CHAPTER 11

SUSTAINABILITY AND RESILIENCE IN THE EXTENDED VALUE CHAIN: THE CASE OF STMICROELECTRONICS

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ABSTRACT

In recent years, both academics and institutions have acknowledged the crucial role multinational enterprises (MNEs) can play in addressing the sustainability challenges, as formalized by the sustainable development goals (SDGs). Nevertheless, because of their extensiveness and their design as country-level targets, SDGs have proven challenging to operationalize at a firm level. This problem opens new and relevant avenues for research in international business (IB). This chapter attempts to frame the topic of extended value chain sustainability in the IB literature. In particular, it addresses a specific topic, that is, how sustainability and resilience-building practices interact in global value chains (GVCs). To do so, the present study develops the case of STMicroelectronics (ST), one of the biggest semiconductor companies worldwide.

Keywords: Sustainability; resilience; global value chains; semiconductor industry; STMicroelectronics; responsibility

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1. INTRODUCTION

On January 1, 2020, firms woke up into the 'Decade of Action': 10 years that should lead to achieving the SDGs. Herein, the private sector – representing 75% of global gross domestic product (Guterres, 2019) – was ascribed a leading role in accomplishing the SDGs (Van Tulder et al., 2021) and MNEs have an active role in this. The transition towards sustainable ways of organizing business activities is a strategic imperative (Van Tulder et al., 2021). Yet, many companies still have not fully incorporated sustainability in both general and specific terms into 'their core business strategies, operations, and cultures' (Deloitte, 2021).

Recent calls for action and research (Baldassarre et al., 2020; Ghauri et al., 2021) highlight the importance and the need for further research on MNEs' responses to climate change as it strongly impacts their 'strategy, business models, and operations across different national systems' (Ghauri et al., 2021, p. 5).

MNEs have fragmented their value chains across the globe in the last 40 years, encouraged by the rise of trade liberalization, technological improvements for communication and coordination and new opportunities to increase cost efficiency (e.g. lower labour costs in emerging economies). The phenomenon has become so prominent that the United Nations Conference on Trade and Development estimated that in 2013 about 80% of world trade took place within the so-called GVCs (UNCTAD, 2013).

A GVC includes the full range of activities that are required to bring a good or service from conception through the different phases of production to delivery to final consumers as well as disposal after use (Cattaneo et al., 2010; Gereffi & Fernandez-Stark, 2011). In the perspective of the 'global factory' as formalized by Buckley and Ghauri (2004), MNEs are identified as the 'orchestrators' of GVCs: they coordinate globally dispersed value chain activities through more precise use of ownership and location strategies (Buckley, 2011).

Despite the most recent dynamics about GVCs becoming shorter and/or more concentrated (Ciravegna & Michailova, 2022; The Economist, 2022), MNEs are still responsible for the greatest majority of intermediate goods exchanges across the globe. World exports of intermediate goods increased by 21% in the fourth quarter of 2021, accounting for $2,629 billion, with a yearly recovery of 28% if compared with 2020, the peak year of the COVID-19 pandemic (WTO, 2022). Moreover, the last available data show that Trade in Value Added reached $82,962 billion worldwide in 2018, with a 6.3% increase with respect to the previous year (OECD, 2021a). Finally, in the first half of 2022, global foreign direct investment (FDI) flows reached $972 billion, recording the largest levels since 2013 (OECD, 2022).

GVCs are complex structures and they can be analysed from four different and interconnected perspectives (Bair, 2009; Gereffi & Fernandez-Stark, 2011): (i) the input–output structure, which encompasses all the activities of the VC; (ii) the geographical configuration of activities; (iii) the governance structure and (iv) the institutional context in which the VC operates.

Firstly, the input–output structure allows to identify the main activities and segments of the GVC and its analysis provides insights into the dynamics within

each segment of the VC (e.g. sourcing practices or preferred suppliers) (Gereffi & Fernandez-Stark, 2011). This level of analysis is the closest to the operational level and it identifies where value is created. From a sustainability perspective, the analysis of the input–output structure addresses issues such as responsible sourcing (Guo et al., 2016) and circular economy (CE) business models (De los Rios & Charnley, 2017).

Secondly, MNEs have increasingly offshored value chain activities, that is, they relocated parts of production to foreign locations, irrespectively of the ownership mode (Kinkel & Maloca, 2009). Nowadays, value chain activities are often globally dispersed and different activities are usually carried out in different parts of the world. The location of value chain activities can potentially hinder or enhance the company's ability to address sustainability challenges depending on the available local resources.

Thirdly, GVCs can be analysed according to their governance structure, that is, 'authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain' (Gereffi, 1994: p. 97). MNEs can choose to outsource some or all of their VC activities, that is, to obtain semi-finished products, finished products or services from an outside company if these activities are traditionally performed internally (Simchi-Levi et al., 2004). The governance aspect is important for sustainability too: largely pushed by public opinions, MNEs are increasingly considering non-financial factors when making crucial business decisions. There is a trade-off between the benefits of outsourcing and the ability of MNEs to control how subcontractors implement sustainability standards (Narula, 2020): for example, it took Samsung a dedicated external audit to discover that among its Chinese suppliers 33 broke local regulations on insurance, 39 paid fixed wages without compensation for overtime, 33 cut pay as a disciplinary measure and 48 let minors (employees aged 16–18) handle chemicals (The Guardian, 2014).

Finally, GVCs exist within an institutional context, which is particularly relevant in the perspective of analysing value chains and their impact on sustainability. Local and international policies can have a substantial impact on MNEs' value chains: an example is the USA–Mexico–Canada Agreement (USMCA) entered into force in 2020, replacing the North American Free Trade Agreement (NAFTA). Differently from NAFTA, the protection of worker rights and the enforceability of labour provisions were major concerns throughout the USMCA negotiations. The new agreement requires member states to adopt and maintain worker rights as stated in the 1998 Declaration on Fundamental Principles and Rights at Work, in addition to acceptable conditions of work, including concerning minimum wages, working hours and occupational safety and health (U.S. Department of Labor, 2022a). In this context, the Mexican executive branch introduced a bill that, if enacted, would effectively eliminate, in most cases, the use of service companies in Mexico: it attempts to strengthen employment and abolish practices that harm labour rights and reduce the obligations of employers (EY, 2020). Consequently, local service companies providing specialized services and MNEs operating under subcontracting agreements in the country will need to evaluate the impacts the reform's impacts on their operations and adjust them accordingly.

By reporting the case of ST, this chapter aims at presenting a best practice for the development of a sustainability strategy that encompasses the MNE business model and its relationship with other GVC actors. We address the topic of extended value chain responsibility and how this well-rounded approach to sustainability can be complementary to a company's efforts towards resilience building.

2. GVCs AND SUSTAINABILITY

Sustainability is defined as the 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development, 1987, p. 24).

Despite the relevance of addressing sustainability challenges for the well-being of the world population, to date, it is still not clear how to interpret, measure and operationalize it (Green et al., 1998). At present, the most extensive attempt to identify actionable approaches was the drafting of 17 SDGs by the UN Sustainable Development Summit in 2015: these goals promote the joint effort of MNEs, institutions and local businesses for the improvement of environmental, social and economic conditions (Ghauri et al., 2017). Nevertheless, because of their extensiveness and their design as country-level targets, SDGs have proven challenging to operationalize at the firm level: they leave it up to MNEs, one of the key actors in building sustainable behaviours, to integrate the goals into their operations (Montiel et al., 2021).

This is particularly relevant, considering that MNEs' GVCs significantly contribute to climate change (World Bank, 2019). Firstly, MNEs shape the depletion of finite natural resources, such as biomass, fossil fuels, metals and minerals: in 2017, one-third of the total volume of material resources extracted in the world economy – which has tripled since 1970 – was employed in the production of internationally traded goods (International Resource Panel, 2020). Secondly, GVCs influence the amount and type of waste generated during the production process: for example, the electronics industry, which is GVC-intensive, produces more than 70% of the toxic waste in US landfills (Holgate, 2018). Moreover, the back-and-forth transport of goods across long distances directly contributes to climate change with CO_2 emissions from international freight transportation, accounting for about 7% of total emissions globally in 2015 (World Bank, 2019).

Furthermore, over the past decades, following the low-cost labour imperative, MNEs have offshored relevant parts of their value chains in emerging and developing countries: over time, this approach has raised important concerns about social sustainability. Social sustainability as defined by McKenzie (2004, p. 18) entails

> [all] formal and informal processes, systems, structures and relationships [that] actively support the capacity of current and future generations to create healthy and liveable communities[…] equitable, diverse, connected and democratic and provide a good quality of life.

Subcontractors may perpetrate unethical – and at times unlawful – social practices within GVCs. For example, in 2017, a journalistic investigation reported 18

suicide attempts and 14 confirmed deaths in Foxconn – Apple's main outsourcee in China – connected to the poor work and living conditions the employees are subjected to (The Guardian, 2017). More recently, the U.S. Department of Labor (2022b) reported that an American subcontractor for the Korean car giant Hyundai engaged in oppressive child labour by employing young workers under the minimum age of 14 in Alabama. The International Labor Organization (2021) reports that, in 2020, 9.6% of children aged 5–17 years were engaged in child labour worldwide, with 4.7% of them being involved with hazardous work, that is, work that directly endangers their health, safety and moral development.

Almost 2 million people die from work-related causes each year, such as exposure to long working hours and workplace exposure to air pollution, asthmagens, carcinogens, ergonomic risk factors and noise (World Health Organization, 2021a). These deaths are disproportionately concentrated in Africa, South-East Asia and the Western Pacific Region (World Health Organization, 2021b).

Environmental and social sustainability-related issues are concerning for firms' international value chain activities, both primary and support ones,[1] and regard MNEs and their outsourcees in both developing and developed countries. Their pervasiveness has led IB researchers to increasingly address the issue of extended value chain responsibility. The idea of 'extended value chains' emphasizes how value-creating activities – both primary and support – can extend beyond MNEs' direct control (Vachani & Post, 2012). In the case of outsourced value chain activities, relationships with subcontractors are mostly regulated through contractual agreements and the MNE has limited visibility and control over the outsourcee behaviour, depending on the level of power asymmetries between the entities (Cox, 2001; Strange, 2011). Moreover, the extended value chain includes suppliers beyond the first-tier, which have no formal relationship with the MNE but are still practically involved in the value creation, potentially exposing the MNE to serious social and environmental risks. Nevertheless, increasingly, MNEs are being held accountable for the adoption of sustainable practices of other actors within the extended value chain: as orchestrators, they are seen as the most impactful entity, and the promoters and facilitators of the sustainable practices cascade throughout the extended value chain (McKinsey, 2016; Montiel et al., 2021; Villena & Gioia, 2020).

From the environmental sustainability perspective, this issue has been studied among researchers of sustainable supply chain management: it is not enough for MNEs to build green supply chains by accounting for the environmental impact of their purchasing strategy, manufacturing process and distribution (Badi & Murtagh, 2019); they need to make sure that suppliers and customers adhere to environmentally friendly practices. This new perspective has moved both institutions and companies to evaluate how sustainable goals can be best achieved by taking a business model approach. For example, in 2015, the European Commission launched the so-called 'circular economy (CE) package': an economic model based on the CE integrates all value chain functions into a non-linear production and consumption system to optimize the efficiency of resources, production processes and consumption habits within the system itself, rather than seeking efficiency of individual components or functions separately.

The implementation of CE practices, such as closed-loop supply chains (CLSC), combines large environmental benefits with radical changes in business models associated with a possible increase in risk (Masi et al., 2017; Murray et al., 2017). Moreover, GVC literature suggests that MNEs may be the initiators of these CE practices, defining standards for product and process requirements of suppliers (Yamin et al., 2015). However, the dynamics of application of CE practices may depend on the type of governance existing in the GVC, according to the power asymmetries between lead firms and suppliers (Ashby, 2018; De Marchi et al., 2019; Gereffi & Lee, 2016).

From the social sustainability perspective, the employment of sustainable practices and policies has predominantly been investigated in the context of headquarter–foreign subsidiary relationships, in which MNEs should transfer sustainable social practices using their power to directly control the foreign entity (Iatridis & Kesidou, 2018; Tashman et al., 2019). Recently, Castaldi et al. (2022) widened the context of analysis by investigating the transfer of socially sustainable practices along the extended value chain and proposed two governance strategies that can come into play. On the one hand, MNEs can implement an audit-based governance strategy, by imposing unilateral top-down pressures on suppliers to implement social sustainability policies in their daily working routines (Locke et al., 2009; Lund-Thomsen & Lindgreen, 2014). On the other hand, MNEs can implement a more developmental, capacity-building form of governance (Alexander, 2020; Lund-Thomsen & Lindgreen, 2018) that seeks to 'change suppliers' day-to-day managerial practices in ways that may also support improved social performance' (Distelhorst et al., 2017, p. 710), for example, MNE's active provision of training.

In conclusion, collaborative dynamics between actors are emerging as relevant and under-investigated mechanisms for the adoption of sustainable practices throughout GVCs. This perspective is in line with SDG 17, for which one of the targets is the enhancement of the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources to support the achievement of the SDGs.

3. GVCs, SUSTAINABILITY AND RESILIENCE

Alongside value chain sustainability, IB researchers have increasingly taken an interest in the investigation of value chain resilience (Buckley, 2021; Gereffi, 2020; Ku et al., 2020; Strange, 2020): the two concepts have recently started to be associated, but the study of their relationship is in its early development (Fahimnia et al., 2019).

Although it was already an established topic in operations management, the study of resilience in IB took hold after the Covid-19 pandemic. This particular event has dramatically exposed the fragility of international production networks vis-à-vis extremely uncertain environments. After its outbreak in November 2019 in China, the pandemic determined an income decline of 37% for more than 80%

of MNEs by September 2020 (Saurav et al., 2020), a decrease in 2020 global FDI flows by 40% and a decrease in greenfield investment projects and cross-border M&A by more than 50% (UNCTAD, 2020). After witnessing these dramatic consequences, IB researchers have advanced resilience as a value chain endowment to overcome sudden disruptions (Ciravegna & Michailova, 2022). However, value chain resilience isn't exclusively associated with disruptions such as the pandemic, but with a wider variety of uncertainty factors, such as the degradation of geopolitical relationships among countries (e.g. trade wars and actual warfare) (Buckley, 2022) and climate change. The latter is especially relevant for GVCs: the increasing threat of natural disasters (i.e. geophysical, meteorological, hydrogeological, climatological and biological) poses a distressing risk for business continuity and logistics (Ghadge et al., 2020; Oh & Oetzel, 2022). An example is the devastating ripple effect the Fukushima earthquake of 2011 had on the semiconductor value chain, resulting in a disruption in silicon wafer production, discontinuation of memory chips production and ultimately consumer products (Lohr, 2011). This kind of empirical evidence has encouraged researchers to explore the touchpoints between sustainability and resilience, both in their conceptualization and implementation (Negri et al., 2021).

At the conceptual level, resilience and sustainability have overlapping purposes. Previous IB studies mostly define resilience as the 'ability of a system to return to its original state or move to a new, more desirable state, after being disturbed' (Christopher & Peck, 2004, p. 4). In this perspective, both sustainability and resilience aim at achieving the survival of a system (Mehrjerdi & Shafiee, 2021): sustainability is focussed on the long-term system survival through the optimized management of human and environmental resources; resilience aims at prolonging the system lifespan by managing the negative consequences of a disruption.

Even though studies on the integration of the two concepts are still sparse, it is possible to identify some common underlying themes.

Firstly, institutions appear to play an important role in both value chain sustainability and resilience. Recently, Gereffi et al. (2022) conceptualized resilience as a multilevel construct, which can be analysed from three different perspectives, that is, the GVC, the firm and the State. Institutions are seen as facilitators of resilience (Gereffi et al., 2022; United States, 2021), by acting either on the lead firm or on the context in which it operates. Institutions can 'guide' MNEs in their decision-making process concerning the value chain, by requiring specific sourcing or geographical configurations according to the industry (Dallas et al., 2021). Institutions can also reduce unnecessary heterogeneity of norms and standards to facilitate production inputs substitutability (OECD, 2021b), support SMEs and workforce capability development with ad hoc investments (The White House, 2021; UN, 2021), and negotiate favourable international trade policies (Gereffi, 2021). Concurrently, institutional pressures can influence MNEs' sustainability efforts, including those that emerge from the SDGs (Van Zanten & Van Tulder, 2018). The SDGs themselves are an indicator of how effective institutions can be in enhancing sustainability since they define the most widely accepted sustainability targets.

Secondly, from the GVC perspective, the governance structure is relevant for both resilience and sustainability. Previous studies on value chain resilience have focussed on how entry modes and levels of subsidiary ownership can concur with the reaction of GVC in case of uncertainty (Song, 2017). These studies look at resilience from the structural governance perspective, that is, decisions on formal ownership and control of value chain activities along the value chain. More recent studies have started to investigate how resilience can be influenced by *managerial* governance, that is, 'decisions pertaining to learning and knowledge transfer in the GVC, relationship management, resource recombination, contractual details, coordination and monitoring' (Kano et al., 2022, p. 27). The sharing and processing of information collected from value chain actors enhance MNEs' visibility along the value chain and support the planning and coordination of business activities (Sinkovics et al., 2011; Wong et al., 2020). Visibility enables the identification of potential disruptions, allowing better management of inventories, replacement of disrupted production capacity at short notice and rerouting of value chain activities to alternative sites or suppliers (Brandon-Jones et al., 2014; Dilyard et al., 2021). Therefore, as for sustainability, control and visibility along the value chain are crucial themes for value chain resilience.

Thirdly, the adoption of CLSCs is gaining relevance also for value chain resilience. In view of creating value and environmental care, CLSC has been highlighted as a proper system for the reduction of resource exploitation and waste (Soleimani et al., 2017; Zhen et al., 2019). Previous studies in the supply chain management field have investigated how CLSC can support MNEs in dealing with disruptions and uncertainty in general (Chen et al., 2015; Ivanov et al., 2018; Jabbarzadeh et al., 2018a). More recently, researchers have started to investigate how CLSC structure can facilitate the dissemination of sustainable practices while enhancing the value chain ability to face disruptions (Jabbarzadeh et al., 2018b; Mehrjerdi & Shafiee, 2021).

Finally, like sustainability, resilience is not considered an ability that can be cultivated with the MNE efforts alone, but it requires nurturing collaborative relationships with other value chain actors, such as suppliers, institutions, consumers and other MNEs from compatible industries (Gereffi et al., 2022).

Although the investigation of the topic is still at its early stage, Negri et al. (2021) already proposed a definition of sustainable and resilient supply chains, which entails the integration of 'economic, environmental and social considerations in the business system, while dynamically preparing, adapting and reacting to unexpected disruptions, to meet the stakeholder requirements and improve firm profitability and competitiveness in the short and long term' (p. 2868).

4. THE CASE OF ST

This chapter presents the case of ST and focusses on how sustainability and resilience interact in the company's value chain. Information for the company overview and value chain description was derived from the company's 2021 Form

20-F for the United States Securities and Exchange Commission, the company's annual reports and materials for investor relations and ORBIS database.

The data sources for the company's strategy are secondary data, that is, company's sustainability reports of the last years and news outlets, and one in-depth semi-structured interview with Dr Alberto Della Chiesa, Executive Vice President Supply Chain in ST.

4.1. The Industry

4.1.1. Semiconductors and Sustainability

Semiconductors have become ubiquitous in our daily life: from smartphones, personal computers and home appliances to Industry 4.0 machinery, they are the enablers of our contemporary lifestyles. Consequently, in the last few years, the global demand for semiconductors has surged. Because of the increasing production volumes and the resource-intensive nature of the manufacturing process (Ahmad, 2007), today, the industry is responsible for a significant carbon footprint. For example, the semiconductor industry accounts for about 2% of the total US electricity consumption in the manufacturing sector (Gopalakrishnan et al., 2010). Moreover, the largest Taiwanese semiconductors producer exploits as much electricity as Sri Lanka's 21-million population and is expected to use up 12.5% of the island's annual power consumption by 2025 (Bloomberg, 2022).

The Greenhouse Gas Protocol, which was set up by the World Resources Institute and the World Business Council for Sustainable Development in 2001, identifies three categories of emissions for the semiconductor industry (McKinsey, 2022). Scope 1 emissions arise directly from foundries, primarily from gases that are used during the production phases. This first type accounts for 35% of total emissions of a typical foundry. Scope 2 emissions indirectly arise from purchased electricity, steam, heating and cooling equipment and account for 45% of total emissions. Finally, Scope 3 emissions include all other indirect emissions in a company's value chain, from suppliers' practices to the usage of products containing semiconductors. Many semiconductor producers have started to acknowledge their impact on the environment and they have set sustainable – and at times ambitious – goals concerning the decrease of energy consumption, optimization of energy supply and reduction of process gas emissions. Moreover, governments and international institutions have started to provide incentives for an evolution towards a more environmentally sustainable semiconductor industry. For example, in August 2022, the Biden administration approved the 'CHIPS and Science Act': while its main objective is to foster a national semiconductors value chain, the Act could direct an estimated $67 billion towards accelerating the growth of zero-carbon industries and conducting climate-relevant research (The Atlantic, 2022).

Because of their relationships with subcontractors and/or suppliers in emerging and developing countries, semiconductors companies and electronics producers, in general, face risks of being associated with poor socially sustainable practices. For example, in 2022, the US Department of Labor included electronic devices and silica-based products like semiconductors among those goods at risk of being

produced with forced labour in Xinjiang, that is, the Chinese region where the government has reportedly detained more than a million Muslims in reeducation camps since 2017 (OHCHR, 2022). Moreover, workers directly engaged in the manufacturing process handle toxic materials. Scientific trials required by industry players have demonstrated that the handling of these materials without the necessary precautions is associated with a doubled probability of miscarriages in female employees (Bloomberg, 2017). Despite their relevance and urgency, social sustainability issues have been addressed much less by companies in the semiconductor industry if compared to their effort for environmental sustainability.

4.1.2. Building Resilience Against Uncertainty in the Semiconductor Industry

Beyond sustainability, the last few years have been extremely trying for the semiconductor industry in other aspects. The COVID-19 pandemic caused a shock to both global demand and supply, creating a dual challenge for semiconductor companies (McKinsey, 2020). If, on one hand, lockdowns imposed by governments worldwide have initially reduced the demand for semiconductors in industries such as the automotive, they have also caused an explosion in demand in others, like smartphones and PCs (Bloomberg, 2021). For what concerns the supply side, there were already difficulties in obtaining inputs for production before 2020. However, the pandemic exacerbated these trends by disrupting the supply chain through a series of COVID-19 shutdowns, especially in Asia (U.S. Department of Commerce, 2022). At the moment of writing, we are experiencing a significant semiconductor shortage that is continuing to affect auto production, raising electronics prices and even threatening the availability of machinery for semiconductors production plants (The Wall Street Journal, 2022). Moreover, the Russia–Ukraine war has the potential to exacerbate semiconductor supply chain issues: the most immediate risk is to the supply of specific raw materials used in semiconductor manufacturing such as neon and palladium (KPMG, 2022) that could be used as a geopolitical pawn.

Although the semiconductor industry is historically volatile and players are accustomed to industry cycles, the events of the last few years have proved to create a 'perfect storm' that has deeply challenged all players involved.

In light of past disruptions and recent developments, both academics (Ivanov & Dolgui, 2022; Matsuo, 2015) and practitioners (Accenture, 2020; KPMG, 2021) have highlighted the need to develop more resilient value chains in the semiconductor industry.

4.2. ST: An Overview of the Company

ST is one of the world's largest semiconductor companies. It is a global independent semiconductor company, headquartered in Geneva, that designs, develops, manufactures and markets a broad range of products used in a wide variety of applications. ST serves four markets, that is, automotive, industrial, personal electronics and communications equipment, computers and peripherals. For the automotive and industrial markets, the company serves a wide customer base

with a broad and deep product portfolio. In the remaining segments, ST adopts a selective approach both in terms of the customers served as well as in the technologies and products offered, while leveraging a broad portfolio to address high-volume applications. Moreover, the company's products are employed in Smart Mobility applications, that is, innovations to make driving safer and greener, in the energy sector, to increase efficiency and support the use of renewable energy sources, and in Internet of Things (IoT) technologies.

In 2021, the company's major customers in terms of revenues included Apple, Bosch, Continental, Delta Electronics, HP, Huawei, Intel-Mobileye, Samsung, Seagate and Tesla. However, ST serves more than 200,000 clients in total.

ST is an R&D-intensive company: it currently owns approximately 18,500 patents and pending patent applications, corresponding to approximately 9,400 patent families, including 543 original new patent applications filed in 2021.

The company employs about 48,000 people worldwide, 17.5% of which in R&D. In 2021, ST reported revenues of $12.8 billion, so distributed: 41% from the Americas, 34% from the Asia Pacific Region and 25% from the Europe, Middle East and Africa (EMEA) region.

4.3. ST Value Chain

ST value chain is organized in a matrix structure, with geographic regions interacting with product groups. Both geographic regions and product groups are supported by shared technology and manufacturing operations and by central functions. These central functions are designed to enable the company to facilitate communication among the R&D, production, marketing and sales functions. The remainder of this paragraph describes the strategy behind the structure of ST value chain.

Because of its strategic role, ST carries out the R&D function in-house, within innovation centres that allow the company to quickly and cost-effectively introduce new products in the market. These innovation centres are located in North America, Europe and South-East Asia. However, collaborative relationships with customers, competitors, research organizations, universities and suppliers have become strategic for ST. This collaborative network enhances R&D efforts by providing the company with the opportunity of sharing costs, acquiring technical know-how, and access additional production capacities.

ST value chain involves three critical types of suppliers. Firstly, the company interacts with equipment suppliers, that is, third parties that provide production machinery, such as chemo-mechanical polishing equipment. Secondly, material suppliers provide the company with raw materials needed for production, such as silicon, chemicals and gases. In particular, the semiconductors manufacturing process employs many materials with volatile prices due to the specificity of the market. Thirdly, ST employs external silicon foundries and back-end subcontractors to outsource parts of wafer manufacturing and assembly and testing of finished products. In fact, over the years, ST has consistently subcontracted a portion of total manufacturing volumes to external suppliers. In 2021, the company subcontracted approximately 24% of the total production value. Nevertheless, ST directly operates seven front-end and seven back-end manufacturing sites, which

are located in Europe, Asia and North Africa. Overall, ST procures materials, goods and services from approximately 6,500 tier 1 suppliers of various types and sizes. In 2021, around 49% of procurement was with suppliers based in Asia and 44% in Europe. Moreover, 37% of total procurement volume is managed locally and the rest is managed centrally at corporate level.

Sales and marketing activities are organized as a combination of regional and key account coverage. The three regional sales units report to the headquarters and are located in the Americas, South-East Asia and EMEA regions.

Finally, distribution is carried out by third parties, that is, distributors and sales representatives. Distributors usually handle a wide variety of products, including those of ST competitors. Their role is to assist the company in fulfilling customers' demand by delivering orders, but they also work on business development. On the other hand, sales representatives do not handle directly competing products and serve as intermediaries for the placement of orders with the company.

4.4. Sustainability of the Extended Value Chain

For a long time, ST has adopted a proactive approach to sustainability. Since 1991, the company's sites have received more than 70 awards for excellence in all areas of Corporate Responsibility, from quality to corporate governance, social issues and environmental protection. ST has been a signatory to the United Nations Global Compact since 2000 and a member of the responsible business alliance (RBA) since 2005. The company's approach to sustainability is based on four main pillars. Firstly, ST aims at developing responsible products and technologies in terms of product life cycle, that is, eco-design, responsible sourcing, low-footprint manufacturing, product power efficiency, its sustainable applications and end-of-life recycling. Secondly, ST aims at ensuring people's health, safety and well-being and the respect of labour and human rights along its value chain. Thirdly, the company has started to work towards a circular system to achieve carbon neutrality, reduce waste and water usage and address local scarcity risks. In fact, in 2020, the company announced the goal to become carbon neutral by 2027. Fourthly, ST conceptualizes sustainability also in terms of embedding risk management in the business activities within the extended value chain. From this outset, it is already possible to note how ST approach to sustainability is extremely holistic, encompassing the company's business model and its relationships with third parties. For this reason, ST maintains an open dialogue with its stakeholders on all matters, including sustainability.

In practice, ST supports the achievement of the SDGs through the design of specific goals and targets for 11 of the 17 SDGs, which apply both company-wide and to the extended value chain. For example, in compliance with SDG 8[2] and SDG 17,[3] ST developed a programme entitled 'Responsible Supply Chain', which actively engages its suppliers.

The following paragraphs will detail how ST includes and engages its stakeholders in the goals setting and capability-building processes for sustainability.

4.4.1. Goals Setting

In setting its sustainability strategy, ST aims at developing long-term objectives. However, once defined, these objectives are periodically re-evaluated because of the ever-changing nature of sustainability challenges. ST works on both the identification and re-alignment of sustainability objectives in collaboration with its key stakeholders. The system with which the stakeholders are engaged in the procedure is called a 'materiality exercise' by ST and includes three phases. In the first phase, the company identifies relevant sustainability-related topics by reviewing industry standards, new regulations, CSR trends, benchmarks and stakeholder requests. Subsequently, ST selects priority topics on a preliminary analysis of pertinence and importance in terms of risk, impact and opportunity for the company. This prioritization process is carried out in collaboration with nine categories of stakeholders, that is, employees, customers, investors, suppliers, local partners, national and local authorities, academic entities, industry associations and media. In the second phase, ST executives are asked on a voluntary basis to estimate the potential negative or positive impact of each identified topic on the company's business. Moreover, internal and external stakeholders are contacted to complete an online survey to rate the importance of each topic according to them. The outcome of this phase is a 'materiality matrix' derived from executive and survey inputs, aggregated with input from ST sustainable development experts based on megatrends, external factors and alignment with company values. The materiality matrix represents each sustainability issue against the importance attributed by stakeholders and impact on company business. Finally, ST carries out a strategy validation phase, by developing a comprehensive sustainability strategy based on the crucial identified topics and setting long-term goals.

4.4.2. Building Capability for Sustainability

To build sustainability capability within the company, ST provides environment, health and safety (EHS) training to its employees. EHS training is provided through dedicated e-learning platforms, workshops and events (e.g. EHS week). In 2021, ST trained 72% of its manufacturing employees on social responsibility issues. In its approach to social sustainability, the company aims at raising awareness of labour and human rights issues relevant to the local context by training employees on the RBA code of conduct. Moreover, to encourage sustainable behaviour, ST integrates specific sustainability objectives into the compensation schemes of senior executives and employees, focussed on safety, climate change, gender diversity and employee engagement.

However, this level of commitment is extended to ST's relationships with third parties.

ST requires its suppliers to implement RBA standards and encourages International Organization for Standardization (ISO) and Occupational Health and Safety Assessment Series (OHSAS) certifications to address sustainability risks. However, the company also supports suppliers in raising their awareness and capability to comply with the required standards. ST provides suppliers with dedicated training on risks in areas such as labour (including working hours and

forced labour), ethics, health and safety, environment and management systems. Training is conveyed through the e-learning platform as well as webinars and in-person training. Moreover, suppliers are invited to attend dedicated events concerning sustainability (i.e. the aforementioned EHS week) and the theme of sustainability is discussed in trade roadshows organized by ST worldwide. In 2021, the company trained over 400 suppliers' employees representing more than 200 companies. In addition, ST global community supports suppliers' continuous improvement through ongoing dialogue and sharing best practices. For example, ST supported its key supplier in Malaysia in migrant worker management. Faced with the issue, the supplier reached out to ST and its management team was invited to the local ST site to enhance their awareness of the company's RBA requirements and learn ST's migrant worker management methods could be adopted to improve the supplier's practices.

Collaborative relationships on matters of sustainability are also extended to customers, in particular, concerning the carbon neutrality goal. An ongoing dialogue with customers in the product development phase allows ST to develop efficient and compact power and energy management solutions. The product development phase, in collaboration with customers, is carried out following three principles. Firstly, products are developed in compliance with legislation and customer's EHS requirements. Secondly, ST employs an 'eco-design' approach, by taking into consideration the environmental impact of the device during its whole lifecycle, therefore proposing power-efficient and low-carbon products. Thirdly, products are developed for responsible applications, that is, applications that provide sustainable benefits for human welfare or the environment, such as planet-friendly and human-welfare-responsible products. In 2021, the percentage of ST new products classified as responsible was 69%.

In addressing SDG 4[4] and SDG 10,[5] ST also invests in training for local communities in which it operates. As for 2021, the company has a strategic community programme: 'STEM your way'. The programme aims to raise awareness in young people about the importance of Science, Technology, Engineering and Mathematics (STEM) subjects and inspire them to explore STEM-related careers. It includes specific events to inspire young children who tend to be curious, open-minded and less influenced by their peers and for girls to encourage more diverse talents by combating gender stereotypes in science and technology.

ST also promotes industry-wide addressing of sustainability: the company works alongside other semiconductor companies by joining industry associations. At present, ST is a member of the European Semiconductor Industry Association (ESIA) and its Corporate Environment Director leads the ESIA EHS committee. ST aims at collaborating with competitors to work towards a proactive approach to EHS responsibilities. Interactions with association members consist of working groups on resource conservation, air emissions and chemicals but also participation in consortiums, conferences and seminars (Table 1).

The provision of training is a significant engagement instrument for three key stakeholders: employees, suppliers and local partners. More, in general, ST approach is proactive in providing third parties with strategic resources to

Table 1. Stakeholders Engagement Instruments.

Stakheholder	Engagement Instruments
Employees	• Seminars, conferences and forums
	• VP communication meetings
	• Recognition, awards and contests
	• Intranet, Internet, news, emails and videos
	• Training, workshops
	• Employee surveys
	• Application week and EHS week
Suppliers	• Meetings
	• Audits
	• Supplier training
	• Surveys
	• EHS week
	• Technical roadshows
Customers	• Trade shows
	• Conventions and technical seminars
	• Audits and site visits
	• Joint seminars, conferences, blog, technodays, workshops and webinars
	• Meetings
Local partners	• Partnerships
	• Conferences, conventions and meetings
	• Site visits
	• Donations, training, volunteering and local initiatives
Industry associations	• Memberships in public–private partnerships, international and European associations
	• Participation in consortiums and in working groups of electronic industry associations
	• Meetings, conferences and seminars

Source: Authors' own elaboration from ST Sustainability report 2022.

develop awareness and competencies to address sustainability challenges along the whole value chain.

4.5. Sustainability and Resilience Synergy

In ST sustainability reports, the word resilience appeared for the first time in 2018, as an evolution of the business continuity concept, which has been present since 2014. Nevertheless, it is possible to notice a significant acceleration in addressing the issue of resilience after the pandemic. In 2021, ST has extended its risk management approach to encompass a dedicated resilience management system (RMS). This system aims at achieving business continuity for both the company and the whole value chain. The RMS addresses four main types of

disruptions: site unavailability, that is, disruptions affecting business continuity of manufacturing sites; people unavailability, that is, lack of skilled workforce; IT system disruptions, that is, cyber-attacks; critical sourcing and logistics/transportation disruptions.

The complementarity of resilience and sustainability is evident starting from how the company addresses disruptions derived from natural disasters. In this case, both environmental and resilience teams work closely together, in a comprehensive task force, to address physical risks resulting from climate change. The objective of this ongoing task force includes both the identification of possible disruption sources and the development of strategic approaches to address them.

However, the synergy between resilience and sustainability in ST is particularly evident in two main spheres: the relationship with suppliers/subcontractors and the recruitment of skilled workforce.

In matters of resilience, ST considers the building of strategic partnerships with its suppliers and subcontractors to be crucial. In fact, in the last few years, the company has worked to achieve closer relationships in the forms of direct investments and/or long-term contracts. However, while commitment in long-term contracts (i.e. 3–5 years) allows a higher safety in case of disruptions, ST goes beyond, by including also the vertical integration of operations when it comes to strategic inputs of production. The close partnership with other GVCs actors, and suppliers, in particular, consists also in 'sharing knowledge' across the value chain in three forms: (i) the sharing of real-time production information (e.g. inventory levels) to enhance the visibility of the value chain, by adopting dedicated software and technology, (ii) develop 'business continuity plans' and share them with other actors of the GVC for increased coordination in case of disruption and (iii) actively support value chain actors in case of disruptions by sharing best practices. For example, this was the case during the pandemic. A corporate crisis team (CCT) developed the company's global response to the COVID-19 pandemic, by taking the lead of local crisis teams at regional, country and site levels to address the complexity of local conditions. The CCT worked following two overarching priorities: firstly, protect people health and safety, of both employees and third parties; secondly, executing business continuity plans across the whole supply chain, working closely with third parties. In some cases, this meant training local partners to develop control and tracing techniques and reduce the spread of the infection in order to ensure business continuity. The building of collaborative relationships and the sharing of best practices for resilience is complementary to the activity of training and resource sharing ST has developed for addressing sustainability issues with value chain actors.

Another disruption risk for ST, and more in general for the semiconductor industry, is the difficulty to find skilled workers. In fact, in some areas, the company is experiencing a lack of specialized personnel because ST's requirements fall outside the normal structure of state schools and universities. ST had over 5,000 job openings end of 2022. The company directly addresses this issue by developing partnerships with universities and other higher education institutions, by implementing internship programmes and research collaboration. However, it is also indirectly addressed by the training activity of local communities that

ST has included in its sustainability strategy. In fact, with its STEM programme, the company spreads awareness about its area of activity and can potentially push interested people to seek higher education in the field in the regions where specialized workforce is lacking.

Therefore, in some areas, the goals for resilience and sustainability are overlapping and the respective initiatives can be complementary.

5. CONCLUSION

The present chapter tried to explore the possible synergies existing between sustainability and resilience in the GVC context. It provides preliminary evidence on the crucial role of collaborative relationships within the orchestrating MNEs and third parties involved in the value chain activity. The chapter also aims at encouraging future research on how GVCs dynamics between location and governance can affect these synergies.

NOTES

1. Primary activities (i.e. inbound logistics, operations, outbound logistics, marketing and sales and service) are those activities that are involved in the creation of the company's offer and its sale and transfer to the buyer as well as aftersale assistance. Support activities (i.e. procurement, technological development, HR and infrastructure) are those activities that support the primary activities and each other by providing purchased inputs, technology, human resources and various firmwide functions (Porter, 1985).
2. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
3. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.
4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
5. Reduce inequality within and among countries.

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