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ORIGINAL PAPER

Steel trade structure and the balance of steelmaking technologies in non-OECD countries: the implications for catch-up path

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Abstract

The landscape of the steel industry has changed significantly since the start of the twenty-first century. The countries of the Organisation for Economic Co-operation and Development (OECD) have played an active role in the global steel industry. However, in the past decade, non-OECD countries have also caught up with trends. Non-OECD countries have developed from peripheral players to major centres of global steel production and trade, and they should continue to play a crucial role in the global steel market as a result of steady capacity additions. In addition to changes in the composition of the global steel market, there has been a gradual change in the structure of production technologies in the global steel industry. With the increasing importance of the electric arc furnace (EAF) route, does the blast furnace/basic oxygen furnace (BF/BOF) route still play an important role for non-OECD countries to catch-up with OECD countries? This study provides an in-depth analysis of non-OECD countries' steel production and trade, and the results indicate that the balance of steelmaking technologies is associated with steel trade structure in non-OECD countries. The BF/BOF route is more likely to be significant for non-OECD countries to become net exporters of steel and diversify and/or to upgrade exports of steel products.

Keywords OECD · Non-OECD · Steelmaking technologies · Catch-up · Export sophistication · Export diversification

JEL classification F14 · L61 · O14

Introduction

The countries of the Organisation for Economic Co-operation and Development (OECD) have played an active role in the global steel industry.[1] However, in the past decade, non-OECD countries have also caught up with trends. This has significantly changed the structure of the industry. Some non-OECD countries have rapidly growing steel industries, supported by abundant steelmaking raw materials, very low costs of energy and labour, and growing domestic demand. Non-OECD countries now appear to be participating more in the globalisation process (Kowalski et al. 2015), and steel has been impacting world markets for goods and services.

Since the start of the twenty-first century, non-OECD countries have accounted for an increasing share of global steel demand, with steel import volumes growing significantly to satisfy infrastructure and industrial development needs. To increase the self-sufficiency rates of non-OECD countries and to press forward with industrialisation, extensive ironmaking/steelmaking investments have been carried out in these countries (OECD 2015a). As a result of several investments, non-OECD countries have experienced significant growth in production. China is the principal engine for growth, thereby affecting the global steel market, as well as the global steelmaking raw materials market (Ericsson 2011). Non-OECD countries surpassed the OECD's crude steel output in 2004, with their share

[1] The OECD had 35 member countries as of April 2018. Abbreviated names of the countries are available in Appendix Table 6.

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of world crude steel output increasing from 41.6% in 2000 to 70.2% in 2016, indicating that non-OECD countries have played a significant role in the global steel market (Fig. 1a, b and Appendix Table 7).[2] As a result of China's rapid capacity expansion and its accession to the World Trade Organisation in 2001, the country has become the largest producer and consumer of steel, as well as the world's biggest steel exporter.[3] Aside from China, the gap of crude steel output between OECD and non-OECD countries (excluding China) has been shrinking over the last decade.

In addition to changes in the composition of the global steel market, there has been a gradual change in the structure of production technologies in the global steel industry (Fig. 2a, b). Crude steel is produced via two primary production routes, that is, the integrated steelmaking route, based on the blast furnace/basic oxygen furnace (BF/BOF) and the electric arc furnace (EAF) route. Since the past several decades, efforts to modernise steel production facilities have continued in several countries, and steel mills have been replacing out-dated facilities (e.g. open-hearth furnaces [OHF]) with BF/BOF and EAF furnaces. In the OECD, the BF/BOF route has been the major steelmaking technology, accounting for 57.7% of its production in 2016. However, the share of the EAF route in OECD countries has grown over the past few years in line with growing ferrous scrap reservoirs. Turning to non-OECD countries, the BF/BOF technology has played a dominant role, with its share climbing to 80.5% in 2016. The increase in BF/BOF production in non-OECD countries has occurred mainly in China. Conversely, the importance of the EAF technology in non-OECD countries (excluding China) continues to grow.

Non-OECD countries have developed from peripheral players to major centres of global steel production and trade, and they should continue to play a crucial role in the global steel market as a result of steady capacity additions.[4] Thus, the developments in non-OECD steelmaking countries have been receiving increasing attention from governments and the industry. The question posed in this study is as follows. With the increasing importance of the EAF route in some non-OECD countries, does the BF/BOF route still play an important role for non-OECD countries to catch-up with OECD countries? Given the scale and importance of the global steel industry, understanding the structure of non-OECD countries is crucial for both the industry and policymakers.

The aim of this study is to better understand the structure of non-OECD countries and to explore the relationship between production processes and steel trade structure. The remaining paper proceeds as follows: the 'Literature review' section, the 'Stylised facts and analytical framework' section, the 'Data and methodology' section, the 'Analysis and results' section, and lastly the 'Conclusion' section which draws conclusions and discusses directions for further research.

Literature review

Catch-up industrialisation in the steel industry

Several studies have discussed the issue of 'catch-up' of latecomers in the steel industry (e.g. Shin 1996; Sato 2013, 2016; Kawabata 2016, 2017; Lee and Ki 2017; World Steel Association 2018a). The theory of catch-up industrialisation (e.g. Hirschman 1958; Gerschenkron 1962) is closely linked to the development pattern of developing countries in the steel industry (Kawabata 2016),[5] and it explains the rise of latecomers in the global steel industry (Lee and Ki 2017). Sato (2013) suggests some common patterns of development, namely, the structure of the steel industry in a country shifts with economic growth (i) from import substitution of downstream facilities (i.e. rolling or surface treatment) to import substitution of upstream facilities (i.e. ironmaking or steelmaking); (ii) from long products to flat products; and (iii) from low value-added steel products to high value-added steel products. The historical pattern in the steel industry shows that latecomers have caught up with frontrunners and have overtaken them by adopting newly available technologies (Kawabata 2017), and Fig. 3 supports this development path.

Export sophistication and export diversification

Issues related to export sophistication and export diversification are closely linked to the discussion on catching-up. Upgrading export via quality improvements has been one of the major issues on the global development agenda, and major

[2] Figures for production and trade in this study are taken or calculated from the World Steel Association (2017) and the International Steel Statistics Bureau (ISSB 2017), unless otherwise indicated. Rankings of crude steel output for OECD and non-OECD countries, crude steel output by processes data, and key steelmaking raw materials data are available in Appendix Table 7.

[3] Chinese steelmaking capacity increased significantly from 149.6 million metric tonnes (mmt) in 2000 to 1119 mmt in 2016, according to data from Wirtschaftsvereinigung Stahl (2017).

[4] Currently, India is the second largest steel producer among non-OECD countries and the world's third biggest steel producer, but the country is expected to become the world's second largest steelmaking country in the future, since the Indian Government is aiming to increase its steelmaking capacity to increase from 122 mmt in 2015–2016 to 300 mmt in 2030–2031 (Ministry of Steel 2017). Aside from India, Iran is aiming to expand its steelmaking capacity to 55 mmt by 2025 (Imidro 2016). Among the Association of Southeast Asian countries, Vietnam's government plans to increase steelmaking capacity to 66.2 mmt by 2035 (Ministry of Industry and Trade 2016), while Indonesia is targeting an increase of capacity from 11.2 mmt in 2016–2017 to 50 mmt in 2021–2035 (Indonesian Iron and Steel Industry Association 2017).

[5] According to Gerschenkron (1962), a late-starting industrial country may be able to enjoy faster growth than an advanced country, by importing existing technology from abroad, instead of developing its own technology, since doing so could save time and costs.

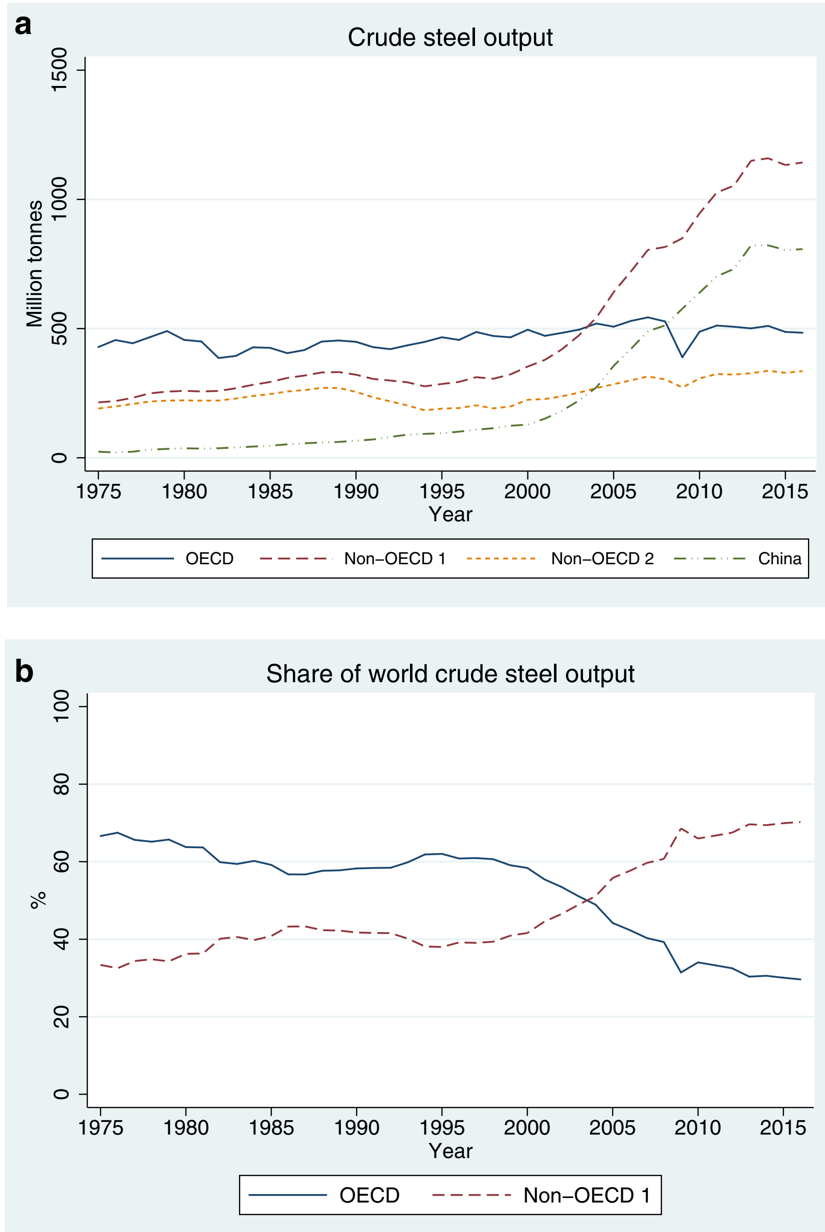


Fig. 1 **a**, **b** Development of crude steel output (1975–2016). Non-OECD 1, non-OECD countries, including China; Non-OECD 2, non-OECD countries, excluding China. Source: Author's calculations based on data from the World Steel Association (various issues)

international organisations have discussed how developing countries can increase the value-added content of their exports and diversify their export product (Zhu and Fu 2013). A number of recent international trade studies emphasise that export sophistication promotes faster and sustainable economic growth, suggesting that the level of technological sophistication embodied in a country's export portfolio indicates the country's economic development (Lall et al. 2005; Rodrik 2006; Hausmann et al. 2007; Minondo 2010; Jarreau and Poncet 2012). In recent years, several studies have introduced different indicators to measure the sophistication of a country's exports (Rodrik 2006; Hausmann et al. 2007; Schott 2008; Minondo 2010; Xu 2010). However, some studies have shed light on export diversification, indicating that developed countries have more diversified export structure than developing countries do (Hesse 2009; Agosin et al. 2012). Export diversification is significant for achieving a higher level of economic development, as it seems to be the only way for a developing country to transform itself into a modern economy that can produce and export similar goods to developed country exports (Chandra et al. 2007).[6]

[0] However, this does not apply to some countries. For example, Australia has been a major exporter of natural resources, although the country is a high-income OECD country.

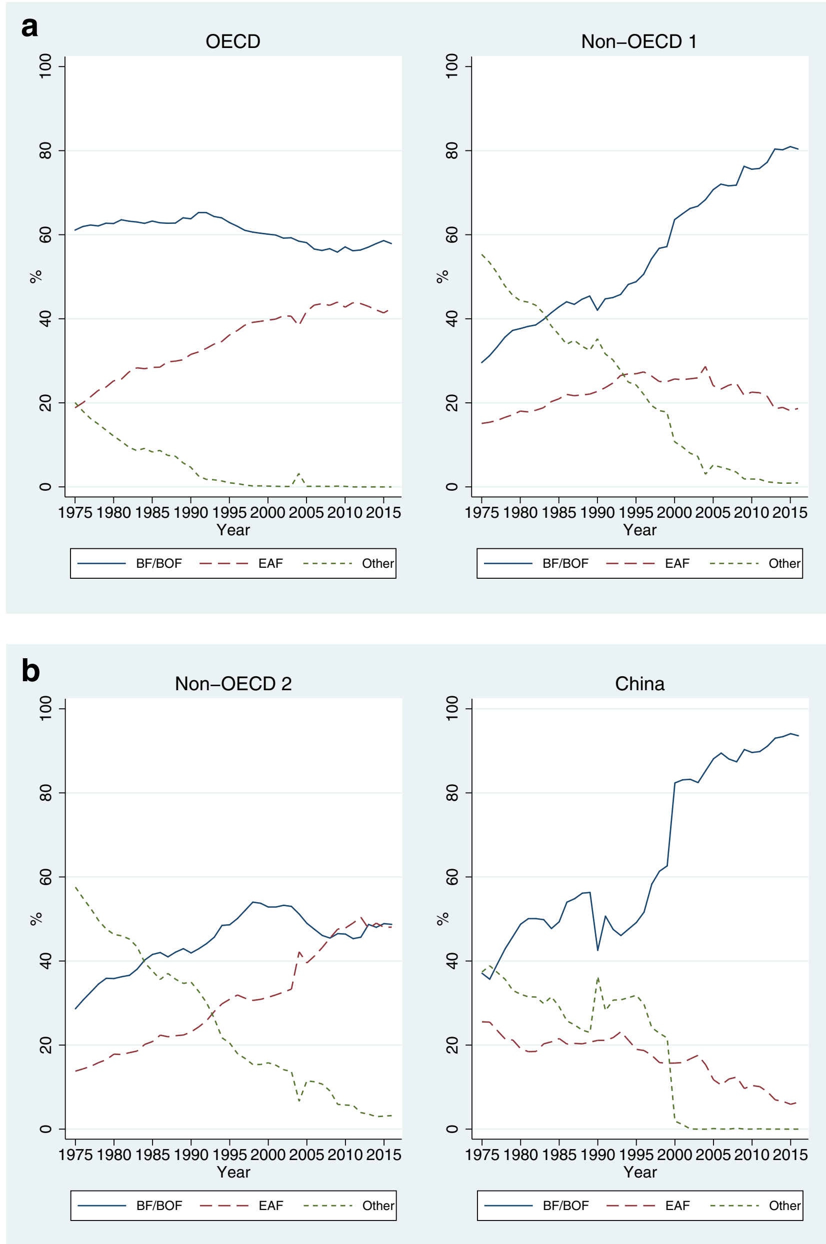


Fig. 2 **a**, **b** Crude steel output by processes (1975–2016). Non-OECD 1, non-OECD countries, including China; Non-OECD 2, non-OECD countries, excluding China. Source: Author's calculations based on data from the World Steel Association (various issues)

Development of emerging markets/developing countries in the global steel industry

With respect to the steel industry, some existing literature focuses on the development of emerging markets/developing countries. On the demand side, the OECD (2015b) shows that non-OECD countries have higher steel intensity (measured by apparent crude steel use per unit of gross domestic product) levels than those of OECD countries owing to growth in manufacturing industries and increased investment in fixed assets. However, Crowson (2018) has raised questions about future trends in China's materials usage, including steel. Moreover, Humphreys (2018) argues that the growth of countries in the South and Southeast Asia has positive implications for future mineral demand, including steel demand.

On the supply side, Brun (2016) and Kawabata (2017) analysed the current situation of excess capacity in the global steel industry, suggesting that excess capacity in some emerging markets/developing countries promotes low value-added steel exports. With regard to steel trade, de Carvalho and Sekiguchi (2015) examined the steel trade specialisation patterns in major steelmaking countries. They show that some steel producers in emerging markets/developing countries move up the value chain and begin exporting more sophisticated steel products. Sekiguchi (2017) indicates that

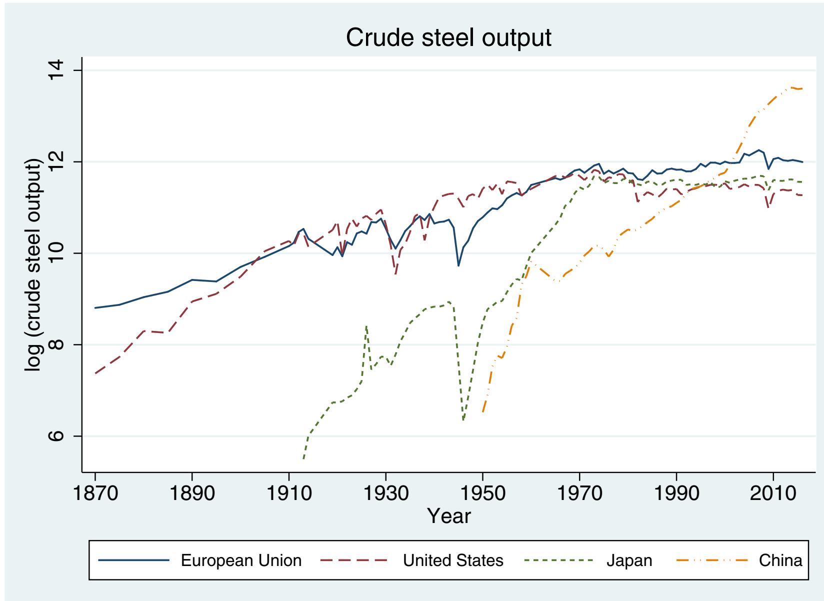


Fig. 3 Catch-up of latecomers in the global steel industry (1870–2016. Source: Author's calculation based on data from Wirtschaftsvereinigung Stahl (2017)

the balance of steelmaking technologies and the stage of a country's development determine the export structure of major steelmaking countries. The author suggests that catch-up of emerging markets/developing countries with OECD countries has been limited because of the huge gap between emerging markets/developing countries and advanced countries from the viewpoint of value creation. The POSCO Research Institute (POSRI) (2016) analysed competition of steel trade between East Asian countries and suggests that China's rapid development has intensified competition with neighbouring OECD countries.

The issues of export diversification and export sophistication are important topics in the fields of international trade studies and industrial development when considering the catch-up of emerging markets/developing countries with advanced countries. However, not much attention has been paid to these issues in the steel industry. To address these issues, detailed analysis is performed in this study.

Stylised facts and analytical framework

Types of steel firms

There are mainly three types of steel mills, namely, (i) integrated mills, (ii) mini-mills, and (iii) re-rolling mills (D'Costa 1999). Generally, integrated mills require BF/BOFs and rolling mills,[7] while mini-mills are small-scale steelmaking plants based on the EAF route.[8] Finally, re-rolling mills (steel firms that do not have ironmaking/steelmaking facilities) transform the shape of semi-finished or intermediate steel products.[9]

Choice of steelmaking technologies

It is important to investigate the reasons for choosing production processes. There are at least three reasons for the choice of steelmaking technologies. The first relates to the amount of steelmaking raw materials in the countries, as the steel industry is reliant on a number of raw materials, particularly iron ore, coking coal, and ferrous scrap. In the BF/BOF process, iron ore and coking coal are key raw material inputs, while ferrous scrap is used for the EAF process (World Steel Association 2013a).[10] The costs of steelmaking raw materials are the largest part of total operating costs for both the BF/BOF and EAF producers (McLellan 2011). Therefore, the steelmaking raw materials endowment could be an important factor for some countries for the choice of steelmaking technologies, contributing to lower operating costs (Wood Mackenzie 2018).[11]

The second reason relates to quantity of steel products and initial investment costs. Generally, building an integrated mill

[7] There are also integrated mini-mills with plants for using direct reduced iron (DRI) plants, EAFs, and rolling mills.

[8] Mini-mills, based on the EAF route, are generally smaller and simpler to construct and operate than integrated mills based on the BF/BOF route, and hence, the name 'mini-mills' (World Steel Association 2013b).

[9] In the case of South Korea, POSCO and Hyundai Steel are classified as integrated mills, while Dongkuk Steel is regarded as a mini-mill. Hyundai Hysco was a South Korea's re-rolling mill, although Hyundai Steel acquired Hyundai Hysco in July 2015.

[10] The DRI process can also be used in the EAF route.

[11] For example, Brazil can produce at low cost using high-quality Brazilian ore.

that produces a large amount of steel is a capital-intensive process. However, a mini-mill, which produces smaller amount of steel than an integrated mill does, requires only a fraction of the resources. The minimum efficient scale of an integrated mill with a large-sized BF is 3 mmt with an initial investment cost of USD 4 billion, while a mini-mill's minimum efficient scale is 0.3 mmt with an initial investment cost of USD 100 million (Sato 2016).

The third reason is quality of steel products. While integrated mills produce a wide variety of steel products, including high value-added flat products used in manufacturing industries (e.g. automotive and home appliances), mini-mills produce long products principally used in the construction industry (D'Costa 1999). However, some industry analysts note that EAF-based steel firms have played an increasingly large role in the flat steel market (Laplace Conseil 2012a), although the BF/BOF process can still produce more types of steel than the EAF process.

Locations of steelworks

The locations of steelworks have changed significantly since World War II. The locations of steelworks in major steelmaking countries have shifted from being close to mineral rich areas to being near coastal areas. This is because some countries import steelmaking raw materials from abroad based on the premise that using high-quality imported steelmaking raw materials is a strategy that ensures the long-term operation of steelworks (Kawabata 2012). Indeed, establishing steel mills in coastal areas has become a common practice in some major steelmaking countries (e.g. the USA, Japan, and South Korea) (World Steel Association 2018b). Although major steelmaking countries in the OECD, such as Japan, South Korea, and Germany, have adopted the BF/BOF route, they lack domestic sources of iron ore and coking coal, thus accounting for a significant share of world imports (OECD 2010). Therefore, most OECD countries are heavily or wholly dependent on imported iron ore and coking coal, although some countries are relatively large ferrous scrap generators. Aside from the OECD countries, China's steel production has also been moving from inland regions to east and coastal areas (World Steel Association 2018b). The role of steelworks in coastal areas is expected to increase in India as well (Ministry of Steel 2017).

Capacity expansion in upstream (ironmaking/steelmaking) facilities

A number of OECD countries, such as Japan and South Korea, have employed large-sized BFs (with inner volumes of more than 2000 m^3) (Korea Iron and Steel Association (KOSA) 2015; China Iron and Steel Association (CISA) 2015).[12] Since the start of the twenty-first century, we have witnessed a construction boom of large-sized BFs in non-OECD countries. This tendency is particularly noticeable in China and India.[13] China's steelmaking capacity has increased significantly, supported by several important coastal steelworks with large-sized BFs over the last few years (OECD 2015c). India's steelmaking capacity has also expanded with several upstream investments in DRIs/EAFs and large-sized BFs,[14] and the role of the BF/BOF route is expected to continue growing with many new investment projects that are iron ore/coking coal-intensive (OECD 2015c).

The BF/BOF technology has gained importance in some EAF-oriented non-OECD countries in recent years. For example, some EAF-oriented non-OECD countries (e.g. Indonesia and Vietnam) have been entering a new field of business with integrated steelworks that adopt BF/BOF technology in order to meet industrial development needs.[15]

Types of steel products

There are five broad categories of steel products, namely, (i) ingots/semi-finished products, (ii) long products, (iii) flat products, (iv) steel tubes, and (v) other steel products. Flat products and steel tubes are higher value-added products than ingots/semi-finished products and long products (Fig. 4a).

[12] For instance, POSCO has operated five of the 14 super-sized BFs in the world, including the world's largest—Gwangyang BF no. 1 (6000 m^3), Pohang BFs no. 3 and 4 (5600 m^3), and Gwangyang BFs no. 4 and 5 (5500 m^3) (POSCO 2017).

[13] According to CISA (2015), China has blew up 88 large-sized BFs since the start of the twenty-first century, while India has begun operating 13 large-sized BFs since 2000 (KOSA 2015).

[14] It should be noted that the Indian steel industry is characterised by the existence of a large number of small steel producers that utilise DRI plants (Ministry of Steel 2017). The DRI route has played a crucial role in India and the country has been the world's largest DRI producer, although the BF route has larger ironmaking production capacity than the DRI route in the country (Ministry of Steel 2018). In India, large steel firms (e.g. Tata Steel and Steel Authority of India Limited) produce steel through the BF/BOF route, while other major steel producers (e.g. Essar Steel and Ispat Industries) employ DRIs/EAFs (Mandal and Sinha 2013).

[15] For instance, PT Krakatau POSCO formally began operating its first blast furnace in December 2013 in Indonesia. PT Krakatau POSCO's integrated steel mill project was part of Indonesia's economic development acceleration master plan, called the Master Plan for the Acceleration and Expansion of Indonesia's Economic Development (MP3I), which emphasises connectivity in the country (Government of Indonesia 2011). In Vietnam, Formosa Ha Tinh Steel Corporation fired up its first blast furnace in May 2017 and the second one in May 2018. The BF/BOF route is expected to continue to increase, supported by new investment projects that are iron ore/coking coal-intensive (Ministry of Industry and Trade 2016). In addition, Alliance Steel (M) Sdn, a China-invested greenfield integrated steel project in Malaysia, fired up its first blast furnace in March 2018 and the second one in July 2018, which is likely to impact the balance of steelmaking technologies in the country.

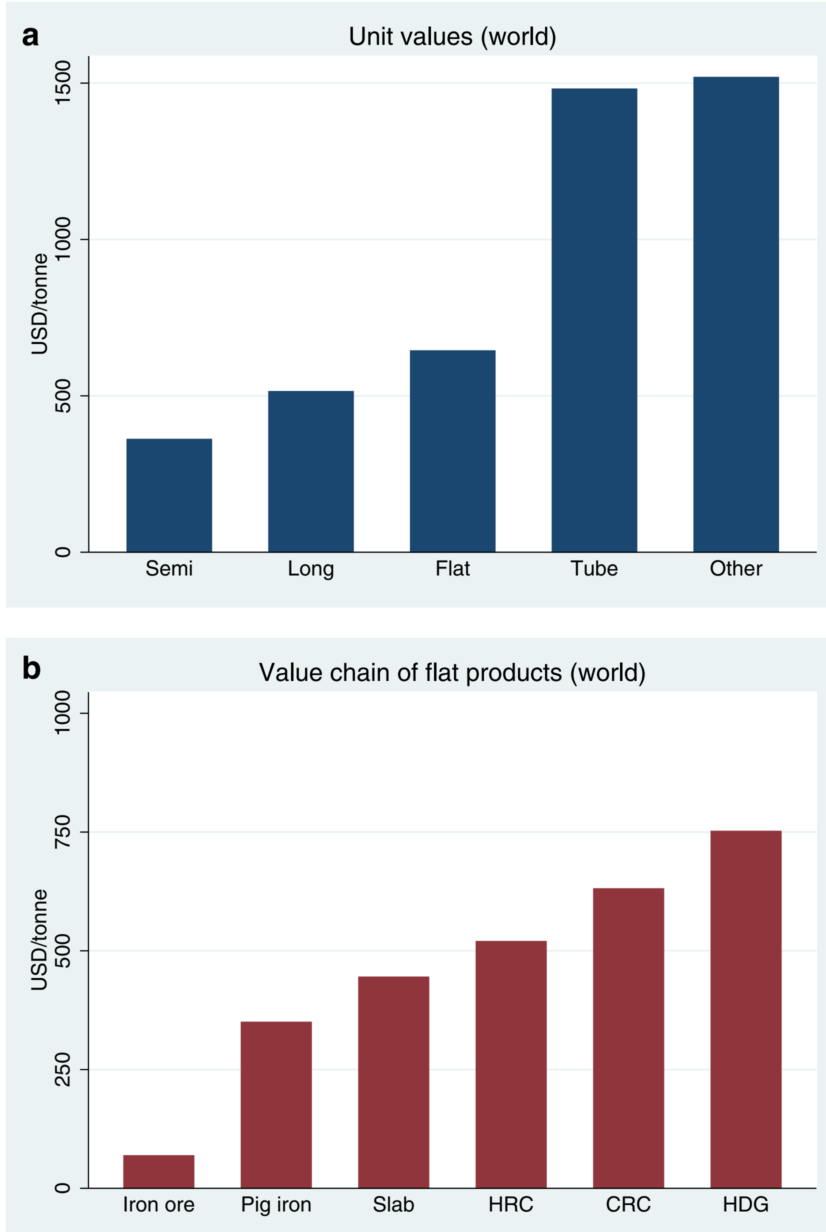


Fig. 4 **a**, **b** Unit values of broad categories of steel products (2016) and value chain of flat products (H2 2017). HRC, hot rolled coil; CRC, cold rolled coil; HDG, hot dip galvanised sheet/coil. Source: Author's calculations based on data from the ISSB (2017) and Steel on the Net (2018)

The values of other steel products differ by item because the category includes several types of steel products.[16] The value of the steel product increases at each step of the process (Fig. 4b). In the integrated mill, iron ore and coking coal are transformed into pig iron, then slab, and then hot rolled coil. They also can be transformed into cold rolled coil and hot dipped galvanised sheet/coil.

[16] Other steel products range from wire to steel castings.

Analytical framework

Dichotomy between OECD and non-OECD countries

This study aims at investigating the production and export structure of developed/developing countries in the global steel industry with the dichotomy between OECD and non-OECD countries, which is used as a proxy for the classification of 'developed' and 'developing countries'. This dichotomy is significant when comparing the structure of developing

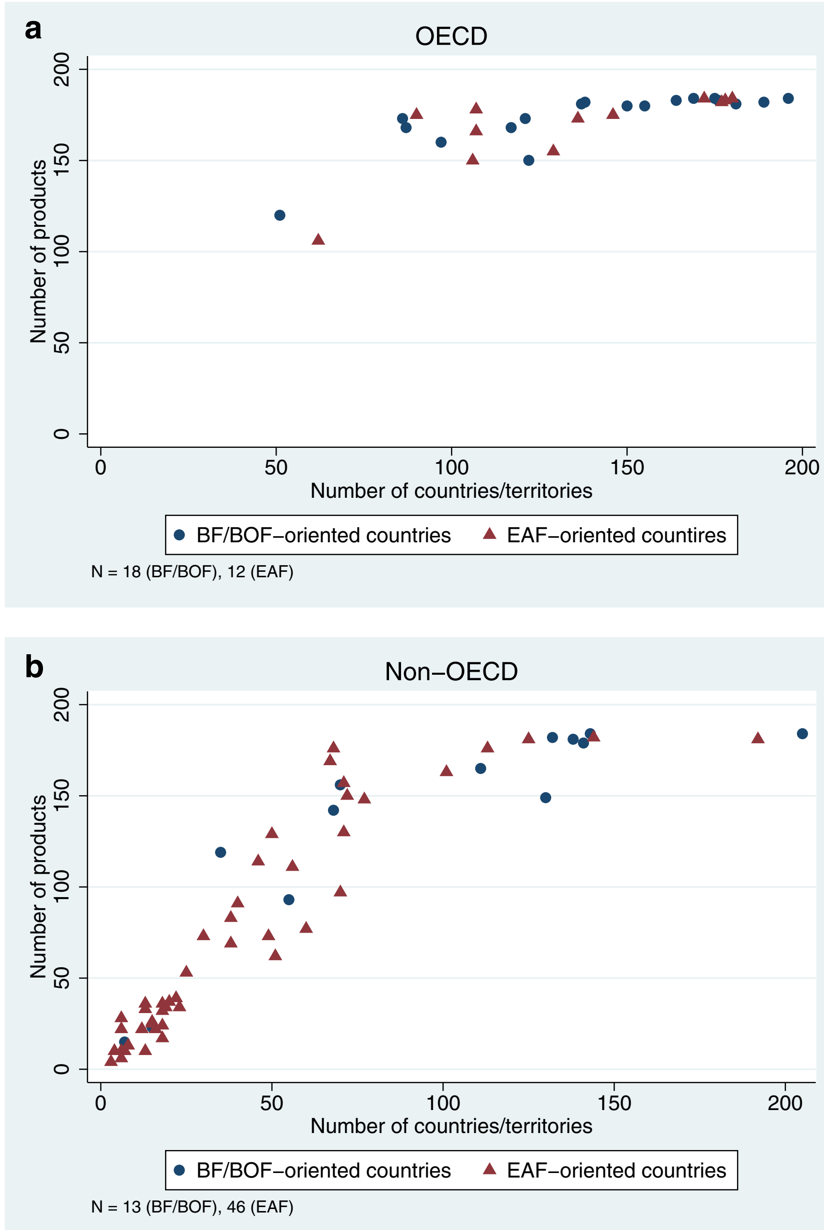


Fig. 5 **a**, **b** Number of export products and export markets (2016). The figures show countries for which production data by processes were available in 2016. Source: Author's calculations based on data from the ISSB (2017)

countries with developed countries.[17] This classification would help better understand the development of emerging markets/developing countries in the global steel industry. The OECD Steel Committee Meeting, a crucial forum to address the challenges facing the global steel industry, has pointed out that

> … the global steel industry's capacity to produce steel has increased rapidly since the early 2000s, after two decades of little growth. Most of the growth in steelmaking capacity has occurred in non-OECD economies, to support growing construction and manufacturing activity, as well as to help build the infrastructure necessary for the economic development of these emerging economies (OECD 2015a, p. 7).

Therefore, it is important for the steel industry to keep track of the evolution of non-OECD countries, given that this classification has important implications for the global steel market.

[17] For example, Chien and Hu (2007) analysed renewable energy and macroeconomic efficiency with the dichotomy between OECD and non-OECD countries.

Table 1 Steel exports and imports in volume terms by product (2016), mmt

	Steel product (broad category)					
	Semi	Long	Flat	Tube	Other	Total
Exporters						
OECD	14.3	56.9	144.8	20.1	8.4	244.5
Non-OECD (excl. China)	41.3	19.9	48.9	7.7	3.4	121.2
China	0.0	46.6	48.1	10.1	3.2	108.1
Total	55.6	123.4	241.9	37.9	15.1	473.8
Importers						
OECD	30.4	49.1	135.2	19.0	9.0	242.8
Non-OECD (excl. China)	25.6	49.4	86.7	14.6	5.0	181.3
China	0.3	1.5	11.1	0.4	0.3	13.6
Total	56.3	100.0	233.0	34.0	14.3	437.6

Source: Author's calculations based on data from the ISSB (2017)

Dichotomy between BF/BOF-oriented countries and EAF-oriented countries

In this study, a BF/BOF-oriented country denotes one whose share of BF/BOF is greater than 50% in total crude steel output in 2016. On the contrary, an EAF-oriented country denotes a country whose share of EAF is greater than 50% in total crude steel output in 2016.

Hypothesis

The literature review and stylised facts give rise to the following hypothesis.

- If a steel firm in non-OECD countries chooses the BF/BOF process, the firm may be able to produce not only a large amount and wide variety of steel products but also more sophisticated items aside from commonly used items and then may begin exporting these products. In short, non-OECD countries with higher share of BF/BOF route are expected to become net exporters of steel and diversify and/or upgrade exports of steel products.

Generally, the BF/BOF route enables mass production and provides an abundant product line-up, including high value-added steel products. Indeed, major advanced steelmaking countries (OECD countries and Taiwan) have adopted the BF/BOF route in order to provide high value-added steel products (Sekiguchi 2017). The BF/BOF process could be a significant determinant of whether non-OECD countries become net exporters of steel and diversify, and/or upgrade exports of steel products.

The primary question is the relationship between steelmaking technologies and steel trade patterns in non-OECD countries. The expectation is that the relationship is positive, since it seems essential for a non-OECD country to adopt the BF/BOF technology to have a similar structure to the OECD. This hypothesis can be verified using three indicators, namely, the (i) trade balance index (TBI), (ii) Herfindahl index (HI), and (iii) export similarity index (ESI).

Data and methodology

Dataset

The development of steel production has important implications for steel trade patterns. The analysis of non-OECD countries' trade patterns proceeds under the assumption that their exports reflect non-OECD countries' domestic production, as well as their exports to the global market, since exports make up the part of the production system that is entirely subject to international competition. Moreover, trade data are more readily available and more coherent than production data, and therefore, they enable direct comparisons between countries (United Nations 2013).

The data were obtained from the ISSB's Trade Enquiry System, an online database of steel trade data in volume and value terms (ISSB 2017). An important limitation of this dataset is that the data are available only from 2008. Therefore, the data cover 2008 to 2016. The data were classified based on the ISSB's product categories and regional aggregation (ISSB 2010a, b). Since data from only major steel exporters/importers were available, mirror trade data (i.e. data reported by trading partners) were used for some countries. Trade data in value terms were used for the analysis of trade balance, export diversification, and export sophistication. Trade values based on the UK pound were converted to US dollars using the OECD's exchange rate database (OECD 2017). The present study covers 122 countries, of which 89 (30 OECD and 59 non-OECD countries) have production data by processes.

Methodology

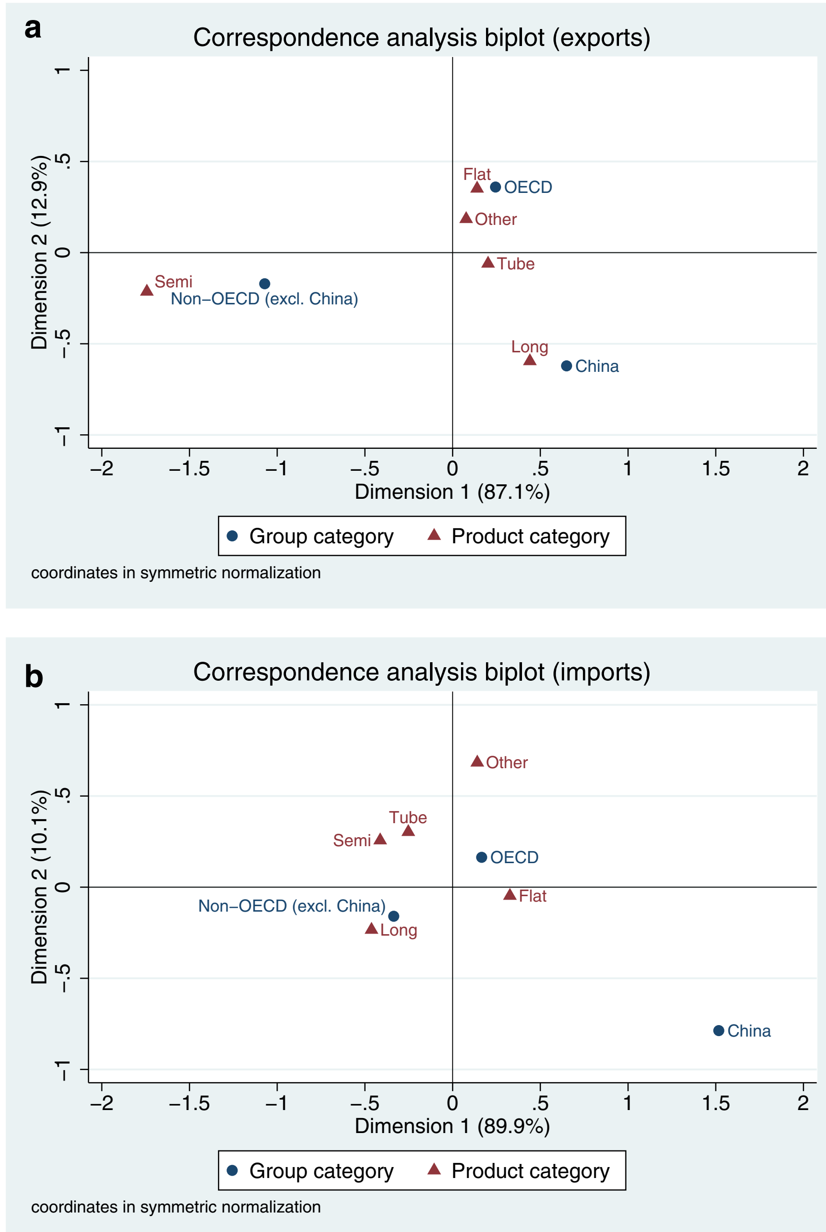
To shed light on non-OECD countries' trade structure, several methods were used in this study.[18]

Trade balance index

The TBI can measure a country's export competitiveness. Lafay (1992) introduced the TBI as a measure to analyse whether a country has specialisation in exports (as a net

[18] The category of steel products in this study is based on the ISSB's classification, which is available in both Appendix Tables 8 and 10.

Fig. 6 **a**, **b** Correspondence analysis for steel exports and imports in volume terms by product (2016). Source: Author's calculations based on data from the ISSB (2017)



exporter) or in imports (as a net importer). The index is defined as follows:

$$\mathrm{TBI}_{si} = (X_{si} - M_{si})/(X_{si} + M_{si})$$

Here, TBI_{si} represents the TBI of country s for steel product group i, and X_{si} and M_{si} denote exports and imports, respectively, of the i group of steel products by country s. The index value ranges from − 1 to + 1 ($-1 \leq \mathrm{TBI} \leq 1$). The TBI equals − 1 if a country only imports; in contrast, the TBI equals + 1 if a country only exports.

Herfindahl index

The HI, developed by Herfindahl and Hirschman, is the most commonly used measure of export diversification (Chandra et al. 2007). The HI is formulated as follows:

$$\mathrm{HI} = \sum_i \left(\frac{x_{si}}{Xs}\right)^2$$

Here, x_{si}/Xs is the share of total exports attributed to the i group of steel products. The HI ranges between 0 and 1 (0 ≤

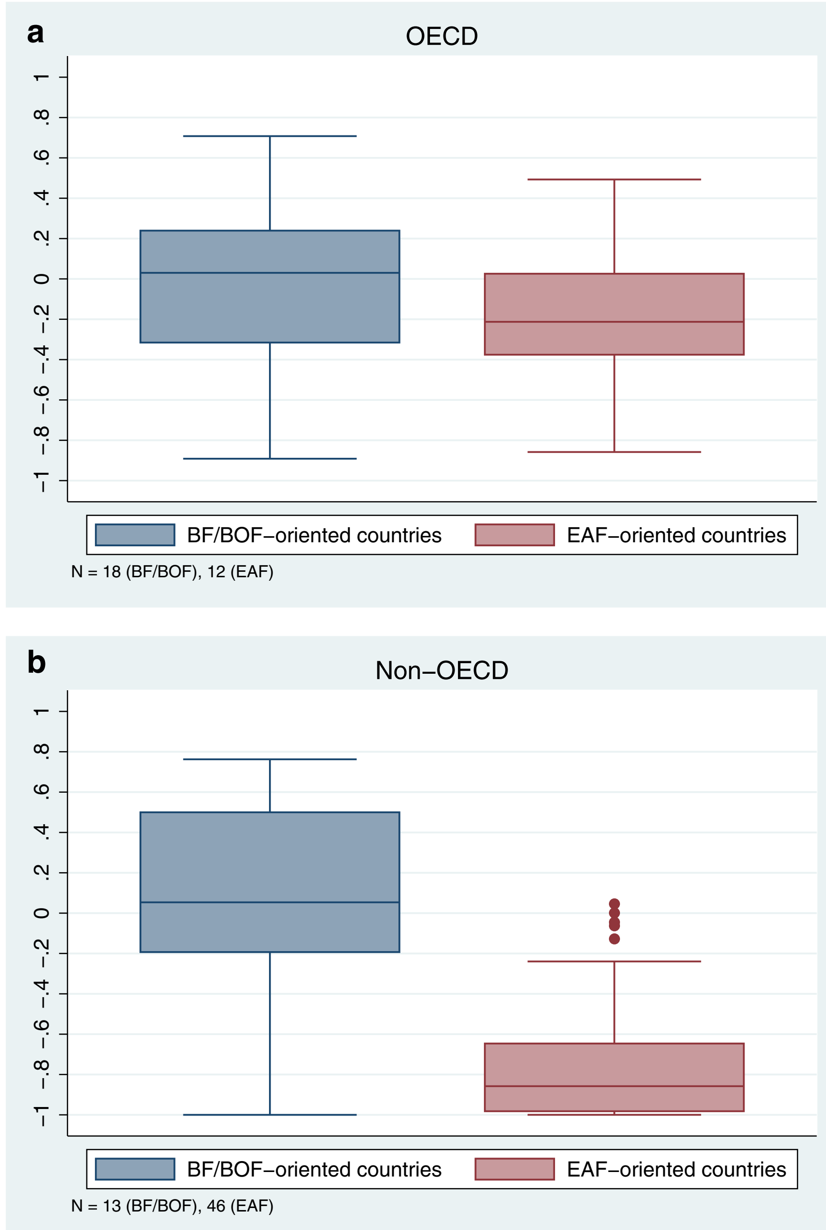


Fig. 7 **a**, **b** TBI values for total steel products (2016). The figures show countries for which production data by processes were available in 2016. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)

HI ≤ 1). Lower values of the index represent more diversification, and thus, countries with highly diversified export baskets are likely to have lower values.

Export similarity index

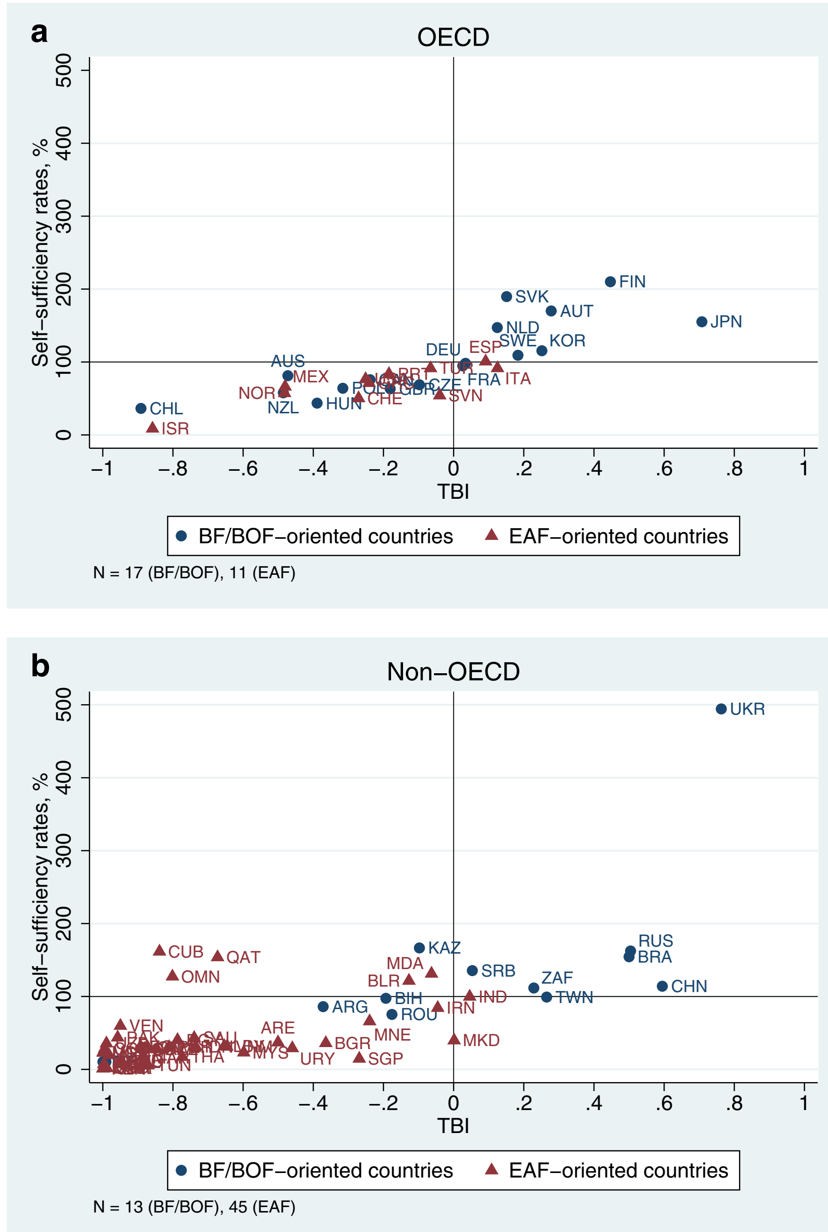
Finger and Kreinin (1979) introduced the ESI tool. The index has been used to determine the relative sophistication of a country's exports by comparing the export bundle of a country with that of the OECD (e.g. Schott 2004; Schott 2008; da Silva and Drumond 2011). Aside from relative sophistication, the ESI can show a country's 'catch-up' with others through a time-series analysis (da Silva and Drumond 2011). The calculated ESI can also be used to assess which countries compete more directly with the OECD.[19] The ESI is formulated as follows:

$$\mathrm{ESI}_{\mathrm{sd}} = \sum_i \min\left(\frac{x_{si}}{Xs}, \frac{x_{di}}{Xd}\right)$$

Here, ESI_{sd} is the ESI between countries s and d, and x_{si} and x_{di} are the shares of product i in all the exports of countries Xs and Xd, respectively. An ESI value of 1 corresponds to identical export structures and a value of 0 to completely dissimilar export structures.

[19] POSRI (2016) uses the ESI to analyse the competition of steel exports between Asian countries.

Fig. 8 **a**, **b** Self-sufficiency rates and TBI values (2016). The figures show countries for which production data by processes and apparent crude steel use data were available in 2016. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)



Analysis and results

Overview of steel production/trade structure of OECD and non-OECD countries

Magnitude of production and dominance of market share

There is a huge gap in the magnitude of crude steel output between OECD and non-OECD countries. In 2016, OECD's crude steel output was 484.1 mmt, while non-OECD's crude steel output reached 1142.9 mmt. With respect to major steelmaking countries in the OECD, Japan is the largest steel-producing country, followed by the USA, South Korea, Germany, and Turkey. The top-five steelmaking countries accounted for 67.6% of the OECD's crude steel output in 2016. However, China has been playing a dominant role among non-OECD countries, representing 70.7% of non-OECD countries' crude steel output in 2016. Among non-OECD countries, the top-five steelmaking countries (China, India, Russia, Brazil, and Ukraine) accounted for 90% of crude steel output in 2016.

Trade balance

Since 1990, the OECD has been a net exporter of steel, except when the steel industry was running practically at full capacity

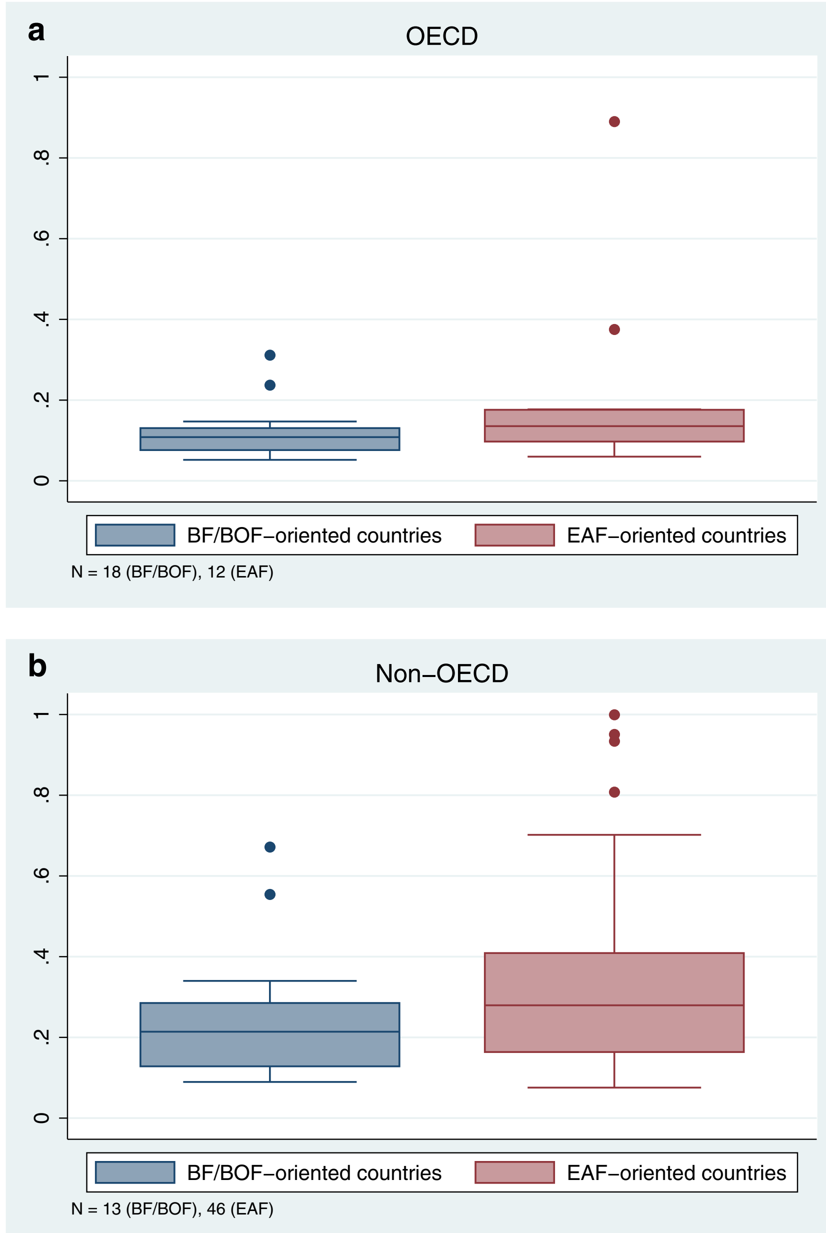


Fig. 9 **a**, **b** HI values (2016). The figures show countries for which production data by processes were available in 2016. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)

owing to strong domestic demand. These countries have supplied high value-added steel products, but imported ingots/semi-finished products, as well as commercial grades of steel products (Laplace Conseil 2012b). Conversely, non-OECD countries in some regions (e.g. the Middle East, Africa, and Southeast Asia) still have low self-sufficiency rates. These countries were traditionally substantial net importers of steel products, because they had little steelmaking/rolling capacity until the middle of the last decade (OECD 2015a).

Diversification of steel products

OECD countries have a more diverse export structure than non-OECD countries do, as they export a wide range of steel products, from commonly used steel products to high value-added steel products. The number of products and markets is an indicator to display the level of export diversification (World Bank 2013). Figure 5a, b illustrates the positive relationship between the number of exported countries/territories and number of exported products at the six-digit HS-code level, indicating that OECD countries export a wider range of steel products to a greater number of trading partners. With respect to the number of export products and export markets by steelmaking technologies, BF/BOF-oriented countries appear to be more diversified and connected with international steel trade. This result supports earlier notions that the BF/BOF-oriented countries can produce wide range of steel products.

Table 2 Ranking of non-OECD countries with the lowest HI values in 2008 and 2016

Rank	2008		2016	
	Country	HI	Country	HI
1	China	0.087	Singapore	0.076
2	Malaysia	0.093	India	0.078
3	Thailand	0.094	China	0.090
4	India	0.098	United Arab Emirates	0.090
5	Singapore	0.103	Thailand	0.095
6	Taiwan	0.111	Malaysia	0.096
7	Croatia	0.118	Croatia	0.099
8	Vietnam	0.123	Romania	0.103
9	South Africa	0.139	Taiwan	0.125
10	Romania	0.143	South Africa	0.128
11	Iran	0.148	Indonesia	0.139
12	Bulgaria	0.155	Jordan	0.152
13	Kazakhstan	0.157	Vietnam	0.157
14	Montenegro	0.167	Saudi Arabia	0.158
15	Philippines	0.168	Bulgaria	0.162
16	Ukraine	0.193	Byelorussia	0.164
17	Kenya	0.203	Colombia	0.172
18	Venezuela	0.208	Ukraine	0.178
19	Indonesia	0.209	Tunisia	0.197
20	United Arab Emirates	0.211	Libya	0.198

The countries for which production data by processes were available in 2016 are shown. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)

Sophistication of steel products

Although the difference in steel exports in volume terms between OECD and non-OECD countries is less, the gap is huge in value terms, suggesting that the structure of steel exports of OECD countries is more sophisticated than that of non-OECD countries. In 2016, OECD countries' steel exports reached 244.5 mmt, while non-OECD countries, including China, exported 229.3 mmt of steel products. However, for steel exports in value terms, there is a huge gap between them. The OECD's steel exports are nearly twice as much as non-OECD countries' steel exports (see Appendix Table 8).

Product mix

Table 1 provides an overview of steel exports and imports by a broad category of steel products in volume terms in 2016, namely, (i) ingots/semi-finished products, (ii) long products, (iii) flat products, (iv) steel tubes, and (v) other steel products.

To obtain insights into the structure of OECD and non-OECD countries, correspondence analysis was performed to indicate product areas with specialisation (Fig. 6a, b).[20] Four results stand out. First, the OECD is closely associated with flat products, other steel products, and steel tubes, indicating that the OECD is a key supplier of high value-added steel products.

Second, China is specialised in long products, but is more closely associated with items that OECD countries mainly export than in items exported by non-OECD countries (excluding China).

Third, non-OECD countries (excluding China) tend to export more ingots/semi-finished products than OECD countries do.

Finally, with regard to steel imports, the OECD is specialised in flat products, while non-OECD countries (excluding China) are most closely associated with long products.

Export competitiveness

It is important to distinguish whether each country is a net exporter or net importer to show the difference between the OECD and non-OECD countries in order to elucidate the role of steelmaking technologies in steel trade. Figure 7a, b illustrates the differences in distributions of TBI values between BF/BOF-oriented countries and EAF-oriented countries for both OECD and non-OECD countries in 2016, indicating that BF/BOF-oriented countries are more competitive than EAF countries. This tendency is particularly noticeable among non-OECD countries.

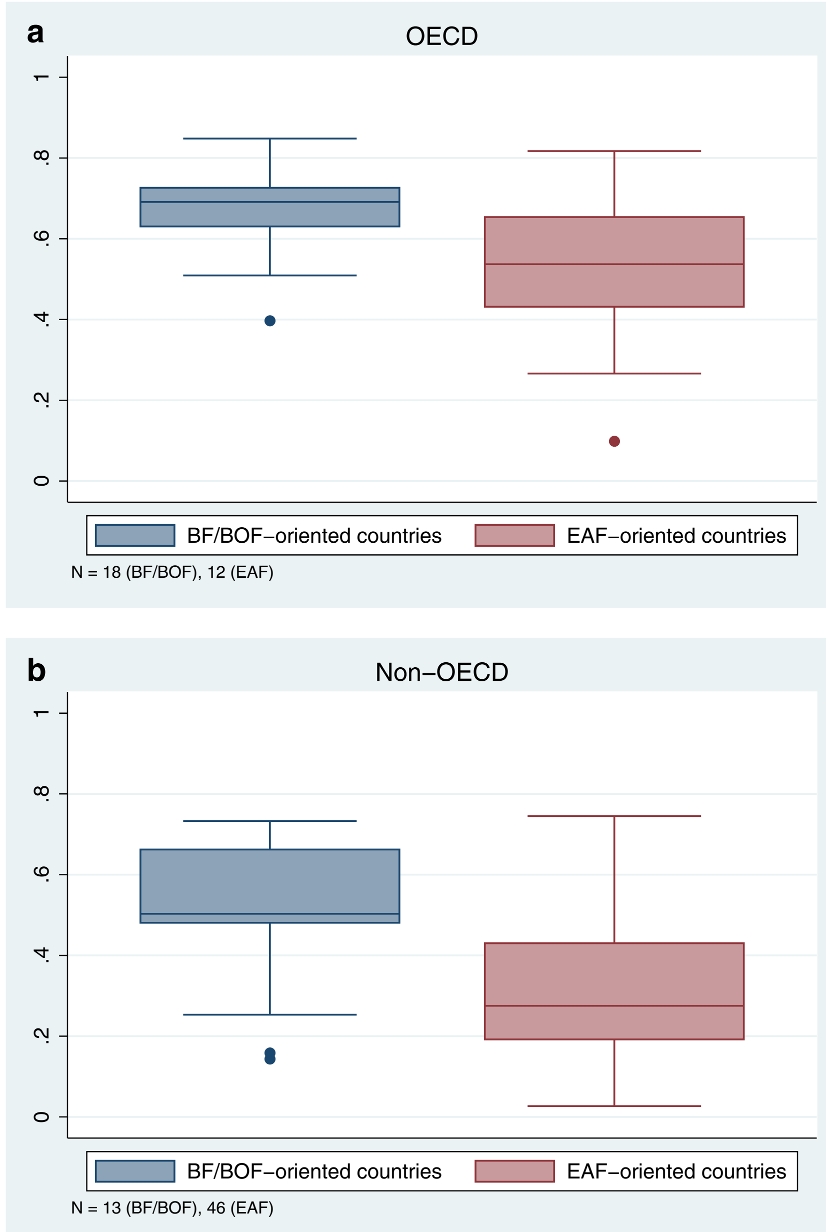
Generally, developing countries have been aiming to increase their so-called 'self-sufficiency rates' (crude steel output as a share of apparent crude steel use) and improve their balance of trade. Figure 8a, b shows the relationship between the self-sufficiency rates and values of TBI for both OECD and non-OECD countries, indicating that BF/BOF-oriented countries have higher self-sufficiency rates and TBI values than EAF-oriented countries do. In non-OECD countries, Ukraine has the highest self-sufficiency rate of approximately 494%, reflecting a high degree of export orientation of steel producers in this country. Aside from Ukraine, other CIS countries, such as Kazakhstan and Russia, also have high self-sufficiency rates. On the contrary, EAF-based non-OECD countries have low self-sufficiency rates, showing a greater reliance on imported steel.

Export diversification

The issue of export diversification is important for both OECD and non-OECD countries. Figure 9a, b shows that OECD countries have low HI values because they export a wide variety of steel products, as shown in Fig. 5a. In addition, BF/BOF-oriented non-OECD countries tend to have low HI values (Fig. 9b). Furthermore, export diversification prevails

[20] The results of the correspondence analysis are displayed in Appendix Table 9.

Fig. 10 **a**, **b** ESI values (2016). The figures show countries for which production data by processes were available in 2016. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)



in BF/BOF-oriented countries much more than in EAF-oriented countries. The variance within BF/BOF-oriented countries is much smaller, while the variance within EAF-oriented countries is relatively large among non-OECD countries.

Table 2 presents a ranking of non-OECD countries with low HI values in 2008 and 2016.[21] It is important to better understand how the structure of export diversification has changed since 2008. The HI values for some countries have declined since 2008, suggesting that they have tended to diversify their export structure more. For instance, India's HI value decreased from 0.098 in 2008 to 0.078 in 2016, and it surpassed China to become the country with the second lowest HI value among non-OECD countries in 2016. Moreover, the HI values for some countries (e.g. the United Arab Emirates) decreased substantially, indicating that those countries might begin expanding types of steel products. China had the lowest HI value among non-OECD countries in 2008, but its HI value slightly increased from 0.087 in 2008 to 0.09 in 2016.

[21] Data for 2008 were the oldest data provided by the ISSB (2017).

Table 3 Ranking of non-OECD countries with the highest ESI values in 2008 and 2016

Rank	2008		2016	
	Country	ESI	Country	ESI
1	China	0.747	India	0.745
2	Taiwan	0.707	South Africa	0.733
3	Thailand	0.701	China	0.716
4	Malaysia	0.697	Taiwan	0.715
5	Singapore	0.680	United Arab Emirates	0.679
6	India	0.648	Romania	0.662
7	South Africa	0.646	Singapore	0.648
8	Romania	0.609	Malaysia	0.644
9	Vietnam	0.590	Thailand	0.603
10	Ukraine	0.572	Vietnam	0.546
11	Iran	0.568	Egypt	0.546
12	Brazil	0.562	Croatia	0.543
13	Croatia	0.551	Russia	0.531
14	Bulgaria	0.542	Morocco	0.529
15	Kazakhstan	0.528	Brazil	0.527
16	Indonesia	0.520	Indonesia	0.509
17	Russia	0.516	Saudi Arabia	0.503
18	United Arab Emirates	0.495	Ukraine	0.503
19	Macedonia	0.487	Serbia	0.493
20	Venezuela	0.486	Argentina	0.483

The countries' ESI values vis-à-vis the OECD aggregate and the countries for which production data by processes were available in 2016 are shown. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)

Export sophistication

The similarity of non-OECD products exported to aggregate OECD products can be used as a proxy to measure a country's relative export sophistication.[22] Figure 10a, b provides ESI values for both OECD countries and non-OECD countries by steelmaking technologies in 2016.[23] It is natural that individual OECD countries have high ESI values, but there are discrepancies between the BF/BOF-oriented countries and the EAF-oriented countries in the OECD. This result confirms that the BF/BOF process has been the dominant steelmaking technology for OECD countries. In general, the BF/BOF-oriented countries tend to have higher ESI values than EAF-oriented countries do. Moreover, the variance within EAF-oriented countries is larger than that within BF/BOF-oriented countries.

Analysis of the similarity of non-OECD countries' export products to the aggregate OECD serves two purposes. First, this comparison provides the relative sophistication of non-OECD steel exports. Second, examining the similarity of non-OECD countries with the aggregate OECD indicates how non-OECD countries compete with the OECD. Table 3 presents a ranking of non-OECD countries with high ESI values, showing how the ranking of ESI values has changed since 2008. The export structures of some non-OECD countries are becoming increasingly similar to those of OECD countries, suggesting that they are increasing their presence in products traditionally dominated by OECD countries. On the contrary, some countries have diverged from the OECD or have not experienced significant change in their export structures.

Exports from some countries are increasingly similar to those from the OECD. For example, India's export overlap with the OECD increased between 2008 and 2016, jumping from 0.648 in 2008 to 0.745 in 2016. India has become most similar to the OECD among non-OECD countries, followed by South Africa, China, and Taiwan. Moreover, South Africa's ESI value increased from 0.646 in 2008 to 0.733 in 2016, and the country was second out of 59 non-OECD countries in terms of the ESI value in 2016. China was most similar to the OECD among non-OECD countries, indicating that the country is facing considerable competition from the OECD. The ESI values of some Middle East and North African countries (e.g. the United Arab Emirates and Egypt) increased substantially, suggesting that those countries have begun exporting more sophisticated steel items.

Appendix Table 11 provides a cursory glance at how the structure of steel exports has changed in the 20 countries since 2008, using the highest ESI in 2016. Some countries have tended to be more specialised in flat products since 2008. This tendency implies that they have moved up the value chain and begun exporting more sophisticated items. For example, exports of flat products have become more important for India; cold rolled sheets/coils, one of the high value-added items, accounted for 11.5% of India's steel exports in 2016. Examination of products exported by the United Arab Emirates shows a notable change, that is, the rising share of flat products in its exports. Vietnam's export pattern is also shifting quickly, moving from ingots/semi-finished to flat products. However, the share of Chinese exports of flat products and steel tubes has declined, while its share of long product exports increased sharply from 22.0% in 2008 to 29.3% in 2016.

Relationships between trade balance index, Herfindahl index, and export similarity index

This study has examined TBI, HI, and ESI, suggesting that simultaneously achieving net export status, export diversification, and export sophistication would enable the steel industry structure of non-OECD countries to approach that of OECD countries. In the analysis up to this point, evaluation of each

[22] Detailed steel export data for the OECD are presented in Appendix Table 10.
[23] ESI values for OECD countries are individual OECD countries' values vis-à-vis the aggregate OECD.

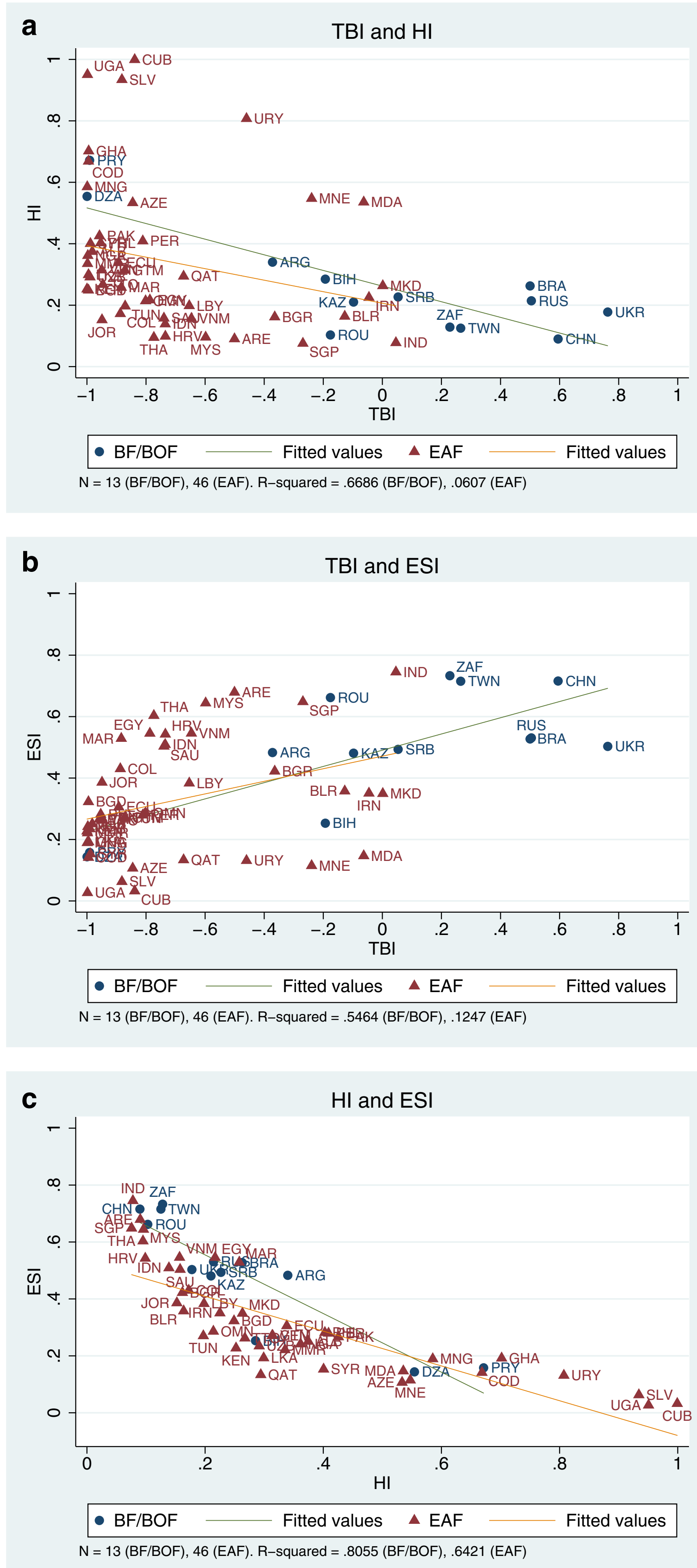


Fig. 11 **a**–**c** Relationships between values of TBI and HI, values of TBI and ESI, and values of HI and ESI (2016). The figures display countries' ESI values vis-à-vis the OECD aggregate and show countries for which production data by processes were available in 2016. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)

Table 4 Indicators used in the cluster analysis

Indicator	Abbreviation
Share of BF/BOF process in total crude steel output	BF/BOF
Trade balance index	TBI
Herfindahl index	HI
Export similarity index	ESI

Source: Author

indicator has been undertaken. Therefore, further investigation of export structure should be undertaken to examine the relationships between the three indicators.

Figure 11a–c shows the relationships between each indicator in 2016. The three indicators appear to be correlated with each other. However, this tendency is particularly noticeable among BF/BOF-oriented non-OECD countries.

First, there are positive correlations between TBI values and HI values, although this tendency can be seen only in BF/BOF-oriented non-OECD countries (Fig. 11a). High values of TBI are associated with low HI values, and the BF/BOF-oriented non-OECD countries are scattered in the lower right-hand corner.

Second, TBI values are correlated with ESI values in BF/BOF-oriented countries (Fig. 11b). The BF/BOF-oriented non-OECD countries are concentrated in the upper right-hand corner, while several EAF-oriented non-OECD countries are scattered in the lower left-hand side.

Finally, there are negative correlations between HI values and ESI values (Fig. 11c). Low values of HI are associated with high ESI values. The BF/BOF-oriented non-OECD countries have lower HI values and higher ESI values than EAF-oriented non-OECD countries do.

Grouping

In order to group and identify competitive non-OECD countries according to their production/trade structure, non-hierarchical cluster analysis was performed for all non-OECD countries for which production data by processes were available in 2016. The clustering of non-OECD countries was based on various production/trade indicators. The analysis was conducted using four indicators, namely, (i) share of BF/BOF process in total crude steel output, (ii) TBI values, (iii) HI values, and (iv) ESI values. These indicators are shown in Table 4. The analysis yielded four clusters of relatively homogeneous countries. These clusters represent the best results in terms of possibilities for interpretation.

The results of the non-hierarchical analysis are presented in Fig. 12 and Table 5. The first cluster consists of BF/BOF-oriented non-OECD countries. However, countries in the first cluster seem to have low degree of export orientation of steel producers, since most countries are net importers of steel and have high values of HI and low values of ESI. Countries in the second cluster mainly use EAF technology, and they are net importers of steel, but they have relatively low HI values and high ESI values. Aside from mini-mills and integrated mills, re-rolling mills might play important roles in steel exports in the

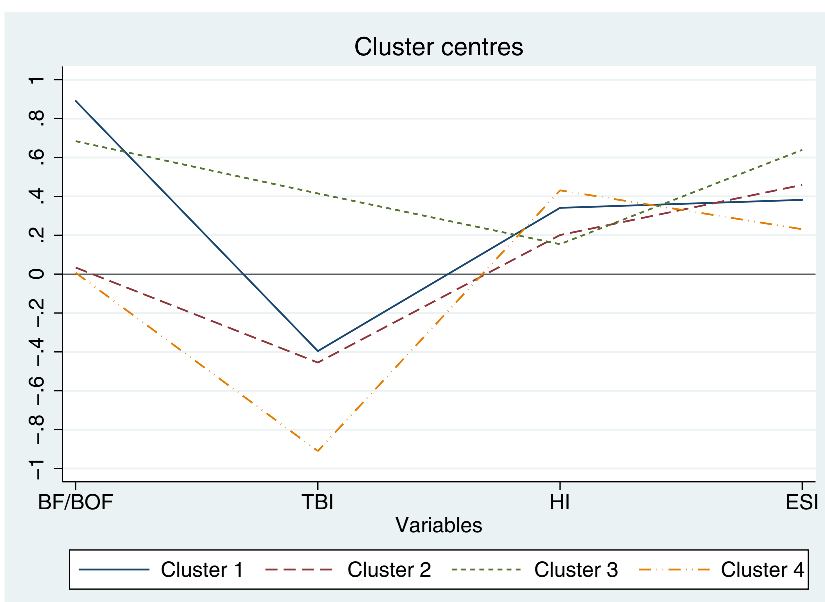


Fig. 12 Results of cluster analysis (2016). The *y*-axis shows mean values of the respective variables for individual clusters. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)

Table 5 List of countries by group based on the cluster analysis results (2016)

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Romania	Bulgaria	Russia	Albania
Bosnia-Herzegovina	Croatia	Ukraine	Azerbaijan
Serbia	Macedonia	Brazil	Uzbekistan
Kazakhstan	Montenegro	South Africa	Cuba
Argentina	Byelorussia	China	El Salvador
Paraguay	Moldova	India	Guatemala
Algeria	Egypt	Taiwan	Trinidad and Tobago
	Libya		Colombia
	Iran		Ecuador
	Saudi Arabia		Peru
	United Arab Emirates		Uruguay
	Indonesia		Venezuela
	Malaysia		D.R. Congo
	Singapore		Ghana
	Thailand		Kenya
	Vietnam		Morocco
			Nigeria
			Tunisia
			Uganda
			Jordan
			Oman
			Qatar
			Syria
			Bangladesh
			Mongolia
			Myanmar
			Pakistan
			Philippines
			Sri Lanka

The countries for which production data by processes were available in 2016 are shown. Source: Author's calculations based on data from the World Steel Association (2017) and the ISSB (2017)

second cluster. The third cluster consists of BF/BOF-oriented non-OECD countries, except India,[24] and they are net exporters of steel. Moreover, non-OECD countries in the third cluster have low HI values and high values of TBI and ESI, suggesting that these countries are the most competitive among non-OECD countries. Several major steelmaking countries, such as China and Russia, are in the third cluster.[25] Finally, all countries in the fourth cluster mainly use the EAF process and have low values of TBI and ESI but high values of HI.

Conclusion

This study examined the structure of non-OECD countries in the global steel industry. The results of the analysis indicated that the balance of steelmaking technologies is associated with steel trade structure in non-OECD countries. As confirmed by the analysis, the BF/BOF route is more likely to be significant for non-OECD countries to become net exporters of steel and diversify, and/or to upgrade exports of steel products.

The study suggested that the choice of BF/BOF technology in non-OECD countries is a necessary, but not sufficient, condition for the catch-up of OECD countries. This is because it is unlikely that all non-OECD countries follow a path similar to OECD countries.

However, the study did not explore other important facts in the global steel industry. First, what are other factors that explain the steel trade structure in non-OECD countries? It would be significant to explore sufficient conditions for the catch-up of OECD countries. Aside from the balance of steelmaking technologies, there may be other significant factors to be considered. Second, why has crude steel output via the EAF route been increasing in both OECD and non-OECD countries in recent years? Although the EAF share of global crude steel production is still lower than that of BF/BOF, this technology is becoming increasingly important in some non-OECD countries.[26] In addition, how China's EAF production will evolve in the future is currently a highly debated issue, given its important role in the global steel industry (McKinsey and Company 2017; World Steel Association 2018b). Finally, what is the relationship between the development of non-OECD countries and growing role of international division of labour? It would be useful to examine the connections and interdependencies between the steel industries of OECD and non-OECD countries. This could have important implications for global steelmaking raw material markets and global steel markets, as focus on the value chain from inputs to the final steel product is important to understand the structure of the global steel industry.

This study focuses on diversification and sophistication of exports from the viewpoint of the steel industry, thereby contributing to the development of the debate on export diversification and export sophistication in earlier research findings in the field of international trade studies. From the viewpoint of industrial development studies, the study provides a broad view of linkages between steelmaking technologies and steel trade structure, while identifying the characteristics of developing countries in the steel industry by comparing their

[24] It is important to note that India's share of crude steel output via the BF/BOF route is relatively high compared to other EAF-oriented non-OECD countries, accounting for 42.7% of its total crude steel output in 2016.

[25] It would be important to explore the reasons for the differences between the first and the third cluster. It is important to shed light on the volume of crude steel output, given the variable could have significant implications for steel export structure. Appendix Table 13 shows crude steel output of four clusters in 2016. These four clusters were analysed using the Kruskal–Wallis test and Steel–Dwass test. The Kruskal–Wallis test showed that crude steel output was significantly different ($p < 0.001$), and the Steel–Dwass test indicated that there was a significant difference between the first and the third cluster (Appendix Tables 14 and 15). Although both countries in the first and the third cluster are BF/BOF-oriented countries, there appears to be a significant difference of economies of scale owing to the magnitude of crude steel output. Since non-OECD countries in the third cluster are major steel producers, there are also discrepancies with other clusters in crude steel output.

[26] The BF/BOF route has been a major technology globally, accounting for 73.8% of global crude steel output in 2016.

structure to that of developed countries. In addition, the study sheds light on both major steelmaking countries and minor ones with less focus on the global steel industry. Despite some limitations, this study provides important implications for understanding the structure of non-OECD countries in the global steel industry.

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Appendix

Table 6 Abbreviations of country names

Country (OECD)	Code	Country (non-OECD)	Code	Country (non-OECD)	Code	Country (non-OECD)	Code
Australia	*AUS*	*Albania*	*ALB*	Jamaica	JAM	Sudan	SDN
Austria	*AUT*	*Algeria*	*DZA*	*Jordan*	*JOR*	*Syria*	*SYR*
Belgium	*BEL*	*Argentina*	*ARG*	*Kazakhstan*	*KAZ*	*Taiwan*	*TWN*
Canada	*CAN*	Armenia	ARM	*Kenya*	*KEN*	Tajikistan	TJK
Chile	*CHL*	*Azerbaijan*	*AZE*	Kuwait	KWT	Tanzania	TZA
Czech Republic	*CZE*	Bahrain	BHR	Kyrgyzstan	KGZ	*Thailand*	*THA*
Denmark	DNK	*Bangladesh*	*BGD*	Lebanon	LBN	*Trinidad and Tobago*	*TTO*
Estonia	EST	Bolivia	BOL	*Libya*	*LBY*	*Tunisia*	*TUN*
Finland	*FIN*	*Bosnia-Herzegovina*	*BIH*	Lithuania	LTU	Turkmenistan	TKM
France	*FRA*	*Brazil*	*BRA*	*Macedonia*	*MKD*	*Uganda*	*UGA*
Germany	*DEU*	*Bulgaria*	*BGR*	*Malaysia*	*MYS*	*Ukraine*	*UKR*
Greece	*GRC*	*Byelorussia*	*BLR*	Malta	MLT	*United Arab Emirates*	*ARE*
Hungary	*HUN*	Cameroon	CMR	Mauritania	MRT	*Uruguay*	*URY*
Iceland	ISL	*China*	*CHN*	*Moldova*	*MDA*	*Uzbekistan*	*UZB*
Ireland	IRL	*Colombia*	*COL*	*Mongolia*	*MNG*	*Venezuela*	*VEN*
Israel	*ISR*	Costa Rica	CRI	*Montenegro*	*MNE*	*Vietnam*	*VNM*
Italy	*ITA*	*Croatia*	*HRV*	*Morocco*	*MAR*	Zimbabwe	ZWE
Japan	*JPN*	*Cuba*	*CUB*	*Myanmar*	*MMR*		
Latvia	LVA	Cyprus	CYP	Nicaragua	NIC		
Luxembourg	*LUX*	D.P.R. Korea	PRK	*Nigeria*	*NGA*		
Mexico	*MEX*	*D.R. Congo*	*COD*	*Oman*	*OMN*		
Netherlands	*NLD*	Dominican Republic	DOM	*Pakistan*	*PAK*		
New Zealand	*NZL*	*Ecuador*	*ECU*	Panama	PAN		
Norway	*NOR*	*Egypt*	*EGY*	*Paraguay*	*PRY*		
Poland	*POL*	*El Salvador*	*SLV*	*Peru*	*PER*		
Portugal	*PRT*	Georgia	GEO	*Philippines*	*PHL*		
Slovak Republic	*SVK*	*Ghana*	*GHA*	*Qatar*	*QAT*		
Slovenia	*SVN*	*Guatemala*	*GTM*	*Romania*	*ROU*		
South Korea	*KOR*	Honduras	HND	*Russia*	*RUS*		
Spain	*ESP*	Hong Kong	HKG	*Saudi Arabia*	*SAU*		
Sweden	*SWE*	*India*	*IND*	Senegal	SEN		
Switzerland	*CHE*	*Indonesia*	*IDN*	*Serbia*	*SRB*		
Turkey	*TUR*	*Iran*	*IRN*	*Singapore*	*SGP*		
United Kingdom	*GBR*	Iraq	IRQ	*South Africa*	*ZAF*		
United States	*USA*	Ivory Coast	CIV	*Sri Lanka*	*LKA*		

Countries whose production data by processes were available in 2016 are highlighted in italic. Source: Author based on data from the World Steel Association (2017)

Table 7 Major steel-producing countries (2016). mmt, %

Rank	Country (OECD)	Crude steel output (mmt)	Share of crude steel output in OECD (%)	Crude steel output by processes (%)		Iron ore output (mmt)	Coking coal output (mmt)	Ferrous scrap generation (mmt)
				BF/BOF	EAF			
1	*Japan*	104.8	21.6	77.8	22.2	–	–	43.5
2	United States	78.5	16.2	33.0	67.0	42.0	50.6	68.6
3	*South Korea*	68.6	14.2	69.3	30.7	0.8	–	23.5
4	*Germany*	42.1	8.7	70.1	29.9	0.4	2.2	22.1
5	Turkey	33.2	6.9	34.1	65.9	6.7	0.7	7.5
6	Italy	23.4	4.8	24.3	75.7	–	–	14.0
7	Mexico	18.8	3.9	26.1	73.9	10.0	3.0	8.9
8	*France*	14.4	3.0	66.1	33.9	–	–	9.6
9	Spain	13.6	2.8	33.4	66.6	–	–	7.0
10	*Canada*	12.6	2.6	55.4	44.6	48.7	26.0	8.1
11	*Poland*	9.0	1.9	56.8	43.2	–	13.1	5.7
12	*Belgium*	7.7	1.6	69.3	30.7	–	–	na
13	*United Kingdom*	7.6	1.6	80.6	19.4	–	0.1	10.1
14	*Austria*	7.4	1.5	91.0	9.0	2.1	–	na
15	*Netherlands*	6.9	1.4	98.7	1.3	–	–	na
16	*Czech Republic*	5.3	1.1	94.4	5.6	–	3.4	2.9
17	*Australia*	5.3	1.1	75.7	24.3	841.8	189.3	3.6
18	*Slovak Republic*	4.8	1.0	93.7	6.3	–	–	na
19	*Sweden*	4.6	1.0	67.4	32.6	26.9	–	na
20	*Finland*	4.1	0.8	67.1	32.9	–	–	na
21	Luxembourg	2.2	0.4	0	100.0	–	–	na
22	Portugal	2.0	0.4	0	100.0	–	–	na
23	Switzerland	1.5	0.3	0	100.0	–	–	na
24	*Hungary*	1.3	0.3	81.7	18.3	–	–	na
25	Greece	1.2	0.2	0	100.0	–	–	na
26	*Chile*	1.2	0.2	70.7	29.3	17.3	–	na
27	Norway	0.6	0.1	0	100.0	1.2	–	na
28	Slovenia	0.6	0.1	0	100.0	–	–	na
29	*New Zealand*	0.6	0.1	100.0	0	2.1	1.2	0.6
30	Israel	0.3	0.1	0	100.0	–	–	na
	OECD	484.1	100.0	57.7	42.3	1000.0	289.5	na
Rank	Country (non-OECD)	Crude steel output (mmt)	Share of crude steel output in non-OECD (%)	Crude steel output by processes (%)		Iron ore output (mmt)	Coking coal output (mmt)	Ferrous scrap generation (mmt)
				BF/BOF	EAF			
1	*China*	807.6	70.7	93.7	6.3	113.7	592.0	186.3
2	India	95.5	8.4	42.7	57.3	184.5	54.7	22.1
3	*Russia*	70.5	6.2	66.9	30.8	108.1	83.4	30.5
4	*Brazil*	31.3	2.7	77.3	21.1	431.4	–	11.1
5	*Ukraine*	24.2	2.1	70.0	7.0	80.2	6.1	5.7
6	*Taiwan*	21.8	1.9	64.2	35.8	–	–	5.5
7	Iran	17.9	1.6	12.2	87.8	40.1	1.0	na
8	Vietnam	7.8	0.7	30.0	60.0	0.9	–	na
9	*South Africa*	6.1	0.5	62.2	37.8	68.1	3.5	2.6
10	Saudi Arabia	5.5	0.5	0	100.0	–	–	na
11	Egypt	5.0	0.4	11.4	88.6	2.5	–	0.0
12	Indonesia	4.7	0.4	0	100.0	0.0	1.0	5.0

Table 7 (continued)

13	*Kazakhstan*	4.3	0.4	98.6	1.4	14.0	10.5	na
14	*Argentina*	4.1	0.4	56.7	43.3	0.2	–	1.5
15	Thailand	3.8	0.3	0	100.0	0.1	–	3.7
16	Pakistan	3.6	0.3	0	100.0	–	–	na
17	*Romania*	3.3	0.3	68.1	31.9	–	–	na
18	United Arab Emirates	3.1	0.3	0	100.0	–	–	na
19	Malaysia	2.8	0.2	0	100.0	11.6	–	3.2
20	Qatar	2.5	0.2	0	100.0	–	–	na
21	Byelorussia	2.2	0.2	0	100.0	–	–	na
22	Oman	2.0	0.2	0	100.0	–	–	na
23	Colombia	1.3	0.1	19.2	80.8	0.8	–	na
24	*Serbia*	1.2	0.1	100.0	0	–	–	na
25	Peru	1.2	0.1	0	100.0	10.0	–	na
26	Philippines	1.1	0.1	0	100.0	1.0	–	1.6
27	*Bosnia-Herzegovina*	0.8	0.1	100.0	0	1.8	–	na
28	Uzbekistan	0.7	0.1	0	100.0	–	–	na
29	*Algeria*	0.7	0.1	100.0	0	1.0	–	na
30	Ecuador	0.6	0.1	0	100.0	–	–	na
	Non-OECD 1	1142.9	100.0	80.5	18.6	1106.0	784.8	na
	Non-OECD 2	335.3	29.3	48.9	48.3	992.3	192.8	na

BF/BOF-oriented countries are highlighted in italic. There are also other steelmaking processes other than the BF/BOF and the EAF processes (e.g. the OHF process). China's iron ore output is converted, so that its iron ore content is about equal to that on average in the rest of the world. Malaysia and Thailand's iron ore output are not for steel production. *Non-OECD 1* non-OECD countries, including China; *Non-OECD 2* non-OECD countries, excluding China. Source: Author's calculations based on data from the World Steel Association (2017), United Nations Conference on Trade and Development (UNCTAD) (2017), International Energy Agency (IEA) (2017) and the Japan Ferrous Raw Materials Association (2017)

Table 8 Overview of steel trade by product (2016). mmt, USD million

Code	Broad category	Product description	OECD Volume	Non-OECD Volume	OECD Value	Non-OECD Value
Exports						
1	Semis	Ingots	0.6	1.9	820.2	722.7
2	Semis	Semis	13.6	39.4	6406.9	12,154.9
3	Semis	Semis total	14.3	41.4	7227.0	12,877.6
4	Long products	Bars and rod in coils	14.7	15.9	8833.5	6066.7
5	Long products	Deformed reinforcing bars	14.8	6.8	6036.6	3267.0
6	Long products	Hot rolled bars and flats	8.1	32.2	6599.0	10,787.1
7	Long products	Cold finished bars and flats	3.2	1.5	5366.5	1673.7
8	Long products	Hot rolled light sections	2.8	5.2	2074.8	2436.4
9	Long products	Hot rolled heavy sections	11.0	3.8	6142.0	1816.2
10	Long products	Rails and rolled accessories	2.3	1.1	1743.8	609.5
11	Long products	Long products total	56.9	66.4	36,796.3	26,656.5
12	Flat products	Hot rolled wide strip	48.5	37.6	24,127.6	16,056.3
13	Flat products	Hot rolled plates	21.2	13.2	15,316.4	5753.4
14	Flat products	Hot rolled sheets	0.5	0.3	292.0	202.6
15	Flat products	Cold rolled plates/sheet: coils/lengths	23.0	13.6	20,607.9	9173.6
16	Flat products	Hot rolled strip	2.9	0.4	2338.3	409.7
17	Flat products	Cold rolled strip	3.4	0.8	5950.4	1267.3
18	Flat products	Tinplate and tin free steel	5.0	2.2	4022.0	1534.4
19	Flat products	Zinc-coated sheets and strip	30.2	15.5	21,118.0	8589.0

Table 8 (continued)

Code	Broad category	Product description	OECD Volume	Non-OECD Volume	OECD Value	Non-OECD Value
20	Flat products	Other coated sheet and strip	7.7	11.8	7647.6	7118.0
21	Flat products	Electrical sheet	2.2	1.3	2557.7	1071.7
22	Flat products	Electrical strip	0.4	0.2	562.2	171.4
23	Flat products	Flat products total	144.8	97.1	104,540.2	51,347.4
24	Steel tubes	Steel tubes, seamless	5.1	6.6	11,633.9	7140.5
25	Steel tubes	Steel tubes, welded	14.0	9.7	16,553.7	8016.1
26	Steel tubes	Steel tube fitting	1.0	1.5	8354.5	4455.3
27	Steel tubes	Steel tubes total	20.1	17.8	36,542.0	19,611.8
28	Other steel products	Wire	4.5	4.3	5877.9	3692.5
29	Other steel products	Forged bars	0.5	0.7	1156.9	567.2
30	Other steel products	Forgings	0.7	0.3	2457.0	883.3
31	Other steel products	Tyres, wheels, and axles	0.6	0.1	1810.5	263.9
32	Other steel products	Points/switches/crossings	0.2	0.1	682.2	171.1
33	Other steel products	Forged/cold finish sections	0.1	0.3	214.9	207.8
34	Other steel products	Cold formed sections	1.1	0.2	1183.0	190.3
35	Other steel products	Welded structural sections	0.1	0.1	329.5	117.2
36	Other steel products	Steel castings	0.7	0.5	2042.3	1029.5
37	Other steel products	Other steel products total	8.4	6.6	15,754.3	7122.9
	Grand total	Steel products	244.5	229.3	200,859.8	117,616.3
Imports						
1	Semis	Ingots	0.8	1.2	1050.1	516.6
2	Semis	Semis	29.6	24.7	12,025.6	10,089.2
3	Semis	Semis total	30.4	25.9	13,075.6	10,605.8
4	Long products	Bars and rod in coils	14.4	13.6	8037.8	6940.9
5	Long products	Deformed reinforcing bars	9.1	12.0	3799.3	6600.8
6	Long products	Hot rolled bars and flats	8.5	13.1	6519.8	6795.2
7	Long products	Cold finished bars and flats	3.7	1.2	5004.4	1803.0
8	Long products	Hot rolled light sections	2.4	3.9	1807.0	2178.3
9	Long products	Hot rolled heavy sections	9.2	5.5	5293.2	3039.9
10	Long products	Rails and rolled accessories	1.8	1.5	1412.5	1184.1
11	Long products	Long products total	49.1	50.9	31,874.0	28,542.2
12	Flat products	Hot rolled wide strip	45.6	38.6	23,115.5	18,411.0
13	Flat products	Hot rolled plates	20.2	14.2	13,664.8	8604.9
14	Flat products	Hot rolled sheets	0.3	0.4	250.6	257.9
15	Flat products	Cold rolled plates/sheet: coils/lengths	20.0	14.6	19,208.8	10,924.9
16	Flat products	Hot rolled strip	2.7	0.6	2125.1	706.1
17	Flat products	Cold rolled strip	2.8	1.2	4688.7	2347.9
18	Flat products	Tinplate and tin free steel	4.5	2.8	3891.4	3238.8
19	Flat products	Zinc-coated sheets and strip	29.5	14.7	19,881.5	10,280.4
20	Flat products	Other coated sheet and strip	7.5	8.4	6888.6	6858.1
21	Flat products	Electrical sheet	1.7	2.0	1737.1	2047.3
22	Flat products	Electrical strip	0.5	0.2	607.6	270.5
23	Flat products	Flat products total	135.2	97.8	96,059.6	63,948.1
24	Steel tubes	Steel tubes, seamless	4.9	6.2	9086.2	10,497.8
25	Steel tubes	Steel tubes, welded	12.8	7.7	14,577.6	9590.4
26	Steel tubes	Steel tube fitting	1.4	1.1	7826.2	5543.1

Table 8 (continued)

Code	Broad category	Product description	OECD Volume	Non-OECD Volume	OECD Value	Non-OECD Value
27	Steel tubes	Steel tubes total	19.0	15.0	31,490.0	25,631.3
28	Other steel products	Wire	5.2	3.3	6074.9	3694.5
29	Other steel products	Forged bars	0.6	0.5	1048.8	598.5
30	Other steel products	Forgings	0.6	0.2	1917.3	874.6
31	Other steel products	Tyres, wheels, and axles	0.4	0.1	1163.8	407.3
32	Other steel products	Points/switches/crossings	0.4	0.1	644.2	298.7
33	Other steel products	Forged/cold finish sections	0.2	0.4	222.8	280.0
34	Other steel products	Cold formed sections	0.7	0.3	839.5	286.2
35	Other steel products	Welded structural sections	0.1	0.1	197.0	126.9
36	Other steel products	Steel castings	0.7	0.2	1847.0	559.4
37	Other steel products	Other steel products total	9.0	5.3	13,955.2	7126.2
	Grand total	Steel products	242.8	194.8	186,454.4	135,853.6

Source: Author's calculations based on data from the ISSB (2017)

Table 9 Results of correspondence analysis (2016)

Dimension	Singular value	Principal inertia	Chi2	Per Cent	Cumulative %
Exports					
dim 1	0.4205	0.1768	83.75	87.06	87.06
dim 2	0.1621	0.0263	12.45	12.94	100.00
Total		0.2031	96.20	100.00	
Imports					
dim 1	0.1332	0.0177	7.77	89.93	89.93
dim 2	0.0446	0.0020	0.87	10.07	100.00
Total		0.0197	8.64	100.00	

Source: Author's calculations based on data from the ISSB (2017)

Table 10 OECD's steel exports in value terms in 2008 and 2016. USD million, %

Code	Broad category	Product description	2008		2016	
			Value	% share	Value	% share
1	Semis	Ingots	2529.1	0.7	820.2	0.4
2	Semis	Semis	21,751.3	6.2	6406.9	3.2
3	Semis	Semis total	24,280.4	7.0	7227.0	3.6
4	Long products	Bars and rod in coils	14,579.9	4.2	8833.5	4.4
5	Long products	Deformed reinforcing bars	17,213.6	4.9	6036.6	3.0
6	Long products	Hot rolled bars and flats	12,363.2	3.5	6599.0	3.3
7	Long products	Cold finished bars and flats	9035.4	2.6	5366.5	2.7
8	Long products	Hot rolled light sections	4080.9	1.2	2074.8	1.0
9	Long products	Hot rolled heavy sections	14,112.0	4.0	6142.0	3.1

Table 10 (continued)

Code	Broad category	Product description	2008		2016	
			Value	% share	Value	% share
10	Long products	Rails and rolled accessories	2346.6	0.7	1743.8	0.9
11	Long products	Long products total	73,731.6	21.2	36,796.3	18.3
12	Flat products	Hot rolled wide strip	35,881.9	10.3	24,127.6	12.0
13	Flat products	Hot rolled plates	32,887.8	9.4	15,316.4	7.6
14	Flat products	Hot rolled sheets	411.6	0.1	292.0	0.1
15	Flat products	Cold rolled plates/sheet: coils/lengths	30,981.6	8.9	20,607.9	10.3
16	Flat products	Hot rolled strip	4217.0	1.2	2338.3	1.2
17	Flat products	Cold rolled strip	8218.7	2.4	5950.4	3.0
18	Flat products	Tinplate and tin free steel	6039.1	1.7	4022.0	2.0
19	Flat products	Zinc-coated sheets and strip	25,583.9	7.3	21,118.0	10.5
20	Flat products	Other coated sheet and strip	10,217.1	2.9	7647.6	3.8
21	Flat products	Electrical sheet	5205.9	1.5	2557.7	1.3
22	Flat products	Electrical strip	1364.0	0.4	562.2	0.3
23	Flat products	Flat products total	161,008.7	46.2	104,540.2	52.0
24	Steel tubes	Steel tubes, seamless	25,784.0	7.4	11,633.9	5.8
25	Steel tubes	Steel tubes, welded	28,985.3	8.3	16,553.7	8.2
26	Steel tubes	Steel tube fitting	11,606.2	3.3	8354.5	4.2
27	Steel tubes	Steel tubes total	66,375.5	19.0	36,542.0	18.2
28	Other steel products	Wire	8211.5	2.4	5877.9	2.9
29	Other steel products	Forged bars	2357.0	0.7	1156.9	0.6
30	Other steel products	Forgings	4011.5	1.2	2457.0	1.2
31	Other steel products	Tyres, wheels, and axles	1743.9	0.5	1810.5	0.9
32	Other steel products	Points/switches/crossings	987.9	0.3	682.2	0.3
33	Other steel products	Forged/cold finish sections	510.5	0.1	214.9	0.1
34	Other steel products	Cold formed sections	2013.7	0.6	1183.0	0.6
35	Other steel products	Welded structural sections	354.2	0.1	329.5	0.2
36	Other steel products	Steel castings	2930.5	0.8	2042.3	1.0
37	Other steel products	Other steel products total	23,120.6	6.6	15,754.3	7.8
	Grand total	Steel products	348,516.7	100.0	200,859.8	100.0

Source: Author's calculations based on data from the ISSB (2017)

Table 11 Steel exports by product in value terms in 2008 and 2016. Per cent share of total steel exports

Product description (code)	Ingots/semis (3)		Long products (11)		Flat products (23)		Hot rolled sheets/coils (12 + 14 + 16)		Cold rolled sheets/coils (15 + 17)		Zinc-coated sheets/coils (19)		Electrical sheets/coils (21 + 22)		Steel tubes (27)		Seamless (24)		Welded (25)		Other steel products (37)	
Country	2008	2016	2008	2016	2008	2016	2008	2016	2008	2016	2008	2016	2008	2016	2008	2016	2008	2016	2008	2016	2008	2016
India	9.8	7.9	11.6	10.8	37.4	44.9	9.6	11.6	5.9	11.5	14.5	12.0	0.3	0.5	29.9	20.5	5.4	3.1	21.0	12.6	11.3	15.9
South Africa	2.8	2.8	10.4	10.4	70.8	70.5	23.9	23.0	23.4	24.1	10.0	11.5	0.0	0.0	9.7	8.8	4.3	2.7	3.8	3.1	6.4	7.5
China	2.1	0.0	22.0	29.3	45.3	45.8	14.0	13.9	6.6	6.3	4.4	9.0	0.3	0.7	25.0	19.0	14.6	7.6	6.9	6.6	5.7	6.0
Taiwan	3.3	2.7	15.7	13.0	67.4	71.3	15.9	21.3	27.1	25.7	9.7	9.4	2.8	2.8	11.0	10.0	0.5	0.4	7.9	6.7	2.6	3.0
United Arab Emirates	41.6	14.2	19.2	16.7	28.0	41.9	12.2	18.9	7.9	9.0	3.3	7.4	0.2	2.1	8.7	18.0	5.2	4.2	2.8	10.2	2.4	9.2
Romania	4.8	2.7	7.3	12.8	56.8	43.5	18.8	13.7	9.8	14.4	1.7	2.9	1.9	2.1	25.7	33.6	18.8	22.2	3.5	5.4	5.4	7.4
Singapore	1.0	0.8	16.2	25.3	30.6	25.9	6.6	2.9	6.3	5.8	3.8	2.3	0.2	2.4	43.1	35.4	23.9	16.3	11.7	8.1	9.0	12.6
Malaysia	16.0	3.9	17.2	8.1	30.9	42.8	11.0	2.7	6.8	24.0	1.9	4.6	0.4	0.8	25.1	26.1	3.8	4.7	17.7	14.3	10.8	19.0
Thailand	4.4	4.0	19.0	22.0	46.9	22.5	15.7	0.7	14.1	13.3	2.3	4.2	0.2	0.1	23.8	35.5	2.0	7.8	14.1	14.2	5.9	16.1
Vietnam	30.0	0.1	9.2	6.5	41.0	66.7	6.8	0.9	9.4	23.6	1.9	16.7	1.0	0.8	15.5	21.1	0.6	3.4	8.9	14.4	4.3	5.5
Egypt	1.9	1.5	11.0	17.6	85.1	73.3	72.3	37.9	0.7	11.2	10.2	20.6	0.1	0.0	0.2	3.4	0.2	0.2	0.0	3.1	1.6	4.2
Croatia	1.9	1.5	19.6	25.2	14.7	26.5	1.2	4.9	1.1	2.4	3.3	1.5	0.2	0.8	50.9	32.1	23.1	3.2	18.3	11.3	12.8	14.7
Russia	47.7	41.2	12.1	14.2	30.6	33.7	12.7	18.8	6.1	5.1	0.7	1.6	5.9	3.4	8.0	9.0	3.3	3.1	4.4	5.4	1.6	1.9
Morocco	0.1	0.0	0.0	6.8	94.6	87.0	0.2	12.2	4.1	13.3	50.1	8.6	0.0	0.0	4.2	3.8	1.9	0.8	1.0	1.1	1.0	2.4
Brazil	47.1	48.2	16.0	13.8	24.1	28.5	5.7	12.6	6.2	4.6	2.4	5.7	0.9	0.2	9.7	7.7	2.9	5.7	6.0	1.7	3.1	1.8
Indonesia	2.4	25.0	14.5	5.0	52.0	29.3	2.9	3.6	7.0	8.3	2.0	0.4	0.2	0.1	29.4	34.2	19.5	17.9	5.5	6.5	1.6	6.5
Saudi Arabia	0.2	1.2	7.4	3.2	85.4	36.9	52.3	24.1	1.0	2.9	0.0	3.5	1.4	0.0	5.6	51.2	1.8	14.9	3.5	23.4	1.4	7.5
Ukraine	37.6	35.1	19.7	26.3	29.7	30.9	9.4	10.6	2.9	4.8	0.5	1.4	0.0	0.0	11.8	6.5	6.2	4.9	5.6	1.4	1.2	1.2
Serbia	0.1	1.6	1.5	1.8	90.0	82.5	39.4	40.7	12.3	18.0	0.9	1.1	0.0	0.1	5.2	10.0	0.4	0.5	3.7	7.5	3.3	4.0
Argentina	4.1	3.4	6.3	9.9	11.6	20.7	4.1	11.0	3.4	7.8	1.6	0.7	0.1	0.1	76.4	62.5	69.7	56.1	5.2	2.3	1.7	3.5
OECD	7.0	3.6	21.2	18.3	46.2	52.0	11.6	13.3	11.2	13.2	7.3	10.5	1.9	1.6	19.0	18.2	7.4	5.8	8.3	8.2	6.6	7.8

Source: Author's calculations based on data from the ISSB (2017)

Table 12 Results of cluster analysis (2016)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
N	7	16	7	29
BF/BOF	0.8906	0.0335	0.6839	0.0066
TBI	− 0.3965	− 0.4547	0.4146	− 0.9104
HI	0.3415	0.2012	0.1536	0.4311
ESI	0.3820	0.4591	0.6387	0.2310

The figures refer to mean values of the respective variables for individual clusters. Source: Author's calculations based on data from the ISSB (2017)

Table 13 Crude steel output of four clusters (2016) mmt

Cluster 1	Crude steel output (mmt)	Cluster 2	Crude steel output (mmt)	Cluster 3	Crude steel output (mmt)	Cluster 4	Crude steel output (mmt)
Romania	3.3	Bulgaria	0.5	Russia	70.5	Albania	0.1
Bosnia-Herzegovina	0.8	Croatia	0.0	Ukraine	24.2	Azerbaijan	0.2
Serbia	1.2	Macedonia	0.2	Brazil	31.3	Uzbekistan	0.7
Kazakhstan	4.3	Montenegro	0.1	South Africa	6.1	Cuba	0.2
Argentina	4.1	Byelorussia	2.2	China	807.6	El Salvador	0.1
Paraguay	0.0	Moldova	0.1	India	95.5	Guatemala	0.3
Algeria	0.7	Egypt	5.0	Taiwan	21.8	Trinidad and Tobago	0.0
		Libya	0.5			Colombia	1.3
		Iran	17.9			Ecuador	0.6
		Saudi Arabia	5.5			Peru	1.2
		United Arab Emirates	3.1			Uruguay	0.1
		Indonesia	4.7			Venezuela	0.6
		Malaysia	2.8			D.R. Congo	0.0
		Singapore	0.5			Ghana	0.0
		Thailand	3.8			Kenya	0.0
		Vietnam	7.8			Morocco	0.5
						Nigeria	0.1
						Tunisia	0.1
						Uganda	0.0
						Jordan	0.2
						Oman	2.0
						Qatar	2.5
						Syria	0.0
						Bangladesh	0.1
						Mongolia	0.1
						Myanmar	0.0
						Pakistan	3.6
						Philippines	1.1
						Sri Lanka	0.0
Total	14.4	Total	54.8	Total	1056.9	Total	15.6

Source: Author's calculation based on data from the World Steel Association (2017)

Table 14 Results of the Kruskal–Wallis test (2016)

Crude steel output	Cluster 1	Cluster 2	Cluster 3	Cluster 4
N	7	16	7	29
Average of the ranks	34.93	34.84	55.71	19.93
p value	$p < 0.001$**			

Source: Author's calculation based on data from the World Steel Association (2017)

**p statistically significant at 0.01

Table 15 Results of the Steel–Dwass test (2016)

		p value
Cluster 1	Cluster 2	0.9990
Cluster 1	Cluster 3	0.0084**
Cluster 1	Cluster 4	0.0626
Cluster 2	Cluster 3	0.0016**
Cluster 2	Cluster 4	0.0102*
Cluster 3	Cluster 4	0.0003**

Source: Author's calculation based on data from the World Steel Association (2017)

*p statistically significant at 0.05, **p statistically significant at 0.01

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