TEXTE
06/2024

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Cost allocation and incentive mechanisms for environmental, climate protection and resource conservation along global supply chains

Analysis of the cotton, tin, natural rubber, coffee and iron ore supply chains

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German Environment Agency

Umwelt Bundesamt

TEXTE 06/2024

Ressortforschungsplan of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

Project No. (FKZ) 3722 14 101 0

Report No. (UBA-FB) FB001403/ENG

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On behalf of the German Environment Agency

Imprint

Publisher
Umweltbundesamt (German Environment Agency)
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Report completed in:
September 2023

Technical supervision by:
Section I 1.4 and III 2.2
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Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4804

Dessau-Roßlau, January 2024

Abstract: Cost allocation and incentive mechanisms for environmental, climate protection and resource conservation along global supply chains

The research project "Cost allocation and incentive mechanisms for environmental, climate protection and resource conservation along global supply chains" (Project number 3722 14 101 0) commissioned by the German Environment Agency, analyses (dis)incentives for and barriers to the implementation of environmental measures as well as the exchange of information between different actors along selected global supply chains. The project focuses on five supply chains from raw material to the end product that represent key sectors of the German industry with a high potential for environmental and human rights risks: cotton/readymade garments; tin/tin solder; natural rubber/car tyres; coffee/coffee for consumption; iron ore/quality steel for automotive industry). This report summarises the results of the first of five work packages, which aims to gain a comprehensive understanding of the current functioning of the selected supply chains, existing power structures, barriers and incentives, and the institutional framework for environmental protection, information sharing and cost-benefit distribution. After an introduction to the relevance of globalised production and trade and their impact on the environment, the study provides a brief review of the management and economic literature and its corresponding sub-disciplines related to the governance of sustainability in global supply chains. Section 3 presents supply chain profiles of each raw material/commodity, analyses market and power structures, presents the typical value chain from the raw material to the end product, identifies the main environmental impacts, highlights current trends and developments, and contextualizes each supply chain within the institutional framework that provides incentive mechanisms and barriers to environmental protection. The report is based on a comprehensive qualitative analysis of relevant studies, reports, databases and online tools. To supplement the existing data and sources, the team conducted interviews with experts from various segments of the supply chains as well as civil society organisations active in the respective supply chains.

Kurzbeschreibung: Kostenverteilungs- und Anreizmechanismen für Umwelt- und Klimaschutz und Ressourcenschonung entlang globaler Lieferketten

Das vom Umweltbundesamt in Auftrag gegebene Forschungsprojekt „Kostenallokation und Anreizmechanismen für Umwelt-, Klima- und Ressourcenschutz entlang globaler Lieferketten" (Forschungskennzahl 3722 14 101 0) analysiert (Fehl-)Anreize und Barrieren für die Umsetzung von Umweltmaßnahmen sowie den Informationsaustausch zwischen verschiedenen Akteur*innen entlang ausgewählter globaler Lieferketten. Das Projekt konzentriert sich auf fünf Lieferketten, die Schlüsselsektoren der deutschen Industrie mit einem hohen Potenzial für Umwelt- und Menschenrechtsrisiken darstellen und betrachtet diese vom Rohstoff bis zum Endprodukt: Baumwolle / Konfektionsware, Zinn / Lötzinn, Naturkautschuk / Autoreifen, Kaffee / Konsumkaffee, Eisenerz / Qualitätsstahl für die Automobilindustrie. Dieser Bericht fasst die Ergebnisse des ersten Arbeitspakets zusammen, das darauf abzielt, ein umfassendes Verständnis der derzeitigen Funktionsweise der ausgewählten Lieferketten sowie der bestehenden Machtstrukturen, der Hindernisse und Anreize und des institutionellen Rahmens für Umweltschutz, Informationsaustausch und Kosten-Nutzen- Verteilung zu gewinnen. Nach einer Einführung in die Relevanz der Globalisierung von Produktion und Handel und deren Auswirkungen auf die Umwelt folgt ein kurzer Überblick über die relevanten Teildisziplinen der Management- und Wirtschaftsliteratur, die sich mit der Steuerung von Nachhaltigkeit in globalen Lieferketten befassen. In Abschnitt 3 werden die Profile der Lieferketten der einzelnen Rohstoffe/Waren bis zum Endprodukt vorgestellt. Die Profile stellen die typische Lieferkette vom Rohstoff bis zum Endprodukt dar, analysieren die Markt- und Machtstrukturen, ermitteln die wichtigsten Umweltauswirkungen, zeigen aktuelle Trends und Entwicklungen auf und ordnen jede Lieferkette in den institutionellen Rahmen ein, der Anreizmechanismen und Hindernisse für den Umweltschutz bietet. Der Bericht basiert auf einer umfassenden qualitativen Analyse von relevanten Studien, Berichten, Datenbanken und Online-Tools. Um die vorhandenen Daten und Quellen zu ergänzen, führte das Team Interviews mit Experten aus verschiedenen Segmenten der Lieferketten und mit Organisationen der Zivilgesellschaft, die in den jeweiligen Lieferketten aktiv sind.

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List of abbreviations

Abbreviation	Explanation
4C	Common Code for the Coffee Community
ADS	Air dried sheets
AIFTA	ASEAN-India free trade agreement
ANRPC	Association of Natural Rubber Producing Countries
ASEAN	Association of Southeast Asian Nations
ASM	Artisanal and small-scale mining
BF	Blast furnace
BOF	Basic oxygen furnace
CBAM	Carbon Border Adjustment Mechanism
CBI	Centre for the Promotion of Imports
CMT	Cut-make-trim
CO_2	Carbon dioxide
CSDDD	EU Corporate Sustainability Due Diligence Directive
CSR	Corporate social responsibility
CSRD	EU Corporate Sustainability Reporting Directive
DR	Direct reduction
DRC	Democratic Republic of the Congo
DRI	Direct reduced iron
DSO	Direct-shipping ores
EAF	Electric arc furnace
EIA	Environmental impact assessments
ETRMA	European Tyre & Rubber Manufacturers Association
EU	European Union
EU ETS	European Emissions Trading Scheme
EUDR	EU Regulation on Deforestation-Free Products
FAO	Food and Agriculture Organization of the United Nations
FDI	Foreign direct investment
FSC	Forest Stewardship Council
FWF	Fair Wear Foundation
GHG	Greenhouse gas
GOLS	Global Organic Latex Standard
GPSNR	Global Platform for Sustainable Natural Rubber
GSP	Generalised Scheme of Preferences
GVC	Global value chain
ICA	International Coffee Agreement
ICAC	International Cotton Advisory Committee
INRA	International Natural Rubber Agreement

Abbreviation	Explanation
INRO	International Natural Rubber Organization
IRMA	Stakeholder Initiative for Responsible Mining Assurance
IRSG	International Rubber Study Group
ITA	International Tin Association
LME	London Metal Exchange
LSM	Large scale mining
MFN	Most-favoured-nation
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
OECD Guidelines	OECD Guidelines for Multinational Enterprises on Responsible Business Conduct
OEM	Original equipment manufacturer
PEFC	Programme for the Endorsement of Forest Certification Schemes
R&D	Research and development
RAOT	Rubber Authority of Thailand
RCEP	Regional Comprehensive Economic Partnership
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
RMAP	Responsible Minerals Assurance Process
RMI	Responsible Minerals Initiative
RSS	Ribbed smoked sheet
SAARC	South Asian Association for Regional Cooperation
SHFE	Shanghai Future Exchanges
SICOM	Singapore Commodity Exchange
SSC	Steel service center
TSR	Technically specified rubber
TWG	Tin Working Group
U.S.	United States of America
UK	United Kingdom
UN	United Nations
wdk	German Rubber Manufacturers Association
WTO	World Trade Organization

Summary

The research project "Cost allocation and incentive mechanisms for environmental, climate protection and resource conservation along global supply chains", commissioned by the German Environment Agency investigates (dis)incentives for and barriers to the implementation of environmental measures as well as the exchange of information between different actors along selected global supply chains. It aims to provide guidance to different stakeholders in the practical implementation of environmental measures along global supply chains and to improve the distribution of cost and benefits in the process.

The project focuses on global supply chains in sectors with a high potential for environmental and human rights risks. We analyse five value chains from raw material to the end product that represent key sectors of the German industry:

- Cotton and the manufacturing of cotton-based, ready-made garments
- Tin and tin solder for the manufacturing of electronics
- Natural rubber and car tyres for the automotive industry
- Coffee for retail and consumer brands
- Iron ore and quality steel for the automotive industry

This report summarises the results of the first work package of the project, which aims to gain a comprehensive understanding of the current structure and organisation of the selected supply chains, the dominant actors as well as the concentration and manifestation of power along the supply chain, the main environmental impacts, and the institutional barriers and (dis)incentives for environmental protection, information sharing and cost-benefit distribution that supply chain actors have to deal with. After an introduction to the relevance of globalised production and trade and their impact on the environment, the report provides a brief review of the management and economic literature and its corresponding sub-disciplines related to the governance of sustainability in global supply chains. Section 3 presents the supply chain profiles of each raw material/commodity to the end product. Each profile aims to:

- analyse the market of each raw material/commodity with a focus on the German/ European market;
- give an overview of the typical structure of the global supply chain from the cultivation/extraction of the raw material to the processing and use of the end product in the German industry, as well as the most important processes and dominant actors along the supply chain;
- highlight the main environmental impacts along the supply chain;
- provide information about key price formation mechanisms and power relationships between stakeholders along the global supply chain that shape the trade of the raw material/commodity;
- highlight the most important environmental protection measures along the supply chain;
- outline current and future trends (market, consumer, technology) and other developments in the corresponding sector;

- give an overview of institutional incentive mechanisms and barriers with regard to existing environmental protection measures.

Methodologically, the report relies on a comprehensive qualitative analysis of relevant studies, reports, databases and online tools. To supplement the existing data and sources, the team conducted interviews with experts from various segments of the supply chains and civil society organisations active in the respective commodity-specific supply chains.

The key findings of the commodity-specific supply chain profiles are briefly summarised below:

Cotton

Cotton is the second most common fibre in the world after polyester and accounts for 24% of global fibre production. As the most widely used natural fibre in the world, it feeds into labour-intensive garment supply chains that are mostly located in low-cost countries in Southern Europe, Eastern Europe and Asia.

Cultivated in over 80 countries, production is concentrated in China, India, the United States, Brazil and Pakistan. Cotton exports are led by the Unites States, Brazil and India. China, India, Pakistan, Turkey and some Central Asian countries export, but mostly keep their cotton for internal value addition and process it further until finishing. In 2021, the most important export countries for clothing, including natural fibres and synthetic materials, were, China – by far – followed by the European Union, Bangladesh, Vietnam and Turkey. Apart from China, South Asian manufacturers from Bangladesh, India and Pakistan dominate cotton-based garment exports, in large part due to the strong backward linkages and domestic availability of cotton in India and Pakistan. In countries like Bangladesh, Cambodia, Myanmar and Vietnam, low value-added cut-make-trim operations predominate. Thanks to its large capacities and strong backward linkages, the Chinese garment industry exports the largest volumes of products based on both cotton and human-made fibres by a wide margin. Europe and North America dominate as consumer markets.

The cotton garment value chain is organised into five stages. The harvested cotton goes through ginning to textile processing where the fibres are processed into yarn and are made into fabrics. Wet processes, such as bleaching, dyeing, washing and printing are particularly resource-intensive and constitute one of the main environmental hotspots in the supply chain.

Power dynamics between buyers and suppliers are largely skewed in favour of downstream buyers (retailers/brands), but may vary with the degree of complexity a supplier commands, the market and the dominant business model. While the highly competitive, auction-based system (e.g. Aldi, Lidl) caters large volumes mostly to the low-end market, some specialty retailers (e.g. H&M, adidas) source directly from a range of key suppliers and fill up their capacity needs from occasional suppliers who tend to be less strictly monitored. The third business model is based more on trust and collaboration to improve key sustainability metrics. Depending on the market, buyers draw on third-party certification of materials, products, the facility or processes from their suppliers. While voluntary sustainability standards have improved certain aspects in supply chains, structural problems (e.g. low prices, environmental degradation) persist and leave workers and society very vulnerable.

European Union directives, policies and related strategies, such as the European Green Deal and the proposed “Corporate Sustainability Due Diligence Directive”, among others, are increasingly promoting due diligence and circularity. This requires new ways of collaboration between buyers and suppliers to adapt supply chain processes and provide data for reporting.

Tin

Tin is a versatile metal with a wide range of applications, and is mainly used in electronics as solder. It plays a crucial role in the electronics industry, and is considered a critical metal in China and the United States, with its status approaching criticality in Europe.

The tin industry operates on a relatively smaller scale with an annual production of 300,000 tonnes, involving around 30 tin smelting companies and roughly 1,000 larger mining sites. The production of tin is highly concentrated, with nine countries accounting for over 90% of global output, and the consumption of tin mainly occurring in ten countries, making up approximately 80% of the world's total tin consumption. The top tin ore exporting countries are primarily situated in the Global South, including countries in Africa, Australia, South-East Asia, and South America. China dominates the import market for tin ore, along with countries like Thailand, and Malaysia, driven by their substantial industrial sectors that are heavily reliant on tin. Refined tin production is concentrated in China, Indonesia, Peru, Brazil, Malaysia, Bolivia, and Thailand, with major consumers including China, the United States, Japan, Germany, and Korea, with China leading in global tin consumption and relying on both domestic resources and imports, including significant quantities from Myanmar.

The tin value chain is organised into five stages. Tin is primarily extracted from cassiterite mineral, with the removal of impurities during concentration, smelting, or refining processes. In later stages tin is exported and imported mainly to markets with high production of consumer electronics, where it is used as solder. The mining of tin constitutes one of the main environmental hotspots in the supply chain and is associated with water contamination, land degradation and topography changes, which leads to land erosion.

The tin value chain has complex power dynamics, due to the varying degrees of influence wielded by different actors. Artisanal and small-scale miners, who often sell to local traders, find themselves in a relatively weaker position due to their limited options in engaging with traders and a lack of updated pricing information. In contrast, large-scale miners possess greater resources and sometimes closer ties with governments, giving them a stronger position. Some smelters have integrated supply chain governance, while others cooperate with various mines and miners. During periods of market deficit, miners gain increased bargaining power due to smelters' dependence on raw materials. Manufacturers, as purchasers of refined tin, typically opt for the most economical supplier. End consumers, such as major electronics companies, have the power to influence the industry's sustainability by demanding responsibly sourced tin.

The ongoing efforts to address environmental impacts in the tin industry include a range of regulatory measures, voluntary certification schemes, and sustainability initiatives. The OECD Handbook on Environmental Due Diligence in Mineral Supply Chains provides guidelines, with a focus on the upstream segment. In addition, there are several European Union directives and policies, including the "Conflict Mineral Regulation", and the proposed "Corporate Sustainability Due Diligence Directive", which increasingly support responsible sourcing and due diligence.

Natural rubber

Natural rubber is used in a wide range of up to 40,000 different products. The biggest demand, however comes from the automotive and tyre industry, where 75% of the world's natural rubber production is used.

Most of the natural rubber produced worldwide is cultivated in a labour-intensive harvesting process by smallholder farmers in Southeast Asian countries such as Thailand and Indonesia. The latter stages of the supply chain are also strongly shaped by Asian countries, with China in particular playing a dominant role in the production and export of tyres. One exception is Côte d'Ivoire, which plays a growing role in the international cultivation of natural rubber as a whole and also in direct imports of natural rubber to Germany. While some Southeast Asian countries have established their own tyre production industries, much of the natural rubber harvest is exported after the initial processing steps (washing and pressing). The largest importer of natural rubber is China, followed by the United States, Malaysia, Japan and India. China also dominates global exports of rubber tyres, followed by Thailand, Germany and Japan. Consumption of car tyres is dominated by Europe and North America.

The natural rubber tyre value chain is organised into five stages. Natural rubber is extracted from *Hevea brasiliensis* trees (by "tapping"), processed into intermediate products (coagulated, washed and pressed), assembled with other raw materials into tyres, exported/imported and purchased by car manufacturers or car owners. The cultivation of natural rubber trees is one of the main environmental hotspots in the supply chain and is associated with risks for negative environmental impacts such as deforestation, soil and water contamination.

Power dynamics in the supply chain are largely skewed in favour of downstream buyers (tyre makers/automotive manufacturers). Smallholders at the beginning of the supply chain in particular usually have little influence on negotiations or purchasing conditions, as they depend on intermediaries who collect raw materials from numerous small farms before reselling it to processors. Further down the supply chain, among processors, tyre makers and car manufacturers, the power is less unevenly distributed. Most tyre manufacturers source much of their natural rubber directly from trusted processing factories, and some interdependencies exist between car manufacturers and tyre makers, at least for new product development. Some tyre and car manufacturers have joined multi-stakeholder initiatives that seek to implement common standards for sustainability compliance along the entire value chain, up to and including cultivation. Third-party certification of materials has so far only been offered and used by a few pioneers on the supplier and buyer side.

It is expected that the European Union's Regulation on Deforestation-free Products in particular will contribute to improved transparency, traceability and due diligence in the natural rubber-tyre supply chain. In addition, a number of institutional measures in consumer markets, particularly under the European Green Deal, as well as trade agreements and legislation in producer countries, are influencing the implementation of environmental protection in the natural rubber tyre supply chain.

Coffee

Coffee represents one of the most popular drinks in the world as well as one of the most extensively traded agricultural commodities with a diverse production base. Most coffee is produced by smallholder coffee farms (and households). Brazil, Vietnam, and Colombia represent the leading coffee-producing countries, contributing significantly to the global coffee supply. On the other hand, the European Union and the United States of America serve as the largest consumer and importer markets worldwide, driving the demand for coffee on a significant scale.

Coffee is overwhelmingly traded in green (unroasted) beans and roasted in the consumption destinations, which limits the ability of production to benefit from the steps that contribute most to value creation. This set-up is supported by differential tariff structures for green and roasted coffee in importing countries, and reinforced via roasters' preference for keeping control over the taste profiles of their blends, in which they mix coffee from various origins. The division of work steps also exists for technological and logistic reasons, including the lack of financial and human resources and infrastructure and the relatively shorter shelf-life of roasted coffee compared to green.

The coffee value chain is highly complex due to its lengthy production steps and its geographical distance between downstream and upstream actors. The coffee value chain is typically characterised as buyer-driven. In this case, coffee roasters have greater power than mid-stream actors or producers. The groups of local suppliers, typically unorganised smallholder farmers, who provide coffee for other intermediaries, such as other farmers, or collectors/traders are the weakest in the value chain.

To understand the distribution of costs and added value along the supply chain, it is informative to understand the way prices are set in the coffee market, where the prices of futures contracts converge with spot market prices upon the time of delivery. In addition, much value is further added and captured during the roasting, packaging, marketing and retail stages of the value chain, which tends to occur in consuming countries. The rise of demand for higher quality and greater knowledge of producer stories has allowed for the development of a specialty coffee niche, where producers of coffees of extraordinary quality are able to access buyers directly.

While the coffee industry provides a source of income to 100 million people globally, it faces issues related to environmental pollution, such as deforestation, water pollution, soil degradation, energy consumption and greenhouse gas emissions, and generated solid waste, due to chemical use and poor practices. At the same time, many actors across the coffee value chain are vulnerable to the negative effects of climate change and climate-change induced price fluctuations. Efforts are being made to address the environmental impacts of the coffee supply chain, which are reflected in trends in regulations as well as in markets, consumption and technologies.

Iron/steel

Iron ore is the most frequently mined metal in the world and Germany one of the world's largest steel producers. The country relies on steel as an input material in many key industries, particularly in the construction and automotive sectors.

The origin of iron ore is mainly concentrated in Australia, Brazil, China and India and dominated by a few large companies engaged in large-scale mining. While Australia and Brazil are leading exporters, China keeps most of its domestically mined iron ore for internal value creation, as it produces more than 50% of the world's crude steel. Additionally, China supplements its demand for iron ore with imports, which account for two-thirds of global imports. Apart from China, it is mostly other Asian countries that are major importers of iron ore (Japan, South Korea) and significant producers of crude steel (India, Japan). Similarly, automotive production is dominated by companies from China, Japan, India and South Korea, with Germany being the only non-Asian player in the top five.

The iron ore-steel value chain is organised into five stages. After the mining and beneficiation of the ore, intermediary products are generally exported/imported. Different production routes are used for further processing and refinement as well as the manufacture of various basic steel products, depending on input materials and the desired result. The products are then sold either to intermediaries or directly to automotive manufacturers. While iron ore mining has severe environmental impacts, e.g. in the form of dust pollution and contamination of water, steelmaking is responsible for very high greenhouse gas emissions.

Power dynamics in the iron ore-steel value chain are largely skewed in favour of upstream suppliers, as the high market share of a few large mining companies gives the mining sector a better position vis-à-vis steel producers and other actors in the supply chain. The steel industry tends to be more fragmented and less dominated by very big companies. But steelmakers are dependent on the continuous supply of raw materials at affordable prices and, at the same time, have to accommodate the requirements of the automotive industry. Profit margins and pricing power therefore tend to be higher in mining while the steel sector usually operates with lower profitability. Information on the typical relationship between steel producers and automotive manufacturers has found to be not easily available. While the power dynamics in the trade of iron ore, the growing impact of spot markets on trade and price negotiations and a strong increase in price volatility of iron ore make for a highly contested framework of purchasing practices, the trade of steel remains largely unaffected by these developments due to the diversity of finished and semi-finished steel products.

The significant negative environmental impacts in the iron ore-steel supply chain are mostly addressed through voluntary (industry-led) initiatives and standards. In iron ore mining, in particular, environmental protection is still in its infancy. The steel industry has seen some progress in the past decades. Currently, a new but strongly growing interest in the production of “green steel” (i.e. low-carbon steel) has led to the initial projects. Sustainability efforts that go beyond the reduction of greenhouse gas and air emissions and cover the entire supply chain are still limited. However, pressure from investors might become an increasingly relevant factor.

On an institutional level, several policies influence the implementation of environmental protection in the iron ore-steel supply chain. While statutory Environmental Impact Assessments are common for the commissioning of iron ore mines, they vary widely in enforcement and effectiveness. The steel industry is most strongly influenced by increasing regulatory requirements regarding emissions of CO_2 and air pollutants and also affected by regulations on corporate sustainability. (Free) trade policies are also relevant for the industry.

In the further course of the project, the findings presented in this report will feed into the development of incentives for effective climate and environmental protection measures and an improvement of transparency and cooperation along global supply chains. The identified solutions will be translated into roadmaps for practical implementation in the respective supply chains. The project will conclude with target group-specific recommendations for the design of operational instruments of supply chain management and recommendations for industry initiatives, governments and intermediaries, among others.

Zusammenfassung

Das vom Umweltbundesamt in Auftrag gegebene Forschungsprojekt "Kostenallokation und Anreizmechanismen für Umwelt-, Klima- und Ressourcenschutz entlang globaler Lieferketten analysiert (Fehl-)Anreize und Barrieren für die Umsetzung von Umweltmaßnahmen sowie den Informationsaustausch zwischen verschiedenen Akteuren entlang ausgewählter globaler Lieferketten. Ziel des Projektes ist es, verschiedenen Akteuren eine Hilfestellung bei der praktischen Umsetzung von Umweltmaßnahmen entlang globaler Lieferketten zu geben und dabei die Verteilung von Kosten und Nutzen zu verbessern.

Das Projekt konzentriert sich auf globale Lieferketten in Sektoren mit einem hohen Potenzial für Umwelt- und Menschenrechtsrisiken. Wir analysieren fünf Lieferketten vom Rohstoff bis zum Endprodukt, die Schlüsselsektoren der deutschen Industrie repräsentieren:

- Baumwolle für Konfektionsbekleidung
- Zinn und Lötzinn für Elektronikprodukte
- Naturkautschuk und Reifen für die Automobilindustrie
- Kaffee für den Vertrieb durch Einzelhandels- und Verbrauchermarken
- Eisenerz und Qualitätsstahl für die Automobilindustrie

Dieser Bericht fasst die Ergebnisse des ersten Arbeitspakets des Projekts zusammen, das darauf abzielt, ein umfassendes Verständnis der aktuellen Struktur und Organisation der ausgewählten Lieferketten, der dominanten Akteure sowie der Konzentration und Manifestation von Macht entlang der Lieferkette, der wichtigsten Umweltauswirkungen und der institutionellen Barrieren und (Fehl-)Anreize für Umweltschutz, Informationsaustausch und Kosten-Nutzen-Verteilung zu gewinnen, mit denen die Akteure der Lieferkette umgehen müssen. Nach einer Einführung in die Bedeutung der Globalisierung von Produktion und Handel und deren Auswirkungen auf die Umwelt folgt ein kurzer Überblick über die relevanten Teildisziplinen der Management- und Wirtschaftsliteratur, die sich mit der Steuerung der Nachhaltigkeit in globalen Lieferketten befassen. In Abschnitt 3 werden die Profile der Lieferketten von den einzelnen Rohstoffen/Waren bis hin zum Endprodukt vorgestellt. Jedes Profil ist unterteilt in:

- eine Marktanalyse für jeden Rohstoff mit Schwerpunkt auf dem deutschen/europäischen Markt;
- einen Überblick über die typische Struktur der globalen Lieferkette von dem Anbau/der Gewinnung des Rohstoffs bis zur Verarbeitung und Verwendung des Endprodukts in der deutschen Industrie sowie über die wichtigsten Prozesse und dominierenden Akteure entlang der Lieferkette;
- die Darstellung der wichtigsten Umweltauswirkungen entlang der Lieferkette;
- eine Übersicht über die wichtigsten Preisbildungsmechanismen und Machtverhältnisse zwischen den Akteuren entlang der globalen Lieferkette, die den Handel mit dem Rohstoff/der Ware bestimmen;
- eine Betrachtung der wichtigsten Umweltschutzmaßnahmen entlang der Lieferkette;

- einen Überblick über aktuelle und künftige Trends (Markt, Verbraucher, Technologie) und andere Entwicklungen in dem betreffenden Sektor geben;
- Erläuterungen zu den institutionellen Anreizmechanismen und Hindernissen im Hinblick auf bestehende Umweltschutzmaßnahmen.

Methodisch stützt sich der Bericht auf eine umfassende qualitative Analyse einschlägiger Studien, Berichte, Datenbanken und Online-Tools. Zur Ergänzung der vorhandenen Daten und Quellen führte das Team Interviews mit Expert*innen aus verschiedenen Segmenten der Lieferketten und zivilgesellschaftlichen Organisationen, die in den jeweiligen rohstoffspezifischen Lieferketten tätig sind.

Die wichtigsten Ergebnisse der rohstoffspezifischen Lieferkettenprofile werden im Folgenden kurz zusammengefasst:

Baumwolle

Baumwolle ist nach Polyester die zweithäufigste Faser der Welt und macht 24 % der globalen Faserproduktion aus. Als die weltweit am häufigsten verwendete Naturfaser wird Baumwolle in arbeitsintensiven Bekleidungslieferketten eingesetzt, deren verschiedene Verarbeitungsstufen meist in Niedriglohnländern in Südeuropa, Osteuropa und Asien angesiedelt sind.

Baumwolle wird in über 80 Ländern angebaut, wobei sich die Produktion auf China, Indien, die USA, Brasilien und Pakistan konzentriert. Führend bei den Baumwollexporten sind die USA, Brasilien und Indien. China, Indien, Pakistan, die Türkei und einige zentralasiatische Länder exportieren, behalten aber einen Großteil ihrer Baumwolle für die interne Wertschöpfung und verarbeiten sie bis zur Konfektionierung weiter. China war im Jahr 2021 mit Abstand das wichtigste Exportland für Bekleidung, einschließlich Naturfasern und synthetischen Materialien, gefolgt von der Europäischen Union, Bangladesch, Vietnam und der Türkei. Neben China, das aufgrund seiner großen Kapazitäten und starken Rückverflechtungen eine herausragende Stellung auf dem Weltmarkt einnimmt, dominieren südasiatische Herstellungsbetriebe aus Bangladesch, Indien und Pakistan den Export von Baumwollbekleidung, der durch lokal verfügbare Vorprodukte und den Baumwollanbau z.B. in Indien und Pakistan stark unterstützt wird. Dabei überwiegen in Ländern wie Bangladesch, Kambodscha, Myanmar und Vietnam Cut-Make-Trim (CMT)-Betriebe mit geringer Wertschöpfung. Europa und Nordamerika beherrschen den Absatzmarkt.

Die Lieferkette der Baumwollbekleidung ist in fünf Stufen organisiert. Die geerntete Baumwolle wird nach der Entkörnung erst zu Garn, dann zu Gewebe verarbeitet. Nassprozesse wie Bleichen, Färben, Waschen und Druckverfahren sind besonders ressourcenintensiv und gehören zu den schwerwiegendsten Umweltbelastungen in der Lieferkette.

Die Machtdynamik zwischen einkaufenden und zuliefernden Unternehmen verläuft tendenziell zugunsten der nachgelagerten Käufer*innen (Einzelhändler*innen/Marken), kann aber je nach Kompetenzstufe des zuliefernden Betriebs, Absatzmarkt und Geschäftsmodell variieren. Während das wettbewerbsintensive, auktionsgestützte System (z. B. Aldi, Lidl) große Mengen vor allem für das untere Preissegment bereitstellt, beziehen einige Einzelhandelsunternehmen (z. B. H&M, adidas) direkt von ausgewählten Stammlieferant*innen und decken ihren zusätzlichen Bedarf auch über Unternehmen, die nur gelegentlich liefern und in der Regel weniger streng kontrolliert werden. Das dritte Geschäftsmodell basiert stärker auf Vertrauen und Zusammenarbeit und wird von einem engmaschigen Monitoring der wichtigsten Nachhaltigkeitskennzahlen begleitet. Je nach Markt greifen einkaufende Unternehmen auf die Zertifizierung von Materialien, Produkten, Anlagen oder Prozessen ihrer Lieferanten durch Dritte zurück. Während freiwillige Nachhaltigkeitsstandards einige Aspekte der Lieferketten verbessert haben (z.B., Gesundheit und Sicherheit am Arbeitsplatz), bleiben strukturelle Probleme (z. B. niedrige Preise, Umweltzerstörung) bestehen, die Arbeitnehmer*innen und die Gesellschaft ernsthaft gefährden.

EU-Richtlinien, Maßnahmen und damit verbundene Strategien wie der Europäische Green Deal und die geplante „Corporate Sustainability Due Diligence Directive" treiben zunehmend die Sorgfaltspflicht von Unternehmen und neue Ansätze wie die Kreislaufwirtschaft voran. Die notwendige Anpassung der Prozesse in der Lieferkette und die Bereitstellung von Daten für die Berichterstattung erfordern neue Wege der Zusammenarbeit zwischen einkaufenden und zuliefernden Unternehmen.

Zinn

Zinn ist ein vielseitiges Metall mit einem breiten Anwendungsspektrum und wird hauptsächlich als Lötzinn verwendet, das eine entscheidende Rolle in der Elektronikindustrie spielt. Zinn gilt in China und den Vereinigten Staaten als kritisches Metall, in Europa ist es auf dem besten Weg, als kritischer Rohstoff eingestuft zu werden.

Die Zinnindustrie ist mit einer Jahresproduktion von 300.000 Tonnen relativ klein und umfasst rund 30 Zinnhütten und etwa 1.000 größere Bergbauanlagen. Die Produktion von Zinn ist geographisch stark konzentriert, wobei über 90 % der weltweiten Produktion auf neun Länder entfallen und der Zinnverbrauch hauptsächlich in zehn Ländern stattfindet, die etwa 80 % des gesamten Zinnverbrauchs der Welt ausmachen. Die wichtigsten Exportländer für Zinnerz befinden sich hauptsächlich im globalen Süden, darunter Länder in Afrika, Australien, Südostasien und Südamerika. China dominiert den Importmarkt für Zinnerz, zusammen mit Ländern wie Thailand und Malaysia, die aufgrund ihrer umfangreichen, stark zinnabhängigen Industriezweige eine wichtige Rolle spielen. Die Produktion von raffiniertem Zinn konzentriert sich auf China, Indonesien, Peru, Brasilien, Malaysia, Bolivien und Thailand. Zu den Hauptabnehmern gehören China, die USA, Japan, Deutschland und Korea, wobei China beim weltweiten Zinnverbrauch führend ist und sowohl auf einheimische Ressourcen als auch auf Importe, darunter erhebliche Mengen aus Myanmar, angewiesen ist.

Die Lieferkette von Zinn ist in fünf Stufen organisiert. Zinn wird in erster Linie aus dem Mineral Kassiterit gewonnen, wobei Verunreinigungen durch Konzentrations-, Schmelz- oder Raffinierungsprozesse entfernt werden. In späteren Phasen wird Zinn exportiert und vor allem in Märkte mit einer hohen Produktion von Unterhaltungselektronik importiert, wo es als Lötzinn verwendet wird. Der Zinnabbau ist einer der größten Umweltbelastungsfaktoren in der Lieferkette und geht mit Wasserverschmutzung, einer Verschlechterung der Bodenqualität sowie topografischen Veränderungen einher, die zu Bodenerosion führen.

Aufgrund der unterschiedlichen Einflussmöglichkeiten verschiedener Akteur*innen, weist die Zinn-Lieferkette eine komplexe Machtdynamik auf. Bergleute im artisanalen und Kleinbergbau, die häufig an lokale Händler*innen verkaufen, befinden sich in einer relativ schwachen Position, da sie nur begrenzte Möglichkeiten haben, mit Händlern in Kontakt zu treten, und nicht über aktuelle Preisinformationen verfügen. Im Gegensatz dazu befinden sich große Minen in einer stärkeren Position, da sie über mehr Ressourcen und manchmal engere Beziehungen zu Regierungen verfügen. Einige Hütten betreiben ein integriertes Lieferkettenmanagement, während andere mit verschiedenen Minen und Bergbauunternehmen zusammenarbeiten. In Zeiten von Marktdefiziten gewinnen die Bergbauunternehmen an Verhandlungsmacht, da die Hütten auf die Verfügbarkeit von Rohstoffen angewiesen sind. Hersteller*innen als Abnehmer*innen von raffiniertem Zinn entscheiden sich in der Regel für die wirtschaftlichsten Lieferant*innen. Endverbraucher*innen, wie z.B. große Elektronikunternehmen, haben die Möglichkeit, die Nachhaltigkeit der Branche zu beeinflussen, indem sie Zinn aus verantwortungsvollen Quellen nachfragen.

Zu den laufenden Bemühungen, die Umweltauswirkungen der Zinnindustrie in den Griff zu bekommen, gehören eine Reihe von Regulierungsmaßnahmen, freiwillige Zertifizierungssysteme und Nachhaltigkeitsinitiativen. Das Handbuch "Environmental Due Diligence in Mineral Supply Chains" der Organisation für wirtschaftliche Zusammenarbeit und Entwicklung (OECD) bietet eine Orientierungshilfe, wobei der Schwerpunkt auf dem vorgelagerten Segment liegt. Darüber hinaus gibt es eine Reihe von Richtlinien und Maßnahmen der Europäischen Union, darunter die Verordnung über Konfliktmineralien und die vorgeschlagene „Corporate Sustainability Due Diligence Directive", die zunehmend auf verantwortungsvolle Beschaffung und die Einhaltung von Sorgfaltspflichten abzielen.

Naturkautschuk

Naturkautschuk wird in etwa 40.000 verschiedenen Produkten eingesetzt. Die größte Nachfrage kommt jedoch von der Automobil- und Reifenindustrie, die 75% der weltweiten Naturkautschukproduktion verarbeitet.

Der größte Teil des weltweit produzierten Naturkautschuks wird in einem arbeitsintensiven Ernteverfahren von Kleinbäuerinnen und Kleinbauern in südostasiatischen Ländern wie Thailand und Indonesien angebaut. Auch die späteren Stufen der Lieferkette sind stark von asiatischen Ländern geprägt, wobei vor allem China eine dominierende Rolle bei der Produktion und dem Export von Reifen spielt. Eine Ausnahme bildet die Elfenbeinküste, die beim internationalen Anbau von Naturkautschuk insgesamt und auch beim Direktimport von Naturkautschuk nach Deutschland eine wachsende Rolle spielt. Obwohl einige südostasiatische Länder eigene Reifenindustrien aufgebaut haben, wird ein Großteil der Naturkautschukernte nach den ersten Verarbeitungsschritten (Waschen und Pressen) exportiert. Der größte Importeur von Naturkautschuk ist China, gefolgt von den Vereinigten Staaten, Malaysia, Japan und Indien. China dominiert auch die weltweiten Ausfuhren von Gummireifen, gefolgt von Thailand, Deutschland und Japan. Der Verbrauch von Autoreifen findet hauptsächlich in Europa und Nordamerika statt.

Die Lieferkette für Naturkautschukreifen ist in fünf Stufen gegliedert. Naturkautschuk wird zunächst (durch ‚Anzapfen') aus *Hevea brasiliensis* Bäumen gewonnen und anschließend zu Zwischenprodukten verarbeitet (koaguliert, gewaschen und gepresst), bevor es zusammen mit anderen Rohstoffen zu Reifen verarbeitet, exportiert/importiert und von Autoherstellern oder Autobesitzer*innen gekauft wird. Der Anbau von Naturkautschukbäumen ist einer der größten Umweltbelastungspunkte in der Lieferkette und birgt Risiken für negative Umweltauswirkungen wie Abholzung, Boden- und Wasserverschmutzung.

Machtdynamiken in der Lieferkette sind weitgehend zugunsten der nachgelagerten Abnehmer*innen (Reifenherstellung/Automobilherstellung) verschoben. Vor allem die Kleinbäuerinnen und Kleinbauern am Anfang der Lieferkette haben in der Regel wenig Einfluss auf die Verhandlungen oder die Einkaufsbedingungen, da sie von Zwischenhändler*innen abhängig sind, die die Erzeugnisse von zahlreichen kleinen Betrieben einsammeln, bevor sie sie an die Verarbeitungsbetriebe weiterverkaufen. In späteren Schritten der Lieferkette, zwischen Verarbeitungsbetrieben, Reifenherstellern und Automobilherstellern, ist die Macht weniger ungleichmäßig verteilt. Die meisten Reifenhersteller beziehen einen Großteil ihres Naturkautschuks direkt von vertrauenswürdigen Verarbeitungsbetrieben, und zwischen Automobilherstellern und Reifenherstellern bestehen zumindest bei der Entwicklung neuer Produkte gewisse Abhängigkeiten. Einige Reifen- und Automobilhersteller haben sich Multi-Stakeholder-Initiativen angeschlossen, die gemeinsame Standards für die Einhaltung von Nachhaltigkeitsanforderungen entlang der gesamten Lieferkette, bis hin zum Anbau, einführen wollen. Die Zertifizierung von Materialien durch Dritte wird bisher nur von einigen wenigen Vorreitern auf der Lieferanten- und Käuferseite angeboten und genutzt.

Es wird erwartet, dass insbesondere die EU-Verordnung für entwaldungsfreie Produkte (EUDR) zu einer verbesserten Transparenz, Rückverfolgbarkeit und Sorgfaltspflicht in der Lieferkette von Naturkautschuk für die Reifenproduktion beitragen wird. Darüber hinaus beeinflussen eine Reihe von institutionellen Maßnahmen auf den Verbrauchermärkten, insbesondere im Rahmen des europäischen ‚Green Deal', sowie Handelsabkommen und Rechtsvorschriften in den Erzeugerländern die Umsetzung des Umweltschutzes in der Lieferkette für Naturkautschukreifen.

Kaffee

Kaffee ist eines der beliebtesten Getränke der Welt und einer der meistgehandelten Agrarrohstoffe mit einer vielfältigen Produktionsbasis. Der meiste Kaffee wird von Kleinbauern und Kleinbäuerinnen (und Haushalten) produziert. Brasilien, Vietnam und Kolumbien sind die führenden Kaffeeanbauländer und tragen wesentlich zum weltweiten Kaffeeangebot bei. Auf der anderen Seite sind die Europäische Union und die Vereinigten Staaten von Amerika die größten Verbraucher- und Importmärkte der Welt und treiben die Nachfrage nach Kaffee erheblich an.

Kaffee wird überwiegend in Form von grünen (ungerösteten) Bohnen gehandelt und in den Verbrauchsländern geröstet, was die Möglichkeiten der Erzeugerländer einschränkt, von den Stufen zu profitieren, die den größten Beitrag zur Wertschöpfung leisten. Diese Konstellation wird durch die unterschiedlichen Zollstrukturen für Roh- und Röstkaffee in den Einfuhrländern unterstützt und durch das Bestreben der Röster, die Kontrolle über die Geschmacksprofile ihrer Mischungen zu behalten, indem sie Kaffee aus verschiedenen Herkunftsländern mischen, verstärkt. Die Trennung der Arbeitsschritte hat auch technologische und logistische Gründe, u.a. mangelnde finanzielle, personelle und infrastrukturelle Ressourcen sowie die relativ kürzere Haltbarkeit von Röstkaffee im Vergleich zu Rohkaffee.

Die Lieferkette für Kaffee ist aufgrund der langen Produktionsschritte und der geografischen Entfernung zwischen den nach- und vorgelagerten Akteuren sehr komplex. Die Kaffeelieferkette wird in der Regel als käufergesteuert charakterisiert. In diesem Fall haben Kaffeeröstungsbetriebe mehr Macht als die Akteur*innen in der Mitte der Kette oder die Erzeuger*innen. Die Gruppen lokaler Lieferant*innen, in der Regel nicht organisierte Kleinbauern und Kleinbäuerinnen, die Kaffee an andere Zwischenhändler*innen wie Bauern und

Bäuerinnen oder Sammler*innen/Händler*innen liefern, sind die schwächsten Glieder in der Lieferkette.

Um die Verteilung von Kosten und Nutzen zu verstehen, lohnt ein Blick auf die Preisbildung im Kaffeemarkt, bei der die Preise von Terminkontrakten zum Zeitpunkt der Lieferung mit Spotmarktpreisen konvergieren. Darüber hinaus wird ein großer Teil der Wertschöpfung während der Röstung, Verpackung, Vermarktung und des Einzelhandels erzielt erfasst, die in der Regel in den Verbraucherländern stattfinden. Die steigende Nachfrage nach höherer Qualität und das bessere Wissen über Geschichten der Erzeuger*innen hat zur Entwicklung einer Nische für Spezialitätenkaffee geführt, in der die Erzeuger von Kaffee von außergewöhnlicher Qualität direkten Zugang zu den Käufern haben.

Während die Kaffeeindustrie für 100 Millionen Menschen weltweit eine Einkommensquelle darstellt, hat sie auch mit Umweltproblemen wie Entwaldung, Wasserverschmutzung, Bodendegradation, Energieverbrauch und Treibhausgasemissionen, sowie mit Feststoffabfällen durch den Einsatz von Chemikalien und unsachgemäßen Praktiken zu kämpfen. Gleichzeitig sind viele Akteur*innen der Kaffee-Lieferkette anfällig für die negativen Auswirkungen des Klimawandels sowie klimabedingte Preisschwankungen. Es werden Anstrengungen unternommen, um die Umweltauswirkungen der Kaffeelieferkette in den Griff zu bekommen, was sich sowohl in Trends bei der Gesetzgebung als auch bei Märkten, Konsum und Technologie widerspiegelt.

Eisenerz/Stahl

Eisenerz ist das am häufigsten geförderte Metall der Welt und Deutschland einer der größten Stahlproduzenten der Welt. Das Land ist auf Stahl als Einsatzmaterial in vielen Schlüsselindustrien angewiesen, insbesondere im Bau- und im Automobilsektor.

Herkunft und Abbau von Eisenerz konzentriert sich vor allem auf Australien, Brasilien, China und Indien und wird von einigen wenigen großen Unternehmen beherrscht, die in großem Maßstab Bergbau betreiben. Während Australien und Brasilien führende Exporteure sind, behält China den größten Teil des im eigenen Land geförderten Eisenerzes für die interne Wertschöpfung, da das Land mehr als 50 % des weltweiten Rohstahls produziert. Außerdem ergänzt China seine Nachfrage nach Eisenerz durch Importe, die zwei Drittel der weltweiten Einfuhren ausmachen. Neben China sind vor allem andere asiatische Länder wichtige Importeure von Eisenerz (Japan, Südkorea) und bedeutende Produzenten von Rohstahl (Indien, Japan). Auch die Automobilproduktion wird von Unternehmen aus China, Japan, Indien und Südkorea dominiert, wobei Deutschland der einzige nicht-asiatische Akteur unter den führenden fünf Produktionsländern ist.

Die Lieferkette von Eisenerz zu Stahl gliedert sich in fünf Stufen. Nach dem Abbau und der Aufbereitung des Erzes werden Zwischenprodukte in der Regel exportiert/importiert. Für die Weiterverarbeitung und Veredelung sowie die Herstellung verschiedener einfacher-Stahlerzeugnisse werden je nach Vormaterial und gewünschtem Ergebnis unterschiedliche Produktionswege genutzt. Die Produkte werden dann entweder an Zwischenhändler oder direkt an Automobilhersteller verkauft. Während beim Eisenerzabbau schwerwiegende Umweltauswirkungen auftreten, beispielsweise in Form von Staubbelastung und Wasserverschmutzung, ist die Stahlerzeugung für sehr hohe Treibhausgasemissionen verantwortlich.

Die Machtdynamik in der Eisenerz-Stahl Lieferkette ist weitgehend zugunsten vorgelagerter Anbieter verschoben, da der hohe Marktanteil einiger weniger großer Bergbauunternehmen dem Bergbausektor eine bessere Position gegenüber den Stahlherstellern und anderen Akteuren in der Lieferkette verschafft. Die Stahlindustrie ist tendenziell stärker fragmentiert und wird weniger von sehr großen Unternehmen beherrscht. Die Stahlhersteller sind jedoch auf eine kontinuierliche Versorgung mit Rohstoffen zu erschwinglichen Preisen angewiesen und müssen gleichzeitig den Anforderungen der Automobilindustrie gerecht werden. Daher sind die Gewinnspannen und die Preissetzungsmacht im Bergbau tendenziell höher, während der Stahlsektor in der Regel mit einer geringeren Rentabilität arbeitet. Während die Machtdynamik im Eisenerzhandel, der wachsende Einfluss der Spotmärkte auf den Handel und die Preisverhandlungen sowie die stark zunehmende Preisvolatilität bei Eisenerz einen äußerst umstrittenen Rahmen für die Einkaufspraktiken bilden, bleibt der Stahlhandel aufgrund der Vielfalt der fertigen und halbfertigen Stahlerzeugnisse von diesen Entwicklungen weitgehend unberührt.

Die erheblichen negativen Umweltauswirkungen in der Lieferkette von Eisenerz und Stahl werden zumeist durch freiwillige (von der Industrie geleitete) Initiativen und Normen angegangen. Insbesondere im Eisenerzbergbau steckt der Umweltschutz noch in den Kinderschuhen. In der Stahlindustrie gab es in den letzten Jahrzehnten einige Fortschritte. Es besteht vor allem stark wachsendes Interesse an der Produktion von "grünem", also kohlenstoffarm produziertem Stahl. Nachhaltigkeitsbemühungen, die über die Verringerung von Treibhausgas- und Luftemissionen hinausgehen und die gesamte Lieferkette umfassen, sind noch begrenzt. Der Druck von Investor*innen wird jedoch zu einem immer wichtigeren Faktor.

Auf institutioneller Ebene beeinflussen mehrere politische Maßnahmen die Umsetzung des Umweltschutzes in der Lieferkette von Eisenerz und Stahl. Während gesetzlich vorgeschriebene Umweltverträglichkeitsprüfungen für die Inbetriebnahme von Eisenerzminen üblich sind, variieren diese stark in Bezug auf Durchsetzung und Wirksamkeit. Die Stahlindustrie wird am stärksten von den zunehmenden gesetzlichen Anforderungen in Bezug auf die Emission von CO_2 und Luftschadstoffen sowie von Vorschriften zur unternehmerischen Nachhaltigkeit beeinflusst. Auch die (Frei-)Handelspolitik ist für die Branche von Bedeutung.

Im weiteren Verlauf des Projekts werden die in diesem Bericht vorgestellten Erkenntnisse als Grundlage in die Entwicklung von Anreizen für wirksame Klima- und Umweltschutzmaßnahmen und eine Verbesserung der Transparenz und Kooperation entlang globaler Lieferketten einfließen. Die identifizierten Lösungsansätze werden in Roadmaps für die praktische Umsetzung in den jeweiligen Lieferketten übertragen. Das Projekt schließt mit zielgruppenspezifischen Empfehlungen für die Ausgestaltung von operativen Instrumenten des Lieferkettenmanagements und Handlungsansätzen für Brancheninitiativen, Regierungen und Intermediäre.

1 Introduction

The globalisation of production and trade has led to a complex web of economic activities in different parts of the world. Multinational companies play a leading role in organising these value chains, taking advantage of their position in the value chain and regional differences in labour, materials, production, infrastructure and compliance with local laws and regulations. The way production and trade have been organised in recent decades has left workers and impoverished communities near production sites to bear most of the costs of poor working conditions and pollution. Certainly, globalised production has also brought benefits to the upstream value chain – but these are often limited to powerful players such as local lead firms. Most economic benefits have accrued to companies at the other end of the value chain in consuming countries who focus on the marketing and retailing of consumer products. To rectify this imbalance, policymakers are beginning to recognise that decades of inaction must be followed by more effective approaches to equitably sharing environmental burdens and economic benefits.

To better manage negative externalities, and negative environmental impacts in particular, leading actors in the supply chain, often under pressure from civil society groups, have implemented various systems and tools. However, research and practical experience have shown that many of these tools (e.g. voluntary sustainability standards, supplier audits and corporate codes of conduct) have done little to elevate the most vulnerable out of poverty and reduce environmental degradation (Clean Clothes Campaign 2019; Dietz et al. 2022). The Organization for Economic Co-operation and Development (OECD) has identified the need for a risk-based, due diligence approach, which is increasingly becoming mandatory in the wake of recent legislative developments (OECD 2022b). This means that companies need to take responsibility for those activities in their supply chain that produce adverse human rights and environmental impacts – namely, identify the problems, take adequate action to prevent, mitigate or end them, and remediate harm.

In order to understand how costs in the supply chain can be distributed more equitably, this interim report, part of the research project "**Cost allocation and incentive mechanisms for environmental and climate protection and resource conservation along global supply chains**" (German Environment Agency, research code 3722 14 101 0), analyses the structure and organisation of the value chains for five different commodities (cotton, tin, natural rubber, coffee, and iron and steel). In doing so, it identifies the dominant actors, the concentration and manifestation of power, the primary environmental impacts, the institutional barriers, and the (in-)effective incentive mechanisms.

After this introduction, Chapter 2 places the topic of cost distribution in global value chains in the context of the academic debate and provides a brief theoretical background. Chapter 3 presents the individual supply chains, from the raw material to a selected final product. The cotton profile traces the cotton value chain from farming to the manufacture of readymade garments. The section on tin analyses the value chain from tin ore mining to solder production for consumer electronics. The natural rubber profile shows all activities, from natural rubber farming to the production of tyres for the automotive industry. Coffee as an agricultural commodity is analysed from cultivation to consumption. The iron and steel section highlights the process steps from iron ore mining to quality steel sheets for the automotive industry. Each profile is complemented by a brief analysis of institutional barriers and incentive mechanisms along the supply chain. This provides insight into aspects such as environmental regulations in producer countries and their enforcement, environmental legislation in consumer countries, trade agreements and policies, and transparency issues. The report concludes with remarks on alternative routes of value creation and on the next steps in the project.

2 Introductory Literature Review

Over the last 50 years, globalisation and the increasing specialisation of production processes has given rise to global value chains (GVCs), in which the manufacture of a product from initial conception to end use and beyond takes place across inter-firm networks on a global scale (Gereffi and Fernandez-Stark 2016). While spurring consumption growth, GVC activities also frequently have significant environmental and social impacts such as deforestation, pollution, and forced and child labour, and have found to be limited in their ability to lift workers and producers out of poverty (de Marchi et al. 2013; Gereffi and Lee 2016; Neilson and Zoe Wang 2019). The uneven distribution of power in GVCs, which favour large, multinational firms (often in the Global North) over their suppliers (often in the Global South), is further seen to perpetuate global wealth and income inequality (Seabrooke and Wigan 2014; Quentin and Campling 2018; Dallas et al. 2019). To explain how power is exerted, Gereffi et al. (2005) proposed "five types of global value chain governance – hierarchy, captive, relational, modular, and market – which range from high to low levels of explicit coordination and power asymmetry." Although power is not limited to buyers at the downstream end, as this study will show, multinational firms drive most of these forms of governance through investment and outsourcing activities, resulting in an uneven distribution of costs and benefits along the value chain.

In response to these challenges, the topics of cost allocation and incentive mechanisms for environmental and climate protection and resource efficiency along global value chains are being increasingly discussed in academic literature and grey papers across a wide range of disciplines. In this sense, this research project is timely and relevant, considering the emergence of corporate social responsibility (CSR) as a focal topic in both economic and social sciences literature, the increased visibility of the United Nations (UN) Guiding Principles on Business and Human Rights, the OECD Guidelines for Multinational Enterprises on Responsible Business Conduct and a heightened awareness of environmental impacts along global supply chains.

The management literature on sustainability is extensive across its disciplines. The dominant focus in management research is on the improvement of financial values, yet emerging limitations and societal objectives have taken centre-stage (George et al. 2016). Core to the debate is how to further increase profits while also fulfilling environmental and social needs, which often appears paradoxical (Hahn et al. 2014). Bansal and Knox-Hayes (2013) argue that "the compression of time and space in and by organizations is disrupting the cycles of the natural environment". The duration between a harmful action and its negative effects is an opportunity to reap profits today and leave it to the future to deal with the created costs – whether to others or to society. Such sustainability considerations have also been taken up by the finance literature (Kölbel et al. 2020).

The spatial dimension described by Bansal and Knox-Hayes (2013) is predominantly addressed in the sustainable supply chain management (Sarkis 2019) and international business literature (Goerzen 2023; Yu et al. 2023). Sustainability beyond the firm boundaries up- and downstream in the supply chain has become a major concern for companies in their decision-making (Auger et al. 2007; Hartmann and Moeller 2014; Grzegorz and Sylwia 2019; Sarkis et al. 2021). Firms are under external pressure to invest into environmental protection in some form along their supply chain – or to disconnect from harmful practices due to sourcing from distant suppliers or sub-suppliers. Berry et al. (2021) reveal how firms moved their production to "pollution havens" to circumvent environmental protection requirements and, as a result, exacerbate local environmental issues. They thus take advantage of a regulatory "race to the bottom" in which countries, driven by global competition for Foreign Direct Investment (FDI), lower their de jure or de facto environmental regulations (Rezza 2014). However, there also exists evidence for the opposite effect – the induced innovation hypothesis – in which foreign firms with high environmental capabilities do not shy away from stringent regulatory environments, but may actually transfer innovations to host countries via their FDI and contribute to a regulatory "race to the top". Bu and Wagner (2016) argue that these effects depend on firm size and capabilities and thus happen simultaneously, demonstrating the complex interactions between institutional environments and business activities. Goerzen et al. (2021) explained the impact of local institutions on the adoption of buyer sustainability requirements.

The economic literature across microeconomic, economic-geographical, meso-economic and political economy subdisciplines further attests to the importance that the concept of sustainability has gained in global value chains, while also focusing on its potential costs. One topic of interest has been the rise of "environmental upgrading", i.e. the "process by which value chain actors design or modify production systems and practices in view of improving the environmental impacts of GVC operations" (de Marchi et al. 2013). de Marchi et al. (2013) identify four environmental upgrading strategies: "beyond compliance leadership", "eco-efficiency", "eco-branding" and "environmental cost leadership". Yet, Ponte (Ponte 2019; Ponte 2022) argues that lead firms (generally buyers such as consumer goods manufacturers or retailers) use their structural and bargaining power to shift the costs of environmental upgrading upstream to producers, generating hidden costs of sustainability while downstream buyers reap "green" profits.

The concept of cascading compliance (i.e. delegating responsibility for compliance with sustainability standards to the respective upstream supplier) allows lead firms to shift their sustainability costs, but may not succeed in engaging suppliers in sustainability efforts, which may lead to an uneven or merely symbolic implementation of sustainability practices (Giuliani et al. 2017; van Assche and Narula 2022). Soundararajan (2023) asserts that cascading compliance burdens suppliers with additional costs and therefore disadvantages already marginalized communities and reproduces inequalities. These additional costs can be entry or certification fees to gain sustainability labels that many small-scale producers cannot afford. Similarly, companies with low supply chain visibility may not be able to sell at higher prices, regardless of certification or socio-ecological standards (Zehendner et al. 2021). This may ultimately provide a disincentive for companies to engage in sustainable practices. Van Assche and Narula (2022) and Grabs and Carodenuto (2021) confirm that demanding increasingly stringent compliance with sustainability requirements may exclude smaller or more marginalised upstream suppliers with lower capacity to comply, unless policies are designed with equity in mind (e.g. via benefit-sharing schemes for compliance through price or non-price mechanisms and payments to offset lost income).

Taking a broader lens, LeBaron and Lister (2021) argue that other hidden costs of global supply chain solutions such as company-led programmes, industry-wide collaboration and multi-stakeholder initiatives include unintended consequences (e.g. prompting layoffs to recoup the costs of environmental certification), perverse effects (e.g. auditing pushing illegal practices such as forced labour deeper into the supply chain), and unacknowledged impacts on societal protection and well-being. Of particular concern are the meso-level impacts of these global supply chain solutions, which may reinforce corporate power and deflect or displace efforts to strengthen state-led agenda-setting, monitoring and enforcement of non-market values. At the same time, the global production networks literature highlights the embeddedness of GVCs in broader institutional contexts and the interconnectedness of inter-firm GVC governance and international, national, and public-private environmental governance (Coe and Yeung 2019). Horner (2017) highlights the role of the state not just as facilitator of firms' participation in global production networks, but also as regulator, producer (state-owned enterprises), buyer (public procurement), and investor (e.g. via sovereign wealth funds). Mayer and Phillips (2017) in turn stress the state's role in the facilitative, regulatory, and distributive governance of GVCs. They also critique the tendency of states to "outsource" governance by delegating a variety of governance functions and authority to private actors, which they associate with regressive distributional outcomes.

Drawing on both types of governance, Ding et al. (2015) investigate various means to distribute environmental costs more evenly along the supply chains and conclude that government incentive policies should be reasonably distributed among supply chain actors through transfer price negotiations. Additionally, cooperation and meaningful engagement on sustainability and the reduction of environmental externalities between supply chain actors may yield a more equal distribution of costs and a reduction in environmental pollution. In contrast, our literature review has found few other practical recommendations on how to improve the equitable distribution of environmental protection costs from an institutional (rather than firm-level, voluntary) perspective. In addition, the literature review has shown that the concepts of power, hidden costs and (dis)incentives to fairly distribute costs along supply chains are most often siloed in their respective disciplines, with very little literature attempting to cross these divides. This leads to knowledge gaps on how sustainability and environmental protection costs can be allocated fairly and evenly among supply chain actors. Resource-specific literature may provide further insight, as will the results of this study.

3 Supply Chain Profiles

A supply chain profile has been prepared for each raw material. The profiles include graphical elements, such as diagrams as well as tables, where needed to present relevant information in a precise and reader-friendly format. Each profile will be structured in a comparable format.

The information presented in the profiles relies on secondary research and key expert interviews with buying and supplying companies from Germany and Asia.

3.1 Cotton-garment

3.1.1 Introduction/background

Cotton is the second most common fibre in the world after polyester and accounts for 24% of global fibre production. At 80%, cotton is the most widely used natural fibre, with 30% of total production processed into finished products for the textile and fashion industry (Lanfranchi and Cline 2021; Cotton Connect 2022). The cotton industry secures the livelihoods of approximately 100 million households, especially in lower-income countries (Voora et al. 2023a). However, resource-intensive production and unsustainable practices have led to high levels of environmental pollution and poverty in some regions (Lanfranchi and Cline 2021).

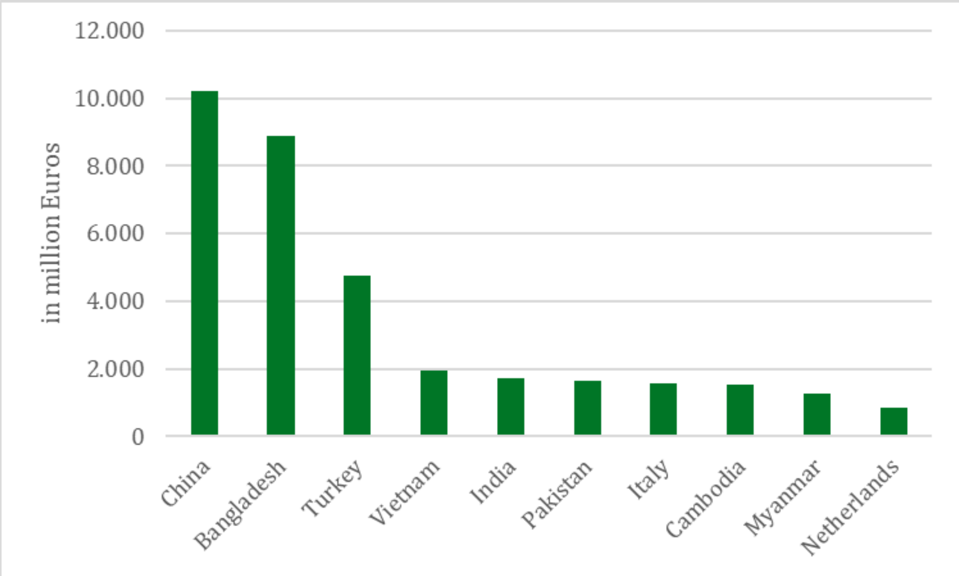
In many societies, cotton played an important role in the early stages of industrialisation. The labour-intensive textile and clothing industry were one of the first industries in Germany. Cotton used to be imported from cotton growing countries and further processed to garments and other articles. Since the 1970s, globalisation has initiated a structural change that has led German companies to outsource labour-intensive, cotton-based clothing production to low-cost countries in Southern Europe, Asia, and Eastern Europe. Instead of cotton, German companies have specialised in the production of more value-added technical textiles, which are often based on synthetic fibres[1]. As clothing consumption has dramatically increased over the years (Changing Markets Foundation 2022)[2], Germany relies heavily on imports, mostly from countries like China, Bangladesh, Türkiye and Vietnam (see Figure 1). In 2020, Germany imported clothing products worth 38.4 billion U.S. dollars, which makes it the second largest importer of clothing in the world after the United States of America (WTO 2022b). Given the high reliance on suppliers of cotton, intermediate and final products, the following profile focuses on the readymade garment supply chain as a cotton-based commodity[3].

[1] Home textiles and technical textiles, which are often made of synthetics, are not considered in this study.

[2] Overall consumption of garments has doubled in the past 20 years to 62 million tonnes.

[3] This supply chain profile uses the terms “readymade garments”, “apparel” and “clothing” interchangeably.

Figure 1: Leading countries of origin for clothing imports into Germany 2022, based on import value by country

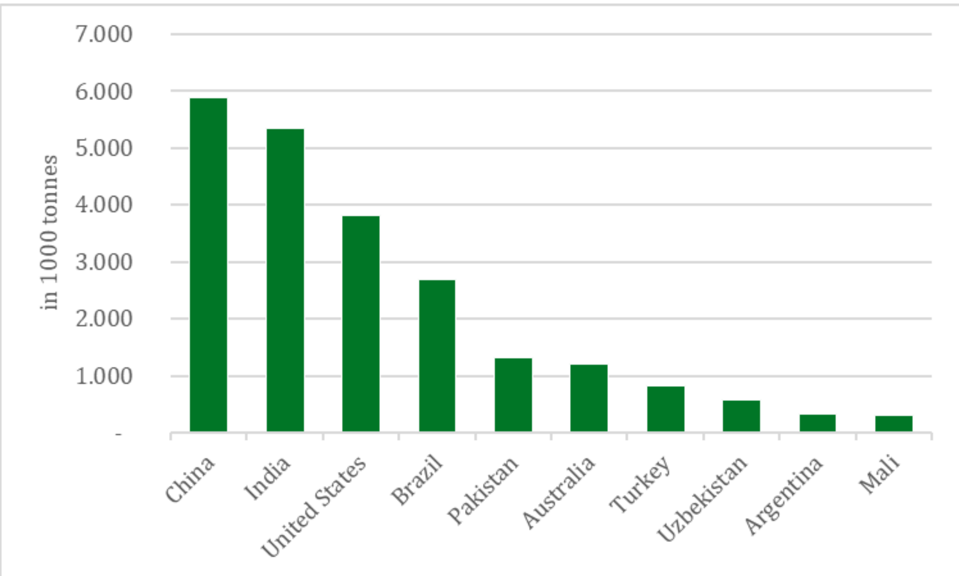


Source: adelphi, based on information from Destatis (2023)

3.1.2 Market structure

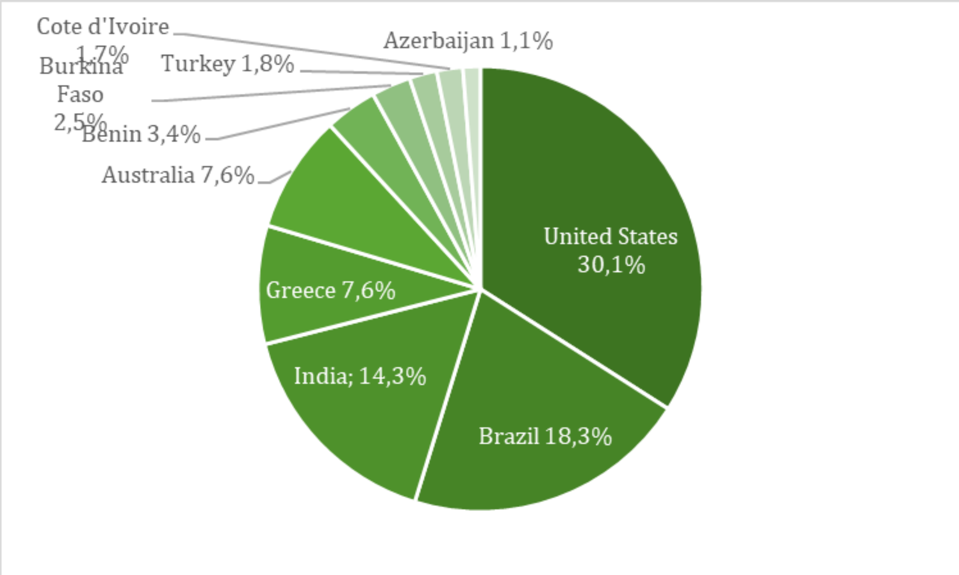
Cotton is cultivated in over 80 countries, with production concentrated in China, India, the U.S., Brazil and Pakistan (see Figure 2). The plant grows in hot and dry conditions, but needs some moisture, which varies with geographical region and may require supplementary irrigation (Voora et al. 2023a). While large farms dominate in the U.S., in the Global South smallholder cotton farming is predominant, producing more than 60% of the global cotton. As a reference, South Asia (Bangladesh, India, Pakistan, Sri Lanka) produced approximately 7.4 million tonnes (29%) of the total cotton production in 2018; 90% of it was genetically modified (Voora et al. 2023a).

Figure 2: Leading cotton producing countries in 2021/2022, by country



Source: adelphi, based on information from U.S. Department of Agriculture (2022)

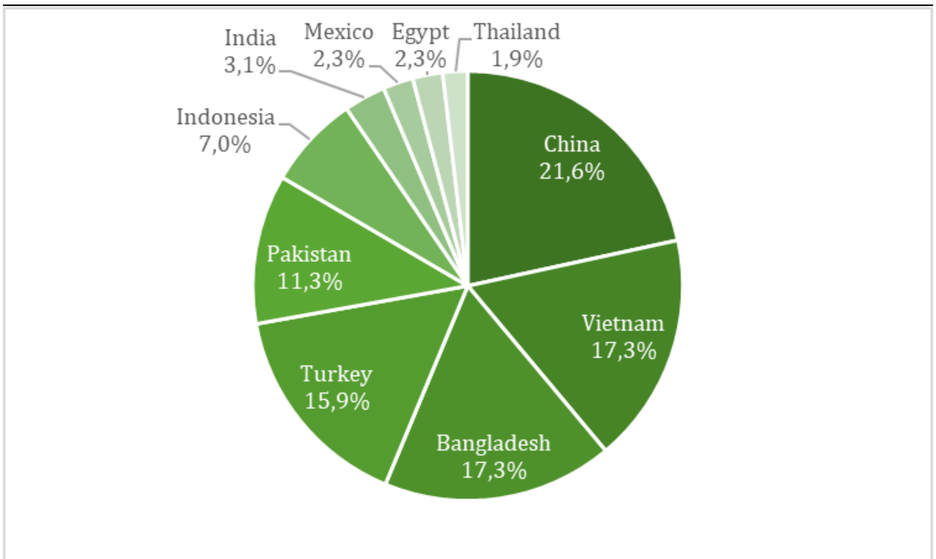
Figure 3: Top 10 export countries of raw cotton, 2021



Source: adelphi, based on information from OEC (2023e)

Cotton exports are led by the U.S., Brazil, India (see Figure 3). China, India, Pakistan, Türkiye and some Central Asian countries export, but mostly keep their cotton for internal value addition and process it further until finishing. China's ranking (32nd), which is lower than in previous years, could be due to two factors: i) allegations of exploitation of Uyghurs in cotton cultivation and subsequent import bans (e.g. by the U.S.) on cotton products from the region (Kimble 2022); ii) China's large processing capacity for the domestic market, partly reflected in in the country being the largest importer of cotton ($3.49b; 18.7%) (see Figure 4).

Figure 4: Top 10 import countries of raw cotton, 2021

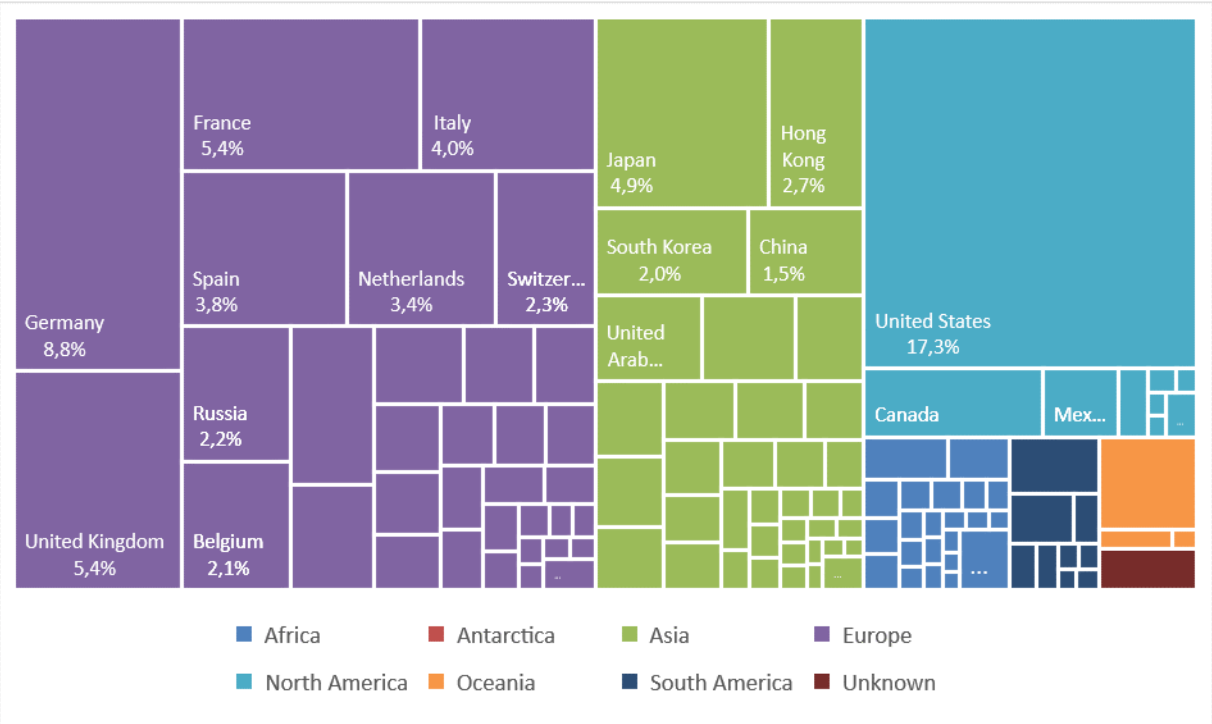


Source: adelphi, based on information from OEC (2023f)

The garment market consists of a large number of producer firms, mostly in the Global South. In 2021, the key export countries for clothing, including natural fibres and synthetic materials, were China – by far – followed by the European Union (EU), Bangladesh, Vietnam and Türkiye[4]. Apart from China, South Asian manufacturers from Bangladesh, India and Pakistan dominate **cotton-based garment exports**, in large part due to the strong backward linkages and domestic availability of cotton in India and Pakistan (ILO 2018). Bangladesh, currently the second largest exporting country of garments, relies on imports of cotton yarn and fabrics, which it then finishes at low labour costs. Southeast Asian countries on the other hand, such as Cambodia, Vietnam, Indonesia and Myanmar, process a larger share of human-made fibres, i.e. synthetic and cellulosic fibres (ILO 2018). In countries like Bangladesh, Cambodia, Myanmar and Vietnam, low value-added **cut-make-trim (CMT) operations** predominate. Thanks to its large capacities and strong backward linkages, the Chinese garment industry exports by far the largest volumes of products based on both cotton and synthetic fibres, strengthening its bargaining position with international buyers, although China's position in the value chain has been weakened lately (see Section 3.1.7).

The **main consumer markets**[5] for cotton-based garments are the U.S., within the EU mainly Germany and France, and the United Kingdom. As data on cotton garment imports are not widely available, Figure 5 refers to all imported garments, that is also those made of synthetic materials. The dominance of Europe and North America as consumer markets in relation to their population compared to Asia is striking.

Figure 5: Countries importing garments, by continent, in 2018 (in percentage)



Source: adelphi, based on data from OEC (2023a)

3.1.3 The cotton-garment value chain

International garment production is increasingly organised in global value chains, with buying companies (e.g., brands/retailers) splitting up their operations, some of which are carried out in-

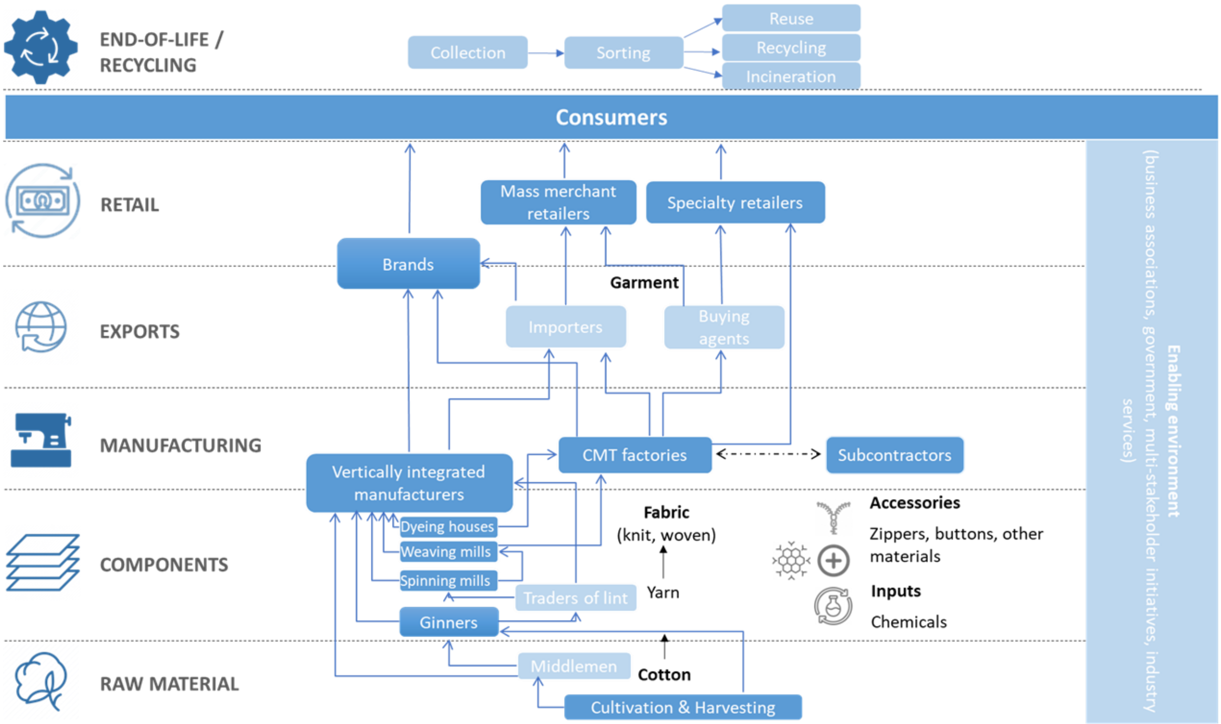
[4] Data about the clothing/garment industry may be inconsistent, involve other sectors (e.g. leather) or use estimations. Unfortunately, reliable data on cotton-based garment exports were not available.

[5] The term consumer market refers to imports. Re-exports are not considered.

house (e.g. R&D, design) or are outsourced to manufacturing firms (suppliers) in low-cost countries.

The **cotton-garment value chain** as portrayed in Figure 6 is organised in five stages (raw material, components, manufacturing, exports, retail) and is to be complemented by post-consumption processes like collection of post-consumer waste, sorting and recycling.

Figure 6: Cotton-garment value chain



Source: adelphi, adapted from ILO (2018)

Cotton farmers grow cotton mainly for its fibre. There are three types of cotton: conventional cotton, sustainable cotton and organic cotton. **Conventional cotton** usually uses seeds that have been genetically modified or treated with chemicals to increase yield (Textile Exchange n.d.). The use of pesticides and fertilisers is essential in the cultivation of conventional cotton. Genetically modified cotton has become a growing industry for countries that are dependent on cotton imports (e.g. Bangladesh), that want to reduce their dependence on Asia because of high transportation and logistics costs (e.g. EU and North American markets) or that need to adapt to the changing climatic conditions (Voora et al. 2023a). **Sustainable cotton** aims to make more efficient use of natural resources such as water, land, carbon and energy, but is not completely free from pesticides and fertilisers (CottonWorks™ n.d.). **Organic cotton** is not genetically modified or treated with pesticides and fertilisers.

The cotton, harvested either by machine or manually, will go through the **ginning** process where the fibre is separated from the seeds and other impurities. Traders purchase large quantities of cotton lint and sell them on to spinners. In the spinning process, the fibres are processed into **yarn** and passed on to the weaving or knitting process, where they are made into **fabrics**. Wet processes, such as bleaching, dyeing, washing and printing are particularly resource-intensive and constitute one of the main environmental hotspots in the supply chain (see Figure 6).

The cotton-garment supply chain is characterised by the **"fast fashion"** business model, which has led to labour rights violations (e.g. child labour, forced labour, bonded labour, lack of freedom of association) and negative environmental impacts in the entire supply chain, from cultivation to manufacturing and end-of-use. Table 1 shows the environmental impacts that are common in the supply chain and therefore relevant for the industry. This does not mean that every impact listed will occur in every cotton-garment supply chain.

Table 1: Main environmental impacts in the cotton garment value chain

Supply chain segments	Environmental impacts
Cultivation & harvesting	Depleting water reserves: high water use for irrigation, deteriorating groundwater reserves
	Decreasing biodiversity: use of genetically modified seeds, fertilisers, pesticides
	Decreasing soil quality: use of fertilisers, pesticides
Textile processing & manufacturing	High water consumption, inefficient use of water, inadequate waste water treatment
	Use of hazardous chemicals, inadequate chemical management
	High energy consumption; use of non-renewable energy sources; increase in greenhouse gas (GHG) emissions

Source: adelphi, based on information from Coscieme et al. (2022) and Voora et al. (2023a)

At the manufacturing level, we can broadly distinguish between **vertically integrated manufacturers** and **cut-make-trim (CMT) manufacturers**[6]. **CMT manufacturers** carry out the final assembly of the garment, i.e. the labour-intensive production steps, such as cutting and sewing. They supply brands/retailers either directly or, more often, indirectly through intermediaries (e.g. importers, buying agents) and are usually contractually obliged by their customers to source their materials (e.g. fabric, accessories) from **nominated suppliers**. The CMT business model is based on competitive prices as suppliers usually charge for the processing stages and not for the final product (Nadvi et al. 2004). **Vertically integrated firms** integrate all processes from spinning onwards, giving them a competitive edge in pricing, volume/size, production costs and transparency, and overall a better bargaining position as there are fewer intermediaries involved (Ahmed and Nathan 2016). According to a cotton standard organisation, there are highly integrated facilities in some geographies (e.g. Pakistan), where companies even go back to growing in order to maintain as much benefit as possible.

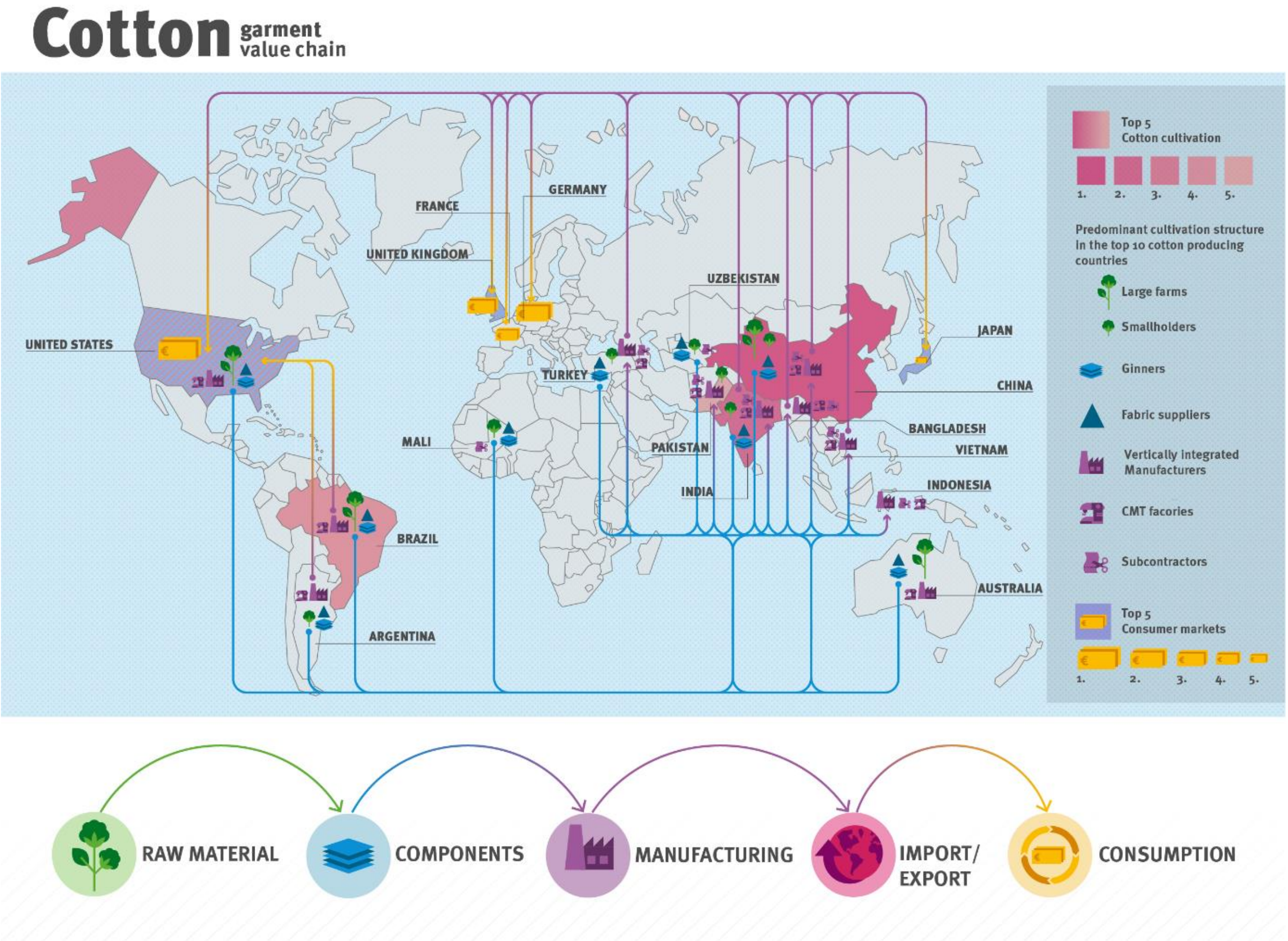
China is a major market for **accessories** (e.g. button, zippers) and **inputs**, such as textile processing and finishing chemicals, which further reduces the price competitiveness of tier 1 producers in other countries, which are heavily dependent on low-cost imports of chemicals and accessories. The final product, i.e. **readymade garments,** can be divided into **woven garments** (e.g. shirts, denim) and **knitwear** (e.g. t-shirts, sweaters). With the demand for knitwear, the use of human-made fibres is also increasing. Many of these factories use blended fabrics.

Based on the data presented earlier, Figure 7 shows selected key structures (main producer/consumer markets; actors) and processes (e.g. product flows) in the cotton garment value chain[7] in a thematic map:

[6] Other business models, such as contract-based services to carry out specific operations, are not considered.

[7] Please note that for practical reasons, the thematic map shows the markets, actors and product flows in a highly simplified way. It does not claim to be exhaustive and does not represent the full complexity of the cotton garment value chain.

Figure 7: Selected key structures and processes of the cotton-garment value chain



Source: adelphi, based on material and data from this text

3.1.4 Pricing

Pricing in the cotton-garment supply chain is particularly complex at the raw material level. In later stages, prices are negotiated between buyers and suppliers to cover the supplier's production cost and allow for some profit margin. Price negotiations are part of a broader framework of purchasing practices that are highly contested between buyers and suppliers, as discussed in more detail in Section 3.1.5.

The Cotlook A Index

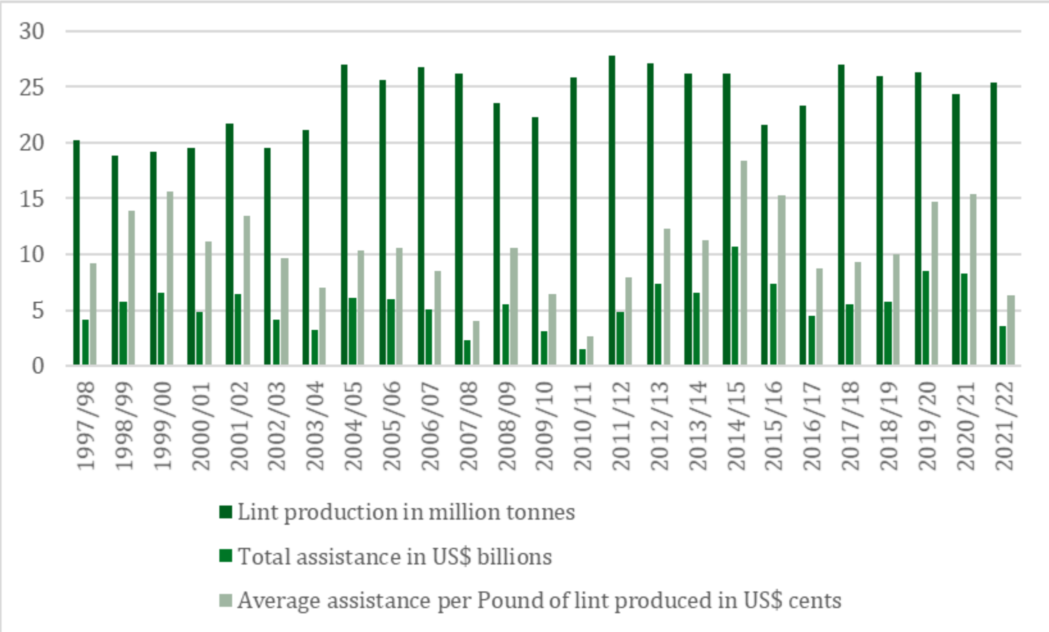
The **Cotlook A Index** is the average of the cheapest five cotton futures quotations in Asia and the benchmark index of the industry. It is used by many buyers and traders as a reference for prices paid to ginners (Voora et al. 2023a).

Cotton is mainly traded in the form of **futures contracts and options**, mostly on the New York futures market (Cotton Outlook 2023a). Cotton futures are used to speculate on the future price of cotton, which involves considerable risk and requires market knowledge. According to Cotton Outlook, less than 2% of contracts are actually delivered. Instead, they are used more as a price finding tool or a hedging mechanism. Other highly speculative forms are derivatives, such as contracts for difference, which are available on online trading platforms and trade on whether the price of cotton will go up or down. As there were significant discrepancies between the futures and the actual cotton values in the past, the **Cotlook A Index** was created, which is now the most important price measure (Cotton Outlook 2023a). Compiled from the five cheapest offering prices for a number of growths to the end users, i.e. the mills, the Cotton A Index assumes that the most competitive growths are likely to be traded the most (Cotton Outlook 2023b). Over the decades, in addition to the importance of the markets, the geographical basis of the quotations has shifted from Europe to the Far East.

Cotton prices are volatile and largely determined by the quality of the fibre, geography, the climatic conditions in which it is grown, and government subsidies (CBI 2020a). Climate and extreme weather events such as floods and droughts have a significant impact on crop yields and thus on prices (Avatrade 2023). Staple length increases the quality of the yarn and thus the final fabric. Countries that produce large quantities of sustainable cotton, like India, affect the prices of both conventional and sustainable cotton – as does China, the country with the greatest demand for cotton. It is noteworthy that the price difference between organic and conventional cotton differs between the countries, which may be related to the specific growths and the availability of inputs, such as fertilisers and pesticides in China, which makes it costlier to shift to organic production. Other factors affecting cotton prices are competing fibres and materials such as polyester, which dominates the textile market with more than 60 million tonnes in 2021, compared to approximately 26 million tonnes of cotton lint in 2020 (ICAC n.d.)[8] . In this context, lower oil prices mean cheaper polyester, which in turn can have an impact on the price of cotton. According to the ICAC (2022), government subsidies to the cotton sector in 11 countries declined from a total of $8.5 billion in 2019/20 to $3.5 billion in 2021/22 (see Figure 8). This is attributed to the negative correlation between subsidies and prices, i.e. when prices are low – as during the Covid-19 pandemic when cotton demand first dropped and was brought back on track after the lockdowns were lifted – subsidies tend to increase (ICAC 2022).

[8] The calculated figure refers to data provided by ICAC n.d., which uses cotton lint, i.e. cotton fibre that remains after cotton seed, leaves and casings have been eliminated during ginning (Textile Exchange n.d.).

Figure 8: Subsidies provided by governments to the cotton sector



Source: adelphi, based on information from ICAC (2022)

3.1.5 Power relationships

While pricing at the commodity level is dominated by the futures market, brands and retailers have more power to impose prices on their suppliers, depending on the business model. This section shows that cost and benefits in the cotton garment supply chain are unevenly distributed, primarily due to power imbalances in the supply chain and purchasing practices where buying companies externalise risks to weaker supply chain partners (Khan et al. 2019; Ethical Trading Initiative et al. 2022).

In general, **governance** in the cotton garment value chain is **dominated by powerful buyers** such as brands and retailers that maintain captive relationships with a large number of suppliers (Gereffi et al. 2005). Following Gereffi et al.'s (2005) approach, lead firms exert control over their suppliers by imposing a set of requirements (e.g. quality, production process and, increasingly, sustainability), increasing the barrier for them to switch buyers. **Brands and retailers**, especially the larger ones, rarely work directly with garment manufacturers, but place orders through **intermediaries**, contracting out manufacturing and sourcing from importers or trading groups/buying agencies (Serdijn et al. 2020). Only a few still have an integrated supply chain with their own production facilities and thus control of most of the operations (ILO 2018). **Retailers** can be divided into **mass merchants** and **specialty retailers**. Mass merchants sell a wide range of consumer goods as well as clothing. Specialist clothing retailers sell only their own brand. Both types of retailers completely outsource the production and rely on importers and trading companies/buying agents (ILO 2018). Brands and retailers in the highly competitive consumer markets control access to the most value-added segments of the cotton value chain, such as R&D, product design or marketing (see Figure 6). When clothing is a rather small segment, such as in supermarkets, it is also common that design activities are outsourced to intermediaries, such as importers.

The power of the buyers of the final product, however, only extends as far as the spinning process (yarn), often only as far as the fabric suppliers. **Power dynamics may well shift** along the supply chain depending on the market and business model. In markets like the U.S., Brazil and Australia, where large, mechanised farms dominate, powerful, multi-million-dollar ginning companies directly source from cotton growers. By contrast, smallholders in South Asia, for example, have less control over pricing as they are mostly dependent on middlemen who act either as brokers (commission agents for ginners) or traders. In general, **cotton farming systems and institutional support** determine the competitiveness of the cotton industry in the respective country. **Smallholder cotton farmers** in developing countries are among the weakest actors in the cotton value chain. Low prices stand against high production costs (e.g. fertilisers, insecticides), lack of market information or lack of funds and availability of quality seeds, which reduces profit margins. Price pressure, in part is also driven by the subsidy regime in the U.S; farmers in more organised economies such as China and the U.S. have better technological capacities and enjoy more institutional support like subsidies for cotton inputs (e.g. fertilisers, harvesting) or quality seeds (Voora et al. 2023a). In the U.S., farmers are paid after ginning, where quality is determined, while smallholders in the Global South are paid based on raw cotton delivered, which in turn disadvantages them. Where farmers are not organised, they are often heavily dependent on powerful ginners and traders, who sell the cotton on to spinning mills and weaving companies or buying teams of brands (Voora et al. 2023a).

The main **business models** of buyers, including brands/retailers, importers and traders, for sourcing cotton-based garments for the German/European mass market can be summarised as is in Table 2. Buyers purchasing large quantities rely on a vast network of suppliers embedded in a highly competitive environment. **Brands/retailers** have **pricing power** and are in a better position to protect themselves from market volatility, as they usually source from importers and trading companies.

- The first dominant business model is the highly competitive **auction-based system**, which is common with **mass merchant retailers** like Aldi or Lidl, catering large volumes to the low-end market. The contract is usually awarded to suppliers through intermediaries (importers, traders) based on a number of criteria, such as quality, price, sustainability and lead time, among others. Interviews with traders and producers suggest that price is ultimately the decisive factor. Premiums for compliance with sustainability standards are not granted – a concern repeatedly voiced by industry representatives such as the STAR Network (Sustainable Textile of the Asian Region), an alliance of Asian manufacturer associations.
- Some **specialty retailers** (e.g. H&M, adidas) source directly from a limited number of **key suppliers** (fabric and/or finished product) who are able to deliver either a specific product or/and large quantities; **occasional suppliers** are used to fill capacity gaps and do not account for more than 10% of the buyer's volume (Aridov et al. 2014). Buying at scale gives companies the capacity to tie large suppliers strategically to their business. Large order volumes on a regular basis may also compensate for unsustainable practices (e.g. low prices, open costing, last minute changes) that reflect the asymmetrical power relationship and often have detrimental consequences for the workforce. If customer oversight is insufficient, there is a risk that official suppliers subcontract additional volumes to sub-suppliers (subcontractors), even though they are not contractually allowed to do so, who are often not subject to internal audit procedures in terms of working conditions or health and safety practices (Labowitz and Baumann-Pauly 2015). Occasional suppliers tend to accept worse conditions just to enter the market, are more connected to buying agencies/trading companies, and receive less support from their customers.
- The third business model takes a more **collaborative approach** and is currently practiced, for instance, by members of the Fair Wear Foundation (FWF), a not-for-profit that works with 130 member brands in the garment industry to improve working conditions in their

supplier factories (FWF n.d.). The focus lies on labour standards; environmental issues are not addressed. Unlike the prevailing "check-the-box" audit approach, FWF members work closely with their suppliers to improve key sustainability metrics, recognising that this is a process rather than an outcome. Alliances with other stakeholders (civil society, unions, academia) are impact-driven to find practical solutions to issues that are often ignored in the market, such as living wages or gender equality (Fair Wear Foundation n.d.). Member brands, which are mostly small and medium-sized companies, are subject to regular performance checks, which are reported on publicly. Trust and collaboration are at the core of this business model, which naturally is difficult to adapt to the mass market. Given the smaller quantities these brands purchase, power is not necessarily concentrated at the downstream end.

Table 2: Dominant business models and governance in the cotton-garment value chain

Business model	Type of buyers	Governance	Type of relationship	Procurement procedure
Auction system	mass merchant retailers	captive	short-term sourcing contracts	highly competitive; price dominant
Mix of key & occasional suppliers	brands, specialty retailers	relational; captive	longer term contracts with strategic suppliers; short-term with others	competitive; strategic factors (e.g. product, size)
Cooperative approach	small and medium-sized	relational	built on trust and joint responsibility; longer term contracts	cooperative; focus on sustainable improvement

Source: adelphi, based on classification by Gereffi et al. (2005) and information from expert interviews

Capabilities are a major factor in power relationships. Interviews with buying and supplying companies conducted as part of this research suggest that the prices of **CMT factories (tier 1)**[9] sourcing from nominated fabric suppliers (tier 2) are set in advance by buyers and fabric suppliers and cannot be re-negotiated, indicating an **imbalance of power** in the supply chain. For buyers, this is a way to ensure that certain sustainability requirements (e.g. certifications) are met. CMT manufacturers can only exercise bargaining power over non-nominated suppliers from whom they are allowed to source directly, but their share is rather small. As described earlier (see 3.1.2), **vertically integrated firms** have more control over their backward linkages and thus a competitive edge in pricing, volume/size, production costs and transparency, and overall a better bargaining position as there are fewer intermediaries involved (Ahmed and Nathan 2016). These capabilities often determine whether a firm can rise to become a key supplier. While CMT factories may well be of strategic value to a buyer because they can offer a specific (e.g. niche) product at a specific cost and thus become a key supplier, their operations

[9] Supply chains can be divided into tiers, with tier 1 being the supplier closest to the final buyer (i.e. brands/retailers, traders, importers). In the textile supply chain, tier 1 would be the final assembly, i.e. RMG factories (cut-make-trim, washing/dyeing/printing). Tier 2 would be the supplier of tier 1, i.e. the fabric supplier (weaving/knitting mills). Tier 3, spinning mills, would supply the yarn to the weaving/knitting mill. Tier 4 could be a gin or, which is more common, the cotton grower. There are also reports that are less granular in their tiering analysis, assigning tier 3 to cotton growers. Vertically integrated factories may comprise several tiers, i.e. CMT plus dyeing/washing/printing (tier 1) plus weaving/knitting (tier 2) plus spinning (tier 3). Some companies in Pakistan even have all production steps under one roof, including cotton cultivation.

are easier to substitute than those of vertically integrated firms or, for instance, specific fabric suppliers. In general – this may vary in individual cases – key suppliers maintain closer ties to their buyers and therefore enjoy better conditions, making them less vulnerable in a variety of aspects, as highlighted in Table 3:

Table 3: Differences in buyer-supplier relationships by supplier importance (tier 1)

Aspects	Key suppliers	Occasional suppliers
Order volume	Continuous, large	Occasional, small
Payment terms	Short-term (e.g. LC at sight, i.e. at the release of the goods)	Long-term (e.g. 60-120 days and beyond)
Commitment	Long-term	Temporary
Sustainability requirements	Required, continuous monitoring (self-assessment, internal audit, third-party audit)	Required, but less stringent controls
Support	Guidance by buyers (quality, sustainability); incorporation in development programmes (sustainability); no financial support	No direct support
Power relationship	Asymmetrical, but supplier is not easily interchangeable	Asymmetrical relationship

Source: adelphi, based on information from expert interviews

3.1.6 Addressing environmental impacts

Environmental laws and regulations aim to protect people and the environment. Regulatory and enforcement bodies in producer countries use different tools to address negative impacts, such as environmental impact assessments or financial sanctions (Sharpe et al. 2022). The authors' field experience in the sector has shown that, due to lacking resources and capacity among local environmental authorities, procedures are often non-transparent and not as strict as required by law, allowing suppliers to circumvent regulations.

Against a backdrop of deteriorating labour and environmental conditions, and major disasters such as the collapse of Rana Plaza, companies have been increasingly pressured to adopt **voluntary sustainability standards** and sign up to international agreements such as the Bangladesh Accord (now: RMG Sustainability Council – RSC). Implementing those requirements has significantly improved occupational safety and health (OSH). However, other labour rights, such as minimum wages (living wages), freedom of association or collective bargaining, which have a significant impact on prices, continue to be violated. Environmental issues have only gained prominence in recent years due to increasing pollution and vulnerability to climate change and related environmental policy developments.

Depending on the market, buyers require third-party certification of materials, products, the facility or processes from their suppliers.

- As for **materials**, among the most important voluntary cotton sustainability standards are Cotton made in Africa (CmiA), Better Cotton Initiative (BCI), Organic Cotton Standard (OCS), FairTrade International Small Producer Organization, Standard with Fibre Crop Criteria, USDA National Organic Program, EU organic programme, Indian National Programme for Organic Production, and the Responsible Environment Enhanced Livelihoods (REEL). The main sustainability standards operating in South Asian cotton markets are Better Cotton, Fairtrade and the Reel Cotton Code. According to the WWF (2023), **voluntary cotton standards** vary in scope, maturity and coverage of sustainability issues. Most of the standards cannot ensure full sustainability in all its social, environmental and economic dimensions. However, non-certified production does not necessarily mean that the agricultural practices are harmful to workers or the environment. Very often, it is financial reasons or inadequate agricultural extension services that prevent smallholders from going through the costly certification process. But only if the working methods and production processes are independently verified, do they provide the level of assurance that customers and end consumers expect.
- The requirements for **products** can contain specifications on the composition to prove that they are safe for use (e.g. OEKO-TEX Standard 100), meaning that all materials have been tested and no harmful substances can be detected in the final product. When entering the EU, products need to comply with the General Product Safety Directive (GPSD: 2001/95/EC) and the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulation (CBI 2022b). Product standards may also prescribe the use of recycled material, such as the Global Recycled Standard (GRS).
- **Process standards** define procedures to carry out tasks and operations to ensure, for instance, quality (e.g. ISO 9001), environmental protection (e.g. ISO 14001), occupational safety and health (e.g. ISO 45001) or energy management (e.g. ISO 50001). They do not set requirements for sustainability performance. There are various social and environmental standards that either analyse and evaluate the manufacturing processes as holistically as possible (e.g. STeP by OEKO-TEX®, Global Organic Textile Standard – GOTS) or limit themselves to specific areas, such as working conditions (e.g. SA8000).

The German Green Button is a meta label that requires companies and products to meet a number of social and environmental criteria and to implement a due diligence process in their supply chain (Grüner Knopf n.d.). Various certifications have already been recognised, such as OEKO-TEX® MADE IN GREEN, OEKO-TEX® STANDARD 100, Bluesign Product, GOTS, Cradle to Cradle, Fairtrade Cotton and SA8000 (Hohenstein 2023). Relevance outside the German market is low. Figure 9 highlights some of the certifications that are common in the garment supply chain.

Figure 9: Selected certifications in the cotton garment supply chain

Source: In Litore; Logowik n.d.; CEO Water Mandate n.d.; it fits - Organic Textile Partner n.d.

In various multi-stakeholder initiatives, companies are working together with civil society organisations, trade unions and government actors to make the textile supply chain more sustainable (e.g. Partnership for Sustainable Textiles, Fair Wear Foundation). They all seek to alleviate power imbalances and improve conditions in the textile sector, without particular focus on cotton. Also, membership initiatives, such as the amfori Business Social Compliance Initiative (BSCI) and the Business Environmental Performance Initiative (BEPI) aim to promote socially and environmentally responsible production conditions (amfori n.d.). While all these initiatives are promising efforts to induce change, few have actually improved collaboration across the sector to improve transparency and reduce power asymmetry, as demonstrated during the COVID-19 pandemic (ILO 2021).

Molenaar et al. (2022) point to low and unstable prices as one of the root causes for environmental externalities, arguing that prices and purchasing practices have not been sufficiently reflected in voluntary sustainability standards. They demonstrate for a number of commodities that persistently low prices discourage producers from investing in profitability and sustainability and eventually exacerbate environmental degradation.

Interviews suggest that large suppliers tend to consider the **sustainability requirements of renowned brands and retailers** to be more stringent, as they maintain their own data validation system (internal auditing and controls, i.e. buyers send their own compliance team for inspection). Reference is often made to corporate Restricted Substances Lists (RSL) and Manufacturing Restricted Substances Lists (MRSL), which may be more demanding than voluntary standards and certifications. In addition, buyers may hire **third parties to verify the data** submitted by the supplier. The level of competence of the suppliers determines whether they can carry out a root cause analysis themselves and take measures against violations of the standards. Normally, customers with access to supplier data point out these violations, e.g. in emission levels (polluting substances), which the suppliers then have to remedy without any support from their customers. Since suppliers are primarily interested in exporting their product with the required certification, they make the effort to meet the standards. Confidence in the data, however, is a major challenge, especially as the audit and certification process is prone to fraud, as evidenced by the case of the Indian organic cotton industry last year (Wicker et al. 2022).

3.1.7 Current/future trends and developments

EU policies and initiatives promoting sustainability, human rights and circularity in the textiles sector have had a limited impact on the industry as of yet. However, this is likely to change in light of the increasing sustainability regulations. REACH has regulated the production and import of chemicals quite effectively since 2007, which the industry has largely followed. With the upcoming EU *Corporate Sustainability Reporting Directive* (CSRD), the EU *Corporate Sustainability Due Diligence Directive* (CSDDD), to be enacted in 2024, and the already enacted German *Supply Chain Due Diligence Act*, companies of certain sizes are or will be required to avoid or remedy human right infringements and certain environmental damages in their supply chains and provide transparency about their due diligence processes. Both buyers and suppliers have understood that sustainability is no longer a “nice to have” but a “must have” and that they need to implement the required practices and collect data for reporting (e.g. Global Fashion Agenda, apparel impact institute). Smaller companies are also increasingly aware of the need to adopt more sustainable practices in areas such as material sourcing, production processes, and waste management, as legislation requirements become more stringent. These practices include the use of recycled or sustainable materials, such as organic cotton, and the adoption of circular business models, such as designing products for durability and repairability and recycling end-of-life products. With the Circular Economy Action Plan 2020, the EU Strategy for Sustainable and Circular Textiles 2022, the proposal for a new Ecodesign for Sustainable Products Regulation 2022 and the proposal to amend the Waste Framework Directive 2023, EU legislation is moving towards a circular economy and extended producer responsibility schemes for textiles (European Commission 2023b; European Commission n.d.). It remains to be seen what the final EU legislation will look like and how strict their performance requirements will be.

The COVID-19 pandemic and the Russian war against Ukraine have highlighted the vulnerability of the global textile supply chain and its interdependencies. Tendencies to move production to countries closer to the home market, also called nearshoring, in this case to the Central-Eastern European region (Dobos 2022), were triggered by supply chain disruptions during the pandemic, especially in China, but curbed by the war in Ukraine. Nevertheless, these events have affected the structure and power relations in the supply chain. Companies had to adjust their operations, and, where possible, move to local sourcing and shorter supply chains to reduce supply chain risk. Several Estonian brands, for instance, withdrew from the Russian market and started sourcing from European countries (Ukraine, Poland, Italy). The large-scale withdrawal of major brands from the Russian market, the strict lockdown measures in China during the COVID-19 pandemic and reports about forced labour in cotton farming in Xinjiang pushed buyers to restructure their supply chains, shifting ginning, spinning and fabric mills to other countries in Southeast (e.g. Vietnam) and South Asia (e.g. Bangladesh). As a result, CMT manufacturers, for instance in Bangladesh, have benefited from shorter lead times and a lowered dependency on imports. This has improved their competitiveness against China, whose dominance in textile processing and finishing chemicals already significantly limits the price competitiveness of tier 1 producers, e.g. in Bangladesh, who are highly dependent on low-cost chemical imports. Table 4 summarises the market, consumer and technology trends that may gain importance in the near future.

Table 4: Market, consumer and technology trends

Market trends	▶ Increasing demand for sustainable and ethically sourced cotton may lead to the development of more transparent supply chains ▶ Growing demand for organic cotton, which, however, currently cannot be matched by the supply (CALIDA 2021; Textile Exchange 2022) ▶ Increasing competition from synthetic fibres, such as polyester, due to their lower cost and simpler manufacturing process ▶ Fluctuations in cotton prices due to global economic and political events ▶ Shifts in global cotton production, with countries such as India and Brazil increasing their share of the market while China's share decreases
Consumer trends	▶ Less purchases due to economic and political uncertainties – inflation and war led to insecurities, which may lower the consumption of apparel ▶ Rising living standards in emerging and developing countries could increase clothing consumption ▶ Rising regulatory requirements and consumer demand for transparency and traceability in the supply chain, with consumers wanting to know where their cotton garments come from and how they were produced ▶ Increasing use of social media and e-commerce platforms to research and purchase cotton products ▶ Rise in circular business models (e.g. repair, second-hand market)

Market trends	▶ Increasing demand for sustainable and ethically sourced cotton may lead to the development of more transparent supply chains ▶ Growing demand for organic cotton, which, however, currently cannot be matched by the supply (CALIDA 2021; Textile Exchange 2022) ▶ Increasing competition from synthetic fibres, such as polyester, due to their lower cost and simpler manufacturing process ▶ Fluctuations in cotton prices due to global economic and political events ▶ Shifts in global cotton production, with countries such as India and Brazil increasing their share of the market while China's share decreases
Technology trends	▶ Development of new technologies and innovations in cotton production (e.g. carbon sequestration) and processing (e.g. more efficient spinning and weaving processes) as well as development of new technologies for recycling of cotton-garment waste ▶ Adoption of digital tools and platforms to aid data-led decision making, enabling greater transparency and efficiency at all levels of the cotton garment supply chain ▶ Artificial intelligence to be used for predictive modelling and decision support, for processing complex documents, rules, terms and technical information, or for translating contracts and agreements with international partners

Sources: adelphi, based on information from Textile Exchange (2022), OECD and FAO (2021), Amed et al. (2022), Cotton Outlook (2023a)

Outlook

The global demand for cotton and apparel is expected to grow steadily, driven by factors such as population growth and rising disposable incomes in emerging markets; at the same time, an increasing awareness of sustainability and ethical concerns are expected to drive the demand for sustainable clothing (Amed et al. 2022). The adoption of new technologies such as automation and digitalisation are expected to increase efficiency and productivity in the industry, while also enabling greater transparency (e.g. digital solutions for reporting) and traceability throughout the supply chain. However, high inflation rates, global warming, the ongoing war in Ukraine, and other geopolitical crises (e.g. China-Taiwan, U.S.-Chinese trade war) make the general outlook unpredictable. Claims made during the pandemic about large-scale nearshoring of manufacturing capacity have faded and remain rather unrealistic, given the investment in markets such as Bangladesh and the loss of manufacturing skills in Europe (Henkel n.d.). Interviews with suppliers in the cotton garment supply chain also indicate that they expect more customer demands to be placed on production, especially with regard to adaptation to climate change and the decarbonisation of the industry. They see the opportunities of automation, but are wary of how artificial intelligence might transform this labour-intensive industry.

3.1.8 Institutional incentive mechanisms and barriers

Environmental legislation in producing countries

In terms of **national legislation**, the four South Asian countries (Bangladesh, India, Pakistan, Sri Lanka) under review by (Voora et al. 2023b) maintain government agencies to monitor the cotton and textile sectors, usually with a focus on research, quality control and export promotion and tending to disregard social and environmental aspects. Seed technology is one of the priority issues in Pakistan, as it contributes to increasing the output of the domestic cotton production

(Pakistan Ministry of Commerce). Pakistan's textile and apparel policy primarily centres around increasing added value and productivity; organic cotton and sustainable practices (e.g. Better Cotton Initiative) are mentioned, but are not at the heart of policy. Isolated attempts have been made to promote organic cotton production, such as the Punjab Cotton Control Order in Pakistan, which refers to ecologically safe seeds that may be used in a certain area (Voora et al. 2023b). The main strategic objective of Pakistan's textile and apparel policy is to rebuild the profitability of cotton producers, focusing on quality, yield and production costs. In India and Pakistan, for instance, governments rely on economic incentives by promoting cotton cultivation through minimum support prices (Voora et al. 2023a; Voora et al. 2023b). There are efforts to re-establish a Cotton Hedge Trading facility to stabilise cotton prices for farmers (Pakistan Ministry of Commerce). Typically, the countries in question have general environmental regulations, with specific parameters for the use of agrochemicals, water protection and prices for farmers. Cotton-specific regulations, particularly on sustainable cotton farming practices, are usually lacking, although some governments (e.g. Pakistan) have started developing long-term strategies to establish an organic cotton production (Baloch et al. 2021). Very often also, exports are regulated, while imports lack policies on sustainable cotton. In Pakistan, as in other countries, there is a duty drawback scheme for value-added textile products (Pakistan Ministry of Commerce). Under the drawback scheme, companies can get taxes refunded if they have paid duties on imported inputs used in the production of textile products that are exported. It is usually only available to manufacturing exporters to add value and, in the case of Pakistan, is conditional on membership in a textile association. The drawback rates of Pakistan ranged from two to four percent in 2020 (Khan 2020).

India, the second largest producer of cotton, has issued a number of policy initiatives aiming to boost the local textile industry. The Cotton Corporation of India (CCI) is a governmental agency reporting to the Ministry of Textiles whose main task is to stabilise cotton prices through price support measures (The Cotton Corporation of India Ltd. n.d.). CCI is a major buyer of cotton, especially in off-season and when prices are falling below the minimum support price. India is the largest producer of organic cotton (38%) and cotton grown on land that is converted from conventional to organic farming, the so-called in-conversion cotton (86%) (Textile Exchange 2022). Pakistan ranks ninth, accounting for less than 2%. Current initiatives and policies mostly seek to establish India as a manufacturing hub aiming for investment, export promotion and employment (Joshi et al.). The Amended Technology Upgradation Fund Scheme (ATUFS) provides financial support to textile mills to modernise their technology (India Ministry of Textiles 2020). The Scheme for Integrated Textile Parks (SITP) finances the establishment of textile parks with adequate infrastructure and common facilities, such as warehouses and training centres (Joshi et al.). As of August 2023, 54 textile parks have been approved (India Ministry of Textiles 2023). The Production Linked Incentive (PLI) scheme for the textile industry provides incentives to increase domestic production capacity. It is primarily aimed at improving India's competitiveness in synthetic fibres and technical textiles where the growth potential is considered highest (India Ministry of Textiles n.d.); cotton is not specifically targeted.

Environmental policy measures in consumer markets

The **European Green Deal** aims to transform the European economy towards climate neutrality by 2050. It requires companies in the EU to make their supply chains more sustainable by ensuring human rights and reducing negative environmental impacts (e.g. carbon emissions) (Siddi 2023). A set of strategies and policies, some of which have already been touched upon in 3.1.6 and 3.1.7. (e.g. CSRD, CSDDD), address human rights and negative environmental impacts of the dominant fast fashion business model. National due diligence laws such as the *German Supply Chain Due Diligence Act* or the French "*Loi de Vigilance*" also play an important role in anchoring the risk-based due diligence process in the company's management systems. Companies above a certain size are now required to carry out risk assessments, for which it is essential to map the supply chain to understand where the main risks lie and take remedial action where necessary. This will be particularly challenging for companies whose business model is to source predominantly indirectly from a large network of suppliers. As laid out in Table 2 and Table 3, collaboration is strongest with key/strategic suppliers or in a business model that is designed for cooperation and long-term partnership from the outset. Several interviews with stakeholders in Bangladesh revealed that management systems and proper data management (e.g. collection, analysis, documentation) are the main challenges for companies in the EU to account for their carbon emissions.

Along with the due diligence legislation, the *EU Circular Economy Action Plan* and the proposal for a new Ecodesign for Sustainable Products Regulation play a major role in reducing negative environmental impacts by transitioning towards a circular economy that ensures products are designed to last, are easy to reuse, repair and recycle (European Commission 2020). To do this, companies need to take a closer look at the composition of their products and move towards materials (e.g. fibres, accessories) that are more durable, reusable, repairable and recyclable.

The *EU Carbon Border Adjustment Mechanism* (CBAM), which is phased in from October 2023 for the import of products that are carbon-intensive or most at risk of carbon leakage, is widely seen as an incentive for industries to innovate and switch to low-carbon energy sources (European Commission 2021). The mechanism does not yet cover the cotton and garment/textile industries, so RMG producer markets like Bangladesh or Cambodia will not be directly affected, although garment manufacturing hubs like Bangladesh expect it to be only a matter of time before the mechanism is extended to other sectors (Uddin 2023). Practitioners see an opportunity for the Bangladeshi RMG sector to incorporate the tariff into the pricing, which has not happened as of yet (Uddin 2023). The Sustainable Global Supply Chains Report criticises a lack of research into the implications of environmental policies for the governance of global supply chains (Altenburg et al. 2022). Carbon pricing and CBAM also draw criticism as to maintaining unequal relationships between buyer and supplier countries, as support for the transformation of energy and production systems is not provided (WTO 2022a). If supplier countries are unable to adapt their trade and sustainability policies to the changing environmental policies of consumer countries, this can have a negative economic impact on trade patterns (UNCTAD 2022).

Trade agreements and policies

Trade policies can be used to create incentives for more environmentally friendly production processes or materials from sustainable, in the sense of certified and verified, sources (Textile Exchange 2021). Textile Exchange sees increased cost as the main barrier to the adoption of environmentally friendly materials like organic cotton or recycled fibres, as they are considered to be the more sustainable choice thanks to a lower carbon footprint than their conventional (virgin) counterparts. Advocating for improved supply chain transparency, materials traceability and data-based environmental impact measurement, the non-profit argues that governments must explore incentives such as tax credits or duty reductions of imported components or finished products (Textile Exchange 2021). There are preferential tariff schemes such as the *EU Generalised Scheme of Preferences* (GSP) which grant preferential access to the EU market if developing countries meet certain criteria on human rights and environmental protection. Bilateral trade agreements, such as the **EU-Bangladesh Cooperation Agreement** from 2001 or the **Cooperation Agreement** between EU and Pakistan from 2004 are built around GSP (Bangladesh) or GSP+ (Pakistan). These agreements include the ratification and implementation of international conventions (Wijayasiri), while the implementation progress is monitored by the EU regularly. In general, countries can lose preferential access in case of grave systematic violations. Discussions are underway to extend the negative conditionality to other conventions that are more concerned with environmental and climate change issues in the new period from 2024 to 2034, as they have been largely ignored in the past period (European Commission n.d.b). Depending on how the EU GSP reconciles trade and environmental issues in the next period and how producer countries deal with it, this could have an impact on the cost-benefit distribution in supply chains.

To illustrate that there is also need for action in the producing regions, it is useful to take a closer look at the relevant **regional trade agreements and policies** that have an impact on the sector. With regard to South Asia (including India, Pakistan, Bangladesh and Sri Lanka) as the most important region for cotton production (Voora et al. 2023b), there are **regional trade agreements**, such as the **South Asian Association for Regional Cooperation (SAARC)**, which establish common goals and fields of cooperation in agriculture, environment and trade. Free trade agreements, such as the agreement on the **South Asian Free Trade Area (SAFTA)**, are considered an instrument for implementing the 2030 Agenda and reconciling trade and the environment. Topics such as the availability and affordability of genetically modified seeds are addressed, however, without critically reflecting on the environmental impact (SAWTEE 2016). According to Voora et al. (2023b), there are several public initiatives to encourage intraregional integration and jointly promote sustainable cotton production and consumption (e.g. **Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation - BIMSTEC** - and SAARC). These initiatives mostly focus on agricultural practices and, with that, on cotton cultivation/production, while regional attempts to address cotton textiles are not known. The SAARC Agriculture Centre (SAC) is a focal point for regional cooperation and shares its knowledge on the use of agrochemicals, water management and farmer incomes in South Asia (Voora et al. 2023b). According to the International Institute for Sustainable Development, regulatory frameworks, good practices, incentives for sustainable practices and recommendations for policymakers were discussed more than once, however, with no particular focus on cotton (e.g. water management, eco-fertilisers) (Voora et al. 2023b). This is supported by other research institutes and non-profit organisations, which argue that the current trade agreements do not provide for concrete commitments on sustainable production practices in the cotton sector and thus are unlikely to reduce negative environmental impacts (Lanfranchi and Cline 2021; Textile Exchange 2021).

Transparency issues

Markets for cotton and cotton-based products are partially protected, generally not very sustainable and lack clarity about prices (WTO 2021). This lack of transparency in the cotton supply chain particularly affects smallholder farmers in developing countries who do not have access to market price information, which impacts their business operations and decision-making (Truscott et al. 2021).

In cotton-producing African countries, generally seed-cotton prices are fixed by governmental agencies in the beginning of a season (WTO 2021). The global downturn during the COVID-19 pandemic prompted many farmers to switch to less price-volatile food crops as cotton prices continued to decline in 2020/21. The current cotton supply chain is characterised by prices being squeezed downwards, while little is known about actual production costs and the level of payments to farmers. Trade models for organic cotton discuss the need to consider quality aspects as much as environmental and social costs (Truscott et al. 2021). In practice, however, the market is not always open to pay a price premium for the added value of environmentally friendly (i.e. organic) cotton, and the benefits are not passed on to farmers (Truscott et al. 2021). The current business model of the mass market does not empower suppliers (manufacturers, farmers) to incorporate the cost of being certified into their pricing. Sustainability is assumed to be cost-neutral, which means that suppliers end up bypassing best practices and harming the environment. When it comes to transparency in the cotton supply chain, data sharing is crucial. In addition to buying and supplying companies, other key stakeholders that need to provide access to reliable data are voluntary supply chain standards, certification bodies, industry associations, and governmental agencies, among others (Truscott et al. 2021; Textile Exchange 2022). Non-profit organisations in the textile and cotton sector, such as Textile Exchange, advocate for more integrated supply networks that rely on good practices, such as greater integration, transparency and engagement with partner organisations along the entire supply chain. Sharing risks, responsibilities and opportunities can only be achieved through closer and longer-term business relationships (Truscott et al. 2021).

3.2 Tin

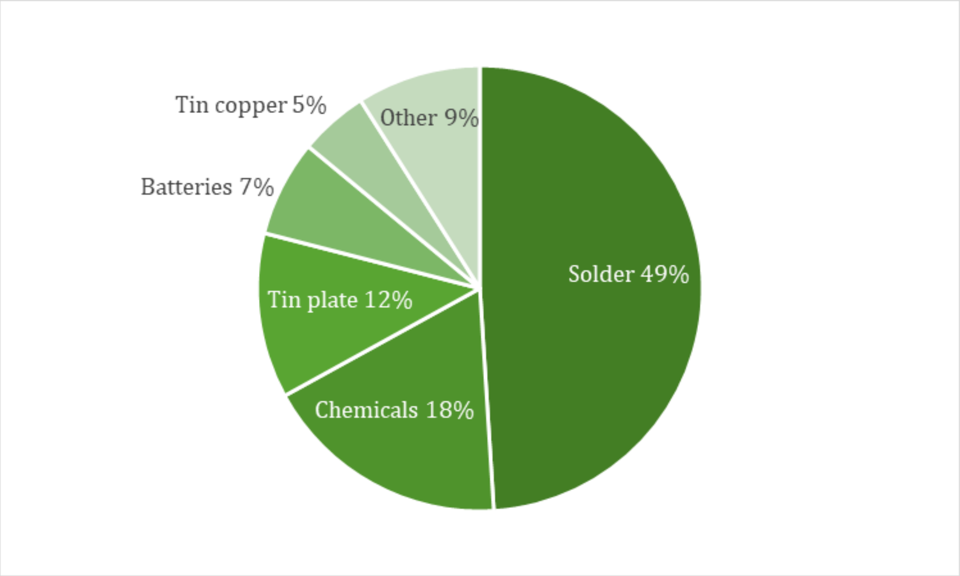
3.2.1 Introduction/background

Tin is a metal and component with various applications, ranging from soldering and tinplate production and electroplating. Tin evolved into an indispensable element in the global economy, contributing to a growing number of products and processes (ITRI n.d.). In Europe, the status of tin is approaching criticality, while it is already considered a critical metal in China and the U.S. (ITA 2020a).

Tin has played a vital role throughout history, dating back 5,000 years when it was combined with copper to create bronze. It was highly valued for strengthening copper and used in tools, weapons, and jewellery. Over time tin's importance grew, leading to the development of solder, pewter, and tin plating; nowadays, tin is also used in chemical production and as coatings (ITA 2020a). Globalisation has impacted the tin industry by expanding market access and stimulating cross-border trade. However, it has also led to market price fluctuations, an increased focus on responsible sourcing and, in recent years, sustainability.

Tin, as a chemically versatile metal, has numerous applications in various sectors (see Figure 10) with the primary application in electronics (mainly as solder) (BGR 2014; BGR 2020; ITA 2020b). Additionally, tin is used in alloy production, flat screen manufacturing, solid fuel cells and lithium-ion batteries (BGR 2014; BGR 2020).

Figure 10: Global tin use by application in 2019



Source: adelphi, based on information from ITA (2020b)

According to First Tin[10], the semiconductor industry is a large consumer of tin as electronic solder, with the industry forecasted to double between 2021 to 2028 due to new emerging technologies like 5G and electric vehicles. Tin is also widely used in the photovoltaic sector, which has been experiencing considerable growth and is also projected to double by 2030 (First Tin 2023).

Europe has several historical tin mining regions and continues to produce tin in Spain, Portugal, as well as in regions bordering Germany and the Czech Republic, with many of the tin production projects aimed at reviving the historic mining operations. Russia has a significant mining production, and in Spain tin is produced as by-product of other mining activities. Germany's CRIRSCO compliant tin resources are approximately 308,000 tonnes along with 207,000 tonnes non-compliant resources[11]. Germany's tin demand is around 20,700 tonnes of refined tin and 200 tonnes of tin oxides per year; there is a demand for secondary tin as well, but the exact quantities are unknown (ITA 2020a). Given the high reliance on suppliers of tin, the following profile focuses on the supply chain for tin solder used for the manufacturing of electronics.

3.2.2 Market structure

The tin industry operates on a relatively smaller scale compared to other mining sectors. With an annual production of only 300,000 tonnes, there are approximately 30 tin smelting companies and around 1,000 larger mining sites.

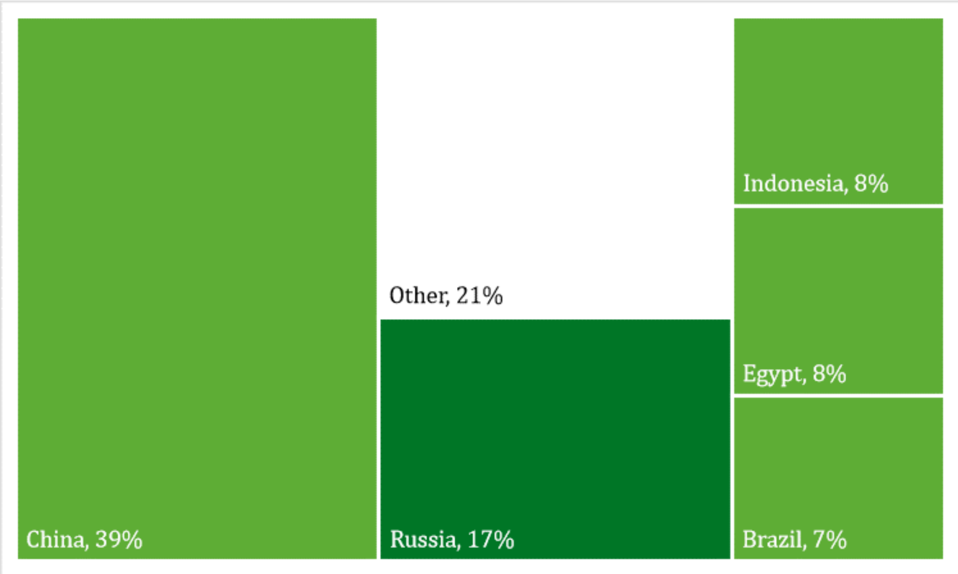
Tin is produced from the mineral cassiterite; it contains various impurities that are removed during concentration, smelting or refining (International Tin Research Institute n.d.). Mining of cassiterite is performed by artisanal and small mines (ASM), as well as by larger scale producers (ITRI n.d.). ASM has a high share of around 27% in global tin production (BGR 2020).

[10] First Tin is an exploration and development group which focuses on tin and other associated metals in the OECD countries.

[11] The tin resources and reserves are reported in accordance with different standards, one of them being the CRIRSCO standards (Committee for Mineral Reserves International Reporting Standards) (International Tin Association 2020b). CRIRSCO compliance means the estimated quantity and quality of tin follows the standards set by the CRIRSCO and the reported data is accurate, reliable, and comparable with global standards (International Tin Association 2020b).

According to the ITA (2020a) the global tin resources[12] were estimated to be around 15.4 million metric tonnes (in 2019). The current global tin reserves are estimated to last a minimum of 18 years, while the resources could extend to at least 50.4 years, according to ITA. The geographical locations of tin reserves are shown in Figure 11.

Figure 11: Global tin reserves in 2019



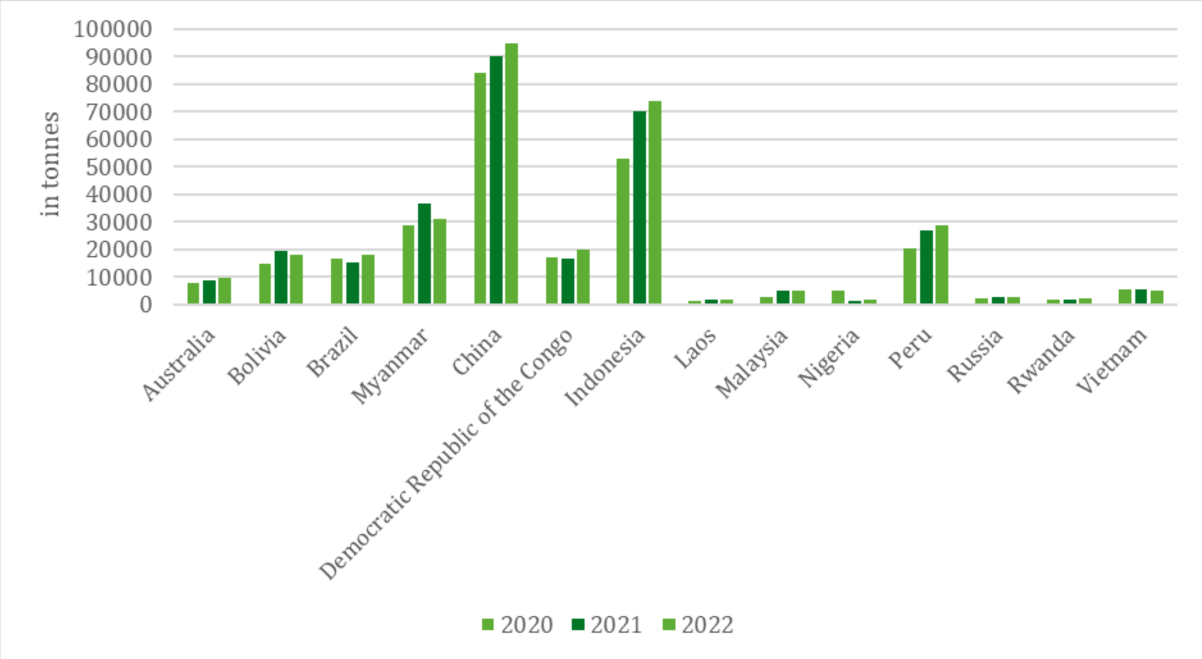
Source: adelphi, based on information from ITA (2020a)

According to Li et al. (2021) the production of tin is highly concentrated, with nine countries accounting for more than 90% of the global output. Similarly, the consumption of tin has largely taken place in ten countries which collectively make up around 80% of the world's total tin consumption (Li et al. 2021).

Global tin mine production has risen steadily from 2020 to 2022, as seen in Figure 12. China and Indonesia lead the way, with China's output projected to increase from 84,000 tonnes in 2020 to 95,000 tonnes in 2022, and Indonesia's production estimated to rise from 53,000 tonnes to 74,000 tonnes. Myanmar also experienced growth, with production expected to reach 31,000 tonnes in 2022. Bolivia and Brazil are anticipated to produce approximately 18,000 tonnes each in 2022, with Brazil seeing an increase from 16,900 tonnes in 2020 and Bolivia from 14,700 tonnes. However, Nigeria's tin production declined from 5,000 tonnes in 2020 to an estimated 1,700 tonnes in 2022 (U.S. Geological Survey 2022; U.S. Geological Survey 2023b).

[12] Tin resources represent tin materials that show promise for profitable extraction in future periods (ITA, 2020). They differ from tin reserves which are tin deposits that have been proven to be economically viable for extraction at the time of reporting.

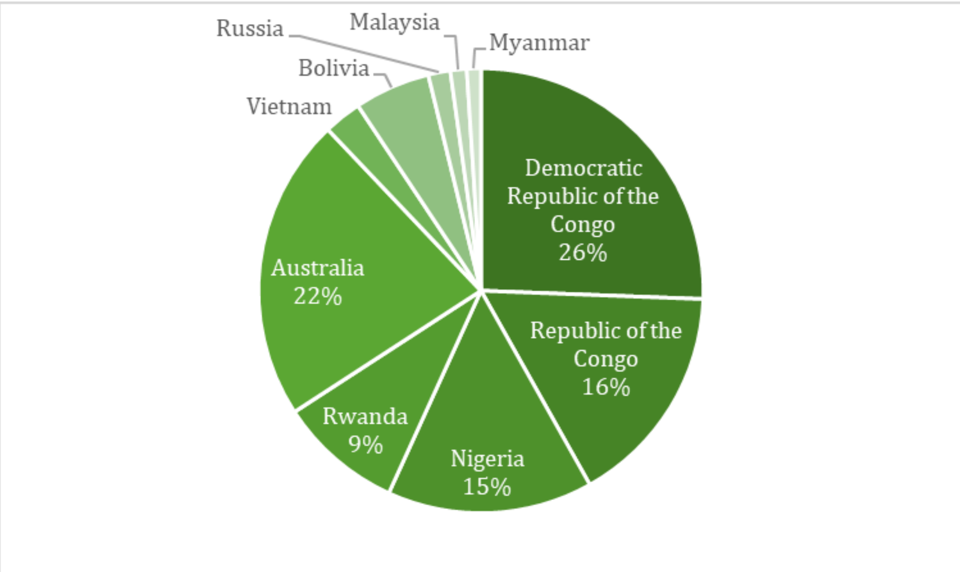
Figure 12: Mine production of tin in tonnes 2020 - 2022



Source: adelphi, based on information from (U.S. Geological Survey 2022; U.S. Geological Survey 2023b)

The primary countries **exporting tin ore** are predominantly found in the Global South. As seen in Figure 13 in Africa, the main exporters include the Democratic Republic of the Congo, the Republic of the Congo, Nigeria, and Rwanda. Beyond Africa, Australia stands out as a significant exporter as well, accompanied by a handful of countries scattered across South-East Asia and South America. To a large extent, the top ten tin ore exporting countries (see Figure 12). This is because large tin mining countries like China also refine and consume the refined tin.

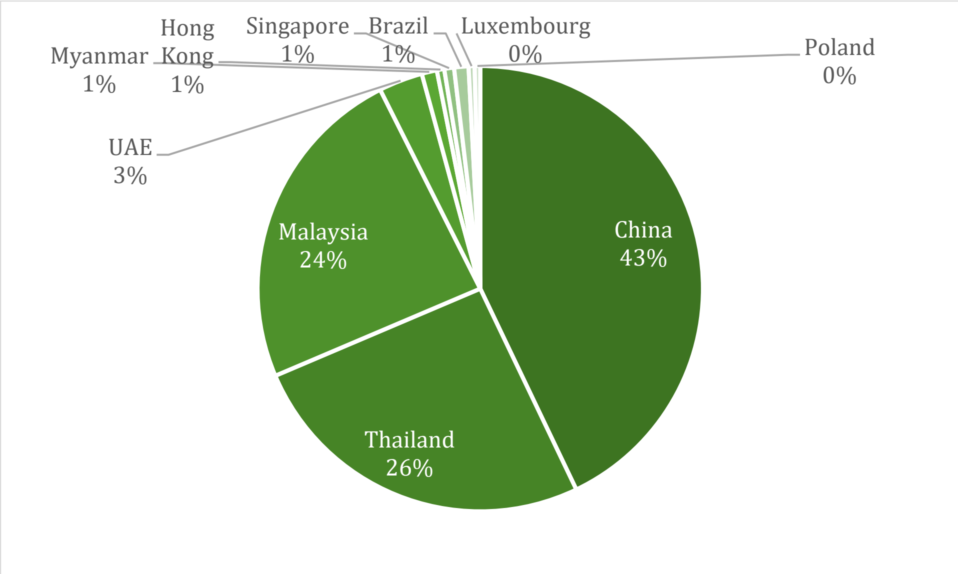
Figure 13: Top 10 exporters of tin ore by share of value in 2021



Source: adelphi, based on information from OEC (2023f)

The **import market of tin ore** as seen in Figure 14 is dominated by countries such as China, Thailand, Malaysia, and the United Arab Emirates (UAE). These nations represent the main importers due to their substantial industrial sectors which heavily rely on tin for various applications.

Figure 14: Top 10 importers of tin ore by share of value in 2021

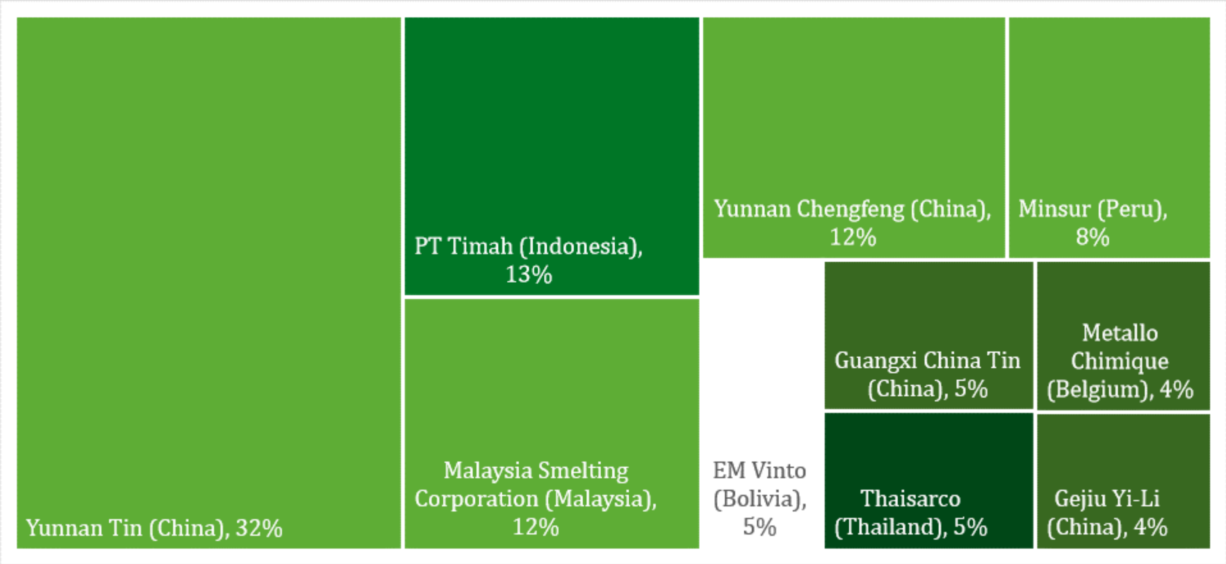


Source: adelphi, based on information from OEC (2023f)

Global refined tin production is concentrated mainly in China, Indonesia, Peru, Brazil, Malaysia, Bolivia and Thailand (Li et al. 2021). The major refined tin consumers are China, the U.S., Japan, Germany and Korea, with China being the leader in global tin consumption (Li et al. 2021). Most of refined tin consumers rely mainly on imports, while China is fulfilling their demand mainly from their own resources (ibid.) in addition to importing large quantities from Myanmar (BGR 2020).

According to the ITRI (2022) the global landscape of tin production in 2017 as seen in Figure 15 was dominated by a handful of key corporations. At the forefront of tin's production was China's Yunnan Tin, with the highest output. PT Timah from Indonesia demonstrated the strength of integrated tin mining on a global scale. The South American company, Minsur from Peru made a notable contribution to the global tin supply. The Malaysia Smelting Corporation (MSC), managed significant tin smelting and refining facilities, further contributing to the world's tin supply. Thaisarco, an established tin production organisation in Thailand, also made a significant impact on the tin production industry.

Figure 15: Leading tin producing companies worldwide in 2017, based on share of production output



Source: adelphi, based on information from ITRI (2022)

Tin's secondary market is a vital part of the global tin industry. One of the main benefits of tin is that it can be recycled easily without losing any quality, allowing it to be refined to high-quality levels (ITRI n.d.). Due to tin's high price, recycling is an economically feasible option and viable business model (BGR 2020).

According to the International Tin Research Institute, the amount of recycled tin has been increasing in recent years, making a positive contribution to the sustainability and circularity of the industry. Considering the re-use of recovered tin alloys like solders, brass, bronzes, and lead alloys, secondary materials make up more than 30% of all tin use in an average year. These alloys can be re-used without having to be re-refined to pure tin (ITRI n.d.).

Approximately two-thirds of Germany's refined tin requirement is imported and distributed by three significant trading firms (trading firms in the tin industry are referred as "brands"), which indicates an oligopolistic market structure, with the majority imports being sourced primarily from Southeast Asia and Belgium. The remaining portion is sourced from the open market, predominantly from South America. German companies like Wilhelm Grillo Handelsgesellschaft mbH and ThyssenKrupp Metallurgical Products GmbH play a critical role here, tying the extraction to end-product manufacture and forming a vital connection in the value chain (Elsner 2014).

There seems to be limited available data on tin solder manufacturing and export/import. Based on existing literature, it is noted that China, being one of the major consumers and producers of refined tin, utilizes over 60% of this material in the form of solder within the electronics industry (Yang et al. 2018). Indonesia exports soldering tin, but the amount thereof is small compared to the exports of pure tin bar (Nangoy and Bernadette 2022). According to the UN Comtrade database[13] the exports and imports of tin are clustered into the following categories: tin bars, rods, profiles and wire (HS6[14] 800300), and pickling preparations for metal surfaces; soldering, brazing or welding powders and pastes consisting of metals and other materials (HS6

[13] The UN Comrade database is an online platform containing detailed trade data by product categories.

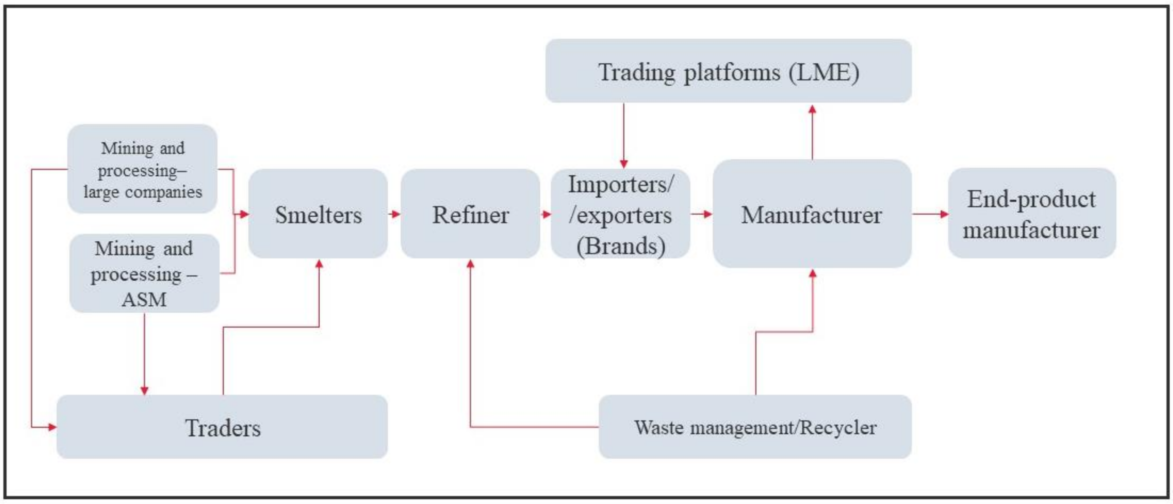
[14] The Harmonized System (HS) is a classification system for goods and products.

381010). There are no detailed HS codes specifically for tin solder. According to the data extracted from UN Comtrade database[15], the main importers of tin products (by value) are China, Mexico, U.S., Hong Kong SAR (China), and India.

3.2.3 The tin value chain

The tin supply chain encompasses a wide range of actors, each playing distinct roles in adding value as seen in Figure 16. There is a moderate concentration of mine production, with a handful of entities dominating the market – e.g. Chinese firms like the Yunnan Tin Company, which have a significant influence (Bundesanstalt für Geowissenschaften und Rohstoffe 2014). However, 27% of tin is produced by ASM, which often lacks regulation and is often associated with negative impacts on the environment and human health. Despite these issues, the relatively large amount of ASM in the commodity extraction plays an important role in driving economic growth in underdeveloped and rural areas by generating more income opportunities. Small-scale mining activities are predominantly concentrated in Southeast Asia, Central Africa (specifically Rwanda, Burundi, and the Democratic Republic of the Congo [DRC]), as well as Brazil and Bolivia (Bundesanstalt für Geowissenschaften und Rohstoffe 2020). The mining operations, depending on the mining type, require different levels of investments. For example, open-pit mines can be operated with simple tools and hence are often run by family-businesses, according to an interview with an industry expert.

Figure 16: Tin value chain



Source: adelphi, adapted from Franken (n.d.), Versik Maplecroft (2017) and expert interviews

According to Vasters and Franken (2020) and interviews with industry experts conducted as part of this research, once the ore is mined, it undergoes processing and concentration, increasing the tin content, then moves on to **smelters,** which convert the enriched ore into a more usable form of tin. **Traders** purchase tin from both large companies and ASMs and sell it to smelters based on the highest bid (Hodal 2012). The smelters rarely operate only with one mine or one trader, according to industry experts. Usually, the smelters acquire tin from several different **mines** or **traders**, making the tracking of the origin of tin ore challenging. Following the smelting and refining processes, the tin is then ready for trading on international platforms such as the London Metal Exchange (LME), although only a small percentage of tin is actually traded on these platforms according to industry experts.

[15] Import data extracted for (BGR 2020) HS6 800300 and HS6 381010.

Intermediaries like LME at this stage contribute value by absorbing the risk of price fluctuations by storing tin in global warehouses and maintaining market liquidity (more detailed information on the LME in Chapter 3.2.4). For companies, in order to trade on LME, it is a requirement to register themselves as **importers/exporters (brands[16])**. The importers/exporters (brands), enhance value by overseeing various export-import tasks such as handling import taxes, declarations, and related activities. **Manufacturers** subsequently acquire tin from them. This phase involves the transformation of the refined tin into various products like solders, tin plates, chemical products, and tin alloys (Pines 2022) and the selling of the components directly to **end product manufacturers**. The relatively high price of tin enables the recycling, which reintroduces tin from used products and waste materials back into the value chain.

According to interview results, around one fourth of mining in Indonesia takes place offshore, which creates a substantial environmental hotspot due to harming the coral reefs and other marine species. Additionally, mining conducted onshore poses other environmental challenges, particularly in relation to the movement of materials and the resulting depletion of fertile soils. The emergence of tin mining in Myanmar approximately five to six years ago has raised concerns as well. In this case, tin is directly sent to China without adequate information on the mining processes e.g. the location of mining (document of origin) or mining license, which hampers transparency and oversight. Tin mining in central Africa, specifically in regions such as the DRC, presents safety issues that require addressing, according to interviews with industry experts.

As highlighted in the paragraph above, the tin value chain presents various environmental challenges at different stages, including mining and processing. Table 5 further illustrates the environmental impacts that are relevant to the industry. It is important to note that not all of these impacts will be present in every tin-electronic solder supply chain.

Table 5: Main environmental impacts in the tin value chain

Supply chain segments	Environmental impacts
Mining	Destruction of flora and fauna: caused by large-scale underground mining operations or open-pit mining, which requires land clearance to access the minerals.
	Marine ecosystem destruction: depleted land-based tin deposits have caused an increase in offshore mining, damaging coral reefs and mangrove swamps that are vital to marine species.
	Poor and improper waste management: practices in tin ore mining harms the water and soil. Mining generates mineral waste which can contaminate water and soil, affect the topography as well as lead to radiation exposure.
	Changes in topography: mining and mining waste causes changes in topography and lead to un-restorable and non-cultivatable land, as well as erosion.
Processing	Toxic exhaust gases: roasting processes produce exhaust gases like sulphur dioxide as well as flue dust which can be hazardous to workers and environment.
	High energy consumption in processing stages; use of non-renewable energy sources; increase in GHG emissions

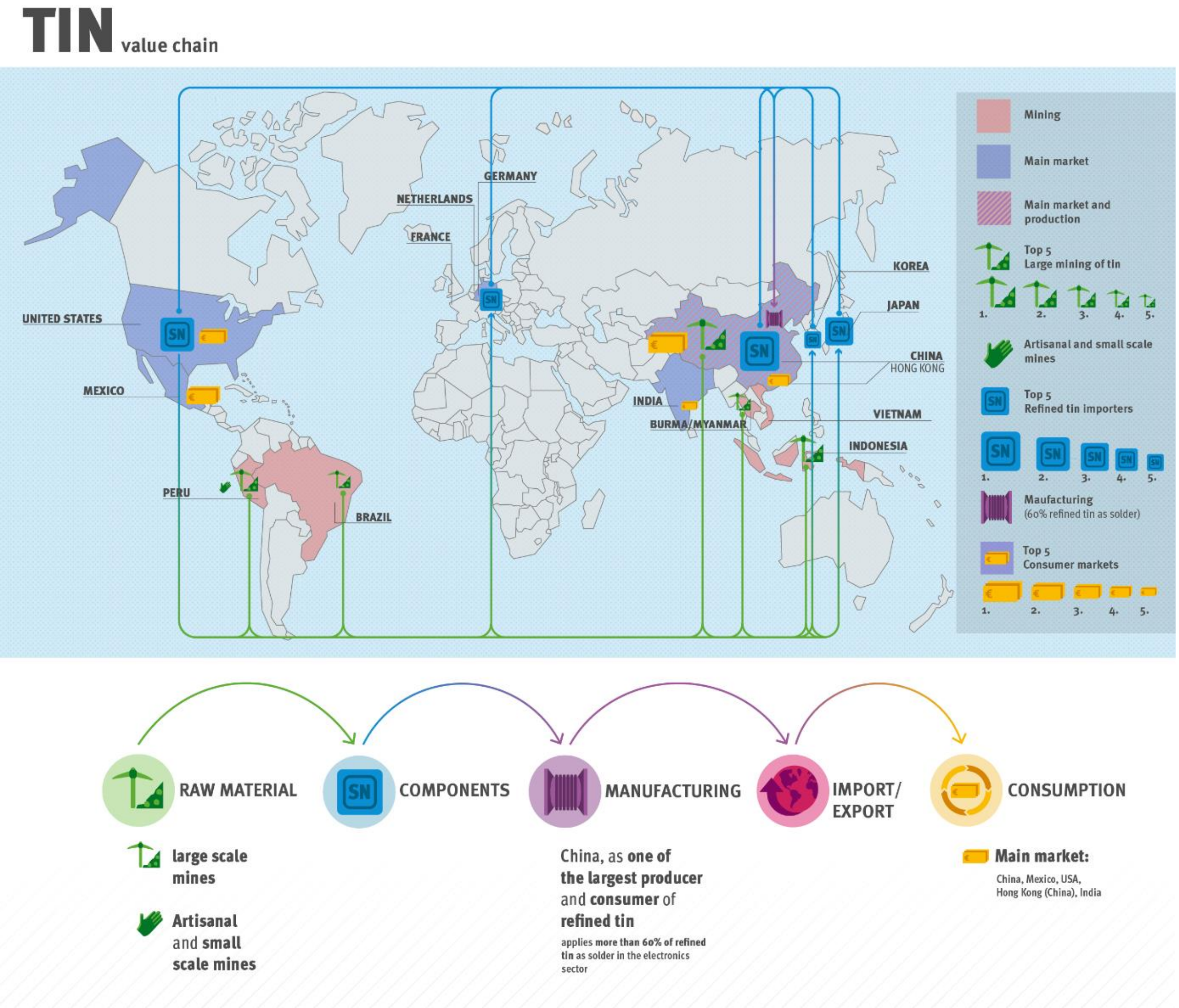
[16] The importers/exporters who register themselves in the LME are called "brands" which is a specific term for the tin industry. Unlike in other sectors, these brands are not consumer facing entities rather traders of tin.

Supply chain segments	Environmental impacts
	Untreated contaminated water: tin ore beneficiation requires large amounts of water. Untreated water can result in the release of contaminants and negatively impacting nearby communities and ecosystems in terms of water availability and quality.

Source: adelphi, based on information from Raw Material Outlook Platform (2023), BGR (2020) and Omotehinse and Ako

Based on the data presented in this chapter, Figure 17 shows in a thematic map selected key structures (main producer/consumer markets; actors) and processes (e.g. product flows) in the tin value chain:

Figure 17: Selected key structures and processes of the tin value



Source: adelphi, based on material and data from this text

3.2.4 Pricing

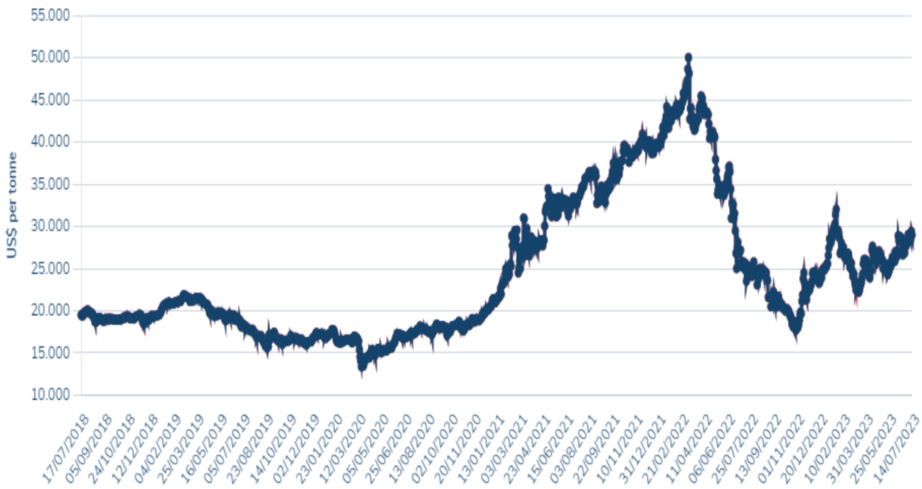
The price of tin is primarily driven by the principles of supply and demand, which are influenced by a variety of global macroeconomic and industry-specific factors. According to Saulich (2023), tin is traded on the London Metals Exchange (LME), which is one of the world's leading platforms for industrial metals. Other significant global exchanges include the Chicago Board of Trade, the New York Mercantile Exchange, and the Shanghai Futures Exchange (SHFE). The LME operates physical warehouses, but only a small percentage of contracts are fulfilled through physical delivery. These exchanges and trading venues serve as marketplaces for buyers (industrial processors/manufacturers and commodity traders) and sellers (producers of refined tin) or brands (traders). Financial institutions also use these trading platforms, but for hedging risks and speculation. The price formed on the LME serves as an internationally recognised reference for the traded metals, and in addition to facilitating trade, institutions like the LME play a role in regulating the industry and setting standards by defining minimum purity requirements for the traded metals and establishing requirements for responsible sourcing and disclosure of information regarding the origin of the metals, in response to public pressure (Saulich 2023). According to an interview with an LME representative, two different types of contracts are traded on the London Metals Exchange: physically settled contracts, which is applicable for tin, and cash settled. The LME operates warehouses in various regions, including North America, the Middle East, South America, and Asia. However, as mentioned above, only a small portion of the world's tin production actually goes through an LME warehouse. There are no LME warehouses in China, Russia, or Africa.

The long-term prices of tin are linked to the LME price, which reflects a global price for delivery to any LME warehouse, and is used throughout the value chain, with percentages added or subtracted depending on the position of the actor in the value chain. According to industry experts, Price Reporting Agencies (PRA) also impact tin prices by collecting and consolidating market prices. However, the tin price leads to higher volatility due to the market's small size. The LME acts as a balancing structure, allowing different actors (like brands/traders) to take advantage of high tin prices by delivering to warehouses and subsequently lowering prices. **In order to participate in the LME,** the seller is required to register as a brand and provide a certificate to verify the purity of the tin, its form, and the company's adherence to human rights standards. The registered importers/exporters (brands) collectively set the LME price. The buyers can then purchase tin from any LME warehouse. However, the traders and producers of refined tin prefer to sell directly to purchasers, with the LME warehouse serving as a last resort. Banks, on the other hand, insist that the producers participate in the LME for insurance reasons. In the case of bankruptcy by refined tin producers, the bank can still deliver some material from the LME warehouses and recoup some of the funds. There are no mechanisms for integrating the environmental or climate costs into the price of tin.

According to expert interviews, 90% of the net revenues from tin mining are paid to miners. The rest is distributed among other actors in the value chain. According to a German tin solder manufacturer, they plan their operations one year ahead, and therefore purchase two thirds of the needed tin quantities directly from their suppliers/brands, which means they enter into contractual agreement for one year with their suppliers. The remaining third is bought during the year as needed. In these cases, the LME price of tin is used as reference during the tin purchase. As a result, there is no pricing negotiations, as the listed price is used. The brands/suppliers add their premium to the LME price to cover their operations.

According to the data listed on LME website (see Figure 18), the LME tin official price curve had significant fluctuations during 2022 and 2023 with a price peak of $34,000 per ton in May 2023 and the lowest price around $28,000 per ton in June 2023.

Figure 18: LME tin price 2018 - 2023



Source: LME (2023)

The global COVID-19 pandemic significantly affected the tin sector in various ways, as indicated by several sources. According to the U.S. Geological Survey (U.S. Geological Survey 2021), the decline in global tin use, which began in 2019, continued through 2020, likely exacerbated by the disruptions caused by the pandemic in mining and manufacturing industries worldwide. However, despite years of stagnation, the consumption of canned foods during the pandemic led to an expected increase in tinplate usage (U.S. Geological Survey 2021).

In Myanmar, the impact of impact COVID-19, in addition to mine flooding and border restrictions, has tightened traditional sources of tin ore (U.S. Geological Survey 2021). The pandemic also resulted in temporary closures of smelters in China due to COVID-19 mitigation measures (U.S. Geological Survey 2023b) as well as worldwide. The price of tin experienced significant fluctuations due to the pandemic's impact on raw material prices. While the price of tin increased, the demand decreased initially due to restrictions on human resources and transportation barriers. However, the electronics and automotive markets showed signs of recovery in 2021, leading to an increase in tin demand (MarketsandMarkets 2022).

3.2.5 Power relationships

The landscape of governance in the tin value chain is fragmented, despite the tin market's relatively small size and limited number of market players, reflecting the varying degrees of influence exerted by the actors.

Power within the tin value chain exhibits a regional concentration. China serves as a prime example, dominating the market through an integrated supply chain comprising local mines, smelters, and industries engaged in the application of processed and refined tin. This dominance is further reinforced by China's status as the principal global importer of tin. The current chapter focuses on actors outside of Chinese tin market, since Chinese market structures differ from markets in rest of the world.

The miners, especially the ASMs, sell the tin to local traders who collect the metal from different sources and sell further to smelters. These traders sometimes finance the mining operations of ASMs. According to expert interviews, **the ASMs may be in a weaker position relative to the traders**, since they may not have a choice with whom to engage in business activities, or they might lack the updated pricing information. Following Gereffi et al.'s (2005) approach, the relationship between **ASMs and traders** can be described as a **captive relationship**. According to industry experts, switching to more sustainable mining practices in ASM would also require getting the traders on board. **The LSMs**, however, in comparison to the ASMs, are in a **more powerful position**, as the LSMs can possess more resources for investments in technologies to drive efficiency, or as larger actors can have closer ties with the governments (as in the case of Indonesia, where there is one state-controlled integrated tin company).

Some **smelters** adopt an integrated approach to supply chain governance by owning their mines, in this case, following Gereffi et al.'s (2005) approach the relationship would be **hierarchical structure based on integrated firm**. However, the more common practice is **cooperation** with a range of mines and miners. The relatively small size of the tin market occasionally precipitates **shifts in power dynamics** among actors. In times of deficit, miners might gain an upper hand due to an increased bargaining power driven by smelters' dependence on raw materials. On the whole, miners are reported to secure around 90% of the net profits from tin, with the balance distributed among smelters with the tin price set on the LME market.

Manufacturers, i.e. the purchasers of refined tin, usually opt for the **most economical supplier**, maintaining relationships with multiple sources (brands) and switching mainly based on price differentials. Since the quality requirements are mandated by LME, the purity of the purchased tin is assumed to comply with standards. These purchasing practices suggests a **captive market** with buyers purchasing from several suppliers. The **price disparities among the brands** predominantly stem from **the premium added on the base tin price**, intended to offset operational costs such as import taxes and other overheads. In addition to cost considerations, manufacturers (purchasers of refined tin) can impose various requirements on their suppliers, e.g. compliance with certain certification schemes or sustainability standards.

The end consumers/purchasers of tin-containing end-products have some **power to dictate sustainability requirements for the industry by driving the demand for responsibly sourced tin**. According to Diprose et al. (2022), the major electronics companies established the Tin Working Group (TWG) in 2021, which was driven by public pressure for enhancing sustainability and traceability in the tin supply chain. The public pressure began with a UK-based NGO, Friends of the Earth, and their Indonesian branch; they documented[17] the social and environmental impacts of tin production in Indonesia and received widespread media coverage. However, the TWG faced challenges, including a lack of commitment to sustainable practices and corporate motivation. Despite this, the TWG garnered support from influential political and economic entities, facilitating the spread of sustainable practices in Indonesia's tin industry. This requires ensuring that these entities receive some benefits, even if those benefits are not directly tied to the regulatory goals (Diprose et al. 2022).

International NGOs, media outlets (Hodal 2012), and **major companies** in the worldwide electronics supply chains **advocated for sustainability,** which empowered Indonesia's government and the national tin corporation to reinforce their dominance in domestic debates over regulatory power and market dominance. However, these efforts are frequently motivated more by the intent to dominate the market and control the revenue generated from tin production, rather than sincere dedication to sustainability standards (Diprose et al. 2022).

Purchasing practices

The main business models to source tin can be summarised as is in Table 6:

[17] The original report was not available online anymore at the time of writing this paper.

Table 6: Dominant business models and governance in the tin value chain

Business model	Type of buyers	Governance	Type of relationship	Procurement procedure
Mix of key & occasional suppliers	Smelters	Hierarchical in case of integrated firm; relational		Price dominant
Mix of key & occasional suppliers	Manufacturers	Captive	Short- to medium term contracts	Highly competitive; price dominant

Source: adelphi, based on classification from Gereffi et al. (2005) and information from expert interviews

The manufacturers of tin-components purchase tin directly from brands. These manufacturers hold the pricing power, as the marketplace is relatively competitive with the stock price as reference for short-to-medium term contracts, according to one actor. However, in recent years some manufacturers have started including sustainability aspects in their assessment of brands, which in turn can reduce the number of players from whom the manufacturers are able to purchase tin. There are some smelters with integrated supply chains, but most of them cooperate with several different miners and/or traders. The power structures between the miners and smelters can shift depending on the market situation.

3.2.6 Addressing environmental impacts

According to Saulich (2023), since 2015, **the LME** falls under the *UK Modern Slavery Act*, which requires companies with a turnover of over £36 million to disclose the measures they've taken against forced labour and human trafficking along their supply chains. In addition, in 2019, the LME made public its **strategy for the sustainable sourcing of metals** and all market participants will be required to comply with this strategy by the end of 2023. This strategy is based on the *OECD Due Diligence Guidance for Responsible Supply Chains of Minerals* from Conflict-Affected and High-Risk Areas. In 2021, the LME introduced **the LME passport**, a tool that allows producers to voluntarily disclose information regarding the sustainability of their products. However, this initiative has faced criticism for insufficiently considering environmental risks and not publishing information on violations. In addition, the LME does not disclose the origins of the metals in their warehouses. While commodity traders sometimes publicize information about refineries, they often do not indicate which mines the metals come from which contributes to lack of traceability.

According to industry experts, the majority of governments require **environmental impact assessments (EIA)** for biodiversity, water and re-cultivation; these must be conducted prior to receiving the permit to start mining activities. While the EIA is a tool for due diligence and corporate responsibility throughout supply chains, the effectiveness of these tools hinges on technical quality, independence, and community participation. However, achieving all these conditions simultaneously is a rare occurrence (Sydow et al. 2021). The ASM sector suffers from a notable absence of environmental protection and supervision, according to expert interviews. For example, in Rwanda, it is common practice for the mine companies to sign a "copy-paste" form about environmental due diligence, without any customisation; this hampers the effectiveness of environmental safeguarding measures. To tackle this issue, there have been suggestions to replace ASM with industrial mining in Rwanda, which holds the promise of improved environmental management practices at the expense of excluding artisanal miners from their livelihoods.

The focus on sustainability has gained momentum in recent years within the tin industry, according to industry experts. The heightened interest in environmental and sustainability issues **from buyers' side** (driven in part by end-product manufacturers) has resulted in a decrease in the pool of the brands from whom sustainability-driven buyers can source their tin. This is resulting in a captive relationship with the remaining suppliers that meet these heightened requirements. The already limited number of brands in the tin market restricts the potential for buyer influence in promoting sustainable practices and addressing environmental concerns, since it is not easy for buyers to switch to other sustainable suppliers. Therefore, when buyers seek more sustainable tin sources, their options for pressuring sellers to adopt sustainable practices are somewhat restricted, although not entirely unattainable. In the Indonesian context, where tin mining, production and exports are predominantly managed by single state-owned company[18], manufacturers have limited flexibility in choosing more sustainable tin sources, although having only one actor might provide easier opportunities for lobbying for more sustainable practices.

However, the buyers and manufacturers of end products (like manufacturers of consumer electronics who use tin solder in their products) and Original Equipment Manufacturers (OEMs), in theory, do possess substantial purchasing power, which they could leverage to improve production conditions in the long run, according to expert interviews. The competitive nature of the industry, where it is important to keep the prices of end-products affordable for the end consumer, often undermines the incentive to pay a higher price for environmentally sustainable resources. Industry experts suggest a potential catalyst for change: if consumers increasingly demand sustainable products and are willing to pay premiums for them, OEMs may start pushing for sustainability from manufacturers. This, in turn, would drive the entire supply chain to adopt more sustainable practices to meet the demand for sustainable tin and the associated premium prices.

Certification schemes

According to Kickler and Franken (2017) and Erdmann and Franken (2022), mining companies have demonstrated an escalating trend in participating in certifications and assurance programmes in the recent years. However, it is important to note that participation in these endeavours remains voluntary. A large number of sustainability schemes have been introduced to tackle selected social and environmental issues in the mining industry as seen in Table 7. Their different requirements reflect a diverse range of sustainability aspects, ranging from environmental conservation to human rights protection. These varied schemes have distinct approaches towards assurance, capacity building, and impact reporting, which allow for tailor-made solutions, making it feasible to target particular problems and cater to specific stakeholders, thereby enhancing the versatility and effectiveness of these initiatives. However, the diversity can lead to information overload and disorientation, triggering scepticism among stakeholders. Harmonised schemes might prove to be a more attractive alternative for stakeholders. The uniformity of such schemes reduces the complexity and cost of implementation, making them a potentially more appealing and feasible option for promoting sustainability in the mining industry.

The study "Sustainability Schemes for Mineral Resources: A Comparative Overview" by Kickler and Franken (2017) reveals that most of the sustainability schemes they analysed (Table 7) operate as independent non-profit organisations, established by diverse stakeholders including

[18] State controlled company with integrated tin mining business model.

supply chain companies, associations, financial institutions, and governments. These schemes cater to specific commodities and the varying needs of different scales of mining. While the majority focus on LSM (53%), a smaller percentage (16%) address the critical issues of ASM. Some schemes, particularly for 3TG (3TG designates the conflict minerals tin, tungsten, tantalum and gold) minerals, have minimum requirements for all company sizes, enabling wide adoption but possibly lesser impact on larger firms. Despite efforts, acquiring comprehensive information on specific sectors like ASM or regions like China remains challengingg (Franken 2019).

Table 7: Selected sustainability schemes for mining sector, covering tin

Sustainability schemes	Implementation of sustainability requirements beyond commitment and reporting[19]	Sustainability commitments in company policies	Sustainability reporting requirements	Requires traceability and tracking of origin of raw material, i.e. mine secondary source	Requires supply chain due diligence on conflict risks and human rights violations[20]
Global reporting initiative (GRI) *			✓		
International Finance Corporation (IFC) *	✓				
Initiative for responsible Mining Assurance (IRMA) *	✓				
Mining Association of Canada (MAC) *	✓				
International Council of Mining and Metals (ICMM) *		✓	✓		
Regional Certification Mechanism (RCM) **					✓

[19] May include due diligence on conflict risks and human rights violations

[20] May include sustainability commitments, reporting requirements and raw material tracking

ITRI Tin Supply Chain Initiative (iTSCi) **					✓
Certified Trading Chains (CTC) **	✓			✓	

*** Commodities covered in the scheme: all, including tin**

****Commodities covered in the scheme: tin, tungsten, tantalum and gold**

Source: adelphi, adapted from Kickler and Franken (2017)

The Responsible Minerals Initiative (RMI) equips corporations with the necessary tools and resources to enable them to make informed sourcing. The RMI's flagship project, the **Responsible Minerals Assurance Process** (RMAP), (previously known as the Conflict-Free Smelter Program), was established with the goal of fostering transparent and sustainable practices in mineral supply chains and it is designed to deter the mining and trading of minerals from contributing to conflict and human rights violations (RMI 2017; RMI n.d.). The RMAP requires independent third-party assessments of the smelter/refiner and their sourcing practices to validate compliance with RMAP standards (RMI n.d.). The RMAP tin and Tantalum standard was developed as a practical framework to audit the operations and practices of tin and tantalum smelters. This standard aligns the RMAP with the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (RMI 2017). The International Tin Association (ITA) and RMI collaborated on creating **the Assessment Criteria for Tin Smelting Companies** (ITA and RMI 2021) which includes criteria for determining smelter's operational conformance with RMI and ITA requirements, the OECD Guidance, as well as regulatory requirements on minerals due diligence (RMI 2023).

The **RMAP Environmental, Social & Governance (ESG) Standard** for mineral supply chains is a newer standard of RMI, which aims to further enhance worker conditions, mitigate environmental and community impacts, and effectively manage governance risks across all mineral supply chains (RMI 2021).

A voluntary industry initiative, the **ITA's Tin Supply Chain Initiative (ITSCI)**, provides a traceability and due diligence membership programme. It aims to enable the international market access of "conflict-free" 3T-minerals (tin, tungsten and tantalum) sourced and traded in DRC and the Great Lakes Region. This initiative includes a traceability system and database, implements due diligence measures, and conducts audits to ensure basic sustainability requirements in relation to conflict-affected and high-risk areas, in line with OECD and UN due diligence guidance. To address the challenges related to sustainability and human rights issues specifically in the DRC due to both large-scale industrial and artisanal small-scale mining, the **Certified Trading Chains (CTC)** initiative was developed**.** The ASM sector in the DRC, in particular, deals with issues like conflict financing, smuggling, and unsafe working conditions. The CTC certification promotes responsible artisanal and small-scale mining in the DRC with the aim of improving control, sustainability, and the livelihoods of artisanal miners and local communities (BGR n.d.).The OECD published a **Handbook on Environmental Due Diligence in Mineral Supply Chains** in September 2023. The handbook outlines how to apply the OECD's six-step due diligence framework to address environmental risks in global mineral supply chains, with a focus on the upstream segment (extraction, processing, refining). It's designed for use by businesses of all sizes throughout the entire supply chain, from mining to retail (OECD 2023a)

Based on expert interviews, environmental management systems also play an important role in the tin value chain, particularly the international standard ISO 14001.

Overall, addressing environmental challenges in the tin sector from the buyer's perspective is a relatively new practice that has its limitations due to lack of oversight in the upstream value chain before the smelting process. The manufacturers are increasingly performing audits in their downstream supply chain to ensure sustainable practices.

3.2.7 Current/future trends and developments

An important trend in recent years has been the increased focus on responsible sourcing and purchasing practices, partly in response to regulations such as the EU Conflict Minerals Regulation and the Dodd-Frank Act in the U.S., as well as growing consumer awareness and demand for ethically sourced products. This has led to the establishment of various industry initiatives aimed at promoting responsible sourcing, such as the RMI and ITSCI (more on voluntary certification initiatives and schemes in Section 3.2.6). Table 8 shows the main market, consumer and technology trends.

Table 8: Market, consumer and technology trends

Market trends	► Upward trend in demand for electronics increases the demand for tin, which in turn leads to rising tin prices ► Increasing focus on responsible sourcing from end-consumers and different market players leads to more sustainable and informed purchasing practices ► Increasing application of voluntary schemes by industry actors downstream ► Increasing price of tin creates more lucrative business opportunities for recycled tin. At the same time, the demand for recycled tin is driven by manufacturer motivation for more sustainable sourcing practices as well as policies which support recycling of tin (e.g. under the green deal) ► Increasing price of tin can lead to exploration of new mining locations and opportunities or revival of old mines in the EU
Consumer trends	► Growing consumer awareness and demand for ethically sourced products
Technology trends	► Technologies for traceability and transparency (e.g. blockchain)

Sources: adelphi, based on information from Franken (2019) and expert interviews

3.2.8 Institutional incentive mechanisms and barriers

Environmental legislation in producing countries

According to industry experts, some governments of tin producing countries have taken several steps in implementing mechanisms to address the environmental concerns of mining tin. For example, mandatory **environmental impact assessments** (EIA) have been established as a requirement before commencing the mining activities, which in the case of LSM are meticulous enough, according to industry experts. That stated, in the case of ASM, they can be either non-existent or fake. Also, the EIAs may lack independent data, particularly in monitoring water quality and formalisation processes. This information scarcity greatly impedes the ability to track the effects of mining activities and provide recommendations to local governments regarding the adoption and enforcement of local laws (Germanwatch e.V. 2021). Even though the governments have set up regulations, they might not have the capacities to enforce them. In addition, corruption can hinder the enforcement of the policies.

As an example of local policies, in the case of Indonesia, robust controls on recultivation (restoration of the land used for mining) have been put in place, mandating miners to contribute to a designated fund which, after the mining operations have ended and the land has been re-cultivated, will be returned to the mining company. However, research findings indicate that the implementation of reclamation obligations in the example of Bangka Belitung island has been inadequate. Despite the presence of sanctions outlined in the reclamation law, their effectiveness in promoting optimal reclamation practices has been limited. This situation has prompted an amendment to the law, emphasising the need for stricter enforcement by the authorities. The amendment aims to address the shortcomings and enhance compliance with reclamation obligations (Haryadi et al. 2023).

Environmental legislation in consuming countries

The tin industry is set to experience significant changes due to policy trends that impact its value chain. These include the Directive on corporate sustainability due diligence (not yet adopted), which requires companies to monitor and mitigate adverse human rights and environmental impacts. The CSRD requires large and listed companies to disclose social and environmental risks and impacts. The *EU Circular Economy Action Plan* (CEAP) promotes recycling and waste reduction, potentially increasing the demand for tin recycling, which in turn can support the growing demand for recycled tin.

Insights from the interviews emphasise that the introduction of new legislation, such as that implemented by the EU, may have limited impact on the tin market due to its concentration in specific regions. China and the U.S. currently dominate the market, and their influence prevails despite regulatory changes. This underlines the importance of considering the prevailing dynamics and influence of major players in the industry. However, larger companies, who make tin purchases in bulk and exert more purchasing power, can have also a larger influence and a trickle-down effect on the less transparent regions. According to expert interviews, the dynamics between China and the West will become an important question in the future. There is a need for more cooperation and transparency. Establishing a circular economy of rare minerals in the West and extracting rare metals from urban mines[21] could provide leverage for the West in future cooperation with China.

Interview results also show that, in the case of central Africa, particularly in the DRC, the mining of tin is regulated under the *Dodd-Frank Wall Street Reform and Consumer Act* of 2010, the first piece of legislation that forced companies to implement due diligence in their operations. According to this legislation, companies are obligated to disclose whether any conflict minerals originated from the DRC or its neighbouring countries. If sourced from these regions, companies are obligated to provide a Conflict Minerals Report, which is subject to auditing by an independent private auditor. The report outlines the due diligence measures undertaken, including details on the facilities involved in conflict mineral production, the country of origin, and the chain of custody of these minerals (IEA 2022).

Trade agreements and policies

Government policies can have an impact on the global tin industry. Indonesia has been a leading country in exports of tin, but due to the government's desire to support domestic smelting

[21] Urban mining is the process of recovering rare metals from discarded waste electrical and electronic equipment (WEEE).

industry, tin export was banned, which affected the global tin prices. The ban was then lifted due to budget deficits (Pines 2022).

According to industry experts, the government of Rwanda is actively driving companies to embrace modern business practices, affected by global pressure to produce conflict-free and environmentally friendly materials. However, it is important to consider the limitations posed by economic feasibility, particularly for smaller mines that lack sufficient financial resources. In contrast, larger mining companies with varying profit margins are in a better position to meet environmental standards. Striking a delicate balance in regulations becomes crucial as there is no "average" mine, and the unique circumstances of each operation must be considered. China's role in global tin trade (both demand and supply) may be a decisive factor in the future, as it can be expected that China will continue consolidating its hegemony in the tin market.

Transparency

Transparency in the tin supply chain is a critical issue, as highlighted by industry experts in interviews. Stock exchanges play a vital role in promoting transparency and responsible practices. Notably, the LME falls under the requirements of the Modern Slavery Act, mandating companies to disclose measures taken against forced labour and human trafficking in their supply chains. Ensuring the traceability of raw materials is increasingly important, leading to the application of innovative technologies and solutions. However, it remains a challenge, as non-compliant tin can still be smuggled into the supply chain undetected. The lack of a single standard for reporting sustainability poses additional difficulties, and the consolidation of collected data for publication would be beneficial. Regarding the facilitation of cooperation between actors along the supply chain, several incentive mechanisms and barriers were identified. One major challenge is the difficulty in ensuring traceability when a company has multiple suppliers; it is hard to track the origin of materials and ensure compliance with sustainability standards. Even integrated companies sometimes source materials from different locations due to price fluctuations, which further hinders traceability and collaboration efforts. China, accounting for approximately 60% of tin production, operates differently in terms of tin trading. Chinese-produced tin is primarily used within China and not traded on international markets. Consequently, the Chinese government is reluctant to share comprehensive information regarding the tin supply chain. This poses an obstacle to achieving full transparency within the global tin market.

In order to enhance the transparency in the supply chain, the International Tin Mining Association introduced the ITSCI Programme, which involves tagging tin mining production, enabling better visibility and traceability throughout the supply chain. ITSCI promotes the responsible sourcing of 3T minerals from conflict-affected and high-risk areas. Aligned with OECD Minerals Guidance, it aims to prevent conflict financing, human rights abuses, and bribery in mineral supply chains (iTSCi n.d.). According to expert interviews, currently, there is no general duty for due diligence and the implementation of schemes like ITSCI are voluntary. However, shareholders are increasingly demanding audits to ensure responsible practices are upheld in mining. Interview results also show that, in the case of central Africa, particularly in the DRC, the mining of tin is regulated under the Dodd-Frank Wall Street Reform and Consumer Act of 2010 (IEA 2022).

Outlook

According to the industry report released by the ITA (ITA 2020a), the recycling of tin is expected to gain more significance as demand continues to rise. The report highlights a long-term upward trend in demand for tin, which is further supported by significant reserves and the potential for an increase in tin recycling. As prices for tin increase, it is anticipated that exploration activities will also expand. Industry experts suggest that these higher prices may serve as a motivation for exploring mining sites within the EU. The potential economic benefits resulting from the rising prices of tin are likely to stimulate the search for new mining locations. The demand for tin is projected to grow due to its extensive applications across various industries. However, the report emphasises the importance of sustainable and transparent tin mining practices in order to maintain the positive reputation of tin and ensure confidence in the supply chain for downstream buyers.

3.3 Natural Rubber

3.3.1 Introduction/background

Natural rubber is used in a wide range of up to 40,000 different products, including household goods, latex gloves, condoms and mattresses (Chanchaichujt and Saavredra-Rosas 2018; GIZ 2022). However, the biggest demand sector is the automotive and tyre industry, which uses around 75% of the world's natural rubber production (Chanchaichujt and Saavredra-Rosas 2018; GIZ 2022). Solid rubber[22], which is mainly used in the manufacture of tyres[23], accounts for around 85% of the natural rubber market (Millard 2019). For this reason, the following supply chain profile focuses on the supply chain for car tyres as a natural rubber-based commodity.

Up to 30 million people worldwide depend directly and indirectly on income from rubber farming, including around 6 million smallholder farmers (ETRMA 2022a; GIZ 2022). At the same time, many households cannot sustain themselves on the income from natural rubber cultivation alone and cultivation as well as processing is associated with negative ecological impacts (see Table 10) (GIZ 2022).

The rubber tree (*Hevea brasiliensis*) has been the main source of natural rubber since the beginning of the 20th century. It was originally grown only in its country of origin, Brazil, until 1876, when an English merchant brought seeds to Malaysia. Nowadays, Brazil hardly plays any role in the cultivation of natural rubber (Haustermann and Knoke 2019). Today, natural rubber production is dominated by Southeast Asian countries (GIZ 2022).

Emerging alternatives such as rubber derived from other plants like the *Caucasian dandelion* or *Guayule,* cannot (yet) fully replace natural rubber from the rubber tree as a key raw material for the production of tyres, because they do not fulfil all the required properties. Even synthetic rubber, which is derived from crude oil and already makes up at least 50% of every tyre, often cannot replace natural rubber 100% because it does not have the same level of resilience and elasticity as natural rubber (Haustermann and Knoke 2019; GIZ 2022). The following supply chain profile will thus focus on natural rubber production from the *Hevea brasiliensis* tree. The production of car tyres in Germany itself is declining (Destatis 2021). Given the high reliance on suppliers of natural rubber, intermediate and final products, the following profile focuses on the supply chain for car tyres as a natural rubber-based commodity.

3.3.2 Market structure

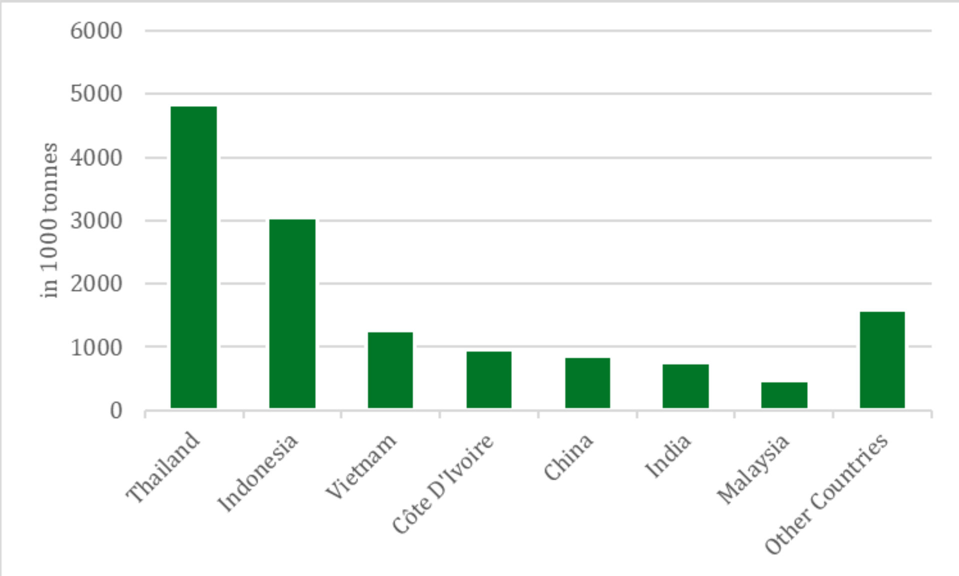
Since the rubber tree (*Hevea brasiliensis*) can only be cultivated near the equator under similar climatic conditions as in its area of origin, the Amazon region (so-called "rubber belt" on both sides of the equator), there is a strong dependence on a few exporting countries. Over 90% of all global natural rubber is produced from *Hevea brasiliensis* trees in Southeast Asia (GIZ 2022). An

[22] As opposed to liquid latex, which accounts for about 15% of natural rubber production and is used for products such as condoms, gloves and baby pacifiers. Depending on the final product and expected quality, the associated value chain for liquid/solid rubber products can vary greatly (Haustermann and Knoke 2019).

[23] Other solid rubber products classified as General Rubber Goods (GRG) include rubber tubes, pipes and hoses, flooring, etc.

increasing amount of trees is also being grown in West Africa, especially in Côte d'Ivoire (Haustermann and Knoke 2019). Since the turn of the millennium, rubber plantations have almost doubled in size to more than 14 million hectares. The majority of production (80%) is carried out by smallholder farmers on plots of less than two hectares (GIZ 2022). Interviews with supply chain experts indicate that large plantation production (similar to palm oil) is becoming more widespread, especially in emerging production countries, but that much of the natural rubber is still produced in smallholder structures, especially in Thailand and Indonesia. In 2021, global **natural rubber production** was dominated by Thailand, Indonesia and Vietnam; followed by Côte d'Ivoire, China, India and Malaysia (see Figure 19).

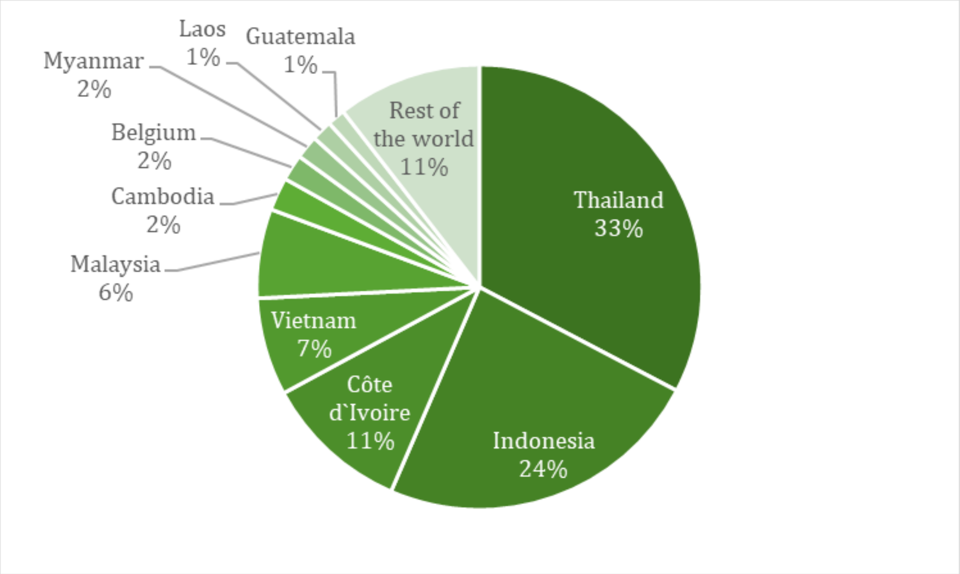
Figure 19: Global natural rubber production 2021, by country



Source: adelphi, based on information from Rubber Board, Statistics & Planning Department 2022

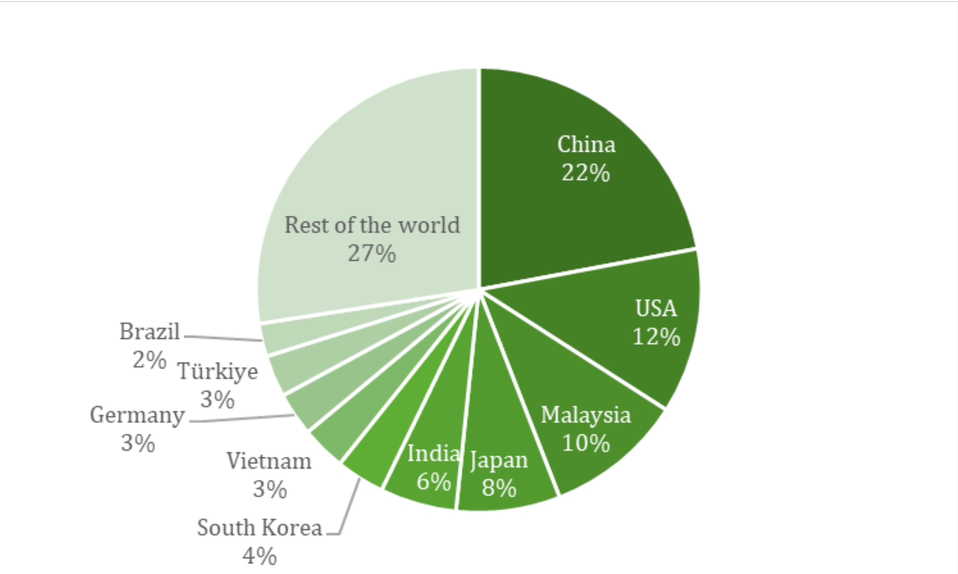
As most producing countries export the majority of their natural rubber products, this also largely corresponds to the leading natural rubber **exporting countries** in terms of export value in 2021 (see Figure 20). In 2021, China was the biggest consumer of natural rubber worldwide (41% of global demand), followed by India (9%), the EU 27 (8%), the U.S. (7%), Thailand (6%), Japan (5%) and Indonesia (4%) (ETRMA 2022a). This is also reflected in China's position as the world's largest importer of natural rubber in terms of value in 2021 (see Figure 21).

Figure 20: Leading natural rubber exporters in terms of value in 2021, by country



Source: Own illustration (adelphi), based on information from World's Top Exports 2022

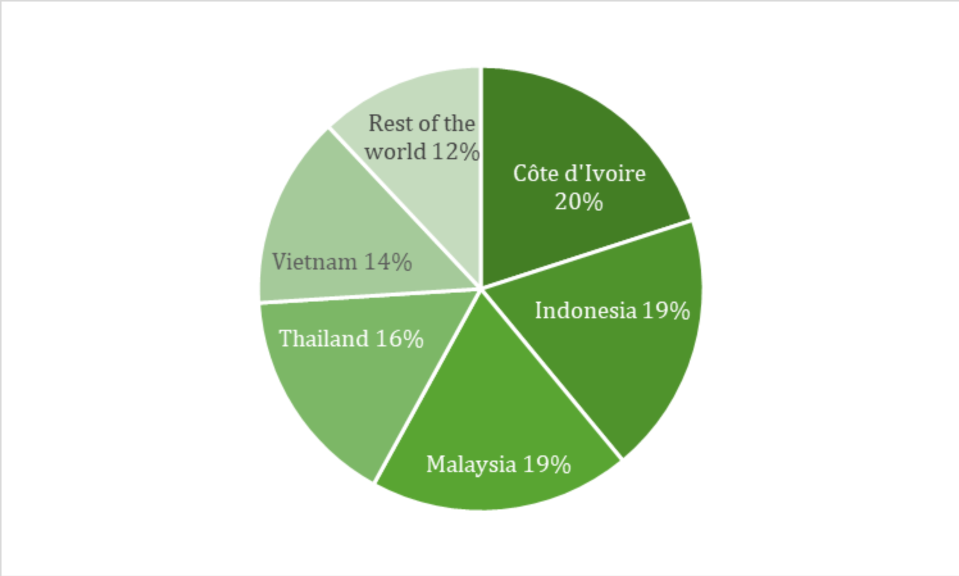
Figure 21: Leading natural rubber importers in terms of value in 2021, by country



Source: Own illustration (adelphi), based on information from World's Top Exports 2022

In 2018, natural rubber imports to Germany came mostly from Southeast Asian countries (see Figure 22), but also 20% from Côte d'Ivoire, where, according to interviewed experts, the cultivation of natural rubber in large plantations is more widespread than cultivation by smallholders.

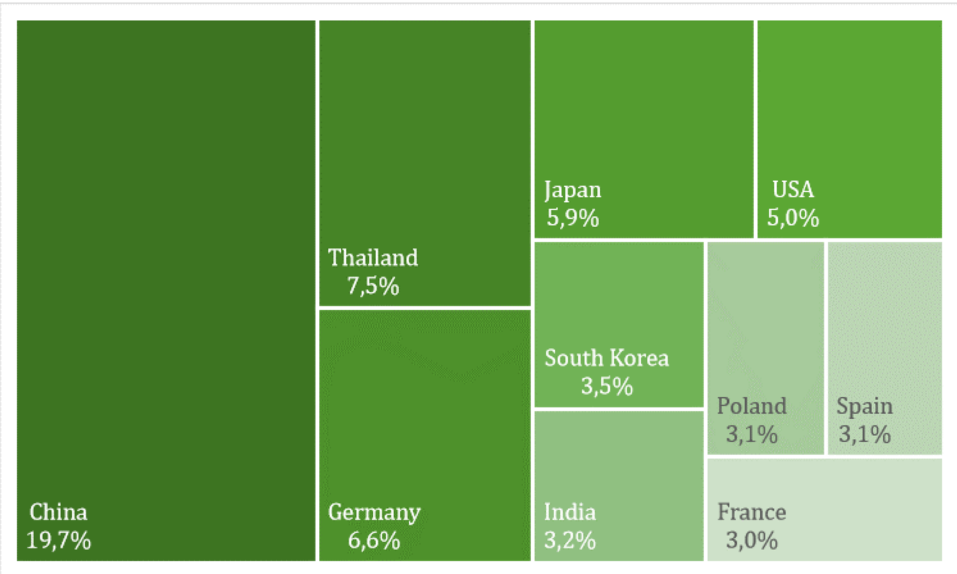
Figure 22: Natural rubber imports to Germany in 2018, by country and share of value



Source: adelphi, based on information from Kraft et al. (2022)

As shown in Figure 23, several rubber-producing countries have established their own tyre industries (Haustermann and Knoke 2019), with China dominating exports with 19.7% in 2021 (OEC 2023e). Overall, the manufacture of tyres is dominated by the Asia-Pacific region, followed by North America, where many of the leading tyre manufacturers are headquartered (Bonafide Research & Marketing Pvt. Ltd. 2023). While there are also tyre manufacturers located in Europe, more than 60% of the tyres sold in Europe in 2019 were imported. The main source of imported tyres is Asia, explicitly China (ETRMA 2019; Bonafide Research & Marketing Pvt. Ltd. 2023). In the Middle East and Africa, the tyre industry is growing but is comparatively small; in South America, the market is also relatively small, but some of the world's largest tyre manufacturers operate manufacturing facilities there (Bonafide Research & Marketing Pvt. Ltd. 2023).

Figure 23: Main rubber tyre exporting countries, by market share



Source: adelphi, based on information from OEC 2023e

In 2020, the world's 15 largest tyre manufacturers included ten Asian companies, three European companies and two American companies. The industry is highly concentrated, with three companies – Michelin Group from France, Bridgestone from Japan and Goodyear from the U.S. – together are responsible for 52% of the total sales of the top 15 tyre manufacturers (see Table 9). In total, the top six companies account for half of the global production sales, with $77 billion in 2020 sales. The leading German company is Continental in 4th place of the top 15 – which, however, earns only 23% of its sales from tyres, while its international competitors are more specialised in tyres (Kraft et al. 2022). This distribution of sales data contrasts with China's leading role in the import of natural rubber and export of rubber tyres, suggesting that many of the international tyre companies operate manufacturing facilities in China and/or that exports from China tend to be in the lower-price, low-revenue segment.

Table 9: Leading tyre producers (2020)

No.	Company (HQ country)	Estimated tyre-related revenue (FY 2020) *(in million EUR[24])*
1	Michelin (France)	20,986
2	Bridgestone (Japan)	18,987
3	Goodyear Tyre & Rubber Co. (U.S.)	10,468
4	Continental (Germany)	9,066
5	Sumitomo Rubber Industries Ltd. (Japan)	6,776
6	Hankook Tyre & Technology Co. Ltd. (South Korea)	4,854

Source: adelphi, based on information from Kraft et al. (2022)

According to the German Federal Statistical Office, the production of passenger car tyres in Germany is declining. In 2020, only 36.6 million passenger car tyres with a value of €4.9 billion were produced (largely due to effects of the COVID-19 pandemic), which corresponds to a decline of 26.6% compared to 2019 and 40.6% compared to 2015. The downward trend also continued in the first half of 2021 (Destatis 2021). The tyre manufacturing segment in Germany is homogeneous and highly competitive and is dominated by large companies (8% of companies employ 26% of the workforce). Only a few tyre manufacturers have their headquarters in Germany. Due to the high importance of the German automotive sector, some foreign companies operate sales, trading or production sites in Germany (Kraft et al. 2022).

The main consumer markets for rubber tyres by market share are the U.S. (18.3% of global import of rubber tyres in 2021), Germany (8%), France (4.8%), Mexico (3.5%), the Netherlands (3.5%), Canada (3.5%), the UK (3.2%), Italy (3%), Australia (2.7%) and Russia (2.5%) (OEC 2023e).

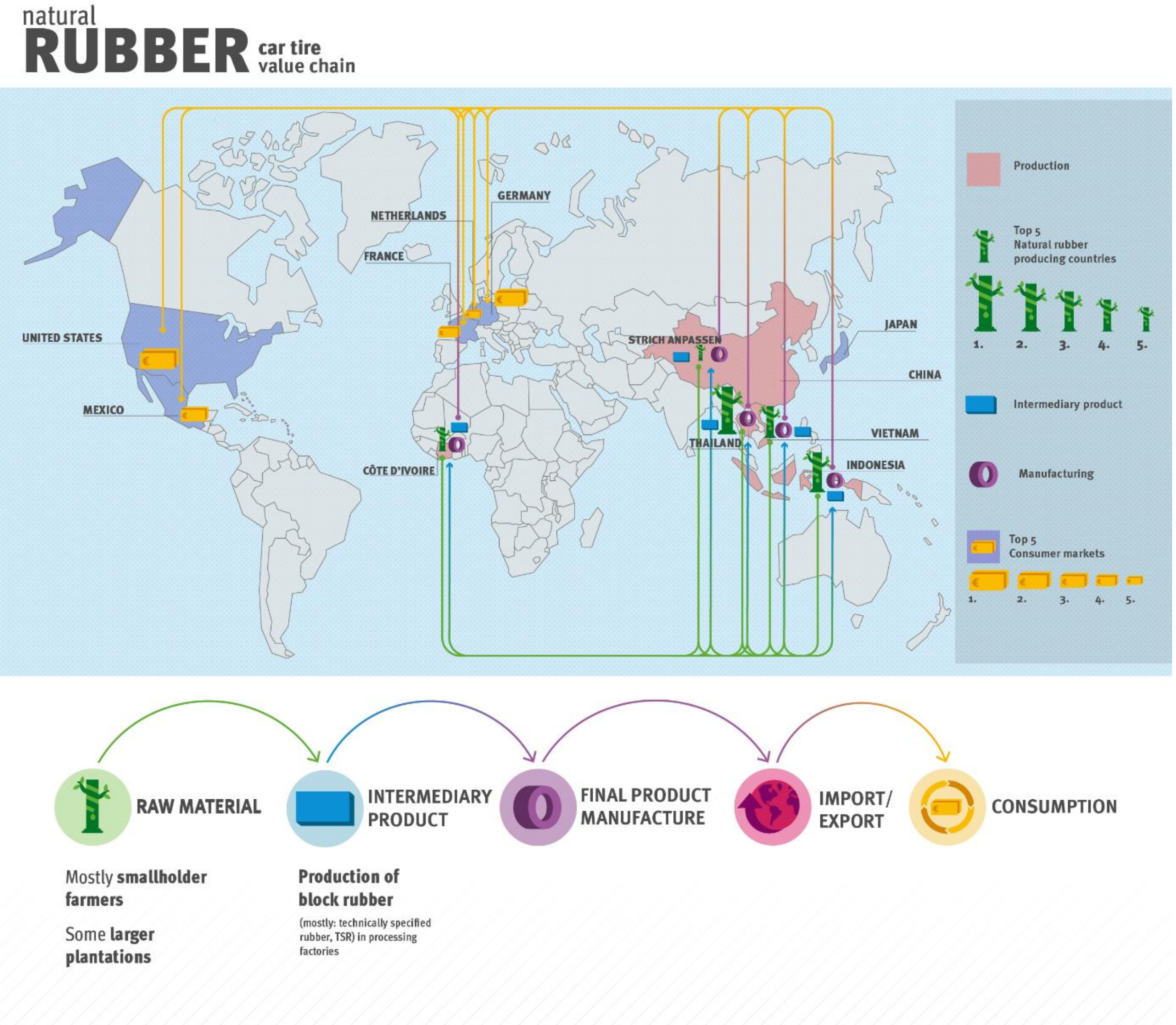
[24] Our conversion from USD, date of exchange rate: 19.06.2023.

3.3.3 The natural rubber tyre value chain

The international supply chain from the natural rubber tree to the car tyre is very complex and fragmented, and varies greatly depending on the quality requirements and regional origin of the natural rubber (Haustermann and Knoke 2019).

The **natural rubber value chain** as portrayed in Figure 24 is organised in five stages (raw material cultivation, intermediary product manufacture, final product manufacture, import/export, consumption) and complemented by post-consumption processes like sorting and recycling.

Figure 24: Selected key structures and processes of the natural rubber tyre value chain



Source: adelphi, based in material and data from this text

Natural rubber trees are predominantly grown as monocultures by **small-scale farmers** as well as in **large-scale industrial plantations** (alternative cultivation methods such as “wild rubber” and “jungle rubber” only account for a small percentage). Small-scale farming is dominant. According to the European Tyre & Rubber Manufacturers Association (ETRMA), about 85% of the world’s natural rubber supply comes from smallholders with an average of only 1.5 hectares of land per person (ETRMA 2020). The extraction of latex from the tree, known as “**tapping**”, is mostly done by hand and can take place for the first time 5-7 years after the tree is planted. After that, natural rubber trees are tapped about every 2 to 3 days (except for a six week break between December and February). When planted in monocultures, rubber trees can be tapped for about 25 years before the latex flow declines sharply. Yields can vary greatly depending on soil, number of trees planted, cultivation and tapping techniques (Haustermann and Knoke 2019). The latex subsequently has to coagulate. This is done either directly on the tree, where the latex is collected as “cup lumps” and then crumbled, washed or ground in factories and **processed** into raw rubber. The process of coagulation and further processing can also take place directly in the factory to achieve different degrees of purity/quality.

In the natural rubber-car tyre supply chain, the highly labour-intensive cultivation of natural rubber by smallholder farmers and at plantations, poses risks for labour and human rights (e.g. forced and child labour, long working hours, low wages/income, occupational safety and health, land grabbing) and can lead to negative environmental impacts (Haustermann und Knoke 2019). The expansion of agro-industrial plantations in particular leads to biodiversity loss and deforestation in some tropical regions (Inkonkoy 2022). **Negative environmental impacts** can also occur during processing. Table 10 shows the environmental impacts that are common in the supply chain and are therefore relevant for the industry. This does not mean that every impact listed will occur in every natural rubber-tyre supply chain.

Table 10: Main environmental impacts in the natural rubber-tyre value chain

Supply chain segments	Environmental impacts
Cultivation	Deforestation & land use change: growing demand for land for plantations and smallholder production
	Disruption of ecosystems & biodiversity loss: monocultures; land use change and deforestation also in producing countries classified as megadiverse by IUCN
	Water quality & availability: irrigation on plantations; use of chemicals and sedimentation through erosion of land
	Air pollutants & GHG emissions: land clearing for plantations by burning; usage of old machinery and fuel choices
	Use of hazardous chemicals: improper use of fertilisers, herbicides, insecticides and fungicides
Processing	Water availability: high water consumption of washing processes, inefficient use of water
	Air pollution & GHG emissions: energy consumption, fuel choices, machine efficiency and use/lack of pollutant removal techniques

Source: adelphi, based on information from Haustermann and Knoke (2019), Tanielian (2018) and expert interviews

At **semi-finished product level**, there are different product variants depending on the product and quality characteristics. Both lower quality brown crepe, block rubber, air dried sheets (ADS) and ribbed smoked sheets (RSS) as well as high-quality specified block and pale crepe rubber can flow into the production of tyres. Block rubber is the most widely used semi-finished natural rubber product today and is available in various standardised qualities (technically specified rubber (TSR))[25]. The first processing steps (coagulation, milling, drying - production of RSS and/or ADS) can take place at the level of local farms or cooperatives. Depending on the equipment, high- or low-grade natural rubber sheets can be produced. These are then bought from **middlemen/traders** and often mixed (so that the production of higher-quality products is barely profitable). In some regions, e.g. Indonesia, cup lumps are instead sold to local traders or directly to larger plantations with their own processing facilities and factories in the area – there are strong regional differences (Haustermann and Knoke 2019). Farmers often produce and sell their natural rubber (from the same crop) to different factories. The factories also often mix rubber from different farms and sell the intermediate product to different tyre and rubber goods manufacturers (ETRMA 2022a). According to interviews with supply chain experts, there can be 7 to 10 steps between the original farmer and the processing factory, collecting different village level and bigger traders/dealers. Traders collect natural rubber from different sources until they reach a quantity that processing factories are interested in buying. This is especially the case in Indonesia, whereas supply chains in Thailand and Côte d'Ivoire tend to be a little less complex.

Globally, around 6 million smallholders sell to about 100,000 dealers and 500 natural rubber processing factories (ETRMA n.d.). Due to the high fragmentation of cultivation, the procurement area of processors is very large compared to other commodities such as wood or palm oil: about 80% of the raw material is sourced from a radius of 150-200 km from the location of the processor, 15% from a radius of 200-500 km and 5% even from a radius of over 500 km (ETRMA 2022a). Along the supply chain, there are several collection and storage points (as natural rubber can be stored for several years), thus "first-in-first-out" is not the norm and natural rubber can travel long distances (ETRMA 2022a).

From the processing facilities, the semi-finished natural rubber products are then shipped to **tyre manufacturers** (Haustermann and Knoke 2019). Some large tyre manufacturers, such as the Michelin Group (Michelin 2021) and Bridgestone (Haustermann and Knoke 2019), also have their own plantations, which are, however, primarily used for R&D (e.g. development of new varieties), or are represented in natural rubber joint ventures with production and processing companies, from which they also purchase natural rubber (intermediate) products (Michelin 2021).

3.3.4 Pricing

Pricing in the natural rubber tyre supply chain is influenced by various (external) factors, especially at the raw material level, where it is particularly complex. In later stages, prices are more often negotiated directly between buyers and suppliers with the aim of covering their production costs and allowing some profit. Price negotiations are part of a broader framework of purchasing practices that are highly contested between buyers and suppliers, as discussed in Section 3.3.5. The following chapter therefore focuses on pricing mechanisms at the commodity level.

Trade in natural rubber is strongly dominated by **physical trade and direct, bilateral contracts** between sellers and buyers. About 75-80% of global physical trade is conducted through direct contracts. Buyers partly compensate for short-term shortages with last-minute

[25] Many producing countries have developed their own standards, so that there are, for example, different types of Standard Thai Rubber (STR), Standard Malaysian Rubber (SMR) and Standard Indonesian Rubber (SIR) on the market. Some countries also specialise in the production of certain semi-finished products, with Indonesia leading the market for TSR products (40% of exports), followed by Thailand and Vietnam (Haustermann and Knoke 2019).

purchases on the spot markets. Only about 5% of physical trade is done through **futures on the stock exchange**. Nevertheless, the speculative prices on the futures exchanges also influence the development of the natural rubber price overall, as they are published transparently on a daily basis and thus used as a price discovery tool/serve as a reference point for the prices on the local markets and many bilateral contracts. The largest exchange (with further increasing trading volumes for natural rubber) is the SHFE, followed by Tokyo (TOCOM) and Singapore (SICOM/SGX) (Haustermann und Knoke 2019). In an interview, a leading tyre manufacturer reported that negotiations on long-term contracts with natural rubber suppliers were often based on stock market prices. For Indonesia, for example, the price of natural rubber, which is traded on the Singapore Commodity Exchange (SICOM), provides direction. The SICOM index price would be quoted as the "base price", which was then supplemented or reduced by certain percentages in negotiations, depending for example on the quality of the natural rubber.

Natural rubber prices are volatile and affected by certain **external factors**, such as oil prices. Both synthetic and natural rubber are used in car tyres and the proportions in which both raw materials are used in a tyre can be adjusted to some extent depending on price and availability. Since synthetic rubber is made from crude oil, it has been observed in the past that as oil prices rise, more natural rubber is used in tyres, increasing the demand for and price of natural rubber at large (Chanchaichujt und Saavredra-Rosas 2018; Tanielian 2018; Haustermann und Knoke 2019). Due to the close link with the automotive industry, natural rubber prices are generally dependent on economic developments, especially in the vehicles market. For example, the price fell sharply during the global economic crisis in 2008 (Haustermann und Knoke 2019; Millard 2019). There is a particular dependence on the central importing country China, especially for the producing countries in Southeast Asia. When economic growth in China weakened in 2019/2020 due to the pandemic, imports of natural rubber also declined, which led to a noticeable oversupply worldwide and thus to a decline in natural rubber prices (Bangkok Post 2020). Natural rubber futures also weakened in light of the COVID-19 lockdowns in China (India Ministry of Commerce & Industry n.d.; Malaysian Rubber Board n.d.; ERJ 2022).

As with other agro-commodities, (extreme) weather events, harvest yields and losses and stocks also influence price developments (Chanchaichujt and Saavredra-Rosas 2018; Haustermann and Knoke 2019). Overall, the price of natural rubber is falling: according to Haustermann and Knoke (2019), one kilogram of rubber (adjusted for inflation and at today's prices) cost around $4 in the 1960s, while the price has fallen to an average of $2 since the early 2000s (with strong price fluctuations). Despite these general factors, the landscape of prices and yields in natural rubber farming is very heterogeneous – even within a single producing country, there can be large differences between regions in terms of farm profitability (Tanielian 2018). According to an interview with a supply chain expert, natural rubber coming from emerging producing countries (e.g. in Western Africa) is cheaper than from some traditional Southeast Asian

The Rubber Authority of Thailand (RAOT)

In Thailand, the **Rubber Authority of Thailand (RAOT)**, which was established by government decree in 2015, plays a central role in pricing. As a central institution, the RAOT aims to manage and support the entire natural rubber sector in Thailand and contribute to establishing Thailand as a rubber manufacturing hub. Among other things, the RAOT publishes daily rubber prices (which can fluctuate depending on the region), which traders and farmers can use as a guide when negotiating prices (RAOT n.d.). RAOT also offers **(e-)auctions** of natural rubber products, e.g. specifically for Chinese buyers, to support trade (Bangkok Post 2018). Similar tasks are also performed by government institutions in other producing countries, including the Malaysian Rubber Board (Malaysian Rubber Board n.d.) or the Indian Rubber Board (Government of India n.d.).

countries. Thus, some farmers in Indonesia and Malaysia have switched to the much more profitable cultivation of palm oil trees and other crops, despite sometimes high conversions costs associated with doing so (Aidenvironment 2016).

Overall, world market prices for natural rubber have fallen significantly since 2012, resulting in lower incomes, especially for smallholders, and affecting plantation owners' ability to pay their workers. In some regions, farmers have therefore switched to growing other crops, timber logging or non-agricultural activities, suspended tapping to wait for natural rubber prices to rise, or joined cooperatives to improve their bargaining position (Inkonkoy 2022).

Government subsidies can also impact pricing along the natural rubber tyre supply chain. In 2017, for example, the European Commission launched an anti-subsidy investigation following a complaint about unfair practices when importing tyres into the EU. The investigation concluded that the Chinese tyre manufacturer China National Tire and Rubber Company (CNRC) had benefited from state support. Among other things, the Chinese government had financially supported the company in its purchase of competitor Pirelli in 2015 (OECD 2022a). Other producing countries, such as Thailand in 2016, at times use subsidies to try to counteract declining world market prices for natural rubber and strengthen their own industries (Bertrand 2016).

As so far very little certified natural rubber is available on the market compared to other raw material supply chains, there are no reliable figures to determine price differentials compared to conventional natural rubber (read more under 3.3.6.)

3.3.5 Power relationships

Due to the high number of highly fragmented smallholder farmers and some plantations at the level of natural rubber cultivation compared to the much smaller number of traders, processing factories and tyre manufacturers, the natural rubber – tyre supply chain is characterised by a significant power imbalance, which also affects pricing and purchasing practices and leads to an uneven distribution of costs and benefits (Chanchaichujt and Saavredra-Rosas 2018; Tanielian 2018; Haustermann and Knoke 2019).

Following Gereffi et al.'s (2005) approach, there are different types of supply chain **governance** along the value chain, from the cultivation of natural rubber to the purchase of tyres by the automotive industry. Smallholder farmers usually sell their rubber to **intermediaries** who know the listed world/local market prices for natural rubber and pay accordingly. This can be rubber farmers with larger farms who also buy latex from their neighbours in order to sell larger quantities, for example in the next town. Haustermann and Knoke (2019) report that intermediaries can be situated at different regional levels: "village, district and provincial level". The relationship between intermediaries and smallholder farmers can in most cases be described as **captive**: suppliers (**smallholder farmers**) are highly dependent on their buyers (**intermediaries/processors**) as they often lack direct contact to lead firms/international buyers, face high switching costs, and lack the capabilities to process rubber themselves. They are confined to a narrow range of tasks (tapping, harvesting, transportation to collection point) and heavily dependent on intermediaries as they organise transport and provide loans to small farmers to fill short-term financial gaps (ibid). Since the extraction of latex takes place in a rhythm of 2-3 days, the process can be very dynamic; in some regions, smallholders decide anew every day to which dealers or processors they will sell their latex, sometimes depending on price developments (ETRMA 2022a). Despite this partial flexibility, farmers are heavily dependent on the prices quoted by intermediaries – partly because the pricing is difficult for smallholders to understand due to the many non-transparent intermediary stations (GIZ 2022). In interviews with local smallholder farmers, Haustermann and Knoke (2019) learned of the practice of traders offering smallholder farmers prices below the listed prices because the quality of the cup lumps offered was allegedly inadequate due to insufficient drying or contamination. Farmers would then have little negotiating leverage, even if they were able to check the current listed prices for natural rubber online (ibid). The quality controls carried out by traders at the collection points for natural rubber and intermediate products such as ADS thus also has a strong impact on pricing. According to an interview with an industry expert, quality inspections are usually commissioned by processing plants. On some occasions, quality checks are already done earlier, at collection points, e.g. at village level, before the natural rubber is transported to (a) processing plant(s).

Another sector expert interviewed for this study also highlighted that smallholders tend to sell to the same collection points because a) of their proximity (farmers have to bear the cost of gasoline for transporting their harvest products to the collection points themselves and thus prefer nearby collection points) and b) social connections (usually, farmers and collectors know and trust each other and build strong local links). This shows that **relational** aspects can also influence the power relationships at this value chain stage, as farmers and intermediaries are often linked through a trusted relationship, based on spatial proximity, but also social and reputational influence (Gereffi et al. 2005).

Processors also enter **captive** relationships with their buyers: **tyre manufacturers** usually cover the majority of their demand through direct contracts including specific requirements (often they demand specific product qualities beyond the standardised TSR system) with trusted processing factories (Haustermann and Knoke 2019).

Many original equipment[26] tyres are custom design. As one car manufacturer and one tyre manufacturer reported in interviews conducted for this study, some tyre manufacturers and **car manufacturers** (Original Equipment Manufacturers: OEMs) exchange information about the specifics and requirements of the tyre before the construction of a new vehicle model begins, carry out product prototyping and testing, and only then conclude contracts.[27] Tyres are highly specialised components that must also meet legal requirements in order to be approved for national markets. Tyre manufacturers then produce the tyre according to the contractually agreed specifications. Depending on the contractually agreed tyre properties, different types of rubber are selected (synthetic rubber is also mixed with natural rubber)[28] (U.S. Tire Manufacturers Association 2020). Thus, when focusing on the original equipment sector, the relationship between **tyre makers** and **automotive OEMs** can be described as a "**modular production network**", in which OEMs and tyre makers enter a joint development process for the highly specified final product. Tyre makers are able to provide OEMs with full packages, reducing the lead firms' need for monitoring and control after initial information and technical standards have been exchanged (Gereffi et al. 2005).

As the supply chain governance structures described above show, **smallholder natural rubber farmers** are among the weakest actors in the natural rubber value chain (Haustermann and Knoke 2019). This is due to various factors: on the one hand, natural rubber farmers can hardly react to sudden price fluctuations due to the long growth phase until the first latex harvest of

[26] In addition to initial equipment, the replacement tyre market plays a key role for many tyre manufacturers. At Continental, for example, only 22% of sales in the tyre segment in 2022 came from business with OEMs, while 78% were generated in the replacement tyre segment (Continental 2023).

[27] According to experts from the automotive industry, this procedure (first: definition of specifications, second: possibly some prototypes, only then: contract between supplier and buyer) corresponds to the usual procedure in the development of new types of vehicles and does not apply specifically only to tyres.

[28] Other raw materials that go into the tyre material are special oils, carbon black, pigments, antioxidants, silica and other additives. Polyester, steel and bronze-coated steel wires are also used for the overall construction of the tyre (U.S. Tire Manufacturers Association 2020).

rubber trees (Haustermann and Knoke 2019). A lack of adequate farming knowledge can lead to the use of inferior cultivation practices such as monocultures, which in the long run lead to soil degradation and low yields for the farmers (Tanielian 2018). According to a 2015 study, over 70% of all natural rubber plantations in Southeast Asia were located in "environmentally marginal zones" where only low yields could be expected (Ahrends et al. 2015). Especially for smallholder farmers in remote regions, the price of fertilisers is also a decisive cost factor (Haustermann and Knoke 2019). According to interviewed experts, smallholder farmers usually have to bear the cost for transport (e.g. gasoline) of their harvest products to the collection points. Thus, in more remote areas, cup lump harvesting is applied, which allows farmers to store and collect their harvest products before transporting them. However, rubber cup lump harvesting involves the additional cost for farmers of buying formic acid for coagulation and are usually of lower quality than liquid latex, leading to a lower price. As a result, after harvesting and transport to the collection point, there is often hardly any profit left with the farmers (Haustermann and Knoke 2019).

Purchasing practices

The natural rubber tyre supply chain as a whole is characterised by direct contracts between seller and buyer, which differ greatly depending on the stage of value creation in terms of duration and contract specifications/requirements for the product. Some of the prominent business models can be summarised as in Table 11:

Table 11: Dominant business models and governance in the natural rubber tyre value chain

Business model	Type of buyers	Governance	Type of relationship	Procurement procedure
Mix of key suppliers & occasional suppliers	tyre makers	captive	mid- to long-term sourcing relationship	competitive; price dominant
Mix of key suppliers & occasional suppliers	automotive OEMs	modular	long-term sourcing relationship	highly competitive; strategic factors (e.g. technical requirements)

Source: adelphi, based on classification by Gereffi et al. 2005 and information from expert interviews

As described in 3.3.3, **smallholder farmers** usually sell their harvest products to **intermediaries** in small quantities, based on trusted and often more long-term relationships. Some large **plantations** and less remote farmers also supply processing factories directly, and some tyre manufacturers run their own plantations (Haustermann and Knoke 2019). Bypassing intermediaries is generally described as a way for smallholder farmers to obtain higher prices. In Thailand and Indonesia, for example, the formation of cooperatives that supply factories directly is supported by the state. However, this is not an option for all actors due to the high degree of fragmentation and the sometimes geographically dispersed smallholder farms (Tanielian 2018; Haustermann and Knoke 2019). Also, plantations (or small-scale farms) often struggle to pay minimum wages due to low profitability (Haustermann und Knoke 2019).

Primary **processing plants** usually buy rubber products from different collectors/sources in order to meet the required quantity to be able to supply their secondary processor within the framework of a pre-agreed price. Thus, price is the dominant factor. Secondary processors then usually export the majority of their intermediate products to the foreign market, amongst others to **tyre manufacturers** via medium- to long-term bilateral contracts (duration of 6-12 months). Especially large tyre manufacturers usually have direct contracts with long-standing, trusted processing companies to cover most of their demand (Haustermann and Knoke 2019). This was confirmed in an interview with a representative of a leading tyre manufacturer who stated that up to 90% of their purchasing volume would be sourced directly from between 70 and 80 natural rubber processing companies worldwide (with a regional focus on Southeast Asia, but also a notable share from Côte d'Ivoire). Smaller volumes would only also be purchased from traders for special products. The expert also stated that, due to stringent requirements for supply contracts on quality requirements, certifications, etc. and a process with various screenings and supplier assessments, it would take at least one year to approve a new facility as a supplier of natural rubber products.

However, according to an interview with an industry expert, some processing plants do not opt for overly long-term contracts in order to be able to renegotiate in the event of price fluctuations. A tyre manufacturer interviewed for this study said that since the price of natural rubber often fluctuates significantly, efforts are made to take this into account and compensate for it in regular negotiations with suppliers. General negotiations would take place every year. Negotiations during the year were possible if a supplier explicitly requested this in order to be able to continue to meet its supply volume.

Tyre manufacturers then either sell their products as replacement tyres to dealers of car spare parts or car owners as end customers, or they enter into contracts with **car manufacturers** for the production of original equipment tyres (Continental 2023). As a tyre manufacturer explained in an interview for this study, orders for the production of new tyre models are typically awarded through a vehicle model-specific contract award mechanism, and often different manufacturers supply the same vehicle model. According to an interview with a German OEM, tyre manufacturers and car manufacturers thus usually enter long-term contracts, as OEMs may not change their tyre suppliers arbitrarily. However, in the case of older vehicle models, different tyre manufacturers may offer the same tyre model after a while, allowing car makers to diversify their tyre supplier network. The automotive OEM stated that intermediate negotiations on the tyre purchase price also take place in existing medium- and long-term contracts, for example in order to account for fluctuating energy prices, which have a strong impact on the manufacturing costs of tyres and vehicles. Overall, the tyre industry is a highly concentrated, oligopolistic sector in which market share gains – at least in Europe – are only possible at the expense of competitors (Kraft et al. 2022).

3.3.6 Addressing environmental impacts

Compared to other sectors (e.g. textiles, cocoa, palm oil), the global natural rubber industry has been late in adopting approaches to improve environmental sustainability in the value chain. According to an industry expert interviewed for this study, this is partly due to a lack of interest from customers. Unlike the clothing sector, for example, demand for sustainably produced tyres and cars that use sustainable materials has so far been less pronounced. There are a few voluntary initiatives at the company level to develop process standards and a couple of product labels and standards that cover natural rubber, but the amount of sustainably produced natural rubber is very limited (Haustermann and Knoke 2019). Accordingly, interviews with industry experts indicate that it is not yet standard market practice to pay price premiums for sustainably produced natural rubber (products).

Two key **international multi-stakeholder initiatives**, specifically the International Rubber Study Group (IRSG) and its Sustainable Natural Rubber Initiative (SNR-i), and the Global Platform for Sustainable Natural Rubber (GPSNR), which emerged from the Tire Industry Project

(TIP), have developed environmental and social **criteria and guidelines** to which member companies have largely committed themselves **voluntarily**. Some of the frameworks do not yet go beyond the respective **national legislation** in producing countries and only partial controls are carried out – which are usually not verified via **third-party evaluation** (Haustermann and Knoke 2019). The GPSNR was only established in 2018 and has since published a joint Policy Framework (to which all members have committed), Reporting Requirements and a Grievance Procedure. The initiative is still working on developing a joint assurance model that follows existing standards established for other raw material industries such as the Forest Stewardship Council (FSC) or the Roundtable for Sustainable Palm Oil (RSPO). GPSNR members currently represent nearly 50% of the world's traded natural rubber volume (Haustermann and Knoke 2019; GPSNR 2023).

In Germany, the German Rubber Manufacturers Association (**wdk**) has developed a **sustainability charter** to which all its member companies have committed themselves. However, within the framework of the wdk charter, the initial aim is to comply with national standards in the country of production (Haustermann and Knoke 2019).

Additionally, the *OECD-FAO* (Food and Agriculture Organization) *Guidance for Responsible Agricultural Supply Chains* provides agri-businesses and investors along the natural rubber tyre supply chain with a common framework and globally applicable benchmark to systematically identify, assess and mitigate negative impacts on people and the environment in their supply chain. While the guidance does not specifically address natural rubber, it does provide an overview for enterprises along agricultural supply chains in general, including food and non-food commodities (OECD and FAO 2016).

In terms of **voluntary quality labels and product-related standards**, the overall market coverage of natural rubber has been very limited so far. This is attributed to the difficult traceability that arises, among other things, from the fact that processors mix natural rubber from different farms. The only voluntary sustainability standards that cover natural rubber are the **Forest Stewardship Council (FSC)**, the **Programme for the Endorsement of Forest Certification (PEFC)**, the **Fair Rubber Association** and the **Global Organic Latex Standard (GOLS)** (see Figure 25)[29]. Most of the labels aim to increase the transparency of the natural rubber supply chain (Haustermann and Knoke 2019). FSC follows the Chain-of-Custody approach and guarantees traceability, which makes the label more suitable for large-scale operations (FSC 2020). In 2021, tyre manufacturer Pirelli produced the first and so far only FSC-certified tyres as equipment for a BMW Group plug-in hybrid car model (FSC 2021). PEFC offers different types of certification: chain-of-custody certification covers the entire supply chain – from plantation to final product (e.g. a tyre), and any actor (producer, processor, trader, etc.) along the supply chain can apply to demonstrate that PECF-compliant sustainably produced natural rubber has been sourced. In addition, PEFC offers certification of individual rubber growers, group certification (where, for example, several smallholders are audited together) and a certification specifically for producers selling products made from recycled rubber (PEFC n.d.). The Fair Rubber Association developed a catalogue of criteria for fairly traded natural rubber in 2018, which is audited by independent auditors. The costs for the audits are borne by the association. Members of the Fair Rubber Association pay a price premium of 0.5€ per kilogram of dry rubber content, which is passed on directly to the suppliers from whom the natural rubber was purchased. The Fairtrade premium is intended to improve the living and working conditions of the rubber producers, especially smallholders (Fair Rubber e.V. 2020). As of July

[29] The Rainforest Alliance also used to offer certification for natural rubber production, but announced in November 2019 that it would phase out certification of natural rubber because fewer than ten rubber operations had been Rainforest Alliance Certified (Rainforest Alliance 2019).

2023, the Fair Rubber Association cooperates with 10 suppliers in Southern India, Sri Lanka, Thailand and Indonesia. The fairly produced rubber however, does not flow into the production of car tyres (but into household items, condoms, bicycle tyres, etc.) (Fair Rubber e.V. n.d.). GOLS covers the entire supply chain from extraction to final product, but is only available for latex products (thus not for tyres) (Haustermann and Knoke 2019).

Figure 25: Selected certifications in the natural rubber supply chain

Not yet applicable to block rubber for tire production

Source: Haustermann and Knoke 2019; Fair Rubber e.V. 2020; FSC 2021; PEFC n.d.

Some individual companies have also moved forward with their own initiatives. For example, Michelin has set a goal of zero deforestation in its supply chain, has all its suppliers audited by EcoVadis and uses the RUBBERWAY app (which was jointly developed by Michelin, Continental and the software developing firm SMAG) to track natural rubber in its supply chain (Michelin 2021). Other tyre producing companies, such as Continental, have also introduced rubber-specific sourcing policies, including procurement guidelines and code of conducts for suppliers. A few car manufacturers have set up zero-deforestation targets, with General Motors being the first one (Haustermann and Knoke 2019).

As the greatest social and environmental impacts occur at the beginning of the supply chain (Haustermann and Knoke 2019; Inkonkoy 2022), farmers are also under the greatest pressure to adapt. At the same time, interviewees emphasised that the transfer of costs of certifications and other initiatives to improve sustainability along the value chain often accumulate at the bottom of the supply chain.

3.3.7 Current/future trends and developments

Despite the natural rubber industry's comparatively late engagement, increased efforts to improve sustainability in the supply chain are likely in the near future, mainly due to new and upcoming regulations at the European level (for details see Section 0).

The COVID-19 pandemic has had a major impact on the rubber industry, partly due to its close ties with the automotive industry, much of which ceased production in 2020 (Jolly 2020). Global natural rubber production fell by 5.1% in 2020. In addition to falling demand from OEMs, this was due to travel restrictions leading to a shortage of personnel in cultivation areas, which resulted in a decrease in tapping days. Growing countries such as Indonesia and Vietnam, which rely more on family-based, smallholder farming, were less affected by labour shortages. According to interviews with experts, the economic slowdown caused by COVID-19 in China, an otherwise key purchasing country, has led to an oversupply of natural rubber in particular, causing rubber prices to fall. The downward trend in global demand for natural rubber continued in 2021 with a 7% decline, due in part to pandemic mitigation measures such as mobility restrictions and declining sales of passenger vehicles (IRSG n.d.). According to expert interviews, travel restrictions also have slowed down the rollout of digital supply chain traceability solutions in some cases, for example because suppliers could not be visited to be trained in the use of new apps and systems. The ongoing war in Ukraine has also had a strong impact on the natural rubber industry. Various tyre manufacturers such as Michelin and Continental have closed their production facilities in Russia (Rubber News 2023a; Rubber News 2023b). The same applies to major automotive OEMs (Dunn 2022).

From a global perspective, the development of markets in developed and emerging countries such as China and India play a critical role for the natural rubber industry. In 2020, the strong recovery of both countries has contributed to a strong increase in the sales market, partly due to demand from the tyre sector. In parallel, there are slight regional shifts at the producer level. In 2022, for example, the Mekong countries (Cambodia, South China, Lao people's Democratic Republic, Myanmar, Thailand, Vietnam) and Côte d'Ivoire played a growing role. (RubberWorld 2022).

Table 12 shows the main market, consumer and technology trends.

Table 12: Market, consumer and technology trends

Market trends	▶ Falling natural rubber prices due to global oversupply ▶ Growing role of Mekong region and Côte d'Ivoire as producing regions/countries ▶ Growing number of projects that aim to boost productivity, improve quality and support direct marketing at cultivation level
Consumer trends	▶ Declining purchasing power worldwide due to economic and political uncertainties – inflation and war led to insecurities, which may lower the consumption of passenger cars and thus tyres ▶ Lack of awareness of sustainability in the natural rubber supply chain among customers, therefore no demand for more sustainably produced tyres
Technology trends	▶ Development of technologies that allow for traceability and improved transparency of the supply chain (such as barcodes, AI-supporting tracing, geolocation etc.) ▶ Research into new seeds that deliver higher yields than their predecessors ▶ Digital networking in real time allows companies to provide services at internationally distributed locations (see i.e. data exchange platform established by Catena-X Automotive Network) ▶ Use of substitutes (such as *Caucasian dandelion* or *Guayule)* ▶ Use of satellite images to monitor deforestation ▶ Use of ethylene tapping to respond to labour shortages in farming

Sources: adelphi, based on information from Kraft et al. 2022 and expert interviews

3.3.8 Institutional incentive mechanisms and barriers

Lack of traceability

A fundamental prerequisite for the reduction of negative environmental impacts in the natural rubber supply chain, such as deforestation, is the traceability of the supply chain back to the farm. Without knowledge of the origin of a natural rubber product, it is difficult to ensure that environmental protection measures have been implemented. The natural rubber supply chain faces particular challenges in this regard, as the supply chain is characterised by a large number of smallholders and intermediaries, which make traceability back to the point of cultivation difficult. In addition, products from different suppliers are mixed at various points in the supply chain, making it difficult to distinguish them later. The possibility of storing natural rubber for long periods and sourcing natural rubber from a wide geographical radius also contribute to the greater difficulty of traceability (Inkonkoy 2022). Various interviewees have referred to a "chicken-and-egg" problem that arises from this context: companies often state that they would like to pay a price premium for compliance with sustainability standards, but that this was not feasible because they could not ensure that this price premium would actually reach their suppliers, especially the smallholder farmers, due to the lack of traceability. Other stakeholders, however, emphasise that the increased bureaucratic requirements resulting from improved traceability and compliance with higher environmental standards or chain-of-custody certification could only be implemented by suppliers if a price premium was provided for this (Haustermann and Knoke 2019; Fair Rubber e.V. 2020). Several interview partners have expressed the expectation that traceability in the natural rubber tyre supply chain will improve significantly as a result of the regulatory requirements of the *EU Regulation on Deforestation-free Products* (EUDR), which will require companies to track their supply chain to demonstrate that their products are not linked to deforestation or forest degradation, starting from the end of 2024.

Transparency issues and power relations

Another key barrier to improving the sharing of costs and benefits along the natural rubber supply chain is the lack of transparency in the pricing process, which arises from a number of factors: on the one hand, the large number of smallholder farmers in the producing countries are often dependent on intermediaries who have the necessary transport infrastructure and relationships to sell the natural rubber to processing facilities. On the other hand, small farmers often lack the possibility to check current world market prices for natural rubber in order to be able to negotiate an appropriate price. Even when they have access to digitally published prices, they are in many cases exposed to the arbitrariness of the intermediaries, who can also depress the price by referring to the allegedly inferior quality of the rubber (Tanielian 2018; Haustermann and Knoke 2019). Haustermann and Knoke (2019) also point out that it is hardly worthwhile for farmers to produce high-quality natural rubber for which they could receive higher returns, because most processing farms mix natural rubber from different suppliers and therefore do not pay a price premium for higher quality products (ibid.). The most frequently mentioned approach to circumvent this imbalance in transparency and power relations is the establishment of cooperatives, in which the farmers join forces and negotiate their prices directly with the processing factories, without going through intermediaries. However, the strong fragmentation, which is sometimes also expressed in large distances between individual smallholders, makes the establishment of cooperatives impossible for some smallholders (Tanielian 2018; Haustermann und Knoke 2019).

There is also discussion about the role of non-physical trade in natural rubber, which is playing an increasing role, especially on the SHFE, which according to market participants could be partly responsible for fluctuations and the price decline of natural rubber in recent years (Haustermann and Knoke 2019). According to Haustermann and Knoke (2019), there are large rubber stocks in China and an oversupply, which leads to low prices on the SHFE and also affects trading in Singapore and Tokyo. The more intransparent the trading on the stock exchanges, the more intransparent the pricing at the local level, as local traders often base their bids on public market prices and bilateral contracts often refer to the SHFE. (ibid.).

(Environmental) Legislation in producing countries

Many natural rubber producing countries have established government-supported organisations to coordinate and support their local natural rubber market, especially against the backdrop of falling natural rubber prices in the past few years. To this end, for example, the *Rubber Authority of Thailand (RAOT),* the *Malaysian Rubber Board* or the *Indian Rubber Board* compile statistics on market development, publish daily natural rubber prices as reference values, and sometimes offer technical or financial support to entrepreneurs and farmers in the sector. In general, however, environmental and social factors do not play a prominent role, and the organisations' mission statements tend to focus on supporting local companies and protecting the market (India Ministry of Commerce & Industry n.d.; Malaysian Rubber Board n.d.; RAOT n.d.)

In addition, some natural rubber-producing countries have published national rubber policies, development and action plans. India's National Rubber Policy (NRP), for example, published in 2019, aims to establish a "well-developed value-chain of environmentally sustainable and globally competitive rubber industry" and includes regulations and proposals for government support for environmental protection and recycling/waste management in the sector (ERIA 2016; India Ministry of Commerce & Industry 2019). In Thailand, various natural rubber-related policies have been introduced, including policies to control the growth of the production and plantation area (supply side policies) and policies aimed at increasing demand for natural rubber (products) (e.g. purchase policy, direct purchase from farmers, investment support in local rubber products) (ERIA 2016). In addition, a rubber farmer income support policy was adopted in February 2023, which aims to stabilise rubber prices and provide subsidies and credit support for Thai farmers. Specifically, this is intended to compensate for losses incurred by over 1.6 million Thai farmers when natural rubber prices fall (Bangkok Post 2023). In Indonesia, domestic trade, export and import of rubber commodities are regulated by various policies of the Ministry of Trade and the Ministry of Industry. However, Andoko (2019) points out that, in relation to the importance of natural rubber production and trade for the local economy, there are rather few regulations for rubber in Indonesia. No specific regulations to protect rubber farmers have been established so far. Emphasis has rather been placed on increasing production and sales, while environmental protection and social aspects remain largely unaddressed (ibid.). In China, a production and important processing country for natural rubber, official guidelines were published in 2017 by the China Chamber of Commerce of Metals, Minerals & Chemicals (CCCMC), which reports to China's Ministry of Commerce, setting out requirements for avoiding social and environmental risks in the cultivation of natural rubber (CCCMC 2017). Compliance with the guidelines has so far been voluntary (Haustermann and Knoke 2019).

Since many of the aforementioned policy initiatives in support of natural rubber famers or environment-related requirements were introduced only a few years ago, it is difficult to assess the impact of the policies to date.

Environmental policy measures in consumer markets

Similar to other global sectors described above, the natural rubber industry will be affected by the increasing human rights and environmental requirements for the supply chain introduced in key consumer countries. Especially new and upcoming regulations at the European level may increase the pressure on actors in the supply chain.

The regulation with the greatest potential to improve traceability, transparency and due diligence in the natural rubber supply chain is the EUDR, which came into force on 29 June 2023. From 30 December 2024 (and 30 June 2025 for micro and small enterprises), companies involved in the trade of certain commodities classified as deforestation-risk commodities (natural rubber, soy, beef, palm oil, wood, cocoa, coffee) must provide traceability down to individual producer plots, conduct extensive due diligence to prevent deforestation in the supply chain, and demonstrate that their products are not linked to deforestation or forest degradation. If they cannot meet these requirements, they may not place the relevant products on the EU market or export them from the EU. In addition, the European Commission will classify the deforestation risk of production countries and ask competent authorities to monitor a greater share of shipments from high-risk areas (European Commission n.d.). Several experts interviewed for this study emphasised that the EUDR will have a major impact on the natural rubber supply chain, leading to a rapid increase in traceability and sustainability initiatives.

Additionally, the foreseen CSDDD the CSRD as well as the already enacted *German Supply Chain Due Diligence Act* are expected to contribute to improved cooperation between suppliers and buyers in the natural rubber sector (Kraft et al. 2022). Approaches to increase the use of secondary materials and improve recyclability, which are influenced by policy initiatives such as the EU's *Circular Economy Action Plan* presented in March 2020, also play a role for the natural rubber industry. In Germany, this is particularly the case because the disposal of used tyres in landfills has been banned since 2003, which has contributed to an increase in material recycling (Kraft et al. 2022).

Other relevant initiatives affecting the natural rubber sector are the EU *Chemicals Strategy for Sustainability* adopted in 2020 and the *EU REACH Regulation* (in force since 2007). REACH obliges companies to register chemical substances used in production, to analyse them with regard to their hazard potential for people and the environment and to reduce the use of harmful substances. The burden of proof as to whether newly used substances are associated with risks lies with the companies (Kraft et al. 2022).

In terms of transparency, the renewal of the EU-wide tyre labelling rules places new requirements on companies in the natural rubber industry. Since May 2021, tyre manufacturers have to provide information on the trade name or brand of the supplier and the tyre type identification (article number) in addition to existing product characteristics (Kraft et al. 2022). The planned *Euro 7 standard*, which for the first time will also include specifications on tyre abrasion, may also have an impact on the supply chain for natural rubber (European Commission, Representation in Germany 2023).

The planned reform of the *European Emissions Trading Scheme* (EU ETS) and the planned introduction of the *Carbon Border Adjustment Mechanism* (CBAM) could also have an impact on pricing and sustainability efforts in the natural rubber trade. Although the GHG emissions of the rubber industry are rather low compared to other sectors such as the metal production industry, deforestation for the cultivation of new natural rubber plantations in particular contributes to the destruction of climate-critical tropical forests. Furthermore, tyres contain up to 200 different raw materials aside from rubber, many of which are covered by the scope of CBAM (ETRMA 2022b). Therefore, a rising carbon price in combination with CBAM can contribute to increased investment in and commitment to climate protection measures at all stages of the natural rubber supply chain (Kraft et al. 2022).

Trade agreements and policies

On both a global and regional level, there have been various attempts in the past to control and coordinate the natural rubber market through trade agreements and to stabilise its price development. The first trade agreement concluded in relation to natural rubber, the *International Rubber Regulation Agreement* (IRRA), dates back to 1943, when the UK, India, the Netherlands, France and Thailand, as important rubber producing nations at the time, formed an alliance to establish a stable and high price for natural rubber. The colonial agreement was replaced in 1997 by the *International Natural Rubber Agreement* (INRA), which was established under the Integrated Programme for Commodities (IPC) of United Nations Conference on Trade and Development (UNCTAD) and renewed in 1987 and 1995. To implement the agreement, the International Natural Rubber Organization (INRO) was established with headquarters in Malaysia. INRA provided price bands as reference prices for natural rubber and provided for an internationally regulated natural rubber buffer stock. Members of the first agreement accounted for a total of 95% of exports and 75% of imports worldwide. When major natural rubber exporting countries left the agreement in 1995, it lost importance and collapsed along with the INRO. The cause was disagreement among the members, as importing countries refused to adjust the reference price for natural rubber against the background of the financial crisis in Southeast Asia. After the collapse of INRA, various regional organisations took up some of the tasks originally implemented by INRO, such as scientific research, compilation of statistics and technical cooperation between exporting countries (Joseph 2022). These included the International Rubber Research and Development Board (IRRDB), the Association of Natural Rubber Producing Countries (ANRPC) and the International Rubber Study Group (IRSG).

Tanielian (2018) points out that while key countries such as China, India and the EU are represented in the IRSG, key producing countries such as Thailand, Indonesia, Malaysia, Vietnam and the Philippines are not represented. Similarly, although the ANRPC represents more than 90% of the world's rubber suppliers, it would not be able to connect manufacturers and consumers outside of South and East Asia. The lack of exchange between sellers and buyers contributes to unfair pricing mechanisms in the natural rubber sector (Tanielian 2018). ETRMA also emphasised that, with an expanded membership, the IRSG could serve as an ideal platform for sharing natural rubber market data, to increase transparency on pricing mechanisms, showing potential to leverage the role that such organisations could play (ETRMA 2011).

In November 2022, with the *Regional Comprehensive Economic Partnership* (RCEP), the world's largest multi-regional free trade agreement was signed. With, among others, Thailand, Indonesia, Vietnam, Malaysia and China, important growing and purchasing countries for natural rubber in the Asia-Pacific region and the Association of Southeast Asian Nations (ASEAN) are among the member states (Nicita 2021). While the potential for economic growth in the member states is often highlighted against the backdrop of the COVID-19-related crisis in many countries, the Free Trade Agreement does not contain any provisions on environmental or labour rights protection. Nor does it contain any provisions regarding deforestation in the context of agro-commodity exports such as natural rubber or palm oil. In this way, it differs from the *Comprehensive and Progressive Agreement for Trans-Pacific Partnership* (CPTPP), which was adopted in 2018 and contains comprehensive environmental requirements to ensure sustainable commodity imports and the protection of biodiversity. Critics fear that RCEP's lack of reference to environmental and labour protection will contribute to a deterioration in the conditions under which natural rubber is grown (Kine 2020).

India opted out of the RCEP negotiations in 2019, due to concern over the protection of its national interest and industries. However, natural rubber as a key trade commodity for India is covered by the *ASEAN-India free trade agreement* (AIFTA) signed in 2003. Joseph and Hari (2019) point out that under AIFTA, many member states apply a "reverse tariff policy" for natural rubber and natural rubber products: India, Malaysia, Indonesia, Thailand and the Philippines, for example, impose higher tariffs on imports of raw materials than on many of the finished rubber products. This would primarily protect the raw materials sector in their own countries (Joseph and Hari 2019).

Outlook

Global demand for natural rubber is expected to increase steadily with an annual growth rate of 2.4% to 2030. Important factors are the recovery of global automobile production after the pandemic-induced shortages and supply bottlenecks, e.g. for semiconductors, which led to a production stop. Above all, the economic development in countries such as China and India is closely linked to the development of the natural rubber market (RubberWorld 2022). The strong dependence on the cultivation of the *Hevea brasiliensis* tree in certain regions does not allow for nearshoring in the deeper supply chain, but at the level of the customer sectors, i.e. tyre manufacturers and automotive OEMs, it can be seen that there is a tendency to purchase more from regional rubber processing companies in order to safeguard against supply bottlenecks (Kraft et al. 2022). Initiatives to improve sustainability are underway at industry and company level and regulatory as well as public pressure is growing, so that a new market for sustainable natural rubber may emerge in the long term. However, the industry is starting from a rather weak starting point, making it difficult to predict when relevant market shares of sustainably sourced and processed natural rubber will emerge.

Interviews with experts revealed some optimism that new technologies for tracking and tracing environmental impacts, such as drone and satellite monitoring of deforestation sites, will have a positive impact on sustainability along the supply chain. However, expectations for rapid and efficient implementation of sustainability measures throughout the supply chain are rather muted, as the high level of fragmentation at the smallholder famer level makes it difficult to apply standardised measures on a large scale. In addition, experts reported in interviews that the crises of the last few years had led some companies to invest fewer resources in the implementation of sustainability measures – on the one hand, because restructuring of the supply chain due to the pandemic and war required full attention, and partly because inflation and supply shortages had reduced the willingness to invest financially in sustainability.

3.4 Coffee

3.4.1 Introduction/background

Coffee represents one of the most popular drinks in the world as well as one of the most extensively traded commodities with a diverse production base that spans 58 countries. 21% of the world's coffee is produced on large estates and farms (>50 hectares); 19% comes from mid-sized estates and farms (5-50 hectares); and the remaining 60% comes from approximately 12.5 million smallholder coffee farms (and households) with less than 5 hectares of land (Dan Rushton 2019). Although the industry provides a source of income to 100 million people globally, it faces issues related to environmental pollution due to chemical use and poor labour practices. At the same time, many actors across the coffee value chain are vulnerable to climate change and climate-change induced price fluctuations (Dzebo and Adams 2023).

The international coffee trade began in the early 20th century, with Brazil initially dominating the market. Brazil's control extended until the Second World War, when other Latin American countries also became involved. In 1962, the first international coffee agreement (ICA) was signed, establishing target prices and export quotas. However, the ICA quota system collapsed in 1989, because sustaining the expense associated with surplus stock and excess production capacity became unmanageable (Pichop and Kemegue 2006). The subsequent dismantling of supply management organisations in producing countries led to a shift in power dynamics, with roasters gaining in bargaining power and the value chain becoming more buyer-driven (Rebeca et al. 2022).

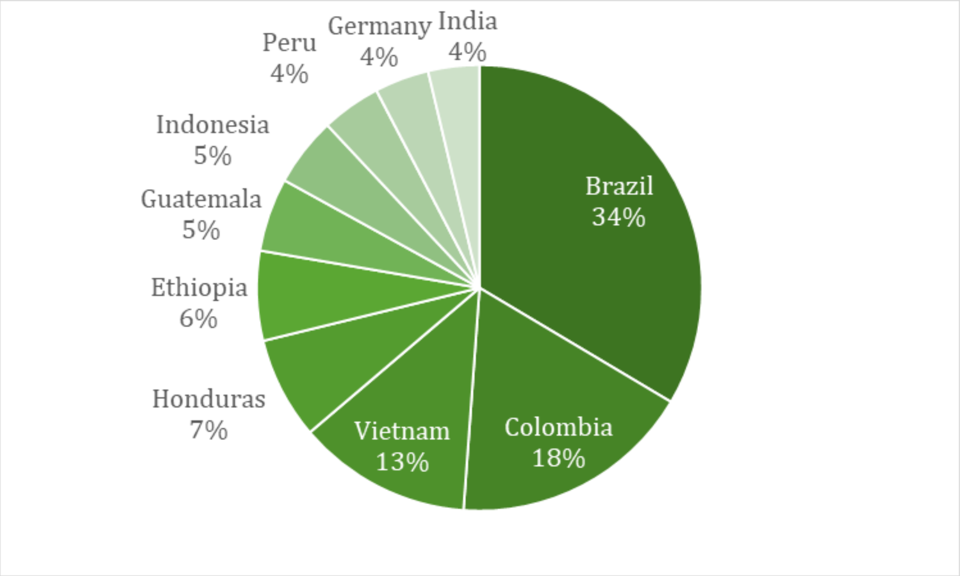
Germany, as the largest importer of green coffee beans in the EU, has a substantial roasting industry that caters to both the domestic and European markets (CBI 2022a). In the year 2021, Germany imported a significant quantity of 1.2 million tonnes of green coffee. Additionally, being one of the largest exporter of coffee products, Germany exported a total of 255.895 tonnes in the same year (Statista 2023e). Germany relies completely on imports, mostly from countries like Brazil and Vietnam. In 2022, Germany imported coffee products worth €5.4B (Statista 2023e). This makes Germany the second-largest importer of coffee in the world after the U.S. (Statista 2023f). Given the high reliance on suppliers of coffee, the following profile focuses on the supply chain of coffee from farming to its sale by retailers/consumer brands.

3.4.2 Market structure

Brazil, Vietnam, and Colombia are the leading coffee-producing countries, contributing significantly to the global coffee supply. On the other hand, the EU and the U.S. serve as the largest consumer and importer markets, driving the demand for coffee on a significant scale (FAO 2023). In 2021, the countries with the largest cultivation area for coffee are Brazil, Indonesia, Côte d'Ivoire, Colombia, Uganda, Ethiopia and Vietnam (Statista 2023d).

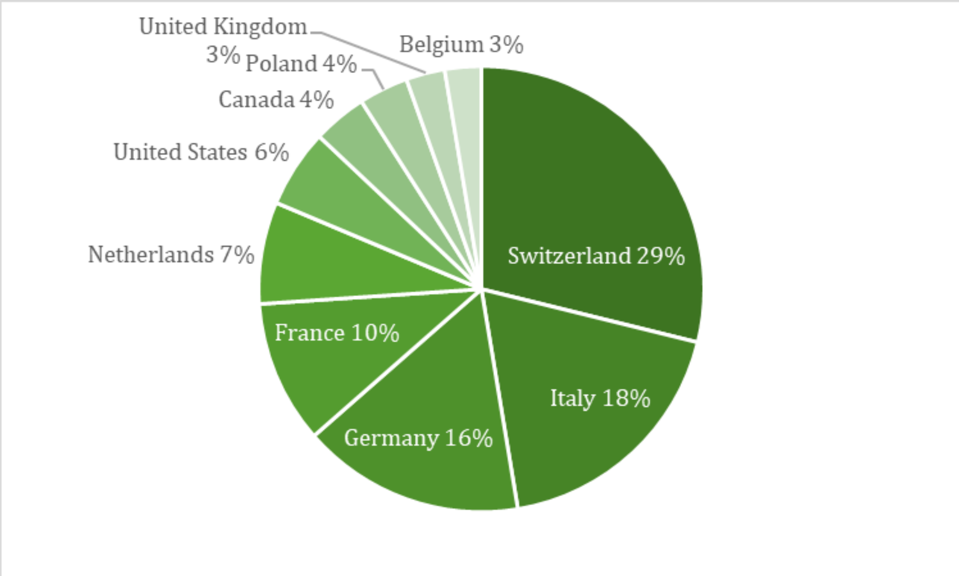
Coffee is overwhelmingly traded in green (unroasted) beans and roasted in the consumption destinations, mostly because of quality reasons, which limits the ability of producing countries to capitalise on value-adding activities. This set-up is supported by differential tariff structures for green and roasted coffee in importing countries (i.e. tariff escalation), and reinforced via roasters' preference for keeping control over the taste profiles of their blends, in which they mix coffee from various origins. However, there are also technological and logistic reasons for this set-up, including, in some origins, the lack of financial and human resources and infrastructure (e.g. reliable electricity) for large-scale processing activities, as well as the relatively shorter shelf-life of roasted coffee compared to green, and therefore preference for roasting closer to the consumer demand (ICO 2011). The top ten countries for green coffee exports are shown in Figure 26, while Figure 27 presents the top ten for roasted coffee.

Figure 26: Top 10 export countries for unroasted coffee in 2021



Source: adelphi, based on information from OEC 2023

Figure 27: Top 10 export countries for roasted coffee in 2021

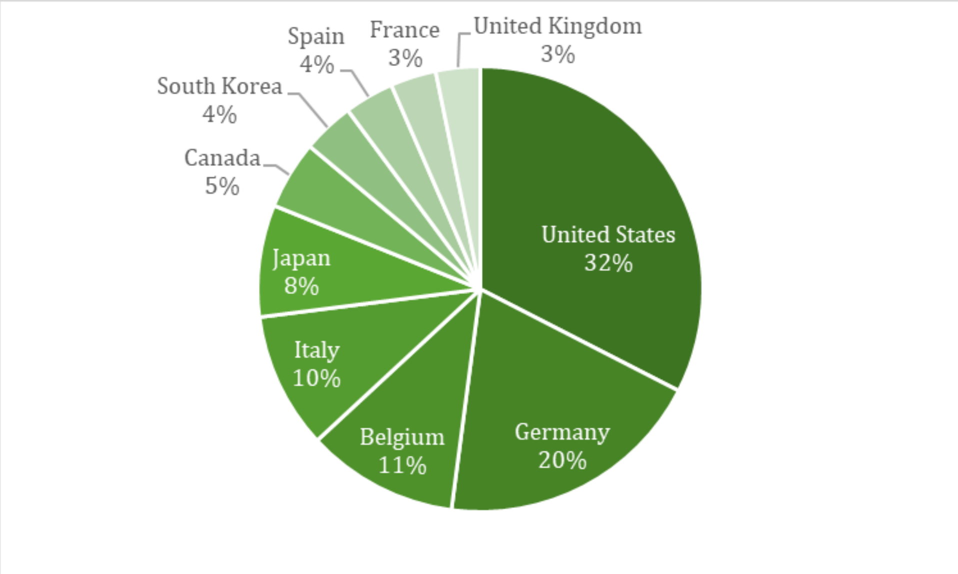


Source: adelphi, based on information from OEC 2023

In 2020/21, Europe was the primary export destination for all forms of coffee, accounting for an average of 46% of exports across different regions, with a range between 38% and 53%. Following Europe, North America and Asia & Oceania held the positions of second and third most important destinations. The geographical proximity and compatibility between the coffee produced and consumed played a significant role in making North America the main recipient of exports from Latin America. Despite comprising 60% of the global population in 2020, Asia & Oceania held the third spot in terms of coffee export destinations. This can be attributed to the relatively underdeveloped local coffee market in Asia and the presence of domestic coffee supply, which limits its prominence as a destination for coffee exports (ICO 2011).

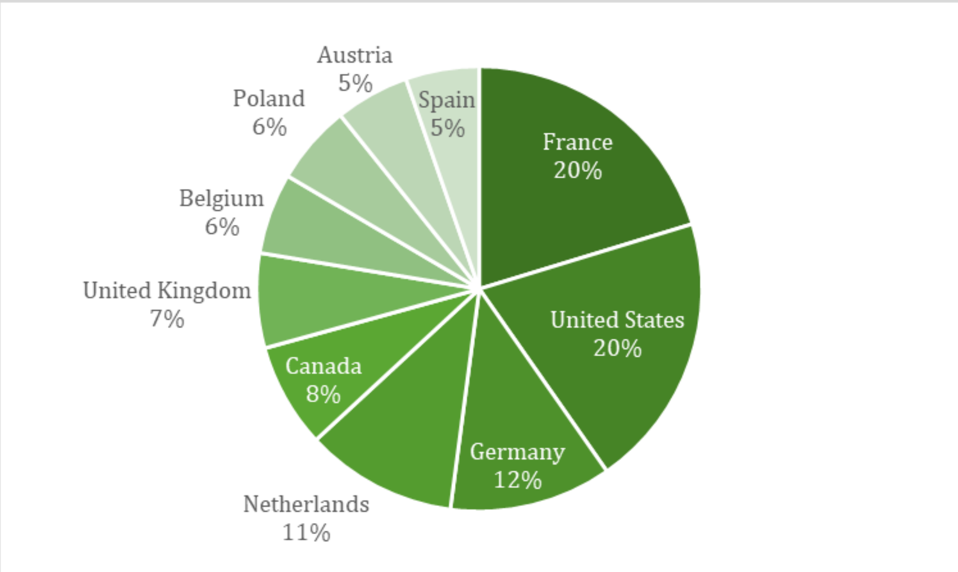
Germany is the third-largest re-exporter of coffee after Switzerland and Italy, followed by France, the Netherlands and Poland in the EU (see Figure 27). At the same time, Germany imports a significant amount of both green and roasted coffee (see Figure 28 and Figure 29). On the global scale, Germany is the second-largest importer of green coffee behind the U.S., followed by Belgium, Italy, and Canada, as seen in Figure 28. Germany was the third-largest importer of roasted coffee in 2021, after France and the United State (see Figure 29).

Figure 28: Top 10 import countries for unroasted coffee in 2021



Source: adelphi, based on information from OEC 2023

Figure 29: Top 10 import countries for roasted coffee in 2021



Source: adelphi, based on information from OEC 2023

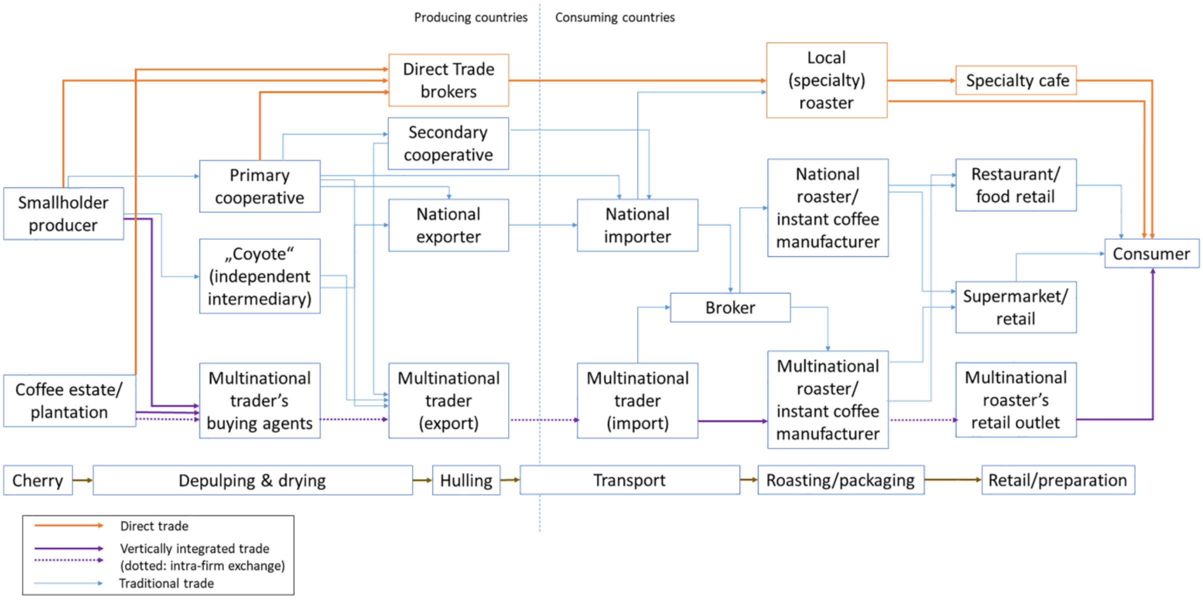
In the year 2020/21, global coffee consumption reached 165.4 million bags (green, equivalent to 9.924 million tonnes). The leading consumer region, Europe, taking a 32% market share, witnessed a decline of 3.6%, whereas North America's market contracted by 0.9%. On the contrary, Asia & Oceania and Africa exhibited robust growth rates, expanding by 9.1% and 3.1%, respectively. The shifts in consumption patterns, marked by a rise in retail and at-home consumption and a decrease in out-of-home consumption, coupled with a thriving global economy, collectively contributed to the coffee consumption increase (ICO 2021).

3.4.3 The coffee value chain

The coffee value chain is highly complex due to its lengthy production steps and its geographical distance between downstream and upstream actors (Marescotti and Belletti 2016). It has numerous production stages and involves various stakeholders, ranging from farmers to end consumers. The coffee value chain often faces scrutiny for its sustainability and accountability practices. In particular, the industry's close association with economically disadvantaged regions, where coffee extraction takes place, has been a subject of criticism (Candelo et al. 2018).

Figure 30 represents an illustration of the coffee supply chain with the involvement and interaction of the various actors. Although there are very strong relationships between origin and destination countries, the actors in the coffee supply chain can be divided into two groups: ones in production countries and the others in the consuming countries.

Figure 30: The coffee supply chain



Source: Grabs and Carodenuto (2021)

The coffee supply chain faces several vulnerability factors that industry, governmental and NGO actors grapple with. They encompass inadequate education, intricate and unstable political and economic conditions in certain countries. In addition, the volatility in markets and pricing, diminished trading capabilities, weakened negotiation power, inequality in information exchanging, the impacts of climate change, and a deficiency in business continuity are also contributed to the supply chain vulnerability.

The coffee industry contributes to negative environmental impacts across supply chain, from cultivation to roasting and end-of-use. Table 13 shows the environmental impacts that are common in the supply chain and therefore relevant for the industry. This does not mean that every impact listed will occur in every coffee supply chain.

Table 13: Main environmental impacts in coffee value chain

Supply chain segments	Environmental impacts
Cultivation & harvesting	Deforestation: the relocation or expansion of coffee farms may lead to the clearance of forests. Deforestation destroys vital habitats, contributes to biodiversity loss, and increases greenhouse gas emissions. This is of particular concern for the future as it is expected that coffee production will move to higher altitudes, which are currently forested.
	Water consumption and pollution: coffee production requires substantial amounts of water for irrigation (though most coffee is currently rain-fed). Improper wastewater management can lead to water pollution, including contamination from agrochemicals and processing byproducts.
	Soil degradation: intensive coffee farming practices, such as the use of agrochemicals and monoculture plantations, can lead to soil erosion, nutrient depletion, and decreased soil fertility. This can negatively impact long-term agricultural productivity and ecosystem health.
Processing and Roasting	Energy consumption and greenhouse gas emissions: coffee production involves energy-intensive processes, such as drying, milling, and roasting. The energy sources utilised, such as fossil fuels, can contribute to greenhouse gas emissions and climate change.
	Waste generation: coffee processing leads to significant amounts of waste (including pulp, husks, packaging waste and wastewater) and inadequate management of the produced waste can result in pollution.

Source: adelphi, based on information from ICO (2020)

Figure 31 shows a summary of the key countries in the coffee value, from cultivation to consumption markets.

Figure 31: Selected key structures and processes of the natural coffee value chain

Source: adelphi, based on material and data from this text

3.4.4 Pricing

The coffee value chain is typically characterised as buyer-driven, meaning that the buyers of the good in question – in this case, coffee roasters – have greater power than mid-stream actors or producers and can influence contract terms and conditions. In the coffee sector, the power of roasters stems, on the one hand, from their high consolidation – only few actors make up over 40% of the retail market, and consolidation has increased in recent years (Grabs 2020). On the other hand, their value chain position close to consumers gives them the power to frame the narratives of what types of coffee are perceived as high quality or sustainable and simultaneously capture the differential price paid by consumers for such goods. Grabs and Ponte (2019) show that, even in a changing market environment, roasters drew on various sources of power to maintain the upper hand in setting expectations that cascaded down the chain without taking on significant shares of costs. These result in asymmetrical price transmission in the coffee supply chain (Ghoshray and Mohan 2021). Moreover, compliance costs are typically passed to producers; even when roasters fund development projects that assist producers on the ground, these are usually small in scale and do not cover the majority of their supply. The funding for such projects also usually comes out of a separate CSR budget, rather than being priced into the good of the commodity itself. Even in the case of certification schemes, premiums tend to be negotiated based on supply-demand dynamics rather than an aim to cover compliance costs (Grabs 2020).

To understand the distribution of costs and added value, it is informative to understand the way prices are set in the coffee market. For reasons of risk management and hedging, coffee – among other commodities – is traded on the coffee futures market (New York in the case of Arabica, London in the case of Robusta). The expectation is that the prices of futures contracts converge with spot market prices upon the time of delivery. Contracts for physical green coffee deliveries thus usually reference futures prices plus/minus a differential based on the country or anticipated quality level, rather than specifying prices outright. The lack of region- or even country-specific futures prices means that different producing origins with very different production costs compete against each other on the world market and that their prices are linked to each other. For instance, if Brazil has a high output, world market prices will decline to reflect this; while the highly efficient Brazilian producers (larger farm sizes on average and possibly using mechanical harvest) may still be able to cover their costs, producers with higher costs – e.g. in Central America – will not and will have to weather long periods where prices lie below their production costs. Speculation on futures markets may further exacerbate price volatility, though that relationship is still contested (Aliaga Lordemann et al. 2021).

Beyond this equalising effect of futures markets on green coffee prices, a lot of value is added and captured during the roasting, packaging, marketing and retail stages of the value chain, which tends to occur in consuming countries and via multi-national roasters who own a wide variety of brands that target various consuming markets. The contrast is particularly stark in out-of-home consumption, where the share of coffee only makes up a fragment of the cost of a cup, with other costs such as ingredients, e.g. milk, labour, taxes, rent of the premises, and overall market and business strategy making up a much greater proportion. Overall, the current estimate suggests that the average export value of green coffee constitutes less than 10% of the $200 to $250 billion in revenues generated within the coffee retail market (Panhuysen and Pierrot 2020).

The rise of demand for higher quality and greater knowledge of producer stories has allowed for the development of a specialty coffee niche, where producers of coffees of extraordinary quality are able to access buyers directly – e.g. via direct trade channels or the Cup of Excellence auctions – and capture higher prices that small-scale, specialty roasters pass on to highly differentiating consumers. The premium status of specialty coffee hinges on the establishment of close relationships between coffee companies and farmers. These relationships are forged by emphasising the coffee's origin and quality, traceability, and potential improvements in the production process. Consumers of specialty coffee are willing to pay higher prices for their brew and, in return, seek knowledge about the beans' origin and cultivation methods. Consequently, the specialty coffee industry aims to communicate the value of origin-centric coffee to enhance its perception of premium quality to increase consumers' willingness to pay higher prices for coffee and the experiences associated with it (Barbosa Escobar et al. 2021). Yet, this model also has its drawbacks. On the one hand, Borrella et al. (2015) find that, while producer prices are higher, they do not receive a higher share of the total price paid by the consumer, meaning that the proportional value capture has not changed. Fischer et al. (2021) show that the high-quality wave may undermine solidary and cooperative values among producer groups as it introduces competitive dynamics on the ground. On the other hand, small-scale specialty roasters themselves often do not have particularly sustainable business models, have to survive on thin margins, and often rely on external financing to survive long-term, whereas the vast majority of consumers are highly price-sensitive and reluctant to pay extra. Additionally, there are challenges related to supply chain vulnerability, which is susceptible to changes in import regulations (such as maximum residue levels), quality fluctuations, and a lack of professionalism in logistics management (lower productivity might increase costs).

3.4.5 Power relationships

Among the various participants in the coffee supply chain, the most vulnerable are often groups of local suppliers, typically unorganised smallholder farmers who supply coffee to other intermediaries like fellow farmers or collectors/traders. Given that cherry coffee has to be processed very quickly, they have little ability to store coffee waiting for better prices and have to accept the day-to-day price offered to them; often they are also in debt, having purchased inputs from the same intermediaries against the promise of future coffee sales and thus have no ability to choose their buyer. They depend on other actors, especially, large corporations within instable markets. Smallholder farmers also face severe consequences from climate change by cultivation activities, which seriously affect their livelihoods. They have to cope with information asymmetries and gaps when establishing relationships with other actors. This lack of information as well as their fragmentation, remoteness, and lack of primary processing capacity reduces their trading and negotiating capabilities. First-level traders frequently exploit these power imbalances by offering lower-than-market prices and underestimating coffee quality (Candelo et al. 2018). It is also difficult for unorganised smallholder farmers to attain sustainability certification due to their lack of capacity and resources. Even beyond smallholder farmers, landless farmworkers are the weakest as their compensation also relies on the farm income and is often limited in the case of small-scale farms while on large farms they may live in exploitative conditions (Specialty Coffee Association 2016) .

In contrast, organised smallholder farmers (cooperatives or farmer groups) are able to pool their crop and overcome the fragmentation that gives commodity producers low bargaining power to a certain extent; their success relies on the quality of cooperative/group management, which can vary significantly. Some cooperatives are also used as vehicles to capture value for their leaders, which negates the potential beneficial function. As mentioned in the previous section, small-scale producers that focus on quality coffee and/or that process coffee at home into dried parchment coffee also have tendentially more power, as they can store their coffee and wait to sell until prices improve. Higher quality is also associated with higher prices, especially if producers score 85 points or above (out of 100 of the standardised scoring system) and have more power in pricing negotiation.

With other actors in the supply chain, traders tend to have power over farmers but not over roasters. Roasters tend to have power over traders. And retailers have more power over roasters, as retailers have influence over the manner in which coffee from roasters is presented to customers. The power pattern is that large actors of all categories (growers, traders, roasters) tend to be more powerful by virtue of their size and market influence.

Depending on types of coffee and types of actors in the supply chain, there are both strategic and occasional suppliers/buyers. For high quality or certified coffee, strategic coffee suppliers/buyers are established. It is also common that traders (small or large) and roasters have both: a stream of certified or otherwise "sustainable" volumes that can be traced better and where longer-term relationships exist, which typically makes up a small share of total volume; and then the larger share which is very much based on a commodity system where producing origins and individual producers are interchangeable.

The power relationships in a global value chain is further elaborated by Ponte (2019) in his book titled "Business, Power and Sustainability in a World of Global Value Chains" and the study by Grabs and Ponte (2019). Besides bargaining power and institutional power (which is mentioned in Section 3.4.8), demonstrative and constitutive power can have some influence in shaping the coffee value chain, in particular (and other GVCs in general). The demonstrative power creates a demonstration effect among competitor suppliers. It works through informal transmission mechanisms between individual actors and is presented by conventions and best practices, including ones on sustainability management – for instance, the demonstrative effects of Starbucks purchasing certified sustainable coffee or Procter & Gamble buying fair trade coffee. On the other hand, constitutive power is found in "broadly accepted norms, conventions, expectations and best practices" (Ponte 2019) and it forms what is acceptable and desirable. In coffee GVCs, this power, for example, is related to effects of new consumption patterns, which are summarised in Table 14.

An examination of the GVC in the coffee sector reveals an imbalance in the global value distribution. The governance structure of the coffee GVC is currently experiencing "diversification and re-consolidation" (Grabs and Ponte 2019). The remarkable growth of the specialty coffee market and the emphasis on high-quality coffee have enabled companies like Starbucks, Keurig Green Mountain, and smaller local specialty roasters to expand their market shares. The specialty segment of the coffee market has been recognised as a strategic long-term investment opportunity. The increased competition in the market has prompted other roasters to strengthen their product portfolios. According to Grabs and Ponte (2019), the recent shifts in the coffee GVC have led to more diverse coffee products. These changes potentially empower producers in coffee-producing countries, especially when introducing new specialty coffees. However, despite these developments, the ongoing efforts to re-consolidate the significant imbalances in bargaining power and the demonstrative power remain. Consequently, those changes suggest that buyers are able to enforce stricter terms on their suppliers (Grabs und Ponte 2019). Based on the study by Gereffi et al. (2005), and in reference to other studies, such as Grabs and Ponte (2019) and Lima and Lee (2023), the governance structure of the coffee GVC is considered as both a market and relational governance type.

3.4.6 Addressing environmental impacts

Since the coffee industry is highly susceptible to the impacts of climate change, small-scale farmers who lack the financial means to relocate their coffee production in response to changing conditions face significant challenges. This situation may result in the unfortunate circumstance where farmers are forced to cease coffee cultivation entirely (ICO 2020). Fluctuating weather conditions, such as higher temperatures and increased variability within seasons, negatively affect coffee yields and quality. Furthermore, climate change leads to reduced water availability and the emergence of new pests and insects, adding further pressures to coffee production in many producing countries.

Research conducted by Sachs et al. (2019) indicates that climate change could lead to the loss of 63-75% of available land for coffee farming within the next three decades, higher than that from the study of Bunn et al. (2015) at 50% by 2050. Consequently, coffee plantations will need to relocate to more favourable areas. However, small-scale farmers may face challenges in migrating, potentially resulting in the abandonment of coffee production (Sachs et al. 2019). As coffee production shifts from lower altitudes to higher altitudes, which are predominantly forested areas, deforestation becomes a consequence. Until recently, coffee has played a relatively small role in global deforestation (Pendrill et al. 2019). Mitigating the issues of deforestation, improvement of local regulations (or implementation) for land conservation, and import regulations to ensure that commodity supply chains are completely deforestation-free may be needed (Basik Treanor and Saunders 2021).

A study by van Rikxoort et al. (2014) highlights that the carbon footprint of coffee is influenced by various factors. These include emissions stemming from soil management, with a notable emphasis on drained organic soils and forest clearance (Barthelmes 2018; Kruid et al. 2021). Additionally, fertiliser production and methane emissions formed during pulping and fermentation from wet processing (ICO 2020) also contribute to carbon footprint of the coffee production. The excessive use of fertilisers and other agrochemicals leads to soil degradation. This phenomenon has emerged as a consequence of the trend toward “technified” or very high productivity systems (“high-input, high-output”). This approach is particularly prevalent in major coffee-producing regions like Brazil, Vietnam, and Colombia. However, plenty of producers around the world use less inputs than would be optimal for them.

In coffee farms around the world, shade trees are planted to protect the coffee plants. These trees offer various benefits, including protection against temperature fluctuations, erosion, and excessive radiation. However, many studies, for example from Muñoz-Villers et al. (2020), Piato et al. (2020) and Koutouleas et al. (2022), suggest that while the use of shade trees has its advantages, there may also be trade-offs in terms of productivity and quality.

Wet processing of coffee requires substantial amounts of water, and the wastewater produced during fermentation often contains high levels of acidic nutrients. Small-scale farmers who perform home processing often dispose of this water by infiltrating it into the soil, which can result in the contamination of downstream water supplies for both humans and animals (ICO 2020). Using large volumes of water can be a consequence of technological path dependence (wet milling established at a time of water abundance) and lack of local regulation (implementation), and also price pressure (better practices cost money). Alternative systems (ecological wet mills (Kraft n.d.) or dry mills) exist, but investment costs are often too high for local actors and need to be covered by third parties such as donors.

Assuring environmental standards

There have been substantial efforts to improve the coffee sector’s sustainability by training farmers in sustainable practices (e.g. integrated pest management (Oliveira et al. 2021; Bikila Takala 2023), or agroforestry) and providing capacity-building on a number of issues (e.g. financial literacy, book-keeping, gender equality, youth empowerment). Such training programmes are offered through development cooperation, company-internal projects (e.g. Tchibo Truemorrow initiative (Tchibo n.d.)), sector initiatives (e.g. the Global Coffee Platform’s Collective Action Initiatives (Global Coffee Platform n.d.)), as well as more systematised certification and verification schemes. Moreover, agri-businesses and investors operating in the coffee supply chain can use the *OECD-FAO Guidance for Responsible Agricultural Supply Chains* as it offers a unified framework and universally applicable standard for methodically recognising, evaluating, and addressing adverse effects on both people and the environment within their supply chain (OECD and FAO 2016).

There are several certification schemes for coffee (see Figure 32). The most widely used are Fairtrade (both Fairtrade International and Fairtrade U.S.), Rainforest Alliance (UTZ merged with Rainforest Alliance in 2018), Common Code for the Coffee Community (4C), USDA Organic, and the European Union organic certification. Roasters have also set up their own company-internal standards such as Starbucks' C.A.F.E Practices and the Nespresso AAA programme.

Figure 32: Selected certifications in the coffee supply chain

Source: CBI (2022c)

Among the various certificates available, there is still a notable gap in comprehensively addressing GHG emissions, which have become a significant concern. Each certificate has its own features. For instance, Rainforest Alliance addresses a wide range of environmental and social aspects, including deforestation, biodiversity, soil quality improvements, increased income, and improved conditions for workers. The Smithsonian Bird Friendly standard sets high standards for agroforestry production with the goal of conserving habitat and protecting migratory songbirds. However, the broader protection of biodiversity has only been marginally addressed by these certifications.

Until recently, environmental improvements have been mainly demand-driven and framed as CSR to use as differentiator for consumers. Buyers will require certification and signal that demand to traders, who then look for the respective volumes, though a number of producers also pre-emptively adopted certifications because of an expectation of higher prices and improved market access (Grabs et al. 2016). When certification is demand-driven by traders, traders would often be the certificate holders and support producers in getting the certification, particularly regarding larger capital expenditures, but they would also select producers that were close to meeting the standard to minimise such costs. When producers decide by themselves to get certified, they assume all the costs. Certification premiums are generally small and are not seen to cover the costs of compliance (Grabs et al. 2016; Grabs 2020).

The assurance of environmental and social certification standards is generally provided via third-party auditors that are selected and paid by the certificate holder. This generates conflict-of-interest problems as all actors involved have an aligned interest in finding farms compliant, as auditors want to generate multi-year business relationships with certificate holders. Industry insiders speak of widespread cases of fraud, rent-seeking, and a lack of confidence in third-party certification's traceability and assurance systems.

At present, buying companies are expected to take on responsibility, especially to comply with due diligence regulation. But, the mechanism of cascading expectations down is the same, as changes have to happen on the farm-level.

A movement toward broader supplier screening as has happened in other industries is only just starting to happen in the coffee sector on a wider level, particularly in response to the *EUDR*.

3.4.7 Current/future trends and developments

The European coffee market is witnessing significant changes, including the growing demand for specialty coffee, expansion of trading company portfolios, and the rise of direct trade and relationship coffee models. Online sales and subscriptions are becoming popular, and consolidation is evident in the mainstream coffee segment. On the consumer side, there is increasing interest in high-quality and sustainable coffee, a curiosity about coffee origin, and a concern for social and ecological impacts. Certified coffees and decaffeinated options are gaining traction (CBI 2020b). In terms of technology, digital platforms and marketplaces facilitate direct trade, while blockchain can be used to enhance transparency and traceability (Singh et al. 2022). Efforts are being made to address the environmental impact of coffee capsules through recyclable and compostable solutions, as well as capsule recycling initiatives. These trends reflect the industry's commitment to transparency, sustainability, and innovation.

The COVID-19 outbreak showed that the coffee GVCs are fragile. They faced challenges due to a diminished labour supply, disruptions and delays in the supply chain. Many producing countries have health infrastructure below the global average, limiting their ability to respond effectively to health crises. Additionally, when the diversification in the supplies is lacking, stocks and inventories are diminished, and logistics operations are redundant, the overall system is susceptible to shocks (ICO 2020).

Table 14: Regulation, market, consumer and technology trends

Regulation trends	▶ Rise of Due Diligence and Green Claims requirements from the EU, Germany, … ▶ Require large companies to increase transparency on human right issues and implement human rights due diligence in their operations and their supply chain ▶ Require more collaborative efforts among key stakeholders
Market trends	▶ Specialty coffee is growing in the European market, which has led to large trading companies expanding portfolio with specialty coffees ▶ Specialised independent trading companies import small volumes of high-quality coffees ▶ Micro-lot exports of high-end coffee roasted in the origin country ▶ Direct trade and relationship coffee models are growing ▶ Online coffee sales and subscriptions are increasing ▶ Increasing consolidation in the mainstream coffee segment
Consumer trends	▶ Increasing interest in high-quality and sustainable coffee ▶ Growing interest in coffee origin ▶ Buying single origin (single variety) coffee ▶ Interesting in "selling of stories" on the coffee packages ▶ Concern about social and ecological impacts

	▶ Health living trends from health benefits from appropriate coffee intake ▶ Growing interest in decaffeinated coffee and specialty decaf coffees due to concerns about high caffeine intake.
Technology trends	▶ New fermentation techniques: carbonic maceration, aerobic fermentation, anaerobic fermentation ▶ Digital platforms and marketplaces connect producers and roasters ▶ Online trading sites facilitate direct trade ▶ Blockchain is gaining ground as a tool to increase transparency and traceability ▶ Increased traceability and digital tools enable consumers to connect with coffee farmers and understand the environmental impact of their consumption ▶ Industry efforts to address the negative environmental impact of coffee capsules through recyclable, compostable, and bio-based solutions, as well as initiatives for capsule recycling

Sources: adelphi, based on information from CBI (2022c)

3.4.8 Institutional incentive mechanisms and barriers

Trade policies

Since the International Coffee Agreement's quota system collapsed in 1989, the global coffee market is organised in a liberalised, free market fashion, with little appetite from most producing or consuming countries to return to supply management. For instance, Tanzania has issued their regulations around coffee export and marketing. In spite of a liberalised, free market context, tariff escalation continues to be an issue, with the EU, Switzerland, the UK, and Japan (but not the U.S.) implementing higher tariffs for roasted, decaffeinated, and soluble coffee than for green coffee according to the WTO's most-favoured-nation (MFN) rates. While bilateral and multilateral Free Trade Agreements and other preferential trade agreements (e.g. Everything But Arms, GSP+, etc.) reduce the de-facto tariff barrier for many exporting countries, this is not true for all countries and products – as an example, Brazil is charged the EU's standard MFN rate on all exports of soluble and instant coffees (ICO 2011).

Environmental regulations in supplier countries

There is a wide range of environmental legislation in producing countries, which tends to correlate with their overall governance performance. In most cases, coffee is not regulated separately but as one agricultural activity of many, which may affect forest cover and pollution levels (e.g. Brazil's Forest Code). In other instances, there are country-specific path dependencies that led to a specific outcome (e.g. in Costa Rica, where the vast majority of coffee is wet-milled, a voluntary agreement between all mills in 1992 led to the installation of water treatment plants in each mill). While it is difficult to provide a comprehensive overview, in general environmental regulations in producing regions are weaker (e.g. with regard to approved pesticides, the use of personal protection equipment, or natural habitat conservation) and less well enforced than in the Global North (Grabs 2020).

Environmental regulations in consumer markets

In consumer markets, safety and environmental requirements play an important role on regulating imported coffee. As a result, imported coffee must meet criteria for food safety, food contaminants, quality, packaging and labelling, CSR and sustainability. These encompass adherence to (future) environmental and sustainability regulations in the EU, such as CSDDD, CSRD and EUDR. Among them, EUDR is considered to have the greatest potential to improve traceability in certain commodities classified as deforestation-risk commodities (natural rubber, soy, beef, palm oil, wood, cocoa, coffee). It could have a major impact on coffee exports, especially for smallholders and in those situations where there is currently little traceability on deforestation issues at the farm level.

While environmental regulations vary and consumption patterns differ, environmental and sustainability strategies for compliance to those regulations are still highly concentrated in multinational corporations such as Nestlé, JAB Holding and similar entities. Nevertheless, it is worth noting that these strategies generally align with the prevailing trends in national-level environmental legislation (Grabs 2020).

Voluntary standards/commitments

In the wake of liberalisation and under pressure from structural adjustment programmes, many producing countries (especially in Africa and Asia) dismantled their coffee institutions (e.g. marketing boards, coffee councils) and left coffee production up to individual farmers' choices. Other producing countries, especially in Latin America, however, refocused their institutions and created powerful quasi-state entities (e.g. the Federación Nacional de Cafeteros de Colombia, the Instituto del Café de Costa Rica) that provide institutional support, e.g. in the form of oversight of coffee contracts and pricing (Costa Rica), and the provision of distributional payments and social investments funded through export taxes (Colombia) (Grabs 2020). In recent years, a number of producing countries have also re-strengthened coffee-focused government authorities as well as public-private partnerships (e.g. the Honduran National Coffee Platform, supported via the Global Coffee Platform). Such institutional arrangements, which bring together public and private stakeholders on a national level, may be important arenas to socialise new (environmental) requirements from importing countries and look for sectoral action to address them.

On an international level, there have also been continued efforts to create multi-stakeholder partnerships and forums for public-private interaction. Key arenas here are the Sustainable Coffee Challenge, the Global Coffee Platform, and the International Coffee Organization's Public-Private Task Force. In addition, industry associations such as the Specialty Coffee Association (SCA) and the European Coffee Federation provide opportunities for sectoral actors to connect. While these arenas have been important to raise awareness and achieve low-hanging-fruit wins, the presence and dominance of large industry actors limits the ability of these forums to initiate structural change that tackles existing power relations.

Outlook

Overall coffee demand in the U.S. and European market is consolidated but there will likely be a continued shift from conventional to specialty coffee and from roasted beans to capsules (which lowers the volume/cup and hence lowers potentially import volumes) according to several market studies such as by Grand View Research (2021), Market Research Future (2022), and statistic data by Statista (2023a).

Small-scale mechanisation (e.g. hand-held harvesting machines (Perfect Daily Grind 2017), small tractors able to work on hillsides) might increase labour productivity, especially important as some regions are battling labour shortage especially during harvesting time. Improved cultivation techniques might boost the yield as well. Shade production might reduce the coffee quality and productivity of coffee fields unless they are carefully implemented. However, there may be a renaissance of shade production systems as more resilient production systems capture carbon on-farm. These systems allow for insetting and lower carbon footprint. The development of disease-, heat-, or drought-resistant varietals is likely to ensure more even harvest under climate change conditions. But it requires producers to replant, which can lead to breaks in income for several years.

Despite the growing consumer demand for coffee and increased production in coffee-producing nations, the primary influence and control in the coffee industry still predominantly reside in importing countries, mainly developed economies. This is where significant value is added to the coffee through processes like roasting, packaging, marketing, and retailing by multinational coffee roasters. Consequently, inequalities in the coffee GVC are typically divided between two main groups: the coffee-producing countries and the coffee-consuming countries. Numerous initiatives spearheaded by multinational coffee roasters have been established with the aim of supporting coffee farmers and promoting sustainability in the coffee supply chain. However, it should be noted that, with the new regulatory requirement in consumer countries, such as for corporate sustainability due diligence or the substantiation of green claims in EU, small and medium-sized suppliers can face significant challenges, especially because they generate insufficient turnover to justify the establishment of audit and control systems or the expenses related to reporting to regulatory authorities. Furthermore, as seen in case of German importers, there might be an increase in the costs linked to the compliance of the laws, such as German supply chain act. Consequently, German import companies might reduce their involvement or adjust their procurement volumes in specific countries (Felbermayr et al. 2021).

3.5 Iron ore-steel

3.5.1 Introduction/background

Iron ore is by far the most commonly mined metal in the world with a large part of globally mined iron ore being processed into steel and steel products (Mallinger and Mergili 2022; U.S. Geological Survey 2023a). Iron, the steel made from it and steel scrap represent essential materials in the engineering and construction industry. Worldwide, more than 6 million people work in the steel industry and 49.3 million are employed in jobs indirectly connected to it.[30] Iron ore mining and iron and steel production are associated with a variety of negative environmental and social impacts (see Table 15). These include, for example, the large amounts of GHG emissions generated by the steel industry, which is responsible for 30% of industrial emissions or 6-8% of total GHG emissions in Germany, the latter also applying to the global level (IEA 2020; Bookhagen et al. 2022; Harpprecht et al. 2022).

Iron has played a crucial role in the history of mankind and has been used in the form of tools since 1200 BC (Küblböck et al. 2022). Forms of steel have been made of iron since the 11th century BC and it has been produced industrially and in larger quantities since the 1850s, when it contributed heavily to processes of industrialisation. While steel production was historically concentrated in Great Britain and later in the U.S. and Germany, the new possibilities of worldwide transport, communication and cooperation, as well as industrial development in Asia since the Second World War, led to a shift in production capacity and a globalisation of the industry (Allen 1979; World Steel Association n.d.). Since the middle of the 20th century, the production and use of iron and steel has increased considerably (Mallinger and Mergili 2022). Over the past 20 years, the production of iron has nearly tripled, from just over 1 billion tonnes in 2000 (Kerkow et al. 2012) to 2.6 billion tonnes in 2022 (U.S. Geological Survey 2023a). Steel production increased tenfold between 1950 and 2021 (World Steel Association 2022).

While the last iron ore mine in Germany closed down in 1987 (Kerkow et al. 2012), Germany is still the largest steel producer in the EU and was the world's seventh largest producer of

[30] In the EU, 2.5 million people are directly or indirectly employed in the steel industry. In 2021, 308,000 were directly employed in the industry, including 81,500 people in Germany (Bookhagen et al. 2022).

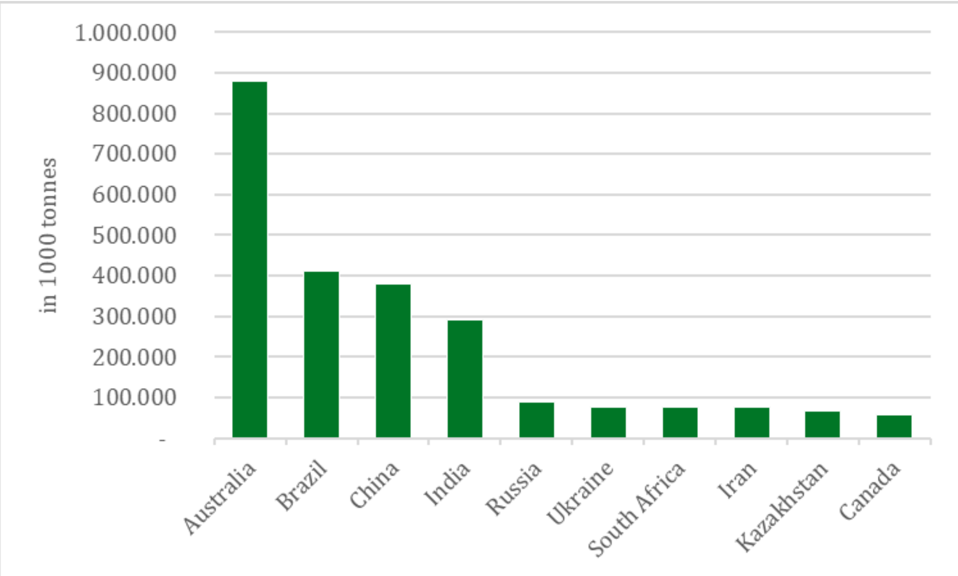
raw/crude steel in 2021 after China, India, Japan, the U.S., Russia and South Korea (World Steel Association 2023). 27% of crude steel produced in the EU in 2022 (with the EU having a share of 7.2 % of global production) came from Germany (EUROFER 2023). In order to meet the needs of the domestic steel industry, Germany imports iron ore, pig iron and additional steel products. Iron and steel combined therefore ranked 9th among Germany's imports in 2021 (OEC 2023b). Steel is particularly important for the German construction and automotive industry, which consumed 35% and 26% of German steel consumption in 2019, respectively (Bookhagen et al. 2022). Globally, patterns are similar, with the remaining steel mainly used for machinery, metal goods and tubes (DERA 2019). Iron and steel account for more than 60% of the material used in car manufacturing, as they are used not only for the body, but also for the chassis, transmission, wheels, suspension and brakes. Production facilities also rely on steel, which is used in robots, conveyors and tools (Kerkow et al. 2012; Weiss et al. 2022). Given the automotive industry's high reliance on suppliers of steel and steel products, the following profile focuses on the supply chain for steel sheets used in the automotive industry as an iron ore-based commodity.

3.5.2 Market structure

The various sectors involved in the iron ore-steel supply chain are highly concentrated, both with regard to the mining of iron ore as a raw material and the processing into pig iron and steel (Küblböck et al. 2022).

Iron ore is mainly mined in LSM structures dominated by large global corporations. Similarly, iron ore production is highly concentrated geographically. In 2022, the four market leaders Vale, Rio Tinto, BHP Biliton and Fortescue Metals Group alone accounted for 80% of worldwide production (Global Times 2021; Küblböck et al. 2022).

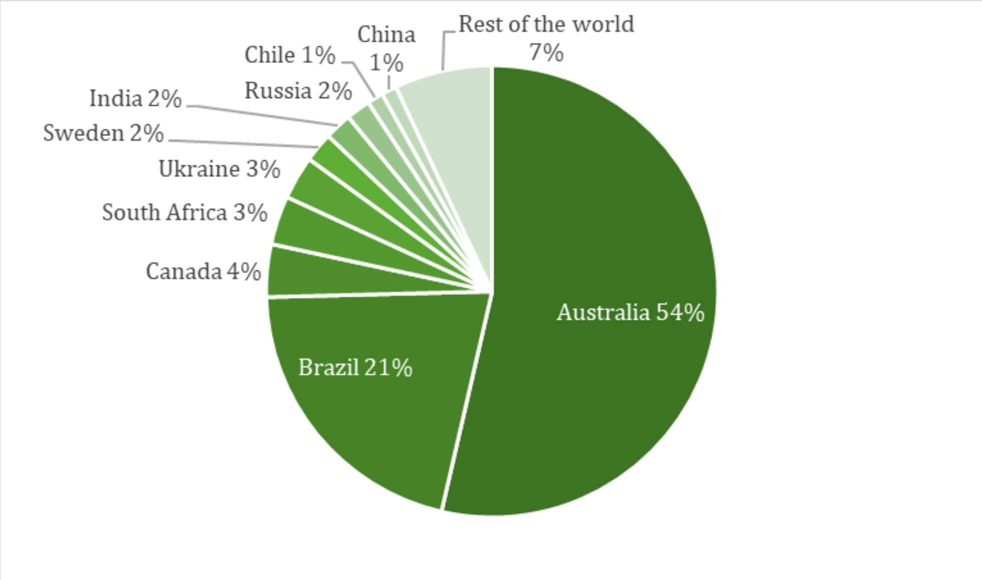
Figure 33: Globally leading iron ore producing countries in 2022, by country



Source: adelphi, based on information from U.S. Geological Survey 2023a

Geographically, Australia, Brazil, China and India were the biggest producers of iron ore, accounting for 75% of global production (DERA 2019; U.S. Geological Survey 2023a) (see Figure 33). As shown in Figure 34, exports are led by far by Australia and Brazil, while China and India retain most of their iron ore production for domestic steelmaking (OEC 2023c).

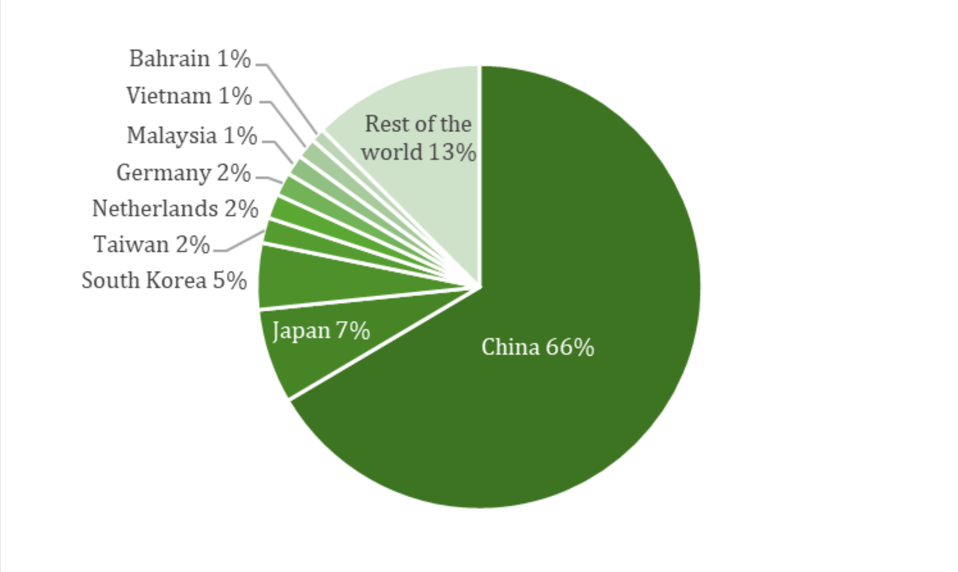
Figure 34: Leading iron ore exporters in terms of value in 2021, by country



Source: adelphi, based on information from OEC (2023b)

Germany is entirely dependent on the import of iron ore. In 2021, Germany imported just under 40 million tonnes of iron ore worth $3.7 billion, mainly from South Africa (27.1%), Canada (23.1%) and Brazil (18.8%), followed by Sweden and Russia. This makes Germany the 6th largest consumer market for iron ore in the world after China, Japan, South Korea, Taiwan and the Netherlands (Destatis 2022; OEC 2023d) (see Figure 35). Overall, however, Germany's share of total global consumption in 2021 was only 1.7%, as China alone accounted for 66% of global iron ore imports worth $146 billion, while Japan and South Korea imported a further 11%. The iron ore market is thus heavily dominated by a few Asian countries (OEC 2023c).

Figure 35: Leading iron ore importers in terms of value in 2021, by country



Source: adelphi, based on information from OEC (2023b)

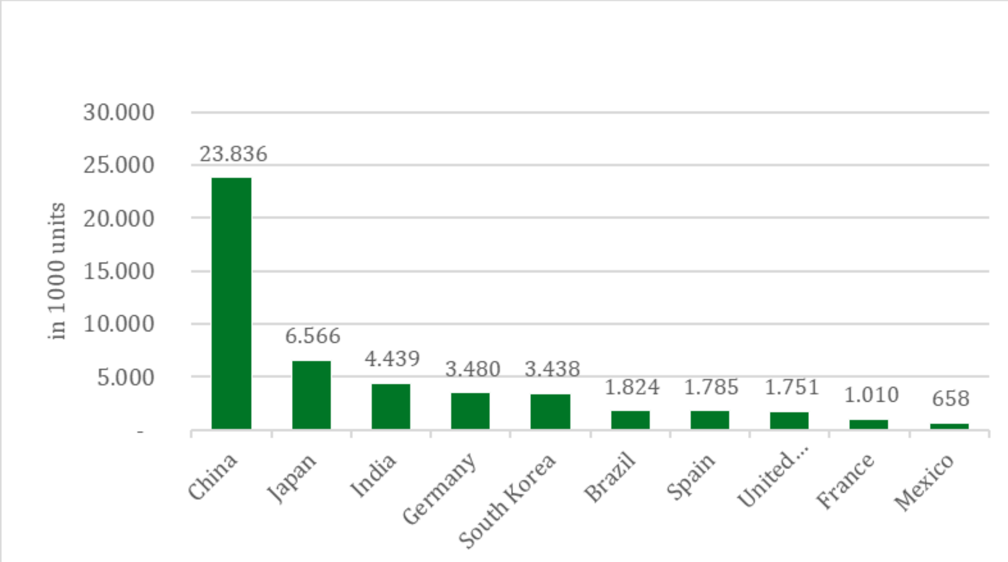
Market dominance is even more pronounced for pig iron and steel. In 2022, more than 60% of global pig iron was produced in China, followed by India, Japan and Russia with much smaller quantities of four to six percent each (U.S. Geological Survey 2023a). In comparison to iron ore and steel, world trade in pig iron is rather small, as its form (liquid hot metal) makes its trade very inefficient. It is therefore largely produced by steelmakers as an intermediary product in steel production. The steel industry therefore usually only buys pig iron on the market to compensate for possible discrepancies between its own production and the quantities required for steel production (Schlemme et al. 2019). The following profile will therefore focus on iron ore as the main input material for steel production.

In terms of steel production, China is again the market leader with a share of more than 50% of global steel production. It is followed by India (6.1%), Japan (4.9%) and the U.S. (4.4%) (U.S. Geological Survey 2023a). Germany produced around 40 million tonnes of crude steel in 2021, making it the eighth-largest steel producer in the world and the largest in the EU (EU27) (Wirtschaftsvereinigung Stahl 2022). The three biggest steel producers in Germany are Thyssenkrupp, ArcelorMittal und the Salzgitter AG (BMWK n.d.). In 2021, global steel exports were led by China, Japan, Russia and South Korea, followed by Germany (23.9 million tonnes), which is at the same time the third largest importer of steel after the U.S. and China, importing 23.3 million tonnes of steel in 2021 (World Steel Association 2022). German steel exports go mainly to EU countries (80%) (Wirtschaftsvereinigung Stahl 2022), while an industry expert stated in an interview that imports to Germany also come mainly from European countries such as Italy, the Netherlands, France and Belgium. This is supported by figures from EUROFER on market supply to European consumers of hot-rolled flat steel products and cold-rolled steel sheets – both of which are important for automotive production: in 2022, more than 75% of the EU market supply of hot-rolled flat products came from European suppliers, while for cold-rolled sheet about 68% of EU demand could be met by European deliveries. For both product types, therefore, only 25 to 30% each was covered by imports from third countries (EUROFER 2023).

Since the German trade balance in steel is almost even, Germany does not appear in the list of the largest net exporters and importers of steel. Indirect exports, however, are much higher. For example, 28.1 million tonnes of rolled steel were exported as a component of cars and machinery (Wirtschaftsvereinigung Stahl 2022).

As these number already suggest, the automotive industry is one of the most important consumers of steel products – on average, 900 kg of steel is used in a vehicle (World Steel Association n.d.). Globally, automotive production is dominated by companies from China, Japan, India, South Korea and Germany with the Chinese production being higher than those of the following five countries combined (OICA 2022) (see Figure 36).

Figure 36: Leading car producers in 2022, by country



Source: adelphi, based on information from International Organization of Motor Vehicle Manufacturers (OICA) 2022

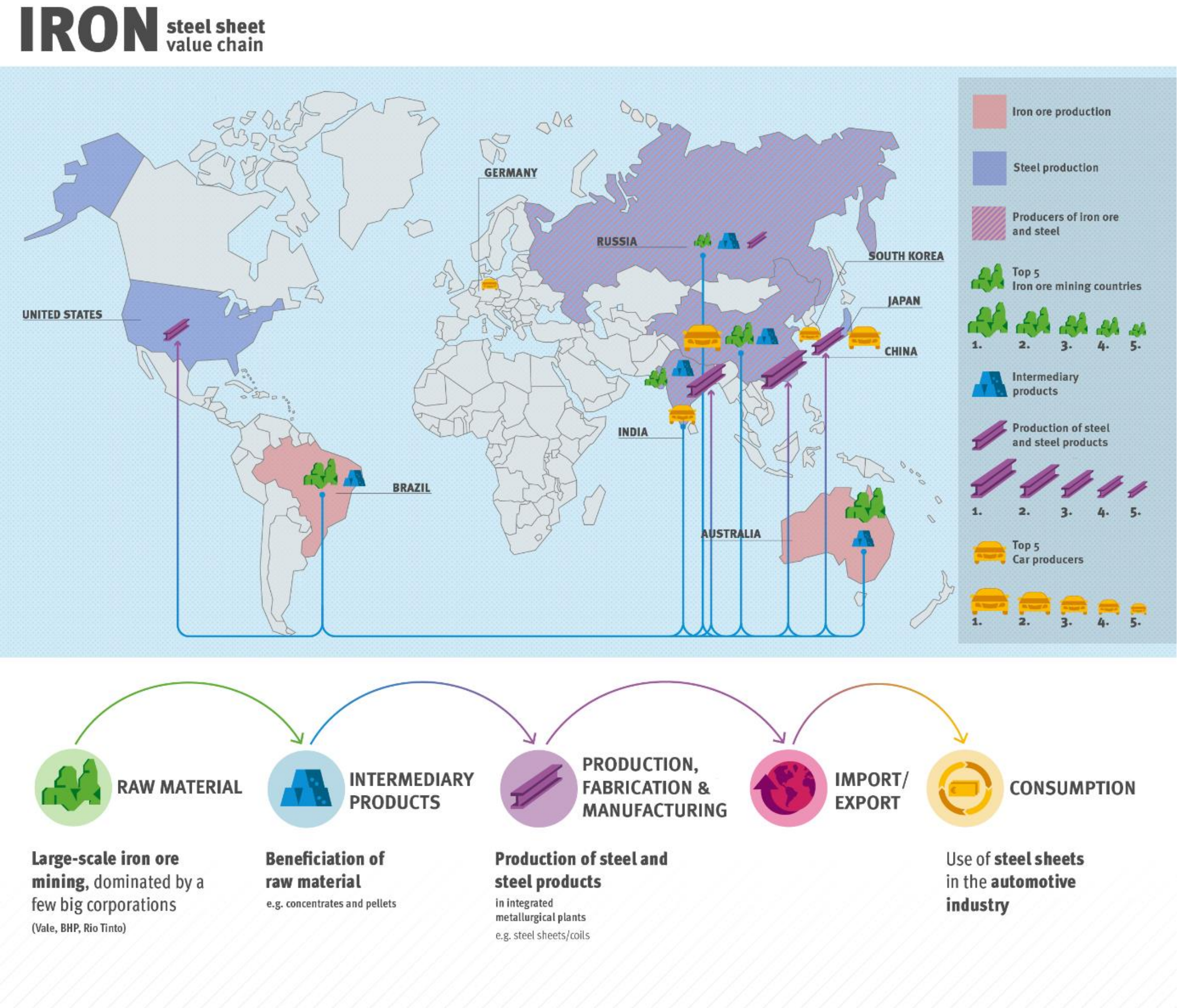
Leading car manufactures include Toyota (11.5%) Volkswagen (6.7%), Honda (5.4%), Hyundai (5.2%) and Nissan (4%), followed by the German brands BMW (3.1%) and Mercedes-Benz (2.9%) (Statista 2023c). In the EU, the automotive industry accounts for 17% of European steel consumption. Germany is the biggest European producer of cars with 42 car factories located in that country (31 in France, 23 in Italy, 17 in Spain). Germany's car exports, worth 92€ billion, account for 59% of total European exports (Grigorenko 2023). In 2022, the three biggest German car manufacturers Volkswagen, BMW and Mercedes-Benz had a revenue of 279.2€, 150.0€ and 142.6€ respectively (Statista 2023b).

3.5.3 The iron ore-steel value chain

Since the maritime transport of bulk commodities such as iron ore has become common, the international iron and steel value chain has become increasingly globalised, with mining companies supplying steelmakers all over the world. But it is particularly China's and other Asian countries' industrial development and growing importance in the iron and steel market that has led to an increase in the trade of iron ore (Küblböck et al. 2022).

The **iron ore-steel value chain** comprises a number of steps, such as the extraction of the mineral, the beneficiation of the raw material, transportation and/or export/import, the production of crude steel and the finalisation of diverse steel products through refinement like steel sheets that are being used in the automotive industry. Figure 37 displays a simplified typical value chain from iron ore mining to the consumption of steel sheets in the automotive industry. Depending on the product and the individual value chain, the production process can include a varying number of suppliers (between automotive OEM and steel maker there can be intermediate suppliers/producers of components), but compared to other metallic raw materials, the iron ore-steel supply chain is relatively short, as confirmed by several experts in interviews. This is mainly due to the fact that large mining or steel companies often combine different processing steps (see Section 3.5.2).

Figure 37: Selected key structures and processes of the iron ore-steel value chain



Source: adelphi, based on material and data from this text

The main input materials used for the production of steel today are coking coal, iron ore and steel scrap. There are two main methods for the production of steel that are based on these materials. Steel production via the blast furnace-basic oxygen furnace (BF-BOF)[31] technique dominates global production, accounting for 71.5% in the year 2022. The second method is based on steel production in electric arc furnaces (EAF)[32] and made up 28.2% of global steelmaking in 2022 (World Steel Association 2023). Similarly, in Germany, around 70% of steel was produced via the BF-BOF route and the remaining 30% via the electric steel route in 2022 (Wirtschaftsvereinigung Stahl 2022). Steelmaking that is based on iron ore accounts for around 70% of global crude steel production, while the rest is obtained from steel scrap (IEA 2020).

As described in Section 3.5.2, international iron ore production is concentrated in only a few countries. The great majority of iron ore is mined in LSM[33]. While some of the ore is exported directly to Europe and Germany (in the form of lumps or fines), part of it is directly processed by the mining company itself or a separate processing company before it is purchased by steelmakers or traders. If this is the case, the beneficiation usually takes place in the country of origin or in regional proximity. Whether the ore is beneficiated before being sold depends mainly on its quality. Direct-shipping ores (DSO) with between 55% and 65% Fe (iron) content are usually exported directly. Lower quality ore is often processed/beneficiated by the mining company to increase its iron content, thus achieving iron ore concentrates which in turn may be used directly or further processed into pellets (Hannah and Fan 2021). Mining companies therefore usually offer a diverse portfolio of intermediary iron ore products of different qualities (measured by Fe content and impurities). The higher prices that can be obtained for products with higher Fe content (higher grade) and lower impurity levels often make beneficiation economically worthwhile for mining companies (Kim et al. 2022).

After beneficiation, iron products marketed in the form of pig iron, concentrates or pellets are sold to traders, steel service centres (SSCs), producers of intermediary products or directly to steelmakers – with the iron ore products usually being exported as part of these process steps. As suggested by the experts interviewed for this study, reasons to sell to traders include the lack of capacity or means of smaller mining companies to store the raw material and handle the complex sales process including contracts, shipment and discharge of the material. While direct contracts with mining companies are often preferred, interviews with industry experts suggest that a small share (maximum: small double-digit share) of iron ore is bought from traders for the European market. Steelmakers then metallurgically process the material using various refining processes, which usually take place in large integrated steelworks complexes (Kerkow et al. 2012; Weiss et al. 2022).

[31] The production of steel in the blast furnace (BF) uses coking coal as a reducing agent to extract oxygen from the ore, resulting in the production of pig iron. This method is usually paired with basic oxygen furnaces (BOF) in which the melted pig iron is further purified through the injection of oxygen and subsequently receives secondary metallurgic treatment, e.g. the adjustment of its chemical composition and the adding of certain properties which give the crude steel its final quality (Küblböck et al. 2022; Hannah and Fan 2021; Stahlinstitut VDEh 2023). This process is also referred to as the primary steel production process, which uses iron ore as the main input material. In addition to iron ore, steel scrap usually accounts for 15-25% of the feedstock (IEA 2020).

[32] Steel production in EAFs mostly relies on the use of scrap steel (scrap-based EAF). Additionally, directly reduced iron (DRI) is used, resulting in the so-called DRI-EAF route. In the process, oxygen is removed by blowing hot gases (carbon monoxide and hydrogen) through the material to produce directly reduced iron (DRI) or so-called sponge iron (tec-science n.d.). Due to the use of gas as a reducing agent, the process takes place at lower temperatures so that the iron ore in the DR plant is reduced in a solid state. DRI therefore still contains a lot of foreign material from the ore (the gangue or slag), and must be melted to form steel which is then carried out in an EAF, where the DRI may be mixed with a varying amount of steel scrap, as far as the product quality considerations allow for it (IEA 2020; BMWK n.d.; Hannah and Fan 2021).

[33] As indicated in reports and confirmed by expert interviews, the share of ASM in iron ore mining is very small and does not contribute significantly to the steel supply chain of the automotive sector. Data on ASM production is not available, but the high capital investment in infrastructure required to mine iron ore and the fact that iron ore is a bulk commodity and the associated economies of scale give the large companies advantages over the ASM. Prices for iron ore would have to be much higher for the ASM to be profitable, according to experts in interviews. Only in countries where there is a closed local/domestic loop with no exports is there a small market for high-grade ore from ASM (ILO 1999).

Depending on their steelmaking process, steelmakers purchase different iron ore products which may lead to slightly different supply chains. For the BF-BOF route, iron ore lumps or natural fines are usually used, which are agglomerated into sinter. Less common is the use of certain concentrates or pellets (Küblböck et al. 2022; Wirtschaftsvereinigung Stahl 2022). In the DRI-EAF production route, direct reduction (DR) plants are usually fed with pellets or, more rarely, with high quality lump or pig iron (Hannah and Fan 2021; Stahlinstitut VDEh 2023). As the production of DRI requires higher quality materials with lower levels of impurities (Hannah and Fan 2021; BMWK n.d.), one reason that limits the global share of direct reduction in the production of steel is the supply of high-grade material (Stahlinstitut VDEh 2023; BMWK n.d.). The main difference from steelmaking in blast furnaces is that DR plants use natural gas instead of carbon (coal) as a reducing agent to remove oxygen from the ore. For this reason, most DR plants are located in the Middle East, where natural gas is cheap (Hannah and Fan 2021; BMWK n.d.). In Germany there is only one production site for DRI at the moment (Wirtschaftsvereinigung Stahl 2022).

The liquid crude steel is finally cast, usually in a process of continuous casting, and turned into slabs, billets or blooms that are then rolled into steel sheets or other long steel products (beams, reinforcing steel, wire, tubes), either in separate processes or in casting rolling mills. Sheets and wire are usually rolled up into coils for transport (Küblböck et al. 2022; Stahlinstitut VDEh 2023; tec-science n.d.).

The production processes in the iron ore-steel supply chain are associated with **negative environmental impacts** as well as social problems and challenges, including human rights violations (e.g. land grabbing and forced resettlement, health related problems, destruction of natural livelihoods) all along the supply chain, from iron ore mining to the production of steel and steel products. Table 15 shows those environmental impacts that are common in the supply chain and therefore relevant for the industry. This does not mean that every impact listed will occur in every iron ore-steel supply chain.

Table 15: Main environmental impacts in the iron ore-steel value chain

Supply chain segments	Environmental impacts
Mining & beneficiation	Depletion of water reserves and deteriorating groundwater reserves through mine dewatering and high water use for flotation beneficiation
	Deforestation and loss of biodiversity/danger to ecosystems through land use for mines and related infrastructure
	Contamination of water through the release of acid mine drainage and waste water (containing heavy metals and industrial refuse) through mine dewatering and the possible leakage from tailing ponds or breach of tailing dams
	Air and environmental pollution resulting from metal and rock dust emissions caused by blasting and open transportation
	Fragmentation of ecosystems by infrastructure created for transport purposes
Refining processes & steel production	High water consumption: risk of water scarcity and conflicts of use between agriculture/drinking water and steel production
	Very high GHG emissions resulting from high energy consumption and the use of non-renewable energy sources
	Air pollution from metal dust

Source: adelphi, based on information from Kerkow et al. 2012; Baeten et al. 2018; Groneweg 2020; Weiss et al. 2022; ENCORE n.d., and expert interviews

In the case of the steel products for the automotive industry, i.e. the focus of this study (focus product: coils), there are different trading channels between the steel producer and steel customer: steel producers sell their products either directly to automotive manufacturers, who for example produce components for the car body from coils in their own stamping plants, to SSCs[34] or manufacturers of components for the automotive industry, who produce customised materials or specific car body parts. Steel producers can also sell their products to intermediaries who market the coils worldwide without adding any value. While no detailed figures are available on which trade route is most widely used in the German automotive industry, EUROFER provides some interesting data on the European market: as of 2023, 53.8% of all EU strip mill products are sold directly to end-users (of which 21.1% goes to the automotive industry), 36.7% to SSCs and 9.5% to merchants (EUROFER 2023).[35] Although the iron ore-steel value chain has a global reach, trade inside the value chain often follows regional patterns, with related value-adding steps of the chain being conducted in neighbouring countries/regions inside East Asia, South-East Asia or Europe or domestically (OECD 2017). Transportation costs as well as regional trade agreements help explain this regional approach, which was also confirmed by various expert interviews. This also applies to steel sheets/coils which are mostly traded regionally, with European steel products being supplied to European car manufacturers, often remaining in the same country. Rare, high- value products are more often exported globally (OECD 2017).

3.5.4 Pricing

Prices in the iron ore-steel supply chain are influenced by a variety of factors, particularly at the raw material level, where the cost of iron ore and coal, energy costs, labour costs, technological developments and also political decisions such as trade agreements, restrictions or tariffs play an important role. In later stages, prices are more often negotiated directly between buyers and suppliers, with the aim of covering production costs and making some profit. Price negotiations are part of a broader framework of purchasing practices that are highly contested between buyers and suppliers, as discussed in Section 3.5.5. The following chapter therefore focuses mainly on commodity-level pricing mechanisms; prices for steel products are only briefly examined.

The specific pricing system for iron ore has undergone significant changes over the past 20 years; for about 40 years, prices were set in long-term contracts negotiated behind closed doors between buyers and sellers and then presented to the public as a result. Since the mid-2000s, however, there has been a tendency to set prices on the basis of benchmarks that track spot market prices (Hannah and Fan 2021; Kim et al. 2022). Due to the increasing instability and fluctuation of prices and the resulting higher price risk in long-term contracts, the financial crisis of 2008 as well as the rapidly increasing demand for iron ore in China, from 2010 onwards contracts started to be largely based on these indices (see box on the next page). Mining companies such as Vale and BHP, who wanted to close the gap between prices in long-term contracts and spot market prices to achieve much higher margins, played an important role in this system change (Hume and Sanderson 2016; Treadgold 2020). As a result, the producer-pricing regime slowly began to disappear. The resulting intense price competition between

[34] Steel service centres function as intermediaries between producers and end users of steel (and other materials) and can be a relevant actor in the automotive industry. SSCs procure large quantities of steel from steel mills and provide processing, inventory management and distribution services. SSCs mostly follow Just-in-Time models that aim at supplying end users with material in customised quantities, forms and timing to align it to production schedules and increase efficiency and reduce inventory costs. As of 2018, almost two thirds of SSCs were located in the Asia Pacific region while Europe accounted for around 15% of SSCs (Grand View Reseach 2023; Tata Steel Downstream Products Limited n.d.).

[35] These figures only give an incomplete picture of the trade in steel plate for the automotive industry, as the automotive sector is only one of the customer industries for strip steel products and steel plate is only one of several categories of strip steel products.

producers further contributed to the volatility of the market. Since then, price volatility has remained much higher than in the decades preceding the financial crisis, again changing drastically with the outbreak of the COVID-19 pandemic and the beginning of the Russian war against Ukraine (Jégourel 2020; Hall 2020; Kim et al. 2022). As shown by the fluctuations of the last two decades and confirmed by industry experts in interviews, the most important factor influencing iron ore prices is the dynamics of global supply and demand.

Because large companies can more easily withstand increased price fluctuations and make investments in the infrastructure needed to mine iron ore, fluctuating price trends contribute to their dominance in the iron ore industry (Global Times 2021; Kim et al. 2022). The so called "big four", Vale, Rio Tinto, BHP Billiton and Fortescue Metals Group, account for 80% of market share, a power that is also reflected in price setting mechanisms. World market prices and prices that steel producers have to pay are thus heavily dependent on these big players (Kerkow et al. 2012).

While the impact of spot market prices on price discovery described above is a global phenomenon, it is mainly the Chinese steel industry that actually trades iron ore on spot markets (Hannah and Fan 2021) (see box on this page). As suggested by research and verified in interviews with industry experts, European steelmakers typically still negotiate contracts directly with their suppliers, thereby avoiding some of the insecurity that price fluctuation on spot markets causes (Kerkow et al. 2012). This is especially true for higher-quality material. This is partly due to the fact that market price dynamics in the iron and steel supply chain differ in complexity depending on the quality of the material that is traded, the steel production route available as well as regional value drivers. As demand for the diverse iron ore products depends to a large degree on the available production capacities, sellers try to sell to customers that have a special need of the product they are offering, e.g. sellers of high-grade iron will look for steelmakers that use DRI as an input material (Hannah and Fan 2021). Due to these dynamics, iron ore that goes to European markets is usually traded via direct longer-term contracts and only a small share is traded on spot markets.

Benchmark indices in the trade of iron ore

Since the breakdown of long-term contracts in 2010, prices on the iron ore market are informed by indices based on spot market sales which are set by independent benchmarking companies such as Platts, Argusmedia and Metal Bulletin (Kim et al. 2022).

The **Platts Iron Ore Index (IODEX)** by S&P Global Commodity has been the primary benchmark for global prices of iron ore. It is used by steelmakers, traders and mining companies for spot market contracts and also serves as a reference/basis for long-term contracts. In the past, the index exclusively assessed the prices of 62% standard ore. However, as this one grade could not reflect the wide variety of iron ore products on the market, different indices were developed for different qualities of ore, each referencing a variety of similar products to index-based specifications where the product's quality is determined either by the natural grade of the ore or is the result of its processing. Today IODEX publishes indices on high- and low-grade ore (e.g. 58% Fe, 65% Fe), as well as for a number of products such as pellets. Qualitative differences in products that exceed these general specifications are priced by trading partners with surcharges or discounts (Fastmarkets 2018; Jégourel 2020; S&P Global Commodity NaN).

For the most common products such as fines and lump, which make up the bulk of the seaborne iron ore market, prices are determined on a daily basis, while for beneficiated products (e.g. concentrates, pellets) weekly indices are published (Fastmarkets 2018).

The increase of price volatility in recent decades has also led to companies increasingly wanting to hedge against price risks through investment in iron ore derivatives. As a result, more financial investors have entered the iron ore market. Today, iron ore is also traded on futures markets. The Chinese Dalian Commodity Exchange, on which iron ore futures have been listed since 2013, is now the most important iron ore financial derivatives trading market worldwide. Due to the steadily growing volume of iron ore traded on futures markets, the influence of trader's bids on future price levels is also increasing, which could exacerbate price volatility in the future (Küblböck et al. 2022).

Pricing mechanisms in China

The pricing mechanisms in China, an important player in the iron ore and steel market, differ drastically from other markets, mainly due to stronger state intervention and political influence. For example, the three largest steel producers in China (China Baowu Steel Group Corp, Hebei Iron and Steel, and Jiangsu Shagang Group) are state-owned enterprises (Steinlein et al. 2022).

These particular characteristics are also reflected in the significant price differences for steel that have been observed in the past. For example, unlike many other countries, China continues to purchase cheaper coking coal from Russia – even after the unlawful attack on Ukraine, which leads to a significant price advantage in steel production. The OECD predicts that the price differences in steelmaking between China and other regions will persist and possibly amplify in the future. One reason for this is that recently a new Chinese state agency, the China Mineral Resources Group (CMRG), was established to further centralise all of China's iron ore procurement in order to lower prices for local steel companies and secure supply with the raw material in the long term (OECD 2023).

Even though the European and German market work rather differently from the Chinese one, the latter is a central factor influencing the global price development for iron ore/steel. In particular, broader developments such as the recent increase in demand for high-grade iron ore (> 63.5% Fe), accompanied by fluctuations in domestic production capacity in China, as well as the increasing focus on reducing CO_2 emissions, are having an impact on the European market. As supply and demand are the main drivers of iron ore prices, recent lower than expected growth in China, for example, has led to a decline in world iron ore prices (Hannah and Fan 2021; Mercier et al. 2022).

While the trading of iron ore and iron ore products has undergone a major shift to trading on spot and futures markets, the steel market and its downstream industries have not evolved in the same way. This is mainly due to the diversity of finished and semi-finished steel products used in different industries, which makes managing price risks much more difficult. Moreover, there are in fact several segmented regional steel markets due to factors such as transport costs and the existence of regional trade agreements (see Section 3.5.3) that limit the global integration of the market. This structure hinders one-off trade, e.g. in the foreign exchange markets (OECD 2017; Jégourel 2020).

The development of steel prices depends strongly on the price of iron ore. Another important factor is the price of coking coal, which is mainly used for the reduction of iron ore in blast furnaces. Other factors are the prices of input materials for the refinery process as well as steel scrap (Mercier et al. 2022). The international steel market is characterised by a strong level of competition, which limits the prices that can be achieved (BMWK n.d.). This is one of the reasons why profits in the steel industry are significantly lower than in the mining industry (Treadgold 2020; Mercier et al. 2022). As the costs of steel production in the EU are higher on average, mainly due to higher raw material and labour costs, the profit margins of European steel producers tend to be lower than in other world regions (Medarac et al. 2020). One unique selling point for European steelmakers that partly compensates these disadvantages is the production of a larger share of high-quality steel products than in other world regions. For this they require higher-quality raw materials (high iron ore grades, low impurities). The production of flat steel products like quality steel sheets for the automotive industry also follows this logic (Fastmarkets 2018). Steelmakers deal with the price mechanisms on the steel market in two ways. When profit margins are higher and steel production is more profitable, it pays to use high-purity ore to maximise production efficiency. When profit margins fall, they resort to lower-grade inputs (Fastmarkets 2018).

3.5.5 Power relationships

As the previous chapters show, China is a key player in the iron ore and steel market and the market activities in the People's Republic also have a significant influence on pricing in global markets, for example. The market structures in China differ significantly from those in the rest of the world market due to strong state intervention (e.g. subsidisation) and operate as a closed infrastructure, partly shielded from world trade. For this reason, the following chapter describes the typical power structures outside the Chinese iron ore-steel products sector.

The initial steps in the iron ore-steel supply chain in particular are characterised by large, financially strong companies dominating significant market components, as economies of scale make the infrastructure investments required in mining and steel production more bearable. Both mining and steel production are highly capital-intensive industries requiring high investments in large equipment and continuous operating and capital expenditure (Kim et al. 2022). This leads to some power imbalance, which can hinder the effective implementation of environmental, climate and resource protection measures due to highly competitive purchasing practices.

Following Gereffi et al.'s (2005) approach, the relationship between **mining companies** and steel producers can be described as a **market**, dominated by **strong suppliers**. Although mining companies usually offer a broad portfolio of product specifications and are also oriented towards market demand and the quality requirements of steel producers, production and value addition take place without much input from the buyer (OECD 2017; Hannah and Fan 2021). The **pricing power** lies with the seller rather than the buyer and the complexity of the information exchanged is rather low, so transactions can be comparatively easily governed. The strong position of large mining companies in particular is reflected in the fact that certain iron ore products (especially in the high-grade segment) originate mainly from certain regions and are only sold by specific companies. For example, DSOs are mined predominantly in regions such as Australia's Pilbara and Brazil's Carajas area, where they are sold by mining companies such as Rio Tinto, BHP and Vale (Hannah and Fan 2021; Eames 2021).

Further down the value chain, where **steel producers** sell their products to the **automotive industry**, a different business model is dominant according to Gereffi et al. (2005). While less information is available on typical contract models at this stage of the supply chain, it became clear from interviews with industry experts that automotive suppliers purchase their steel products from a wider range of suppliers; they buy steel coils for further processing in their own pressing plants directly from steel companies, from dealers, as well as finished components from component manufacturers. This suggests that a **captive market** is more likely, with buyers purchasing from different sources according to their product requirements in order to flexibly meet demand depending on production volumes. In the specific supply chain of steel coils for the construction of cars, many of the complementary activities such as design, process technology upgrading, etc. tend to lie with the automotive component manufacturers or OEMs.

The steel industry is more fragmented and less dominated by very big companies than iron ore mining (Kerkow et al. 2012), but it is still concentrated in comparison to other industries (Küblböck et al. 2022). This is partly due to the heterogeneity of steel products and their uses. In comparison with other commodity-based industries there is a relatively low degree of vertical integration in the steel industry. While multinational companies often manufacture a range of different steel products in their large integrated steelwork complexes, intermediary products are usually traded across different companies and countries (OECD 2017). But as this makes production dependent on the continuous supply of raw materials at affordable prices, parts of the industry began to invest in upstream integration like the acquisition of mining assets when raw material prices became particularly high, also hoping to capture higher margins (McKinsey & Company 2014) as the market is very competitive and margins in steelmaking are rather low (Mercier et al. 2022; BMWK n.d.). At least some companies have already changed their strategies since then, refraining from further pushing into **upstream integration**. Additionally, the industry has begun to invest in downstream activities. Large steel producing companies which own production plants in different locations across the globe may therefore operate all along the entire value chain, handling steps from iron ore mining all the way down to the production of steel products such as elevators in globally spread intra-firm trade (OECD 2017). This **can also lead to shifts in the typical distribution of power** within the supply chain, e.g. towards hierarchical structures based on integrated firms.

Purchasing practices

The main business models to source iron ore for the German/European automotive market can be summarised as in Table 16:

Table 16: Dominant business models and governance in the iron ore-steel value chain

Business model	Type of buyers	Governance	Type of relationship	Procurement procedure
Mix of key & occasional suppliers	Steel makers	Market	Mid-term sourcing contracts	Competitive; strategic factors (e.g. reliable supply, high quality)
Mix of key & occasional suppliers	Automotive industry (OEMs, component manufacturers)	Captive	Mix of short-term and long-term contracts	Competitive; price dominant

Source: adelphi, based on classification by Gereffi et al. (2005) and expert interviews

Suppliers (mining companies) use targeted marketing strategies to achieve the highest possible margins for their products. Producers of the highest-purity ores usually try to sell their products directly to DRI steel mills, as they are willing to pay the price premium for the good quality, since the iron ore can be used directly in their plants without further processing. Here, mostly **bilateral direct contracts** are concluded between mining companies and steel mills, so there is little spot liquidity in the area that could create price transparency for these products (Hannah and Fan 2021). Similar approaches can be seen in the trade of high-quality BF-grade pellets: these are mainly demanded/purchased by steel mills in Europe, Japan, South Korea or Taiwan, due to the nature of their blast furnaces and the stricter local operating regimes with respect to environmental regulation. Here, too, **direct contracts** are mostly preferred, the terms of which are **negotiated quarterly**, as steel mills do not want to risk supply uncertainty by leaving some allocation to spot markets. The high proportion of direct contracts leads to low price transparency for high-value iron ore products. The **productivity** of steel mills is in some cases highly dependent on the products they source from mining companies (Hannah and Fan 2021); for example, Vale's IOCJ product, which serves as a reference for the 65% Fe Fines Index, is among the most sought-after brands in the market for optimising productivity via the sintering process (Argus Media 2019; Hannah and Fan 2021). As described in Section 3.5.4, since 2010 suppliers have also changed the business model of the iron and steel industry towards more short-term contracts that follow indices based on spot market prices. While suppliers are profiting from this change, steelmakers are struggling with volatile world market prices. Passing on higher prices to downstream steel-consuming industries is difficult because contracts on the less financialised steel market are not based on raw-material indices, but negotiated directly. Steelmakers thus carry a high risk, due to the volatile world market prices of iron ore (Bekaert et al. 2021).

In addition, steel producers are not only dependent on the purchase of iron ore, but also on the price development of other key raw materials for steel production, such as coking coal or alloy metals (Mercier et al. 2023). This current/traditional[36] "sandwich position" of steel companies in the supply chain is also reflected in the relatively low profitability of steel producers in recent years. According to the OECD, about 25% of steel producers worldwide operated with a profitability of less than 5% in 2021 (Mercier et al. 2022). At the same time, the largest iron ore miners achieved a gross profit margin (before accounting and other costs) of up to 700% the year before (2020) (Treadgold 2020). Nevertheless, steel producers also exercise a certain power over their suppliers, which is reflected in the **quality controls** they impose on mining companies – for example, according to interviews with experts, each delivery is checked by the steel company to see where the iron ore purchased comes from and whether it meets the quality requirements for Fe content, impurities, etc. This can be checked quite easily for iron ore by means of chemical testing by steel companies.

Information on the typical contractual relationship between steel producers and automotive manufacturers is not readily available. However, interviews with industry experts indicate that automotive customers purchase their steel products from a wider range of suppliers. They buy steel coils for further processing in their own press shops directly from steel companies and from distributors (percentage distribution not known). In addition, finished components are also purchased from component manufacturers for direct installation.

3.5.6 Addressing environmental impacts

Due to the significant negative environmental impacts that can be associated with mining projects, the permit process for new mining sites in most key iron ore mining countries includes environmental provisions that require a statutory **EIA**. The outcome of the EIA informs the permit process (Döhne et al. 2015; Wittmer and Murguía 2015). EIAs are usually implemented by government agencies and must be paid for by the mining companies developing the project (see details in Chapter 3.5.8).

In recent years, voluntary initiatives and standards have been developed as additional instruments for companies in the iron ore-steel supply chain to implement due diligence and set more stringent environmental and social requirements. However, as several experts interviewed for this study pointed out, the market supply of certified iron ore/steel products or equipment is

[36] While this supply chain profile focuses of the status quo, future trends in steelmaking described under Section 3.5.7 might change power relationships within the iron ore-steel supply chain significantly. "Green steel" production based on the EAF route requires different input materials such as high-grade iron ore and scrap steel. This puts mining companies and steelmakers in new power positions, especially in times where demand for "green steel" is high and supply is still low.

quite limited. Iron ore – among other metals – is covered by the stakeholder **Initiative for Responsible Mining Assurance (IRMA)**, established in 2006. IRMA has developed one of the most comprehensive and widely recognised standards for responsible mining, covering environmental issues (e.g. waste management, water, air quality, greenhouse gas emissions, biodiversity) as well as various social and corporate responsibility requirements (IRMA 2018). IRMA requires independent third-party certification for mines of all commodities. As of July 2023, IRMA audits were ongoing for three iron ore mines in Brazil and two iron ore mines in South Africa. To date, only three mines worldwide have undertaken an independent third party audit based on the IRMA standard, none of which are iron ore mines (IRMA n.d.). Companies undergoing the assurance process at site level have to pay for the independent service provider (IRMA 2021). As an industry expert interviewed for the study pointed out, the initial tentative interest in sustainably produced iron ore has so far come exclusively from the automotive industry and partly from the white goods and high-end construction sector. However, as the low number of IRMA-certified mines shows, there is no significant market for certified iron ore as of yet.

The first **multi-stakeholder standard and certification initiative for steel** (by its own account) is the **Responsible Steel Initiative** (first incorporated as the Steel Stewardship Council in 2016). The initiative published their ResponsibleSteel Standard in 2019 (which was slightly updated in 2021), which covers environmental, social and governance issues on the basis of 12 principles. The standard has been criticised for being vague on some requirements and for lacking criteria for responsible sourcing of raw materials – as of yet, the standard only applies to operational steel mills and production facilities that process raw materials for steelmaking. A comprehensive revision of the standard is to be carried out in 2023 (ResponsibleSteel n.d.). As part of the comprehensive review, Responsible Steel intends to cooperate with existing certification programmes for mine sites, including IRMA, Towards Sustainable Mining (TSM) and the Responsible Jewellery Council (RJC). However, auditing of the responsible sourcing of raw materials is voluntary for members (Küblböck et al. 2022). In an interview conducted in the framework of the project, an industry expert emphasised that stakeholders along the iron ore-steel supply chain have so far mostly approached environmental issues in isolation, only in the context of their direct business activities, and that there has been a lack of cooperation and joint initiatives along the supply chain.

In addition, organisations such as the **World Steel Association** and the Global Oil and Gas Industry Association for Advancing Environmental and Social Performance (**IPIECA**) provide their international members with information on due diligence processes and environmental and social sustainability in the steel sector. However, neither of them offers any verification of standards or certification themselves (Küblböck et al. 2022).

Large players in iron ore mining and steel production usually operate individual sustainable supply chain management (SSCM) and due diligence systems (including supplier code of conducts [CoCs], supplier self-assessments etc.) to meet at least minimum legal requirements. For example, social and environmental **standards for steel production facilities and iron ore mines** on environmental management (ISO 14001) or social responsibility of organisations (e.g. ISO 26000) are applied (Rechlin et al. 2022).

The industry's current focus on sustainability issues is on the production of **"green steel"**, i.e. low-carbon steel[37], for which demand from customer industries such as automotive production is also increasing (Faye 2022). The steel industry is responsible for 7-10% of global greenhouse

[37] While there is no uniform definition of "green steel" so far, Verret (2021) suggests a definition of "steel with less than 0.6 tonnes of CO_2 emissions per tonne of steel produced".

gas emissions and is the largest industry in terms of carbon footprint, so a comprehensive shift to low-emission steel production is a priority (Hannah and Fan 2021). Predictions foresee a three-step process towards green steelmaking: 1) optimisation of existing processes (in mining, transportation etc.) to reduce emissions, 2) transitions, e.g. equipping existing plants with carbon capture and storage technology, and 3) switching the entire technology to new production routes, i.e. replacing the BF-BOF production route with DR plants and EAFs, using steel scrap and hydrogen-based DRI as input material (Hannah and Fan 2021; Guevara Opinska et al. 2021; Schreck et al. 2023). Currently, most steel companies seem to be pursuing options 1 and 2 to mitigate environmental impacts, which is reflected in the fact that BF/BOF steelmaking capacities are increasing worldwide, especially in Asia (OECD 2023b). However, some European steel producers, such as the HYBRIT initiative in Sweden and all primary steel producers in Germany, are already working on option 3, the switch to hydrogen-based steelmaking (Hannah and Fan 2021; Schreck et al. 2023). While hydrogen-based steelmaking is the most advanced option, various alternative technologies are being piloted (Koch Blank 2019). Some companies have developed their own **sustainability labels for selected “low-CO_2 produced” products** and offer them on the market. These include bluemint® steels from thyssenkrupp and XCarb™ green steel from Arcelor Mittal. However, both labels/certificates are based on the reduction of CO_2 emissions in conventional steel production in the blast furnace (e.g. through the use of hot briquetted iron instead of iron ores) and work with balance sheet approaches in which total GHG emission savings in production are converted into small quantities of “green” steel output (ArcelorMittal 2021; thyssenkrupp n.d.).

As of now, many low-carbon-alternative products still come at “a cost premium of 50% or more” (BCG 2023). As a result, debates are underway on political control instruments such as the CO_2 tax to compensate for the higher costs in market competition (see Section 3.5.8) (Koch Blank 2019). A 2023 report by the World Economic Forum and the Boston Consulting Group predicts that demand for green materials will grow faster than supply in the coming years due to decarbonisation targets set by many downstream companies, including in the automotive sector (World Economic Forum 2023). This makes the payment of “environmental premiums” for low-carbon material more likely (Faye 2022; Azevedo et al. 2022; World Economic Forum 2023). According to calculations made by McKinsey, demand for low-emission steel will “surge from around 84 million tons in 2021 to nearly 200 million tons in 2030, mainly driven by automotive and construction demand in Europe and China”[38] (Azevedo et al. 2022). According to reports, the first steelmakers have started to demand green steel premiums in negotiations for long-term contracts with car makers, among others (Richardson 2021; Bolotova et al. 2023). As the production of green steel requires, among other things, high-quality iron ore[39], in the future there could also be price premiums for “green iron ore” that meets the higher quality requirements for the production of “green steel” (Faye 2022). However, higher prices are already being charged for high-grade iron ore products, which enable low-emission steel production, but these are the result of a combination of their higher quality, costs for processing and demand (see also Section 3.5.4) (Hannah and Fan 2021).

3.5.7 Current/future trends and developments

Due to the tightening of environmental legislation worldwide to reduce GHG and air pollutant emissions from the steel and automotive industries (for details see Section 3.5.8), both sectors have turned to the development of low carbon products. This translates into a global rise in

[38] In this quote the authors use the unit “ton” and “metric ton” (which corresponds to the unit “tonne” that is used in this publication) inconsistently. We assume that metric tons/tonnes are meant throughout the source.

[39] Alternative input material: steel scrap.

demand for higher-quality iron ore, which allows for low(er) emission steelmaking. Especially demand from China for these high-grade iron ore products has increased significantly since the Chinese government introduced a shift from “quantity” to “quality” steelmaking in 2016. This also increases global market competition for higher-quality iron ore products affecting buyers e.g. from Europe who were considered traditional buyers of these type of ores because of the properties of their BF-BOF steel mills (Hannah and Fan 2021). Similarly, an increase in demand for scrap steel is predicted, which is a possible alternative low emission input material for the EAF production method (but so far has only a small market share) and an increasing demand for recycled steel is predicted, especially from car producers (WMW 2023). Stakeholders along the entire supply chain are slowly starting to work together in the area of emission reduction, as evidenced by collaborations in recent years between car makers and steel makers in the production/sourcing of green steel, such as those entered into by the Volvo Group and SSAB in 2021, General Motors with Nucor in 2021, the Volkswagen Group and Salzgitter AG in 2022, the BMW Group, H2 Green Steel and Salzgitter AG in 2022, and Mercedes Benz AG with H2 Green Steel in 2023 (Green Steel World 2022). However, as the annual figures reflect, these are still fairly new efforts and, as the low number of certified mines for iron ore shows, sustainability efforts that cover topics beyond GHG and air emissions reduction and cover the entire supply chain are still limited (for details see Section 3.5.6).

As for other supply chains, the COVID-19 pandemic and the Russian war in Ukraine have had severe impacts on the supply chains of the iron ore and steel industry with high energy prices as well as supply chain disruptions, leading to soaring commodity prices[40]. The destruction of steel production facilities in Ukraine, in particular, led to slumps and production stoppages in steel production in Europe. European steel producers were therefore confronted with rising iron ore prices and falling steel market prices, which put pressure on their margins. Additionally, rising interest rates and weaker spending were impacting demand adversely, causing prices to decline further (Mercier et al. 2022). The crises have thus put the spotlight not only on the vulnerability of the iron ore-steel supply chain but also shown the volatility of iron ore and steel prices. These developments coupled with bans on exports from Russia also led to some restructuring of steel supply chains with Russia now exporting more than half of its steel to Asian markets (in comparison to 10-20% before the war in Ukraine) (CUMIC Steel Limited 2022; Mercier et al. 2022).

The lingering effects of the war in Ukraine, the global economic slowdown and persistent inflation mean that only limited growth in steel demand is expected in 2024. The OECD also points out that regional differences in steel prices are increasing: In December 2022, steel prices for flat and reinforcing steel products in Europe were 39% and 65% higher than in China. These differences can be partly attributed to the fact that global coking coal prices have risen sharply in the wake of import bans on Russian products, while some countries continue to have access to cheap Russian coking coal – a trend that is expected to intensify (Mercier et al. 2023). Weaker demand from the automotive sector in the EU is also a contributing factor. The production of passenger cars in the EU decreased by 23.5% from 2019 to 2020. In 2021, it fell again by 6.7% and in 2022 it recorded a slight increase of 8.3% for the first time since the COVID-19 induced disruptions (ACEA 2023). Despite continued economic weakness and inflation, car sales registrations in Europe also increased by 26% in March 2023, indicating a recovery in demand (Eckl-Dorna 2023). Accordingly, a slight recovery in steel demand from the European automotive industry is also predicted. While consumption of steel products by the automotive industry increased by 3.3% annually between 2021 and 2022, it slowed down to 1.2% in 2023.

[40] Prices for 62% FE iron ore reached a near 10-year high of $176.45 at the end of December 2020, making iron ore one of the best-performing commodities of the year (Hannah and Fan 2021).

Forecasts predict that demand for steel will continue to fall in 2024 (by 1.8% year on year) (Grigorenko 2023).

Table 17 summarises the market, consumer and technology trends that may gain importance in the near future.

Table 17: Market, consumer and technology trends

Market trends	▶ Fluctuation of iron ore prices with a current increase reflecting the economic recovery after the COVID-19 pandemic ▶ Overall decreasing steel prices (regional and product-specific differences exist) ▶ Increasing financialization of the iron ore market (especially in China) ▶ Decreasing global steel production due to global economic slowdown, high energy prices, accelerating inflation and impacts from the war in Ukraine ▶ Potential long-term trend: geographical shifts of steel mills based on availability of hydrogen and increasing demand for steel scrap ▶ Progressive financialization of the iron ore market
Consumer trends	▶ Global economic slowdown, accelerating inflation etc. lead to decrease in vehicle production, thus also lowering steel demand ▶ Rising demand for “green” steel to meet tightening environmental policy regulations
Technology trends	▶ Steel industry is piloting various low-emission steelmaking technologies, with a current focus on hydrogen-based EAF steelmaking ▶ Rising use of high(er)-grade iron ore products for lower emission steelmaking (especially in China since reform to “quality phase” of steelmaking in 2016) ▶ Adoption of digital tools to increase information sharing and transparency along the value chain

Sources: adelphi, based on information from Jégourel 2020; Hannah and Fan 2021; Mercier et al. 2022 and interviews with industry experts

3.5.8 Institutional incentive mechanisms and barriers

Environmental legislation in producing countries

As illustrated in Table 15, both the mining of iron ore and the production of steel are associated with significant negative environmental impacts. The establishment of new mining sites in the major iron ore mining countries is therefore subject to a statutory permit procedure, which generally includes the performance of an EIA (Döhne et al. 2015; Wittmer and Murguía 2015; Sydow et al. 2021). The EIA is a formal administrative procedure that systematically evaluates the positive and negative impacts of specific mining projects on environmental goods such as soil, water, air, climate, landscape, fauna, flora and habitats. The EIA also serves to implement measures to minimise the negative impacts of a mining project. EIAs are required and monitored by environmental authorities and have become a recognised environmental policy instrument in the mining sector in most countries worldwide. Nevertheless, there are still some shortcomings that can prevent EIAs from being effective management systems for environmental protection. In industrialised countries, this is mostly manifested in a lack of public participation, monitoring and review (Wittmer and Murguía 2015). In developing and emerging countries, on the other hand, economic development and related investments are sometimes prioritised over environmental protection and this, combined with corruption and a lack of resources and trained EIA auditors, could result in poor quality EIAs (Wittmer and Murguía 2015; Williams and Dupuy 2017; Cárcamo et al. 2018; Transparency International Australia 2021; Sydow et al.

2021; Neto and Mallett 2023). Generally, economic interests can compromise the effectiveness of an EIA: in most countries, proponents are allowed to directly contract an organisation for the implementation of the EIA, so that a direct financial dependency exists (Sydow et al. 2021). In addition, the indigenous people's right to consultation and free, prior, and informed consent is often violated in the development of new mining projects (BMZ n.d.). Overall, there are strong regional differences in the legal requirements for EIAs in terms of scope, control, independence of EIA auditors and public disclosure/participation requirements, often leading to unreliable results (Wittmer and Murguía 2015). The dramatic rupture of an iron ore tailings dam at a mine in Brumadinho, Brazil, owned by the world's largest iron ore exporters, Vale SA, in 2019 demonstrated the serious consequences that can result from inadequate or insufficiently implemented and audited regulatory requirements. Shortly before the dam failure, the safety of the plant had been officially confirmed by the German certifier TÜV SÜD (ECCHR 2019). In immediate response to the rupture, the International Council on Mining and Metals, the United Nations Environment Programme and the Principles for Responsible Investment convened the Global Tailings Review, which aimed to develop international standards to help prevent similar disasters in the future. The process, which was led by a multidisciplinary panel of scientific experts and received input from an advisory group that included scientists as well as representatives of industry, international institutions and civil society, led to the launch of the Global Industry Standards on Tailings Management in 2020 (Global Tailings Review 2020; Global Tailings Review n.d.).

Environmental legislation in consuming countries

From an environmental perspective, the iron ore/steel sector has so far been most influenced by increasing regulatory requirements regarding emissions of CO_2 and air pollutants, which are already concretely reflected in shifting market dynamics. Hannah and Fan (2021), among others, name environmental policy as one of the most important "stick factors" influencing the price development of 65%-62% Fe iron ore fines. One of the easiest approaches to reduce GHG emissions and air pollutants in blast furnace steelmaking is to use higher grade ores – as there are fewer impurities in 65% Fe ores, they have better sinter quality, reducing the amount of slag and thus the amount of metallurgical coal consumption, resulting in lower emissions. Steel mills are already prepared to pay premiums for higher iron ore grades in order to avoid pollution penalties or forced shutdowns due to higher emission levels. This is particularly evident in China, a major steel-producing country, where spot demand for higher-grade products rose sharply in 2018 after anti-pollution measures were tightened by the government. This has also led to an increase in the floor level price for higher-grade iron ore products in other regions. Since 2016, China has also been pursuing the longer-term goal of converting its steel mills to EAF production in order to achieve its climate protection goals (Hannah and Fan 2021). In general, the transition to low-carbon steel production is still in its infancy worldwide and will require a lot of time as well as high investments to pay for the costs involved. In order to make low emission steel market-ready and to create a level playing field between e.g. hydrogen-based steelmaking and the traditional BF-BOF route, the planned reform of the *European Emissions Trading Scheme* (EU ETS) and the planned introduction of the *Carbon Border Adjustment Mechanism* (CBAM) can be helpful. The introduction of a carbon border tax on imported products, including steel, can help European steel producers to remain competitive in the international market despite raising costs for the low-carbon transformation. This can be an important stimulus for the European industry to make the necessary investments in green technologies (Hannah and Fan 2021).

Furthermore, legislation on corporate responsibility also plays a role in the supply chain of steel products for the automotive industry. Among other things, new and upcoming regulations at the

European level may increase the pressure on actors in the supply chain to improve transparency, traceability and implementation of environmental and social standards beyond CO_2 reduction. Legislation such as the CSDD, the CSRD as well as the already enacted *German Supply Chain Due Diligence Act* are also expected by the experts interviewed to contribute to improved cooperation between suppliers and buyers in the iron ore/steel sector.

One expert interviewed for this project also highlighted that the pressure from investors regarding sustainability requirements for the steel industry will be much stronger in the future than requirements from buyers, for example from the automotive industry. In the European market, new regulations such as the *Sustainable Finance Disclosure Regulation* of 2021 aim to make financial market participants such as asset managers, insurance companies, pension funds, etc. take their consideration of negative environmental or social impacts into account in their investment decisions by requiring them to regularly disclose their “principal adverse impacts” in statements. The *EU Taxonomy Regulation* of 2020 also aims to steer financial flows towards more sustainable products by providing clarity on which economic activities can be considered “environmentally sustainable” (Holly et al. 2023).

Trade agreements and policies

Overall, the global crises of recent years and COVID-19 and war-related disruptions to supply chains have brought the issue of supply security in the mineral sector to the fore. Many countries are therefore trying to secure access to key raw materials such as iron ore through trade regulations like free trade agreements and export restrictions. Free trade agreements, which also include iron ore, are also being negotiated and/or are in progress between Europe and major iron ore producing countries.

The possible association agreement between the EU and MERCOSUR (Argentina, Brazil, Paraguay and Uruguay), for which negotiations have been ongoing for 20 years, is subject of particularly intense discussion. The proposed trade agreement, which would create the world’s largest free trade zone, would eliminate tariffs on 91% of all goods traded between the two regions (BMWK n.d.b). After an initial agreement had been reached in 2019, negotiations stalled again over environmental issues. In 2021, the EU submitted an addendum to the agreement that sets out sustainability and climate change commitments and introduces penalties for countries that do not meet the targets of the 2015 Paris Agreement on climate change. These additional requirements led to criticism on the MERCOSUR side and a renewed freeze of the negotiations (tagesschau 2023). Environmentalists had repeatedly criticised that, without a comprehensive sustainability chapter, the agreement would contribute to a progressive destruction of the environment in the MERCOSUR countries, including through a further expansion of mining without strengthened environmental requirements (Mirkes n.d.).

Negotiations on a possible free trade agreement between the EU and Australia have also been ongoing since 2018 (BMWK n.d.a). Industry voices see the agreement as a possible step towards securing Europe’s supply of key metallic raw materials (DIHK 2023). According to the EU, the negotiations aim to introduce “ambitious provisions on trade and sustainable development, showing a shared commitment to labour rights and environmental protection (including climate change) in trade” (European Commission 2023a). Details on the content of a possible trade chapter are not known.

Germany’s most important iron ore suppliers have also entered into trade agreements with the EU: the Comprehensive Economic and Trade Agreement (European Commission 2017) with Canada and the Economic Partnership Agreement between the EU and the Southern African Development Community (Botswana, Lesotho, Mozambique, Namibia, South Africa and Eswatini) (European Commission n.d.a).

Against the backdrop of the COVID-19 pandemic, re-shoring strategies were also discussed, in the context of which the production of key products such as iron ore mining and steel products should be brought back to the EU (EU 2021). The trend is reflected, among other things, in the fact that there are now more exploration projects for new mines in the EU than ever before (Harder 2018).

Steel and steel products are also repeatedly the subject of trade policy disputes. In 2017 and 2018, for example, the Trump administration in the U.S. imposed tariffs on imports of steel and other products from China, Canada and the EU in order to protect domestic production and national interests. However, concerns about the implementation of environmental standards did not play a role (EU 2021).

Traceability along the iron ore-steel supply chain

Compared to many other mineral commodities, traceability in the iron ore-steel supply chain is relatively straightforward, especially at the lower levels of the supply chain. Steel companies can usually use laboratory tests to trace the geological regions from which iron ore products originate. Industry representatives confirmed in interviews that geological tracing is already common practice in the quality control of delivered goods (for each sea shipment), when controls reveal a deviation from the required quality requirements in terms of Fe content and impurities. Batch production, where different products from different sources are mixed, affects traceability. The iron ore sector is using various technologies, such as "data storage and retrieval systems, barcode systems, or non-contact tagging systems such as radio frequency identification" to improve traceability and transparency towards customers (Bergquist 2012). The mining sector as a whole is also working on the implementation of blockchain technologies, for example, to increase traceability and transparency in the supply chain and facilitate the implementation of ESG requirements (Ellis 2021). For example, in March 2020, the mining group Vale announced that it had completed its first sale of iron ore using blockchain to the Chinese Nanjing Iron & Steel Group International Trade Co, Ltd. (Vale 2020). Despite the traceability initiatives that have been launched, interviews with experts suggest that there is still some reluctance to disclose the exact composition and origin of iron ore products to customers, because iron ore miners guarantee a certain quality of the product when selling it, but not a specific origin, in order to have cost-sensitive freedom in the composition and the planning of logistics – many iron ore products are blends and do not come from a single mine. There is therefore a good basis for traceability in the implementation of environmental standards, even if these controls are not yet common in the market.

Subsequent steps of mixing and merging with other materials in steel production make geological traceability more difficult, so technological solutions play an even more important role. At the interface between steel companies and the automotive industry, platforms such as the European Automotive Network "Catena-X" are working to improve transparency and the exchange of data on material flows along the supply chain. Catena-X points to current problems: at present, many suppliers are reluctant to share their data because they fear data loss and lock-in effects (Catena-X 2023). This also hinders the sharing of environmental data. For example, as confirmed in interviews with industry representatives, automotive companies at the end of the supply chain face the challenge that their global suppliers do not use a consistent methodology in calculating the carbon footprint of their products. This limits the ability to share consistent targets for reducing emissions in the production process across the supply chain and makes it difficult to measure progress (Steinlein et al. 2022). Initiatives such as Responsible Steel are therefore working to develop uniform solutions and standards at industry level (ResponsibleSteel n.d.). However, some experts emphasised in interviews that, due to conflicts of interest, cooperation in these industry initiatives is slow.

Transparency in price building

The fact that much of the iron ore is traded on the basis of price indices based on spot market prices (index-linked contracts) is unique in the mining industry (Jégourel 2020). While being a good mechanism to deal with the price risks that come with volatility, the system of trading on spot markets is still fairly new and is characterised by a number of problems that result from the brokers' need/will to maximise liquidity instead of focusing on the highest quality of data that can be used for price assessment in indices. These include a lack of transparency, timeliness of information, anonymity of transactions as well as the fact that sometimes orders are placed on the spot market even though the small number of potential buyers of a company's raw material should render this mechanism inefficient. These problems lead to diminished trust in indices, and continued disagreement over pricing (Hall 2020). There is a risk that increasing competitive price discovery mechanisms and decreasing trust between sellers and buyers will also complicate negotiations on price premiums for the implementation of sustainability standards.

Outlook

The world's available resources of crude iron ore are estimated at over 800 billion tonnes with an iron content of about 230 billion tonnes (U.S. Geological Survey 2023a). The World Steel Association 2022, among others, forecasts that these resources will continue to be exploited and that global demand for steel will increase by 20% by 2050. While steel demand from the European automotive sector is forecast to decline over the next few years (Grigorenko 2023), global developments such as urbanisation and industrialisation in fast-growing economies like China and India are driving overall demand. In order to meet the rising demand for steel products, it is expected that new iron mines will be developed and steel mills (also based on the BF-BOF route) will be built. In parallel, however, new technological routes for the recycling and recovery of steel scrap and new low-emission processing technologies, e.g. based on hydrogen, must be further developed and brought to market maturity. Otherwise, the ambitious climate protection targets set for the industry in many countries of the world cannot be achieved (Kerkow et al. 2012).

As the previous sections show, the industry has been slow to address the issue of sustainability, with a strong focus currently on GHG emissions reduction. However, new technological opportunities also aim to improve the monitoring of the implementation of environmental and social standards along the entire supply chain through improved data exchange. At the same time, global crises and supply disruptions, for example in the EU, have led to an increased focus by governments on security of supply, which could lead to a weakening of environmental standards in favour of an economic compromise, for example in negotiations on free trade agreements.

4 Concluding Remarks

Today's global value chains are the result of private industry strategies and tactics designed to optimise their own benefits by maximising profits, reducing expenses, limiting risks and ensuring access to resources at lowest cost – at all stages. They focus on their respective core competencies, access markets across the world, and disengage with perceived disadvantages, with the interest of sellers to increase sales prices and buyers to lower purchase prices (public buyers predominantly followed this approach, too). In this regime, scale and power are the key factors, with any weakness leading to lower profitability. Financial services tend to serve these objectives by hedging risks from increased speculation.

Weak actors in global value chains face rigid barriers to increase power and benefit. Their weakness is often caused historically and structurally. In particular smallholders that are not organised (e.g. in cooperatives) or are located in structurally weak areas (e.g. lack of financial services, weak information and communication technology options) have hardly any means to place their needs and interests. In many cases, multiple efforts by informal local traders (e.g. coyotes in the case of coffee) keep such smallholders distant from official GVC participants.

The century-long legitimisation of companies in the Global North to blur responsibilities for the costs caused by these profit maximising strategies and tactics on a social or environmental level – now or in the future – has established a perspective that seeks individual profits and considers sharing (or investing in GVC participants) only when the profits generated allow it. In this paradigm, suppliers or sub-suppliers who harm the environment or society are held responsible for their practices; how the business practices of upstream companies force them to behave this way is largely ignored – or even denied. Civil society and academia have increasingly criticised the "unsustainability of global capitalism" (Palpacuer and Smith 2021), which has once again demonstrated its proneness to disruption and its negative impact on the most vulnerable (e.g. workers) during the COVID-19 pandemic.

Recent trends are challenging the prevailing paradigm of power and dependence in global value chains. Tightening regulations in the Global North (e.g. European Green Deal, due diligence legislation), societal conversations or investor requirements have become strong external pressures, pushing companies to improve sustainability performance in their own operations and in their supply chains – many trying to respond in ways that have limited impact on their existing business model or affect a sector equally. Yet, changes in consumer preferences, in climate and geopolitical developments enable the emergence of innovative business cases that value sustainability in supply chains, leading to more individual approaches aiming at increasing resilience to secure revenues. In Europe, Canada and China in particular, the targeted transition to a circular economy is causing a fundamental revision of current business models and thus global value chains, resulting in a reconsideration of business purpose implemented with a value co-creation mindset within emerging "Global Value Circles". Whether companies follow a defensive strategy to avoid disadvantages or pursue an entrepreneurial approach to realise advantages, the sharing of costs or benefits in buyer-supplier relationships determines what sustainability issues are addressed and how.

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