33 BRIEFING PAPER

Hard facts and envIRONmental impacts

An overview of the global iron and steel sector

Karin Küblböck
Bernhard Tröster
Michael Eigner

Vienna, June 2022

ÖFSE
Austrian Foundation
for Development Research

DOI: https://doi.org/10.60637/2022-bp33

IMPRINT

Austrian Foundation for Development Research – ÖFSE

A Austria, 1090 Vienna, Sensengasse 3, **T** +43 1 3174010, **F** -150

E *office@oefse.at*, **I** *www.oefse.at*, *www.centrum3.at*

With funding from

Austrian Development Cooperation

Table of Contents

Index of Boxes, Figures & Tables

List of Abbreviations

bn	billion
BNDES	National Bank for Economic and Social Development
CME	Chicago Mercantile Exchange
CRMC	Capital Research and Management Company
DCE	China's Dalian Commodity Exchange
DERA	Deutsche Rohstoffagentur in der Bundesanstalt für Geowissenschaften und Rohstoffe
EAF	electric arc furnace
EC	European Commission
EU	European Union
EUR	Euro
GDP	Gross Domestic Product
IODEX	The Platts Iron Ore Index
mio	million
NMDC	National Mineral Development Corporation
NYSE	New York Stock Exchange
US	United States
US $	US Dollar

Abstract

This briefing paper provides an overview of the global iron and steel sector. It describes the properties of iron ore and delineates the geographical distribution of deposits and trade flows. Further, it explains pricing mechanisms and addresses environmental impacts.

Iron and steel are key materials for industrial production, with iron being used 20 times more than all other metals combined. While extraction of iron ore has almost tripled over the past twenty years, the iron and steel sector remains highly concentrated, with most iron ore extraction taking place in just a few countries, in particular in Australia and Brazil, which account for over half of all iron ore extraction. Indeed, more than two-thirds of the iron ore export market is controlled by only four companies. In terms of global steel production, China accounts for more than half of the market share. Iron ore is also mined in Austria, and significant quantities are imported for steel production, although there is a lack of transparency; Austria is the only country in the EU not to publish statistical data on its iron ore imports since 2018.

Globally, iron and steel represent the largest sector in terms of energy demands, CO_2 emissions and air pollution and are among the world's major water consumers. Prices of iron ore are highly volatile, which has major consequences for exporting and importing countries and makes planning for CO_2 phase-out difficult.

Keywords: Iron ore, steel, trade flows, price volatility, China, Austria

1. Introduction

Iron and steel are key materials for industrial production, and over the coming decades, global demand for steel is expected to grow further. The European Commission (EC) estimates that approximately 12 tonnes of steel are in use for every person in the European Union (EU) (European Commission 2021). Compared to other metals or alloys, steel has almost unbeatable properties – in terms of its durability, heat resistance, and its combination of robustness and flexibility. However, large-scale environmental and climate impacts of steel production in its current forms present a significant drawback. Globally, iron and steel represent the largest sector in terms of energy demands,[1] CO_2 emissions[2] and air pollution and are among the world's major water consumers. Due to global greenhouse gas reduction commitments, efforts to reduce CO_2 emissions in this sector are intensifying (IEA 2021). To achieve this, a significant reduction of the use of primary sources as well as large technological advances would be necessary.

The iron and steel sector is highly concentrated in terms of iron ore extraction and steel production, and in terms of the largest companies. Even though iron ore is mined across some 50 countries worldwide, most iron ore extraction and steel production takes place in just a few countries. In 2019, 54 % of iron (content) was produced in Australia and Brazil (BMLRT 2021),[3] with more than 70 % of the iron ore export market controlled by only four companies – BHP Billiton, Vale, Rio Tinto and Fortescue Metals Group (Hellenic Shipping News 2019). In terms of global steel production, China accounted for 53 % of the market share (World Steel Association 2020c). The iron ore market is characterised by a high interdependence between China and Australia; in 2019, Australia accounted for 54 % of global iron ore exports (Observatory of Economic Complexity n.d.), 82 % of which was imported by China[4] (Hu 2020).

Prices of iron ore are highly volatile, which has major consequences for exporting and importing countries. Over the past ten years, prices fluctuated between 40 US $/tonne and 215 US $/tonne. During the COVID-19 crisis, the price of iron ore increased from 88 US $/tonne in March 2020 to a record high of 215 US $/tonne in July 2021, before falling back to 96 US $/tonne in November 2021 and rising again to 160 US $/ton only five months later. This high price volatility also makes planning for CO_2 phase-out increasingly difficult.

This briefing paper provides an overview of the global iron and steel sector. It starts by explaining the properties of iron ore and delineating the geographical distribution of deposits and trade flows. It then describes price developments and analyses price-setting mechanisms before presenting the most important iron ore producing companies and environmental impacts. In addition, it offers insights into the iron and steel sector in Austria and China, respectively.

---

1 The sector is responsible for around one quarter of global industrial energy demand

2 The global steel industry accounts for around 11 % of total global CO_2 emissions. Compared to emissions per country, the annual greenhouse gas emissions of the global steel industry rank third, after China and the United States (Hasanbeigi 2021).

3 For trade date we refer to the year 2018 and 2019, as 2020 cannot be regarded as a typical year due to the outbreak of COVID-19.

4 Further exacerbated by an import ban of Australian coal, which makes coal import and steel production more expensive for China (see Bartholomeusz 2020)

2. Properties and processing of iron ore

Iron is the most abundant metal within the Earth, making up 5 % of its crust and most of its inner core. It has played a significant role in the history of humanity; its use in the epoch of the "Iron Age" that started in 1200 B.C. was a major step in the development of our modern society as, for instance, iron tools made agricultural work easier and more efficient. The metal has not lost any of its significance since. Today, the use of iron is 20 times higher than all other metals combined (BHP 2019), and its use spans from simple household appliances to space exploration technology. Extraction of iron ore has almost tripled in the past 20 years (BGS 2021).

Iron in its pure form is extremely rare and can be primarily found in deposits from meteors. It occurs mostly in ores containing iron oxide, such as haematite and magnetite. Iron ore deposits are easy to locate due to their magnetic property.

Estimated global resources of crude ore exceed 800 billion tonnes, containing over 230 billion tonnes of iron. Global reserves are estimated at 170 billion tonnes, containing 81 billion tonnes of iron (USGS 2020b).[5] Large reserves can be found in "banded iron formations", with the largest known reserves in Australia. The quality of the extracted ore is extremely variable, with mines in Australia and Brazil containing high grades of iron compared to those in India or China with lower grades[6].

Of all iron ore mined, 98 % is used in the production of steel (BHP 2019). Pure iron itself is relatively soft, but when transformed into steel by adding carbon, it becomes up to a thousand times harder. The main method for steel making is the blast furnace route, using coke or coal at temperatures over 1,500°C to extract the metal from the ore, reducing the iron-ore oxides to pig iron ("raw iron"). The pig iron is subsequently converted to steel by adding carbon and other elements via oxidation based on chemical reactions in the blast furnace. To produce 1,000 kg of crude steel by blast furnace requires an average of 1,400 kg of iron ore, 800 kg of coal, 300 kg of limestone and 120 kg of recycled steel. This method accounts for about 70 % of global steel production (World Steel Association 2020a).

A second steel production method uses scrap steel melted in an electric arc furnace (EAF). The high temperatures needed for this process are generated by two electrodes. Since the raw material used in this route is scrap steel, the energy consumed in this process is only 30–40 % of that required in the blast furnace steel process route. Globally, about 30 % of steel is produced this way.

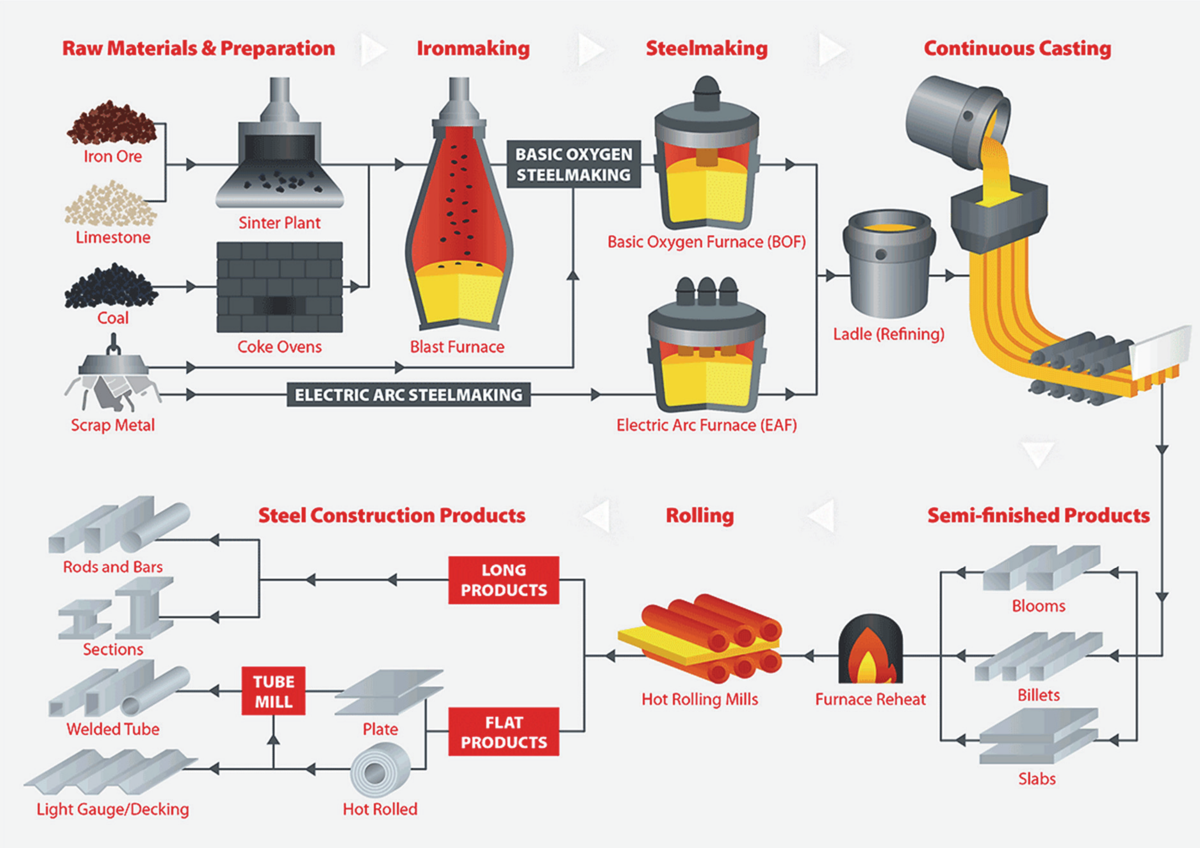
Steel is also the most recycled material on the planet, with a global recycling rate of over 60 %. Recycled steel accounts for roughly 37 % of steel produced today (Metinvest 2020).

---

5 Resource: A concentration of naturally occurring material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible. Reserve Base: part of an identified resource that meets specified minimum criteria related to current mining and production practices. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. Reserves: part of the reserve base which could be economically extracted or produced at the time of determination. The term need not signify that extraction facilities are in place and operative (USGS 2020b).

6 However, as the largest producers are already seeing their high-grade deposits deplete, they turn their attention to lower-grade iron ore deposits, which come with a higher environmental cost and a lower selling price (see Stockhead 2020).

Figure 1: Process of Steel Production



Source: New Steel Construction (NSC 2017)

3. Geographical distribution of iron ore extraction and trade

3.1. Iron ore production

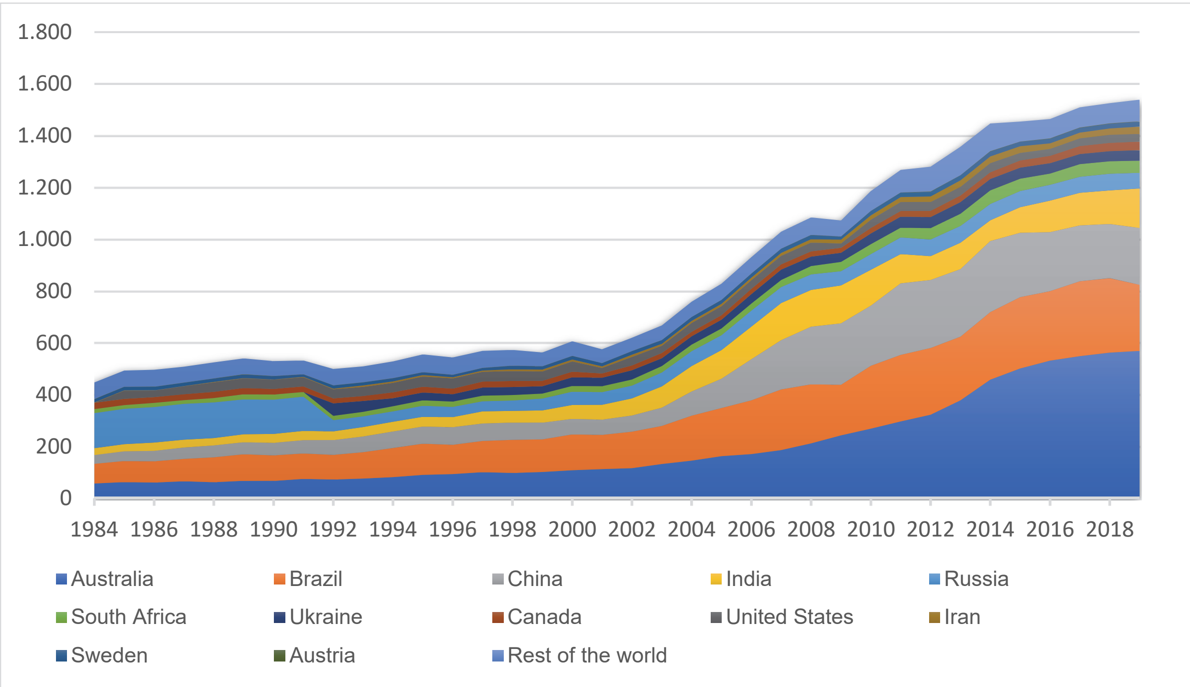
While iron ore is mined in about 50 countries, 75 % of iron ore extraction currently takes place in known reserves across only five countries: Australia, Brazil, China, India and Russia.

1. Australia is the most important country in terms of volume (37 % of global iron ore extraction) and quality (USGS 2021). In 2019, 919 million tonnes of iron ore with an iron content of 569 million tonnes were extracted. Australia also has the largest reserves with 48 billion tonnes of crude ore, with an iron content of 23 billion tonnes. In 2019, 82 % of Australia's iron ore exports were exported to China. Despite an ongoing trade dispute between the two countries, iron ore has so far remained exempt from it (Bartholomeusz 2020; Robertson 2020). It is remarkable, however, that while Australia is the world's largest iron ore extracting country, its steel production is comparatively small. In 2019, it was the 28th largest steel producer, just ahead of Slovakia (World Steel Association 2020a).
2. Brazil, as the second-largest iron ore extracting country, produced a volume less than half that of Australia in 2019 (405 million tonnes with an iron content of 258 million tonnes). In contrast to Australia, Brazil also has large steel producing companies and is one of the ten biggest producers of crude steel worldwide (Venditti 2021). In 2020, iron ore

contributed 66 % to Brazil's total mineral revenue. The country exported 342 million tonnes of iron ore in 2020 (2019: 340 million tonnes).

3. In 2019, China was the third highest iron ore producing country, with 351 million tonnes of iron ore production, containing 219 million tonnes of iron. China is leading in production of pig iron (60 % of total global production) and raw steel (53 % of total global production) (DERA 2019). Most of China's iron ore is used domestically and is usually very low-grade.
4. India is the fourth most important producer, with 238 million tonnes of iron ore and an iron content of 147 million tonnes extracted in 2019. The quality extracted is one of the lowest. India is the second-biggest producer of crude steel, producing mostly for the domestic market.
5. Although Russia's production of iron ore was only one-tenth of Australia's (98 million tonnes, with an iron content of 65 million tonnes), estimated reserves are significant, with 25 billion tonnes of crude ore and an iron content of 14 billion tonnes, surpassing China and India together in terms of iron content (USGS 2020a). Russia is the leading exporter of iron processing products such as raw iron ingots and blocks (47,6 % of global exports) (DERA 2019).

Figure 2 Global extraction of iron (content)

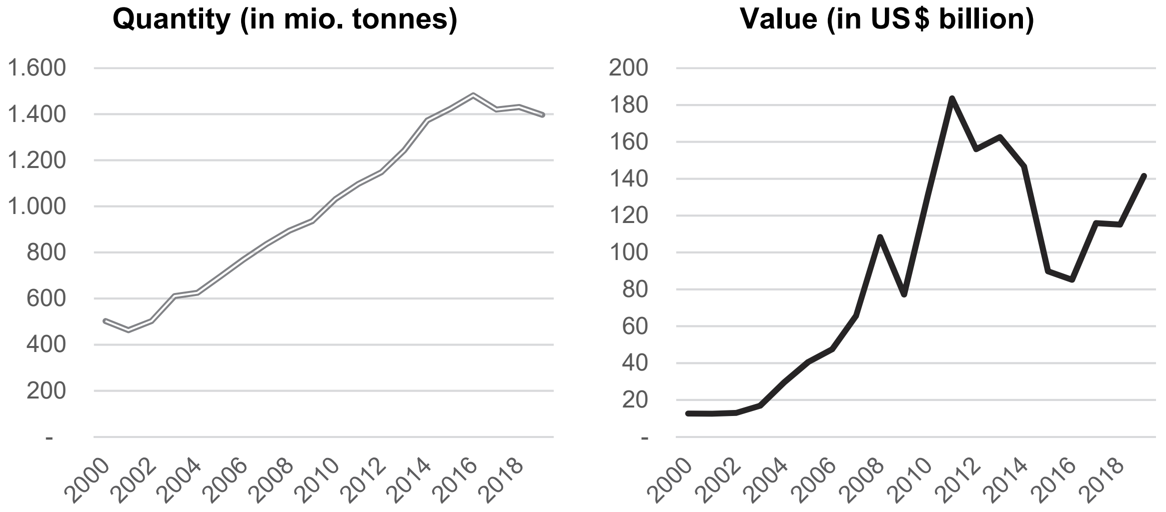


Source: World Mining Data

3.2. Iron ore trade

Global trade in iron ore has grown drastically since 2000. Between 2001 and 2016, the quantity of iron ore imports almost tripled, although this has essentially plateaued since then (Figure 1, left side). The value of iron ore trade increased ten-fold from 2001 to 2011 but has since been subject to large price variations (see Figure 1, right side, and also chapter 3).

Figure 3: Global trade of iron ore 2000-2019



Notes: Sum of imports by country of HS2601; data for 2019 are not yet completed.

Source: UN Comtrade

The increase in trade can be almost entirely attributed to the new dominant role of China in the global iron ore sector. Iron ore imports increased more broadly across Asian countries, while imports to the EU-27 and the United Kingdom (not in the table) are lower in 2018 than in 2000, with their share of global trade having declined drastically.

Table 1: Imports of iron ore by country/region

		Quantity (in mio tonnes)						Share				
	Land/Region	**2000**	**2005**	**2010**	**2015**	**2018**		**2000**	**2005**	**2010**	**2015**	**2018**
	Total	*503*	*697*	*1,032*	*1,424*	*1,431*						
1	China	70	275	618	952	1,065		14 %	40 %	60 %	67 %	74 %
2	EU-27	145	147	129	121	117		29 %	21 %	13 %	9 %	8 %
3	South Korea	39	43	56	73	73		8 %	6 %	5 %	5 %	5 %
4	Malaysia	2	2	3	15	27		0 %	0 %	0 %	1 %	2 %
5	Other Asia	15	15	19	24	24		3 %	2 %	2 %	2 %	2 %
6	India	43	0	1	10	20		9 %	0 %	0 %	1 %	1 %
7	Turkey	4	5	7	10	11		1 %	1 %	1 %	1 %	1 %
8	Vietnam	-	0	0	0	9		0 %	0 %	0 %	0 %	1 %
9	Oman	0	0	0	11	9		0 %	0 %	0 %	1 %	1 %
10	Bahrain	-	4	5	5	9		0 %	1 %	0 %	0 %	1 %

Notes: Imports by country of HS2601; data for 2019 are not yet completed; Data for Austria in 2018 are disclosed and not included in the sum of EU-27.

Source: UN Comtrade

On the other side of the trade balance, iron ore extracting countries have increased their exports drastically. In particular, Australia, as the main supplier to China, was able to increase its market share to more than 50 %. Brazil accounts for more than 25 % of global iron ore exports, while all other countries have relatively little share in total exports. India, as an important source of iron ore in 2000, has reduced its exports significantly.

Table 2: Exports of iron ore by country

		Quantity (in mio tonnes)						Share				
	Land/Region	**2000**	**2005**	**2010**	**2015**	**2018**		**2000**	**2005**	**2010**	**2015**	**2018**
	Total	*503*	*697*	*1,032*	*1,424*	*1,431*						
1	Australia	159	242	399	760	770		32 %	35 %	39 %	53 %	54 %
2	Brazil	138	200	274	358	369		27 %	29 %	27 %	25 %	26 %
3	South Africa	19	25	44	64	58		4 %	4 %	4 %	5 %	4 %
4	Canada	20	17	28	39	40		4 %	2 %	3 %	3 %	3 %
5	Ukraine	16	15	29	40	33		3 %	2 %	3 %	3 %	2 %
6	EU-27	13	14	19	20	24		3 %	2 %	2 %	1 %	2 %
7	India	34	85	104	4	17		7 %	12 %	10 %	0 %	1 %
8	Iran	0	3	15	13	15		0 %	0 %	1 %	1 %	1 %
9	Peru	3	6	8	11	14		1 %	1 %	1 %	1 %	1 %
10	Chile	6	5	10	13	13		1 %	1 %	1 %	1 %	1 %

Notes: Exports as imports by country of HS2601; data for 2019 are not yet completed; Data for Austria in 2018 are disclosed and not included in the sum of EU-27.

Source: UN Comtrade

For the EU-27, the main sourcing country of iron ore is Brazil, with a share of 36 %, followed by Canada (18 %) and Ukraine (17 %). Within the EU, Sweden is the main country with iron ore extraction and supplies and has provided an increasing share to the EU-27.

Table 3: Imports of iron ore by EU-27 countries

		Quantity (in mio tonnes)						Share				
	Land/Region	**2000**	**2005**	**2010**	**2015**	**2018**		**2000**	**2005**	**2010**	**2015**	**2018**
	Total	*144.9*	*147.1*	*129.3*	*121.3*	*117.9*						
1	Brazil	60.4	66.9	54.5	50.6	42.6		42 %	45 %	42 %	42 %	36 %
2	Canada	13.1	9.0	14.2	17.1	20.6		9 %	6 %	11 %	14 %	18 %
3	Ukraine	15.9	11.1	14.5	16.3	19.9		11 %	8 %	11 %	13 %	17 %
4	Sweden	9.8	9.3	11.8	10.9	12.8		7 %	6 %	9 %	9 %	11 %
5	Russian Federation	7.8	10.3	7.9	6.3	5.9		5 %	7 %	6 %	5 %	5 %
6	South Africa	3.1	4.7	4.0	2.7	5.6		2 %	3 %	3 %	2 %	5 %
7	Mauritania	9.7	9.4	5.8	3.6	2.6		7 %	6 %	4 %	3 %	2 %
8	Norway	2.5	3.1	1.3	3.1	1.6		2 %	2 %	1 %	3 %	1 %
9	Liberia	0.1	0.1	0.0	3.0	2.4		0 %	0 %	0 %	2 %	2 %
10	Latvia	0.01	-	0.1	0.00	0.3		0 %	0 %	0 %	0 %	0 %

Notes: Imports by country of HS2601; Data for Austria in 2018 are disclosed and not included in the sum of EU-27; before 2018, Austrian data are not part of the breakdown by country.

Source: UN Comtrade

Box 1: The iron and steel sector in Austria

The iron ore sector has for centuries been an important part of Austria's economy and remains so, with an active iron ore deposit being mined to this day. The "Erzberg", where mining has been taking place for 1,300 years, is the last remaining iron ore mine in Austria, with others having closed owing to high maintenance costs and low-grade ore. A further mine in the Austrian province of Carinthia provides Micaceous Iron Oxides, a scarce natural resource with an iron content of over 85 %. Its primary use is in the infrastructure sector, providing extra protection from corrosion.

In 2019, Austria extracted 3.2 million tonnes of iron ore, containing 1 million tonnes of iron[7], making Austria the 27th biggest global producer of iron. As Austria is home to a relatively large steel industry, it imports considerable quantities of iron ore in addition to its domestic production.

Undisclosed Trade Data

Currently, data on iron ore imports to Austria are not published. Until 2017, statistics on the iron ore codes 26011100 and 26011200 included only the absolute amounts of import values and quantities, but not the countries of origin ('Länderunterdrückung'). Since 2018, the absolute values and quantities have also remained undisclosed ('Totalunterdrückung'), which makes Austria the only country in the EU that does not disclose its iron ore imports. Such a suppression of data is intended to ensure statistical confidentiality when "data […] allow statistical units to be identified, either directly or indirectly, thereby disclosing individual information."[8] The company concerned may submit an application to the national statistical authority for suppression of trade data on an annual basis.[9] The decision is based on the company's share of the total trade in these products.

As the data of national statistical authorities are the basis for other data sources on trade, such as UN Comtrade, the suppression of trade data on iron ore in Austria also means that they are not included in these data. Up to 2017, total values and quantities of Austrian imports are available on a 6-digit level (Harmonized System), but the country of origin is published as "Special Categories". From 2018 onwards, the total suppression of Austrian data excludes these data also on a detailed level. Between 2003 and 2017, the imports of iron ore to Austria varied between 6 and 10 million tonnes.

From 2018 on, Austrian iron ore trade data are only included as part of aggregated trade data in the category HS26 'Ores, slags and ashes', which includes all metal ores. Inclusion of iron ore in this category ensures that Austrian metals trade data are correctly presented. It also allows for a rough estimation of countries of origin, given that iron ore imports can be estimated to account for about 80 % of imports in HS26. The main countries of origin in this aggregate category were Ukraine (53 %), South Africa (24 %) and Brazil (10 %). All three countries are among the Top 10 exporters of iron ore (Table 2).

Steel production in Austria

Over the past 15 years, Austrian steel production remained relatively stable, with an annual output of between 7 and 8 million tonnes of crude steel.[10] This made Austria the 22nd biggest producer of crude steel in 2019 (World Steel Association 2020a). In 2018, 60 % of its steel export volume went to 5 countries. Germany received the largest share with 34 %, followed by Italy (10 %), the Czech Republic (6 %), Poland (5 %) and the United States (5 %) (International Trade Administration 2019).

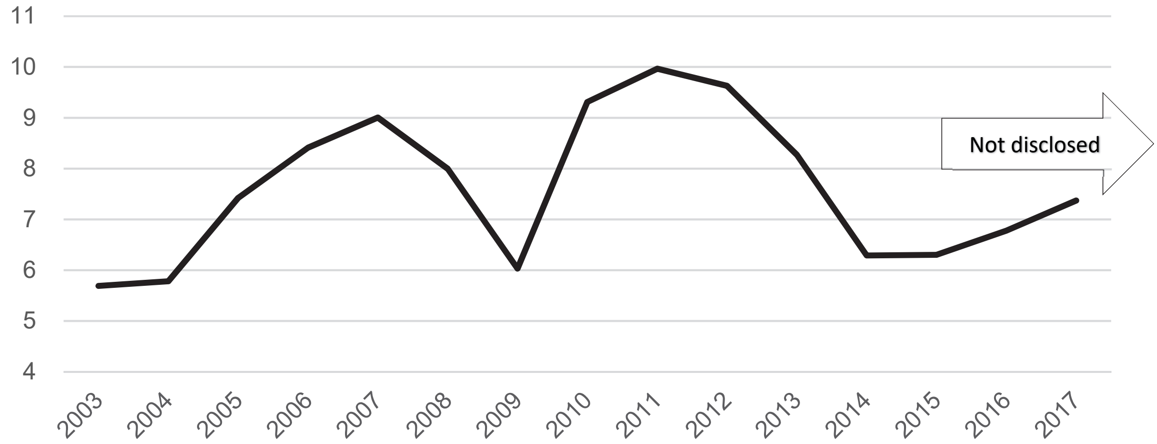
[7] Iron content: WMD, iron ore: estimated from BGS data, which only exists until 2018, but in all years the iron content was 32 % of the iron ore.

[8] https://ec.europa.eu/eurostat/web/research-methodology/statistical-confidentiality

[9] http://www.statistik.at/wcm/idc/idcplg?IdcService=GET_PDF_FILE&RevisionSelectionMethod=LatestReleased&dDocName=001650

[10] https://de.statista.com/statistik/daten/studie/14745/umfrage/oesterreich-stahlproduktion/

Figure 4: Iron ore imports to Austria (in mio. tonnes)



Source: UN Comtrade

The national steel industry comprises 13 companies with over 15,000 employees[11] in Austria. The company Voestalpine AG, headquartered in Linz, Upper Austria, is the biggest company in Austria's steel sector, with 12.7 billion EUR revenue in the business year 2019/20. It is ranked the 51st biggest company in terms of annually produced steel, making it the 5th biggest steel producer in Europe (World Steel Association 2020b).

High climate impact of the Austrian iron and steel sector

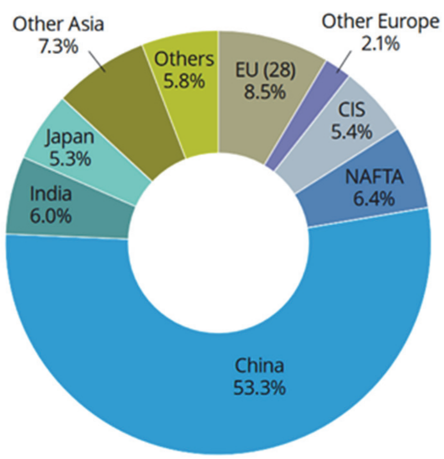
The iron and steel sector accounts for 15 % of total Austrian greenhouse gas emissions (UBA 2021), more than all other industrial sectors combined. Given Austria's commitments to the Paris agreement and related EU targets to reduce greenhouse gas emissions, the iron and steel sector is one of the key sectors where substantial reductions are needed. Austrian steel companies are exploring ways to reduce their future carbon footprint. Voestalpine hosts the world's largest pilot plant for exploring technologies to replace coke and coal with hydrogen, which could be applicable on an industrial scale within 20 years. However, the additional annual energy required for hydrogen production of Voestalpine AG alone would be 30-terawatt hours, which is half of Austria's current electricity demand (Knitterscheidt 2019).

[11] https://www.wko.at/branchen/industrie/bergwerke-stahl/Stahlindustrie-Statistiken.html

Box 2: The iron and steel sector in China

China's rapid economic growth in recent decades has been linked to a massive expansion of its steel production and, consequently, a soaring demand for iron ore. The scale and pace of this development have caused a substantial shift in the global iron and steel sector. Between 1997 – when China first surpassed Japan as the world's leading steel producer – and 2017, global steel production more than doubled, with China responsible for 81 % of that increase (Shioda 2020). Today, China produces more than half of the world's steel (World Steel Association 2020a). Although China itself is a major producer of iron ore (see figure 2), it relies on imports for nearly 80 % of its iron ore consumed (Mining Technology 2021) and accounts for 70 % of the world's iron imports (Terzon/Chau 2020).

Figure 5: World Steel Production, 2019



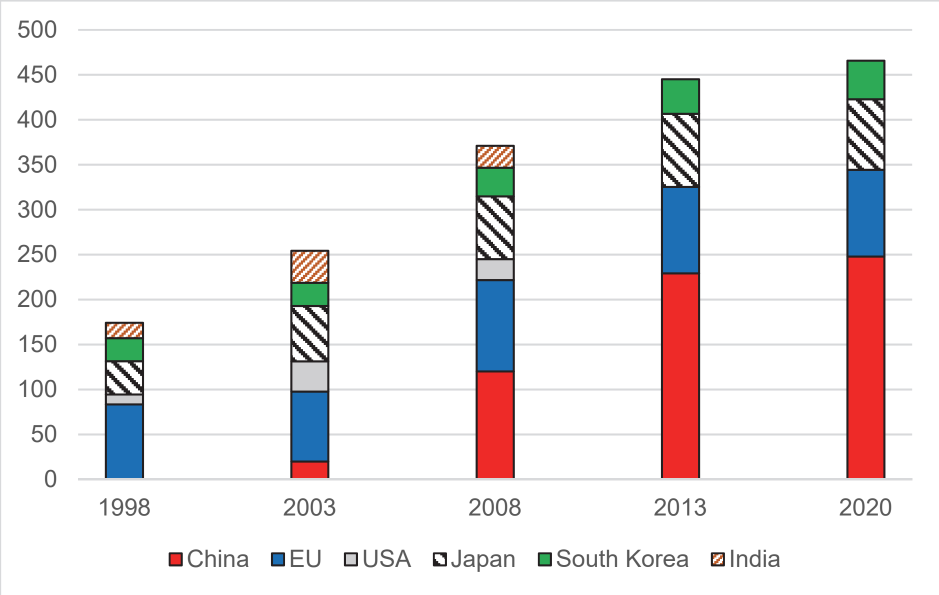
Source: World Steel Association 2020c

This development is also mirrored in the historical ranking of the world's ten largest steelmakers. While in 1998, there was no Chinese company among the top ten steel producers, in 2020, six of the ten companies were from China. In 2019, 57 of the 100 largest steel-producing companies were Chinese (World Steel Association 2020b).

In order to secure its supply of iron ore and to decrease its dependence on Australia, China stepped up its effort to source alternative supplies, aiming to acquire mines abroad. In December 2020, the Chinese Industry Ministry announced that China would accelerate the construction of large iron ore projects in West Africa and Western Australia and strengthen cooperation with Russia, Kazakhstan, Mongolia, Cambodia and other neighbouring countries to boost supply and enhance its pricing power (Zhang et al. 2021; Zhang/Daly 2020).

By far the largest prospective alternative mine is at Simandou in Guinea, with the potential to extract 70-150 million tonnes of iron ore per year, which would represent a large new source of iron ore. However, the project faces significant logistical hurdles, including the requirement for about 650 kilometres of new railway, cutting through vast regions of mountainous terrain. Overall, it is not expected that production at Simandou will start within the next five years or potentially even more (Department of Industry, Science, Energy and Resources 2020).

Figure 6: Countries of origin of the largest Steel Companies, 1998-2020 (produced tonnes)



Source: World Steel Association

Environmental and climate impact

As in other countries, the Chinese iron and steel industry creates substantial environmental impacts. It is responsible for 24 % of industrial energy and 22 % of water use and releases 21 % of total CO_2 emissions (Zhang et al. 2019). As a consequence, in recent years, environmental concerns led to a large number of mine closures in China and, subsequently, to a higher demand for high-grade ores, mainly from Australia and Brazil (Csokasi 2021). The reason for this development is that Chinese mines contain mostly low-grade ores with 20-30 % iron ore content. The use of high-grade iron allows for reduced coking coal consumption and, therefore, lower carbon emissions from steel production. However, even when using high-grade ores, the steel sector is a major driver of carbon emissions. Chinese environmental plans, which target carbon neutrality by 2060, might lead to a reduction in its steel production in the future. At the end of 2020, China's industry minister called on the steel industry to reduce output in order to reach its carbon emission targets. However, at the beginning of 2022, the Chinese government postponed the deadline for peak emissions for the steel sector for five more years (2030 instead of 2025), meaning that steel production will continue at previous levels (Mining.com 2022).

4. Price formation and trends

In recent decades, the iron ore pricing mechanism has experienced substantial transitions, from spot pricing, long-run price negotiations, quarterly pricing, monthly pricing and back to spot pricing (Ma/Zhen 2020; MoneyMorning n.d.). Before the 1950s, the global iron ore supply was organised by spot transactions. In the 1960s, Japan became the major purchaser of iron ore resources and signed a long-term price contract with Australia, which was joined by the United States and various European countries in the 1970s.

Over the following 40 years, prices were set in a benchmark system, consisting of fixed one-year price contracts that were annually negotiated between the major iron ore miners and their main buyers, the largest steel companies (Hume/Sanderson 2016). This system started to break down as a consequence of China's rapidly growing demand. In order to secure its supply, China started to source iron ore from India on an ad hoc basis, leading to the creation of the first spot price indices (ibid.). From 2008, specialised agencies started to compile spot prices, which were increasingly used as a reference.

From 2010, iron ore suppliers relied first on a quarterly and subsequently monthly price (Ma/Zhen 2020). Today prices are determined on a daily basis according to price indices. They are published by price assessment agencies such as Platts, Argusmedia and Metal Bulletin. Those companies compile prices of physical iron ore trades and come up with volume-weighted average daily reference prices. The Platts Iron Ore Index (IODEX) is currently the main benchmark assessment of the spot price of physical iron ore. The price assessment is based on a standard specification of iron ore with 62 % iron content. Lower grades are sold at a discount, while higher grades attract a premium. In the past five years, premiums for high-grade and discounts for low-grade iron ore have increased (Stockhead 2020).

The end of the benchmark system based on fixed-price contracts led to a substantial increase in price volatility and induced the creation of several iron ore derivatives markets to provide companies hedging opportunities against increasing price risks. This, in turn, paved the way for financial investors to enter those markets (Jégourel 2020). China's Dalian Commodity Exchange (DCE), which first listed iron ore futures at the end of 2013, is today the world's largest iron ore financial derivatives trading market. Iron derivatives are further traded at the Singapore Exchange and the Chicago Mercantile Exchange (CME). Since the creation of iron ore futures markets, trading volume, trading value, and positions have been gradually increasing each year. Today, iron ore futures prices in China have price discovery functions, which increases the risk of financialisation of the market (Ge et al. 2019). This means that prices not only respond to changes in fundamental variables such as steel demand, stocks, or exchange rates but also to traders' bets on future price levels. This mechanism results in increased instability – materialising either in a further increase in price volatility or in the development of speculative bubbles (Jégourel 2020).[12]

For the above reasons, iron ore prices have become increasingly volatile, particularly over the last two decades, spiking at US $ 190 tonne in 2007 and 2011, dropping to around US $ 60 per tonne in the interim period. Just four years later, in 2015, iron ore was priced at only US $ 40 per tonne, resulting in a mass exodus of companies from the sector (East 2020),[13] which contributed to an even higher concentration of iron ore producing companies today. In the COVID-19 crisis, the price of iron ore increased from 88 US $/tonne in March 2020 to a record high of 215 US $/tonne in July 2021, before falling back to 96 US $/tonne in November 2021.

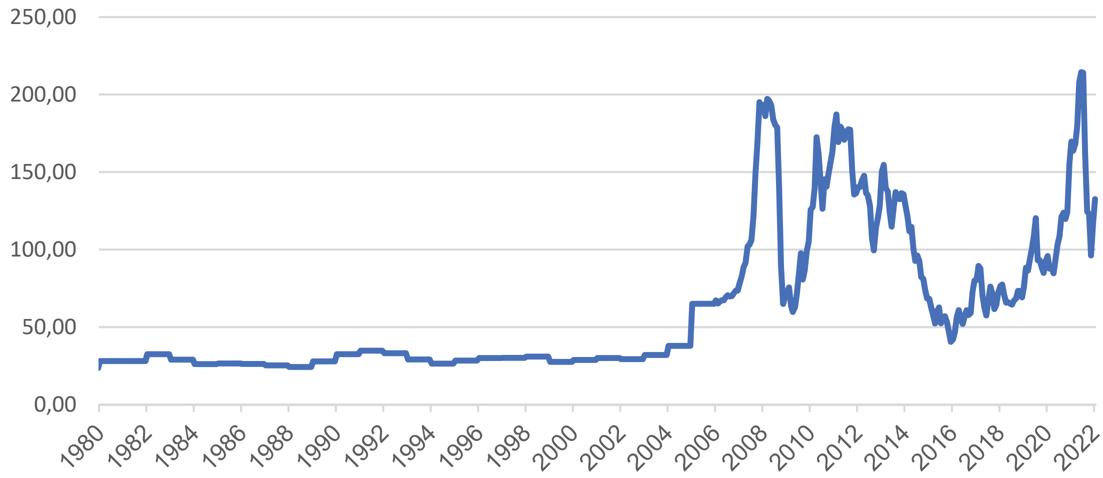
As most iron ore producers receive the spot price (as opposed to a fixed long-term contract price), these fluctuations have a major impact on producer companies.

---

[12] However, there are so far no studies on the effect of the introduction of an iron ore futures contract on the volatility of spot or commercial prices (Ibid 2020)

[13] Prices shrunk by two thirds from US $ 170/dmt to US $ 57/dmt in just three months during the 2008 Global Financial Crisis, then doubled between October 2009 and April 2010, before again shedding 47 % in the following three months. In late 2012, they spiked by 74 % over four months. With global steel markets seeing their sharpest uptrend in over a decade thanks to post-COVID infrastructure spending, it should really come as no surprise to see iron ore prices surging to the current extent. Interestingly, all these volatile periods occurred before the establishment of liquid derivative contracts

Figure 7: Price development of iron ore (compared to the price development of base metals, 1960-2/2021, price indices, base year = average price 2000)



Source: World Bank, https://www.worldbank.org/en/research/commodity-markets

Steel is almost the exclusive product of iron ore, and demand for the metal plays a key role in determining iron ore prices. Because steel is used in most areas of the economy, with construction and the automotive sector being the two biggest consumers, these industries are highly sensitive to macroeconomic factors such as unemployment, interest rates, and Gross Domestic Product (GDP).

5. Largest iron ore producing companies

The mining of iron ore is capital-intensive. It requires large investments in infrastructure and high volumes to be profitable. As a consequence, the market is highly concentrated. In 2020, the largest iron ore producing companies in terms of both their production and market capitalisation were Rio Tinto, Vale BHP Group and Fortescue Metals Group, accounting for 70 % of the export market share. The fifth-largest company, the Indian company NMDC, produced one-tenth of Rio Tinto's iron ore production in 2019.

- **Rio Tinto**

The Anglo-Australian mining company Rio Tinto was founded in 1873 and is headquartered in Melbourne. In 2019, it produced 327 million tonnes of iron ore and had a market capitalisation of US $ 88.6 bn on the New York Stock Exchange (NYSE). It operates in 35 countries, including Brazil, Australia, Serbia, Iceland and Singapore, and owns 16 mines and four port facilities. Besides iron, the company mines bauxite, copper, diamonds, and other minerals.

Rio Tinto has recently come under attack for the destruction of a sacred Aboriginal site in 2020. The company blasted over 46,000-year-old caves in the Juukan Gorge, which was the only inland site that could prove continuous human occupation over this time span (Allam 2020).

- **Vale**

The Brazilian company Vale is a multinational mining company headquartered in Rio de Janeiro. Vale was created in 1942 during World War II as a state-owned company via a partnership between Brazil, the United States, and the United Kingdom to ensure international access to the rich iron ore deposits located in the Iron Quadrangle of Minas Gerais. In return, Brazil was given financial support for a steel mill, which helped to create the material bases to advance the country's industrialisation project (Milanez/dos Santos 2019). The company was privatised in 1997, and control was transferred to the Valepar group, formed by pension funds and international and national financial groups. Some state participation is maintained through the National Bank for Economic and Social Development (BNDES). Since 2016, institutional investors such as BlackRock and the Capital Research and Management Company (CRMC) have become more prominent (ibid.).

Besides iron, Vale also mines nickel, coal, manganese and ferroalloys (Mining Connection.com 2018). In 2019, it produced 302 million tonnes of iron ore, and its market capitalisation at the NYSE was US $ 65 bn. Vale's Carajás iron mine, located in the north of Brazil, is one of the world's largest mining facilities, containing some of the highest-quality ore.[14]

Until 2018, Vale was the world's largest producer of iron ore, producing 385 million tonnes in 2018. Its production was reduced by a fifth in 2019 to 302 million tonnes following the collapse of one of its dams in Brumadinho in February 2019, which caused 270 deaths and vast environmental damage. In November 2020, the company announced that 33 of its 104 Brazilian dam structures had failed stability assessments, with nearly all of the affected dams connected to iron ore facilities (Department of Industry, Science, Energy and Resources 2020). In February 2021, Vale signed an agreement to pay US $ 7 billion in compensation to the state of Minas Gerais. Although the amount to be paid was less than what the state government initially demanded, state officials still called it the biggest settlement in Brazilian history. Vale's shares rose following the agreement (Attwood 2021).

- **BHP Group**

The third of the "big three" iron mining companies is the Anglo-Australian BHP Group, headquartered in Melbourne, with iron ore assets in Australia and Brazil. BHP operates in several countries, such as Brazil, Algeria, Chile, Mexico, and Peru.

BHP was the largest of the iron mining companies in terms of market capitalisation in 2019, with more than US $ 134 bn on the NYSE. BHP's iron ore production in 2019 was 270 million tonnes. Most of its iron ore business is concentrated in Western Australia's Pilbara region. Its production consists of five mines, four processing hubs and two port facilities. The BHP Group is also co-owner of the Brazilian Samarco facility.

- **Fortescue Metals Group**

Fortescue Metals Group is an Australian mining company headquartered in Perth, Western Australia. Similar to Rio Tinto and BHP, Fortescue's iron ore mining is concentrated in the Pilbara region of Western Australia. The company focuses solely on iron ore mining, with a production of 168 million tonnes in 2019 and a market capitalisation of US $ 18.6 bn on the NYSE. Fortescue is one of the lowest-cost iron ore suppliers and is one of the most important exporters of iron ore to China.

- **NMDC**

National Mineral Development Corporation (NMDC) is an Indian mining company owned by the Indian Government. Founded in 1958, it produced 31 million tonnes of iron ore in 2019-20 and had a market capitalisation of nearly US $ 4 bn on the NYSE in 2019.

In recent years, NMDC has been an important contributor to the Indian mineral sector. The Bailadila mine in the state of Chhattisgarh is its main source of iron ore and is believed to

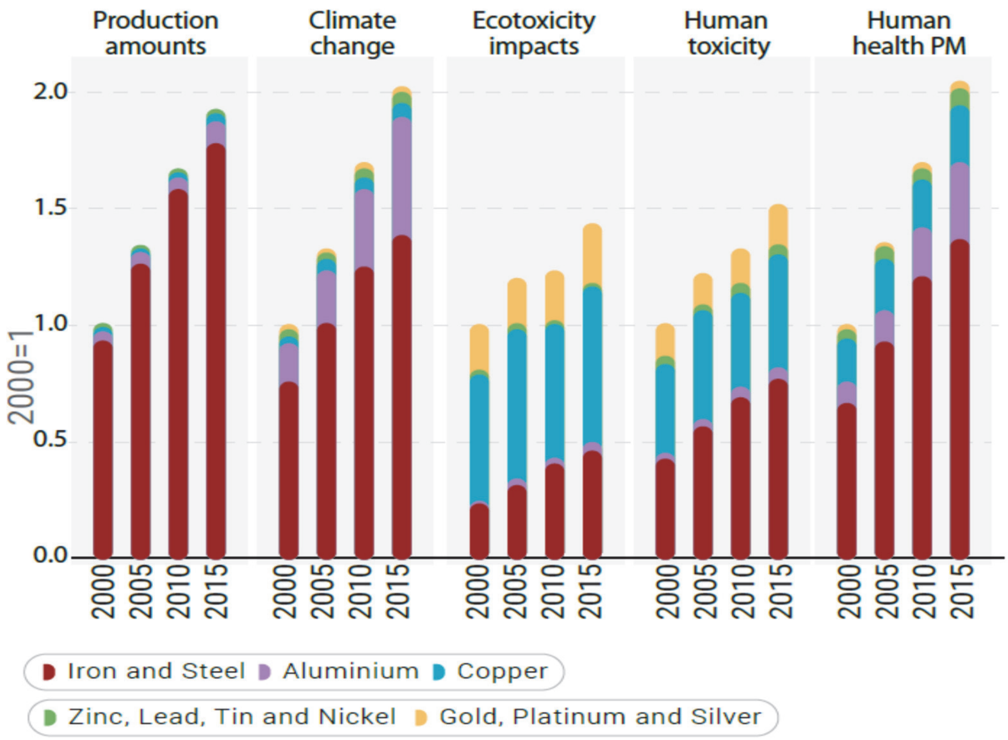
[14] Possessing about 7.2 billion metric tonnes of proven iron ore reserves, its daily production amounts to 300,000 metric tonnes.

contain 1,200 million tonnes of high-grade iron ore. NMDC is also involved in the exploration of other metals and minerals, such as copper, diamond, limestone, gypsum, rock phosphate, bentonite, dolomite, magnesite, graphite, tin, tungsten and beach sands, which are extracted from four mines in India.

6. Environmental impact of the iron and steel sector

The iron and steel industry causes massive environmental and climate impacts. Globally, it is the largest industry in terms of energy needs, CO_2 emissions and air pollution and is one of the most water-intensive industries. It accounts for 20 % of world industrial energy use and 29 % of direct industrial CO_2 emissions (Zhang et al. 2019). Blast furnace production accounts for most of the CO_2 emissions of the iron-steel value chain due to the use of coking coal and injection coal for pig iron production[15]. Alternative processing methods with lower CO_2 emissions are at varying stages of development, although commercial adoption is low. The International Energy Agency estimates that the energy intensity of iron and steel production can only be lowered by 20 % compared to the current state if the best available technology is applied. A transition toward a CO_2-lean steel production involves replacing the use of coking coal with electrical energy, which in turn demands a significant increase in decarbonised electrical energy production. Considering that global steel demand is projected to increase further, an absolute reduction in climate change impacts does not seem realistic (UNEP 2013).

Figure 8: Environmental impacts of metal mining[16]



Source: Anon. 2019

[15] Iron reduction in the blast furnace requires 330 kg of coal and coke per tonne of steel and releases over 400 kg CO_2/t.
[16] Ibid.: p 76

Mining, including iron ore mining, poses a significant risk for rainforests, with 9 % of deforestation of the Brazilian Amazon between 2005 and 2015 attributed to mining activities (Sonter et al. 2017). The world's biggest iron ore mine, Carajás, owned by Vale, caused widescale deforestation with the development of its mining pits, processing infrastructure, the creation of new settlements and the establishment of a 900 km-long railway to transport the ore to the Atlantic. The use of coal for the production of pig iron is an additional driver for deforestation in this region, as charcoal derived from virgin forest wood is increasingly used as a reducing agent instead of coke (ibid.). Charcoal causes CO_2 emissions per unit of steel up to nine times higher compared to the use of coke (Kind et al. 2018).

With the destruction of rainforests, regional hydrological systems are also disrupted. In arid regions, iron mining heavily relies on groundwater, possibly causing water use conflicts and damaging water-dependent ecosystems. In this context, Acid Mine Drainage is an important environmental problem associated with mining. It occurs when sulphur-containing minerals found in ore deposits oxidize through contact with air and water, which potentially pollutes surface water and groundwater and is toxic to vegetation (Kumari et al. 2010). In addition, numerous hydropower plants within the Amazon are directly related to the energy-intensive extractive industry.

Red dust pollution is another environmental problem associated with iron ore extraction. Residents of iron mining regions often suffer from iron ore dust released from smelters around the mine. For example, the biggest port in Australia, Port Hedland, located in the federal state Western Australia, is the source of red iron dust pollution in the area, causing respiratory diseases. Pollution levels in this state are 40 % above the national standard (Mangan/Lewis 2020).

Recycling is one possible pathway towards decreased environmental impacts deriving from iron use. Secondary steel production only causes between 10 and 38 per cent of the climate impact of primary steel production. However, as steel is used in many products with long lifetimes (such as in the construction sector), the scrap amounts available are unable to match the large global increase in steel demand, which, as a result, is met mainly by primary steel. In China, primary steel production increased more than six times between 2000 and 2015. Approximately 20 % of climate change impacts from the iron-steel industry in China are due to exports to other regions (UNEP 2019).

7. Conclusions

Iron and steel are indispensable for industrial production. Extraction of iron ore has almost tripled over the last twenty years, and demand is expected to grow further. This risks exacerbating adverse environmental impacts in producer countries and further increasing CO_2 emissions through iron ore extraction and steel production. Major players in the highly-concentrated mining segment have a responsibility to make mining more sustainable, while companies in the steel and downstream manufacturing segments have to reduce primary demand, apply less CO_2-intense production methods and move toward greater re-use and recycling of products. Policies at national and international levels are needed to accelerate the transformation in the sector, to reduce emissions and to mitigate negative consequences in producer countries. Currently, high price volatility worsens the macroeconomic situation of mineral-rich countries (Tröster/Küblböck 2020) and counteracts efforts to incentivize greener production, for example, through CO_2 pricing. More research on price-setting mechanisms and policy initiatives for price stabilization is necessary to facilitate planning for producer countries and companies and for supporting a transformation towards more sustainability.

References

Allam, Lorena (2020): Rio Tinto condemned by shareholders for seeking legal advice before blowing up Juukan Gorge. The Guardian. *http://www.theguardian.com/business/2020/sep/07/rio-tinto-condemned-by-shareholders-for-seeking-legal-advice-before-blowing-up-juukan-gorge*, 24.03.2021

Anon. (2019): Emissions Gap Report 2019. UNEP.

Attwood, James (2021): Vale to pay $9.2b for one of world's worst mining disasters. Australian Financial Review. *https://www.afr.com/markets/commodities/vale-to-pay-9-2b-for-one-of-world-s-worst-mining-disasters-20210205-p56zra*, 24.03.2021

Bartholomeusz, Stephen (2020): Schadenfreude as Chinese steel mills ask for help from Rio and BHP. The Sydney Morning Herald. *https://www.smh.com.au/business/markets/schadenfreude-as-chinese-steel-mills-ask-for-help-from-rio-and-bhp-20201217-p56oa6.html,* 22.03.2021

BGS (2021): World mineral statistics data for iron ore. *https://www2.bgs.ac.uk/mineralsuk/statistics/wms.cfc?method=searchWMS*, 22.03.2021

BHP (2019): Iron ore

Csokasi, Marko (2021): Iron Ore Trading In 2021: How And Where To Trade The Commodity. Commodity.com. *https://commodity.com/precious-metals/iron-ore/trading/*, 22.03.2021

Department of Industry, Science, Energy and Resources (2020): Resources and Energy Quarterly. 10(4), 164.

Deutsche Rohstoffagentur (DERA) (2019): DERA-Rohstoffliste 2019

East, Angela (2020): Chronic supply crunch = boom time for iron ore juniors. Stockhead. *https://stockhead.com.au/resources/chronic-supply-crunch-boom-time-for-iron-ore-juniors/*, 24.03.2021

European Commission (2021): Towards competitive and clean European steel (Nr. SWD(2021) 353 final)

Ge, Yongbo/Cao, Tingting/Jiang, Ruchuan/Liu, Peide/Xie, Hengxin (2019): Does China's Iron Ore Futures Market Have Price Discovery Function? Analaysis Based on VECM and State-Space Perspective. In: Journal of Business Economics and Management 20(6), 1083-1101. *https://doi.org/10.3846/jbem.2019.10604*

Hasanbeigi, Ali (2021): Global Steel Industry's GHG Emissions. *https://www.globalefficiencyintel.com/new-blog/2021/global-steel-industrys-ghg-emissions*, 24.03.2022

Hellenic Shipping News (2019): How the Iron Ore Market Works. Hellenic Shipping News Worldwide. h*ttps://www.hellenicshippingnews.com/how-the-iron-ore-market-works/*, 22.03.2021

Hu, Tracy (2020): Australia to continue to supply most of China's iron ore despite trade tensions. S&P Global Market Intelligence. *https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/australia-to-continue-to-supply-most-of-china-8217-s-iron-ore-despite-trade-tensions-59208917*, 22.03.2021

Hume, Neil/Sanderson, Henry (2016): How is iron ore priced? *https://www.ft.com/content/aeaaddf4-e5de-11e5-a09b-1f8b0d268c39*, 24.03.2021

IEA (International Energy Agency) (2021): Net Zero by 2050 – A Roadmap for the Global Energy Sector.

International Trade Administration (2019): Steel Exports Report: Austria. Global Trade Monitor.

Jégourel, Yves (2020): The global iron ore market: From cyclical developments to potential structural changes. In: The Extractive Industries and Society, 7(3), 1128-1134. *https://doi.org/10.1016/j.exis.2020.05.015*

Kind, Tobias/WWF Deutschland, WWF Deutschland (2018): Rohstoffboom zwischen Gewinnen und Verlusten Deutschlands ökologischer Fußabdruck durch Stahl und Aluminium.

Knitterscheidt, Kevin (2019): Stahlherstellung: CO_2-freie Produktion bis 2050: Thyssen-Krupp will Hochöfen dichtmachen. *https://www.handelsblatt.com/unternehmen/industrie/stahlherstellung-co2-freie-produktion-bis-2050-thyssen-krupp-will-hochoefen-dichtmachen/23879546.html*, 24.03.2021

Kumari, Sangita/udayabhanu, G./Prasad, Bably (2010): Studies on environmental impact of acid mine drainage generation and its treatment: An appraisal. In: Indian Journal of Environmental Protection, 30/11.

Ma, Yiqun/Zhen, Wei (2020): Market Fundamentals and Iron Ore Spot Prices. In: Economic Record, 96(315), 470-489.

Mangan, Sinéad/Lewis, Chris (2020): “It’s a shit town, but it’s our shit town”: Residents resist miners’ bid to buy them out. ABC News. *https://www.abc.net.au/news/2020-09-11/port-hedland-swallowed-by-dust-from-iron-ore-mining/12636374*, 24.03.2021

Metinvest (2020): Steel: The World’s Most Recycled Material. *https://metinvestholding.com/en/media/news/stalj-kak-samij-pererabativaemij-material-v-mire*, 22.03.2021

Milanez, Bruno/dos Santos, Rodrigo Salles Pereira (2019): Embedded corporate strategies and power: The case of Vale S.A. in Itabira, Brazil. In: The Extractive Industries and Society, 6(3), 889-896. *https://doi.org/10.1016/j.exis.2019.05.015*

Mining Connection.com (2018): Largest Iron Ore Producers in the World in 2017 | Mining Connection – The Link For All Your Mining Resources. *https://miningconnection.com/coal_prep/news/article/largest_iron_ore_producers_in_the_world_in_2017/*, 24.03.2021

Mining Technology (2021): China to accelerate work on iron ore projects in Australia and Africa. Mining Technology. *https://www.mining-technology.com/news/china-to-accelerate-work-on-iron-ore-projects-in-australia-and-africa/*, 24.03.2021

Mining.com (2022): Iron ore price rises to $150 after China eases steel’s green targets.

MoneyMorning (n.d.): Iron Ore. Money Morning Australia. *https://www.moneymorning.com.au/commodities/metals-and-minerals/iron-ore*, 24.03.2021

NSC (2017): An introduction to steelmaking. newsteelconstruction.com. *https://www.newsteelconstruction.com/wp/an-introduction-to-steelmaking/*, 22.03.2021

Observatory of Economic Complexity (n.d.): Iron Ore (HS: 2601) Product Trade, Exporters and Importers. *https://oec.world/en/profile/hs92/iron-ore*, 22.03.2021

Robertson, Andrew (2020): “Ultimately it’s not going to work”: Economist downplays China’s trade threats. ABC News. *https://www.abc.net.au/news/2020-09-10/china-australia-trade-dispute-has-not-extended-to-iron-ore/12648352*, 24.03.2021

Shioda, Tetsuya (2020): Outlook of Iron Ore Supply (Nr. 123). Nippon Steel Technical Report.

Sonter, Laura J./Herrera, Diego/Barrett, Damian J./Galford, Gillian L./Moran, Chris J./Soares-Filho, Britaldo S. (2017): Mining drives extensive deforestation in the Brazilian Amazon. In: Nature Communications, 8(1). *https://doi.org/10.1038/s41467-017-00557-w*

Stockhead (2020): Why iron ore grade is now more important than ever.

Terzon, Emilia/Chau, David (2020): ASX rises as iron ore prices jump to seven-year high. *https://www.abc.net.au/news/2020-12-03/asx-rise-covid19-vaccine-pfizer-wall-street-biontech/12945514*, 24.03.2021

Tröster, Bernhard/Küblböck, Karin (2020): Unprecedented but not Unpredictable: Effects of the COVID-19 Crisis on Commodity-Dependent Countries. In: The European Journal of Development Research, 32(5), 1430-1449. *https://doi.org/10.1057/s41287-020-00313-9*

UBA (2021): Klimaschutzbericht 2021. Wien.

UNEP (United Nations Environment Programme) (2019): Emissions Gap Report 2019. Executive summary. Nairobi.

UNEP (United Nations Environment Programme) (2013): Metal recycling: opportunities, limits, infrastructure: this is report 2b of the Global Metal Flows Working Group of the International Resource Panel of UNEP. Nairobi.

USGS (2021): Iron Ore. *https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-iron-ore.pdf*, 22.03.2021

USGS (2020a): Iron Ore. *https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-iron-ore.pdf*, 22.03.2021

USGS (2020b): Mineral Commodity Summaries 2020.

Venditti, Bruno (2021): Brazil’s 2020 mineral production topped 1 billion tonnes, up 2.5%. Mining.com. *https://www.mining.com/brazils-2020-mineral-production-topped-1-billion-tonnes-up-2-5/*, 22.03.2021

World Steel Association (2020a): Steel Statistical Yearbook 2020 concise version. Belgium.

World Steel Association (2020b): Top steelmakers in 2019. List of companies with tonnage of more than 3 million Mt in 2019.

World Steel Association (2020c): World Steel in Figures 2020.

Zhang, Min/Daly, Tom (2020): UPDATE 1-China to build overseas iron ore mines to ensure supply, boost pricing power. In: Reuters.

Zhang, Min/Singh, Shivani/Chow, Emily (2021): China to “strengthen management” of strategic mineral resources, eyes green upgrade of steel. In: Reuters.

Zhang, Shaohui/Yi, Bo-Wen/Worrell, Ernst/Wagner, Fabian/Crijns-Graus, Wina/Purohit, Pallav/Wada, Yoshihide/Varis, Olli (2019): Integrated assessment of resource-energy-environment nexus in China’s iron and steel industry. In: Journal of Cleaner Production 232, 235-249. *https://doi.org/10.1016/j.jclepro.2019.05.392*

About the authors

Karin Küblböck is an economist and senior researcher at the Austrian Foundation for Development Research.

Bernhard Tröster is an economist and researcher at the Austrian Foundation for Development Research.

Michael Eigner studied Philosophy and International Development at the University of Vienna.