has been illustrated hitherto, the drivers for the adoption of blockchain within supply chain management can be grouped into four main domains: enhanced visibility and traceability, supply chain digitization and disintermediation, improved data security, and smart contracts (Wang et al., 2019).

In accordance with such advantages, worldwide spending on blockchain solutions has been increasing steeply in the last few years, and it is expected to further rise significantly (Wittine et al., 2022). More specifically, blockchain technology market size was estimated to be worth around 3.3 billion $ in 2021, with expectations of growth up to 60 billions by 2028, a CAGR of 44.5% (Bloomberg, 2022). Thus, some practitioners have been comparing today's status of adoption of blockchain to that of the internet in 1990s, suggesting a similar disrupting potential (e.g., Mougayar, 2016). Some authors have also highlighted how blockchains are particularly scalable in light of their decentralized nature, which implies that their adoption doesn't require large upfront investments in data warehouses (Manupati et al., 2022). Even though this is true, it is only one facet of the issue, and it must be acknowledged that blockchains face other scalability issues (Flovik et al., 2021). In particular, one historical counter-argument to blockchains is that they can process only a limited amount of transactions per second. Bitcoin blockchain, for instance, can handle 5~7 transactions per second (tps), while Ethereum's throughput rate is of around 15 tps (Zhang et al., 2022). These are significantly lower than, for example, Visa's capacity of 65,000 tps (Visa, 2018). However, remarkable progress has been made in this regard, and more recent blockchains have successfully managed to outstandingly enhance their scalability. Solana, for instance, a public blockchain launched in 2020, shows an average throughput rate of 2812 tps (Pierro & Tonelli, 2022).

To better acknowledge the maturity and the expectations towards this technology, it may be insightful to observe it through the lenses of the Gartner's Hype Cycle model.
This consists in a graphical representation, ideated and used by the American consultancy firm Gartner, to represent the maturity, adoption rate, and social acceptance of specific technologies. In particular, it proffers that every new technology follows a comparable pattern of public interest and maturity, which can be schematized in five major phases (Figure 5.11).

FIGURE 5.11 - GARTNER'S HYPE CYCLE FOR SUPPLY CHAIN INNOVATIONS, 2022

SOURCE: ADAPTED FROM GARTNER, 2022

When a particular innovation emerges, stories about prototypes and proof-of-concepts trigger significant public interest ('innovation trigger' phase). Especially in the case of disrupting innovations, such interest rises to a point where consumers expect this technology to bring an imminent and disruptive change to the status quo ('peak of inflated expectations'). Soon enough, however, interest wanes as experiments and implementations fails to deliver: e.g., TradeLens blockchain-based tracking platform, jointly developed by IBM and Maersk in 2018 and discontinued in 2022 ('through of disillusionment'). Over time, though, more instances of how the technology can benefit enterprises and society start to crystallize and become more widely understood. As a consequence, second-generation products appear and more firms fund pilot projects building on the technology ('slope of enlightenment'). Finally, further advancements enable the technology to reach high performances, and mainstream adoption follows. Consequently, in this phase, the broad market applicability of the innovation pays off the enterprises that invested in the technology ('plateau of productivity').

Due to the wide range of applicability of blockchain technologies, it would not make sense to determine a general position of this technology on the curve, because its maturity level depends on the sector of interest. For instance, Gartner deems cryptocurrencies to have almost reached the 'plateau of productivity', while the so-called ideal of the Decentralized Autonomous Organization (DAO) would still be in the 'innovation trigger' phase. Thus, as for supply-chain-specific applications of blockchain technology, Gartner holds up that they may currently be approaching the 'trough of disillusionment' phase (see red circle in Figure 5.11). An analysis of the public interest towards this application of blockchain, performed through Google Trends, confirms this assertion (Figure 5.12). In particular, after reaching peak hype in February 2022, the web searches of 'blockchain supply chain' are today - June 2023 - down 47% compared to their all-time-high. Therefore, it is expectable that supply chain applications of blockchain technology will reach the 'plateau of productivity' and widespread adoption in the next few years.

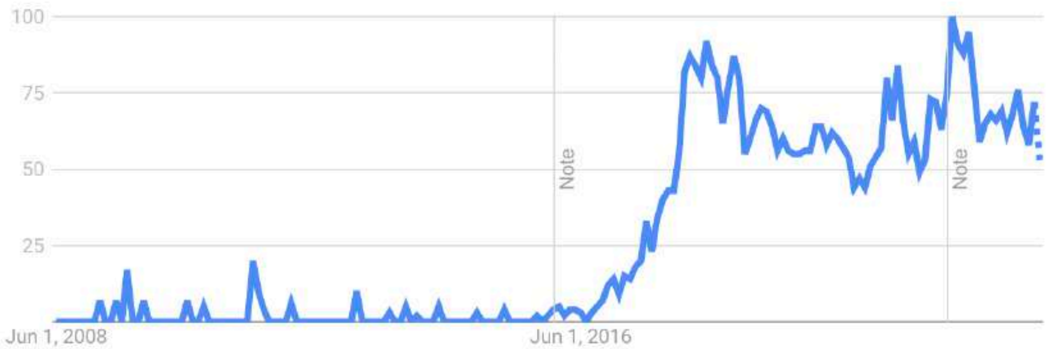

FIGURE 5.11 - INTEREST OVER TIME FOR BLOCKCHAIN APPLICATIONS ON SUPPLY CHAIN
SOURCE: GOOGLE TRENDS, 2023

Nevertheless, these are just projections and, as of today, a scale adoption of blockchain in supply chain management is still far (Angelis & Da Silva, 2019; Queiroz & Fosso Wamba, 2019), despite it being, so far, the business domain in which the adoption of blockchain technologies has been studied the most (Al Shamsi et al., 2022; Taherdoost, 2022). Furthermore, since blockchains are susceptible to so-called network externalities - mainly because of security issues -, and since a only partial adoption could hide the most problematic portions of the value chain from sight (following Lebaron & Lister, 2015, for ethical audits), the full potential of this technology can be exploited only when every stakeholder along the GVC embraces it (Chandan et al., 2023). Thus, while the adoption of blockchain as a universal protocol to foster sustainability along GVCs certainly holds promising potential, at the same time such potential may require several years to be unleashed because of known factors such as the need for upfront investments, resistance to change and opportunism.

With respect to the first criticality, value chain participants may be hindered by the uncertainty in quantifying adoption costs (Canavari et al., 2021). This uncertainty is exacerbated by the complexity in computing the net costs of such adoption, which should take into consideration money saved from prevented environmental disasters and disruptions, new revenue streams generated by sustainability-aware customers, and so on. Still, although cost structure may also significantly change based on the specific blockchain solution adopted (Schulz et al., 2020), many authors agree that it is in fact generally associated with high CapEx and maintenance costs (Manupati et al., 2020; Flovik et al., 2021; Kouhizadeh et al., 2021; Sahoo et al., 2022; Song et al., 2022).

Secondly, the introduction of new technologies is often hindered by managers and workforce being used to the current standard of technology and rejecting novel technologies which they have not mastered yet and upon which they lack education, a phenomenon well documented in business management literature and known as *resistance to change* (see, e.g., Gonçalves & da Silva Gonçalves, 2012; Yilmaz & Kiliçoğlu, 2013).

In this respect, it must also be noted that the digital skills of employees, farmers and other potential users of the blockchain may be inadequate and compromise an effective implementation of the technology (Botton, 2018), particularly in developing countries.

Thirdly, the adoption of such technology at scale may be against the interests of specific players, and in particular it may be hampered by those suppliers or lead firms that currently hide harmful and detrimental practices within their operations, which are in danger of being revealed if the transparency of the value chain were to be enhanced.

In light of these considerations, I argue that that the integration of this technology may be enforced by stakeholders with decision-making authority over the full length of the value chain. In particular, because non-state regulation is more flexible and sensitive to technological innovation compared to traditional state regulation (Hutter, 2006), I observe that, in the near future, the adoption of blockchain at scale should be endorsed and fostered by lead firms seeking to legitimize the sustainability of the full length of their value chains. Hence, I conclude that, if blockchain technology will be widely acknowledge for its potential in fostering sustainability, as I think it will, then such enforcement is likely to be implemented through the private regulation mechanisms seen in Chapter 3, or in the context of multi-stakeholder initiatives, rather than by states through *hard* law.

Nonetheless, this does not exempt states and institutions from developing governance and legislative tools designed around blockchains and smart contracts. Proper policy-making, in fact, should be a priority to safeguard the general public from detrimental practices, including attempts to implicate blockchain nodes in illegal activities and crypto-jacking (Dierksmeier & Seele, 2020).

Furthermore, while the adoption of blockchains in the sustainability governance of GVCs may follow the private regulation hypothesis previously advanced, this does not mean that state institutions may not drive their adoption in other areas. For instance, the governments of Sweden, Estonia and Georgia are planning to use blockchain-based land registries, thereby not only enabling multiple parties to securely hold copies of the registry but also to more quickly resolve property disputes and increase trust (Boeding et al., 2021). In turn, adoption of this technology by state institutions - although outside the direct scope of sustainability governance - may increase the public acceptance and trust towards this technology, thereby accelerating its adoption also in the area of interest.

5.6 Counter-theses

Despite the charming potential of blockchains, conflicting opinions should also be considered. Some authors argue that the adoption of blockchain technology, in the context of sustainability governance, may be nothing more that a reinforcement of third-party audits and disclosure governance, which have so far failed to address environmental and social abuses (Bernards et al., 2022). These authors also argue that adopting blockchain along GVCs may reenforce lead firms' dominant position towards their partners, a possibility that I have evidentiated previously in this chapter. Similarly, others claim that 'far from transforming current modes of governance, [blockchain] risks privileging further the currently dominant technocratic, market-friendly and procedural approach to multilateral climate governance. As such, despite claims about its transformative potential, climate crypto-governance is often imagined by influential actors in an incorporative and incremental rather than radical manner' (Hull et al., 2021).

In this respect, I reckon that these two counter-arguments may be as strong as the arguments supporting the adoption of the technology. In particular, it has to be understood that blockchain technology does not represent a panacea to all the sustainability issues that our planet and societies are facing and, if misused, they may actually be detrimental. Blockchains, in fact, are as righteous and trustworthy as the original data that they secure and make immutable: if the original data are corrupted or untrustworthy, then storing them on the blockchain won't make them true and reliable. This is why data originated by technologies such as IoT or sensors, and swiftly stored on the blockchain, may be preferable inasmuch they are less susceptible to human tampering before getting uploaded to the blockchain.
In light of these observations, it must be acknowledged the nature of blockchains in the quest for sustainability: that is, of *supporting* technologies. As such, they need to be

paired with other tools, technologies, policies and, most of all, good will and cooperation, to be truly impactful.

Yet, critiques to blockchain are not limited to their potential lack of effectiveness or side-effects. The most vigorous area of criticism towards blockchains, in fact, concerns their environmental impact. As of December 2021, 136 state governments have set carbon-neutrality targets, and most of them consider blockchain as a significant tool to achieve such goals (Qin et al., 2023). Moreover, the share of blockchain applications focused on the energy and environmental protection area has grown from 16% in 2020 to 19% in 2021 (Qin et al., 2023). Still, even though this technology can enhance social and environmental sustainability in countless declinations - as extensively illustrated in the present dissertation and in peer-reviewed publications -, we cannot ignore the fact that it is, itself, a primary source of pollution (Sarkodie & Owusu, 2022).
Such concerns are particularly pressing for blockchains that use the so-called proof-of-work consensus mechanism, like Bitcoin, which requires huge computational power and energy consumption (De Filippi & Wright, 2018; Mora et al., 2018; Baur & Oll, 2022). To give a perspective of this, it has been estimated that the energy consumption of Bitcoin, in 2020, equaled that of Thailand (Blandin et al., 2020) and, more pragmatically, that a single Bitcoin transaction, today, produces an electrical footprint comparable to that of a US household over a two months period (de Vries, 2020).
Hence, data on the polluting capacity of blockchains seem quite alarming.

Nevertheless, considering the development trajectories of previous technologies in the past, which became more efficient over time, it could be expected to see developments in this direction also for blockchain. In particular, the adoption of innovative consensus mechanisms can lead to reduced energy consumption. The proof-of-stake (PoS) mechanism for instance, recently adopted by the cryptocurrency Ethereum on 15 September 2022, has been argued to be ~99,95% less polluting than PoW - which was the consensus mechanism previously implemented within the Ethereum blockchain -

(Ethereum, 2023). Scholars, too, similarly agree that it may be thousand-fold more energy-efficient (Schinckus, 2020; de Vries & Stoll, 2021; Truby et al., 2022).

This argument is further strengthened by the Cambridge University Centre for Alternative Finance. In particular, they estimated a decrease of 99,99% in Ethereum's network energy usage after the day of the so-called *merge* - i.e., the day Ethereum switched from a PoW to a PoS consensus mechanism - (Cambridge University Centre for Alternative Finance, 2023).

Figure 5.12 provides an analogy that illustrates of the magnitude of this improvement. In this illustration, if Bitcoin's consumption were equivalent to the height of Merdeka 118 (the world's second-tallest building), Ethereum 1.0's consumption would be comparable to the London Eye (one of the world's tallest observation wheels), and Ethereum in its current form would be as minuscule as a raspberry.

FIGURE 5.12 - COMPARING ENERGY INTENSITY OF BITCOIN, ETHEREUM 1.0 AND POST-MERGE ETHEREUM
SOURCE: CAMBRIDGE CENTRE FOR ALTERNATIVE FINANCE, 2023

Furthermore, drawing from the environmental and scalability issues of PoW, a myriad of other proposals have been advanced, among which the Delegated Proof-of-Stake (DPoS), Proof-of-Authority (PoA), Proof-of-Capacity (PoC), Proof-of-Elapsed-Time (PoET) and many others. Each of these consensus mechanism comes with trade-offs in terms of security, decentralization, fairness , scalability and environmental impact, so the decision on which to implement is not straightforward and depends on various factors, such as the characteristics of the specific application.

Hence, in light of such possible developments, it may be too early to draw conclusions on this matter and, as Schulz et al. (2020) sums up, 'it is certainly too early to stop technological innovation because of energy concerns in particular'. Thus, to successfully tap into the potential of blockchain without doing so at the expense of the environment, I observe that regulation addressing the polluting potential of cryptocurrencies is needed as soon as possible. In particular, it should be aimed at promoting the use of renewable-only energy in cryptocurrency mining activities and/ or at further encouraging alternative systems to the proof-of-work consensus mechanism.

In the meanwhile, MSIs such as the Climate Chain Coalition (CCC) and the Crypto Climate Accord (CCA) have started to set goals to decarbonize the industry. Each with over 200 signatories, they have stressed the importance for the blockchain industry to help achieving the long term goals of the Paris agreement, to develop blockchains innovations for climate change and the achievement of SDG, to adopt proactive strategies to identify and seek to mitigate fraudulent activities associated with the application of blockchains in climate and sustainability governance, and to accelerate the development of 'proof-of-green' mining operations, for example by locating them near by wind farms or hydroelectric power plants (Schultz et al., 2020; Kennedy School Review, 2022).

At the same time. it has to be underscored that, given the emerging nature of the technology and the fact that we just left behind the phase of peak hype, a larger number of critiques may be raised in the near future, as the strengths and weaknesses of the technology are more clearly acknowledged.

5.7 Observations on Blockchains and the geographies of GVCs

Overall, hence, the introduction of blockchain-based systems in GVCs is accompanied by enhanced traceability, transparency, visibility, safety, resilience, trust, efficiency, collaboration, coordination, data integrity, real-time information exchange, and fair trade and pricing (e.g., Takahashi, 2017; Litke et al., 2019; Min, 2019; Mangla et al., 2022; Chandan et al., 2023). Therefore, it can be seen as a promising innovation, likely to bring enormous improvements to value chains, their governance and their sustainability (Lacity, 2018; Kamble et al., 2019; Kamble et al., 2021). The World Economic Forum, unsurprisingly, includes blockchain technology among six computing mega trends that will actively shape the next decade (World Economic Forum, 2015).

But a final consideration inevitably regards how blockchain may redesign the geographies of Global Value Chains, a topic that I find to be central in the context of this dissertation. While I have argued that other Industry 4.0 technologies may be suited to support a re-localization of production (see Chapter 4), conversely blockchain may bring about the opposite effect. While some argue that blockchain, too, may incentivize reshoring dynamics (Marfia & Degli Esposti, 2017), I am instead inclined to favor a different hypothesis. More specifically, in light of its capability to significantly enhance trust, reduce transaction costs, and increase visibility along the value chain, the adoption of blockchain systems may push organizations to even further offshore portions of their value chain, without trading off control over their suppliers due to geographical distances.

Yet, it is important to bear in mind that blockchain is an emerging technology and, as such, its impacts will likely vary depending on several factors, including the specific industry, the adoption rate, and the legal frameworks that will be designed around this technology.

Conclusions

The present dissertation ventured in a cross-section of technology and sustainability, providing an overview of Global Value Chains, the dimensions of sustainability and the related decision-making dynamics in the context of Global Value Chains. The study stressed the significant influence that these global networks exert on worldwide sustainability and underscored the urgency of addressing sustainability issues through a holistic and integrated approach encompassing the economic, environmental, and social aspects of sustainable development. By analyzing trends in publications on economic, environmental and social upgrading on Scopus database, it underscored the pressing nature of sustainability matters and the scholarly practice of studying the three pillars of sustainable development, accordingly, in an integrated and interdependent way.
Subsequently, the core of this work explored the potential impact on the sustainability of Global Value Chains of an emerging albeit controversial technology, blockchain, which is a component of the so-called Industry 4.0 technologies. As a complementary set of technological advancements, these hold significant potential in enhancing the sustainability of GVCs and in redesigning the geographies and value capture paradigms of these networks, as argued in chapter four.

The concept of blockchain is inevitably linked to cryptocurrencies, which represent the first practical implementation of this technology. However, since the introduction of Bitcoin - the first of these digital assets - in 2008, the scope of blockchain has since extended beyond its original niche. This dissertation employed a keywords analysis of Web of Science database to examine the 1000 oldest papers and the newest 1000 papers on blockchain technology up to May 2023. The ensuing analysis highlighted a shift in the research focus towards the inclusion of various other areas of applicability: most notably, supply chains, authentication, interoperability with other industry 4.0

technologies such as IoT and AI, and many other fields as diverse as agriculture and medicine.

Particularly, within the scope of this thesis, blockchain has emerged as an interesting tool to improve the sustainability of Global Value Chains. Its inherent characteristics of decentralization, immutability, security and disintermediation have been found to be a potential leverage to enhance transparency, traceability, visibility, accountability, collaboration and efficiency along Global Value Chains, thereby fostering sustainability. Interestingly, it was also noted, while blockchain literature emphasizes these features as crucial prerequisites for sustainability, they were not identified as key drivers or barriers in the traditional sustainability literature, as objectively reviewed in chapter 3. More specifically, this analysis - performed on a total of 40 relevant papers sourced from Scopus database and Google Scholar - determined that the traditional literature on supply chain sustainability considered regulation, competitive pressures and consumer demands as the most powerful drivers, while institutional deficiency, high costs, lack of sustainability and supply chain unpreparedness were identified as the most powerful barriers. This discrepancy suggests that conventional literature might be lagging in incorporating the relevance of these emerging concepts. Nevertheless, while the adoption of Blockchain indeed opens up an array of opportunities to foster sustainability, it may also hide collateral effects: particularly, by enhancing visibility within GVCs, it may further increase lead firms' control over their suppliers, thus exacerbating the power imbalances inherently present within GVCs.

Furthermore, the present thesis sought to give an overview on the adoption status of the technology, underscoring the rising public interest towards it. This has led to increased spending on blockchain solutions globally, with market size projections indicating significant growth. However, a widespread adoption of blockchain in GVCs is still a distant prospect. Several hurdles are identified, including difficulty in quantifying adoption costs, resistance to change from managers and workforce, inadequate digital skills, and potential opposition from stakeholders engaged in dubious practices, which could be exposed by the introduction of blockchains.

Counterarguments to blockchain, such as scalability issues, doubts about effectiveness, and environmental concerns - primarily energy consumption - were also scrutinized. To navigate these challenges, it was observed that it may be appropriate to establish robust governance and legislative tools, private regulatory mechanisms, and multi-stakeholder initiatives. Most notably, state institutions should devise policies addressing the environmental footprint of blockchain, while the use of innovative consensus mechanisms like proof-of-stake could drastically cut energy consumption, thereby fostering wider acceptance of the technology.

With respect to the adoption of the technology, it was also observed that the promotion of blockchain within GVCs could be mainly driven by private regulation, rather than by 'hard' law. In particular, this was hypothesized because non-state regulation has emerged as the predominant tool for governing sustainability within GVCs and it is more flexible and sensitive to technological innovation compared to traditional state regulation. As a further consideration, it was noted that blockchain's integration might encourage further offshoring of value chain activities due to increased trust, reduced transaction costs, and enhanced visibility. Yet, the eventual impact of blockchain on GVC geographies will be dictated by diverse factors such as industry-specific dynamics, adoption rates, and regulatory frameworks.

In conclusion, as we move forward in the digital age, it appears that blockchains stand poised to significantly influence the evolution of GVCs. However, it is essential to understand that this technology does not represent a panacea in the pursuit of sustainability. Instead, it also may hide potential pitfalls. Thus, the role of blockchains must be acknowledged as that of supporting tools. As such, they need to be combined with other tools, technologies, policies and, most of all, good will and cooperation, to be truly impactful.

Ultimately, it is up to us as humans to harness this technology in a way that promotes sustainability, efficiency, and fairness across Global Value Chains.

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