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The evolution of non-OECD countries in the twenty-first century: developments in steel trade and the role of technology

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Abstract

This study examines the evolution of non-OECD (Organisation for Economic Cooperation and Development) countries in the twenty-first century in terms of steel trade and aims to shed light on how emerging/developing countries have evolved since the early 2000s. For this purpose, the revealed symmetric comparative advantage index and the trade balance index were developed for the whole steel industry and some broad product categories. Further, multilevel analysis over time provided important insights into the catch-up dynamics in non-OECD countries, indicating how they have evolved in recent years. The macro-level analysis showed that there were considerable differences in patterns of comparative advantage and international competitiveness between OECD and non-OECD countries. In the twenty-first century, non-OECD countries certainly experienced a steady increase in steel production/exports; however, the results suggest that only a limited number of non-OECD countries improved their international competitiveness. Nevertheless, some seemed to have gradually gained their comparative advantage, albeit marginally. This implies that although the catch-up of non-OECD countries in the international steel market may be progressing gradually, it is still not enough. The micro-level analysis assessed the linkages between technology selection and export performance of major non-OECD steel-producing countries over time. Although the current catch-up of the steel industry in non-OECD countries is limited, the technology selection of steel firms in some countries in the twentieth century and Chinese steel firms' blast furnace-basic oxygen furnace technology selection in the twenty-first century have significantly impacted their catch-up progress.

Keywords Non-OECD countries · Steel trade · Technology selection · Comparative advantage · International competitiveness

Introduction

The world economy has undergone several transformations in the twenty-first century, including the growing role of emerging/developing countries, exemplified by non-OECD (Organisation for Economic Cooperation and Development) countries.[1] In particular, the growing importance of BRICS countries (Brazil, Russia, India, China, and South Africa) has driven this benign development (Dahlman and Wermelinger 2015). Thus, the rise of non-OECD countries is receiving increasing

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[1] In this study, the dichotomy between OECD and non-OECD countries is a proxy for the classification of 'advanced' and 'emerging/developing countries'. This is important when comparing the structure of emerging/developing countries with advanced countries (see for example, Chen and Yu (2014), Alemani et al. (2016), Azomahou et al. (2018), and Atakhanova and Howie (2020)). This classification is important to better understand the development of emerging/developing countries in the global steel industry (Sekiguchi 2019). This study sheds light on countries for which production data by processes were listed in the World Steel Association (2019a). Abbreviated names of the countries are available in Appendix Table 6.

attention in the economic literature and the industry. The steel industry is a suitable example to discuss non-OECD countries' catch-up at the industry level because it has been closely associated with national economic prowess since the Industrial Revolution (Shin 1996) and thus has been a strategic industry, crucial for latecomer countries' economic development (Mattera and Silva 2018).

What has happened in the global steel industry in the twenty-first century is notable from an industrial development viewpoint since latecomer countries have radically changed the structure of the industry. Although OECD countries had played a major role in the international steel market in the twentieth century, this supremacy has been challenged by the production and export volumes of non-OECD countries in the twenty-first century.[2] Over the last 20 years, the evolution of steel firms in non-OECD countries has fundamentally transformed the landscape of the global steel market.[3] Significant investments in steelmaking capacity have occurred in steel firms of non-OECD countries due to a sharp increase in steel-intensive economic activities (e.g. construction and infrastructure-building). Owing to rapid capacity expansions, non-OECD countries surpassed the OECD's crude steel output in 2004, and the share of non-OECD countries in global crude steel output increased significantly from 44.7% in 2001 to 72.2% in 2018.[4] Thus, the growing role of non-OECD countries is seen as one of the most significant changes in the global steel industry today (OECD 2015a).

The economic literature highlights the goods trade in countries since exports have implications for economic and industrial development (Lall 2000a, 2000b; Rodrik 2006; Hausmann et al. 2007; Schott 2008). Indeed, the empirical evidence in a number of studies indicates that the level of industrial development of latecomer countries can be observed with a focus on the export structure (e.g. Kumagai 2014; Kumagai and Kuroiwa 2020). Therefore, the discussion surrounding industrial development needs to take an international trade approach.

In the global steel market, the concept of catch-up in emerging/developing countries is a highly relevant issue (Sekiguchi 2017, 2019), which is inextricably linked to the discussion about international trade. International steel trade has important implications for catch-up in latecomer countries; steel exports typically reflect technology, productivity, types of production items, and quality of steel products in a country (Sekiguchi 2017).

Another dimension of catch-up relates to technology selection, which has been a crucial agenda for the industrialisation strategy of latecomer countries (Sato 2016). On the linkages between technology selection and steel exports in the 2010s, previous studies (Sekiguchi 2017, 2019) suggested that non-OECD countries that selected the blast furnace-basic oxygen furnace (BF-BOF) route are more likely to become net exporters of steel, gain comparative advantage, and diversify and upgrade steel exports. However, they did not focus on when the technology was selected. This issue raises the following important questions: have non-OECD countries acquired comparative advantage while strengthening international competitiveness in the global steel market in the twenty-first century? Have non-OECD countries that developed in the twenty-first century selected the BF-BOF technology to increase production/exports and upgrade steel products? To address these research questions, this study sheds light on the evolution of the steel trade in non-OECD countries in the twenty-first century. Focus on the linkages between technology selection and export performance could better help assess how non-OECD countries have evolved since the beginning of this century.

The remainder of this paper proceeds as follows. The "Literature review" section provides a brief literature review. The "Stylised facts" section introduces stylised facts in the steel industry. The "Methodology" section explains the methodology used in this study. The "Macro-level analysis" section provides a macro-level analysis that focuses on the evolution of international competitiveness and comparative advantage between OECD and non-OECD countries since the early 2000s. The "Micro-level analysis" section presents a micro-level analysis that indicates the linkages between technology selection and export performance of major non-OECD steel-producing countries since the beginning of the century. The "Summary of findings and implications" section provides a summary of the findings and some implications of the study. Finally, the "Conclusion" section provides the conclusion and limitations of this study.

Literature review

The economic literature suggests that latecomer countries are expected to acquire comparative advantage for a wide variety of goods while improving their international competitiveness as the economy develops (Widodo 2009). Indeed, comparative advantage can change over time (Kowalski 2011), and countries can move up the ladder of comparative advantage from resource-intensive products to labour-, capital-, technology-, and knowledge-intensive products (Balassa 1979; Meier

[2] Evolution of steel export volume by country is presented in Appendix Table 7.
[3] Evolution of the top 30 steel firms is available in Appendix Table 8.
[4] Nominal crude steelmaking capacity in non-OECD countries reached 1683.9 million metric tonnes (mmt) in 2018, which is more than three times as high as the 557.9 mmt capacity level observed in 2001, according to OECD (2020). Figures for production and trade were taken or calculated from the World Steel Association (various years) and the International Trade Centre (ITC) (2021), unless otherwise indicated. Moreover, the information on investment activities was mainly obtained from the OECD (2015a).

1995; Chow 2012). Patterns of trade specialisation vary significantly across countries and industries (Dalum et al. 1998; Laursen 1998). Technology is also closely linked to trade specialisation since the comparative advantage is endogenously determined by past technological change (Redding 1999).

The principle of comparative advantage plays a vital role in trade literature, which is also relevant to the international steel trade. de Carvalho and Sekiguchi (2015) discuss comparative advantage in the context of the steel industry and argue that 'steel trade is determined to a large extent by the comparative advantage of steel producers' (p. 27). Indeed, steel firms have a comparative advantage when the opportunity cost of their production is low, and they tend to focus on specific steel products that have a comparative advantage (Mattera 2018). Thus, focusing on specific steel products can identify where the 'strengths' of specific countries lie (de Carvalho and Sekiguchi 2015; Sekiguchi 2017; Mattera 2018). de Carvalho and Sekiguchi (2015) highlighted trade specialisation patterns in the context of steel trade at a certain point in time. Moreover, Sekiguchi (2017, 2019) discussed the issues of trade specialisation, trade diversification, and trade sophistication for non-OECD countries in the 2010s. These studies argued that non-OECD countries mainly using BF-BOF technology are more likely to have caught up with the steel industries of OECD countries in the international steel market. However, previous studies on the steel trade lacked the perspective of time-series variations in the catch-up of emerging/developing countries. In spite of the importance of technology selection in the steel industry, very little is known about when, by whom, and which production technology was chosen to facilitate the catch-up of non-OECD countries. Given that emerging/developing countries have experienced significant growth in steel output since the twenty-first century, it is important to track the evolution of non-OECD countries with a view of time-series analysis.

Catch-up industrialisation can be discussed at the macro, industry, and firm levels (Sato and Sato 2016). For example, several studies discussed the catch-up of latecomer countries in the steel industry (e.g. Amsden 1989; Shin 1996; Kawabata 2005, 2016a; Sato 2013; Sato 2016; Lee and Ki 2017). 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 2016a). In economic literature, it mainly discusses the development mechanisms of latecomer countries to reduce the gap between them and more developed countries. The main arguments of the theory are (i) economic growth depends on technological progress and (ii) latecomer countries may achieve faster growth than advanced countries by exploiting the so-called advantages of the backwardness hypothesis introduced by Gerschenkron (1962).

Much of the discussion on catch-up in latecomer countries emphasised the role of technology. In the steel industry, technological advances and innovation have played a crucial role in boosting productivity and introducing high value-added steel products (Silva and Mercier 2020). Therefore, production technology is significant for steel trade (Kawabata 2005; Sekiguchi 2017, 2019), and technology selection determines the steel industry's structure in a country (Sato 2010). For advanced countries, it is crucial to make technological progress efforts such as the development of new steel products and manufacturing methods and innovation of facilities. In contrast, emerging/developing countries need to choose which existing technology to use for steel production (Sato 2010). For such countries, steel production suggests a catch-up experience because it reflects capital accumulation, technological progress, and changes in the industrial structure (Sato 2014).

The economic literature highlights the importance of linkage effects between the steel industry and steel-using industries (Kawabata 2003, 2005; Sato 2014; Sato 2016; Jeon 2018; Mattera 2017, 2018). Owing to such high linkage effects with various sectors (e.g. automobile, shipbuilding, and construction), steel consumption is closely linked to the gross domestic product (de Carvalho 2013). Some typical development patterns of latecomer countries are observed in the steel industry, for example, (i) imports meet the steel demand for economic development and industrialisation if the steel industry in a country is not well developed, (ii) steel demand shifts from low value-added products to high value-added products as the economy develops, (iii) production begins when imports reach the minimum economic size, (iv) exports start when production increases to a certain level, and (v) imports, production, and exports change from low value-added products to high value-added products (Toda 1970). In addition, the structure of the industry also shifts as an economy develops (i) from import substitution of downstream facilities (i.e. re-rolling/surface treating facilities) to import substitution of upstream facilities (i.e. ironmaking/steelmaking facilities), (ii) from long to flat products, and (iii) from low value-added to high value-added steel products (Sato 2013). The literature mentioned above mainly discusses some development patterns in the steel industry from the domestic market viewpoint.

In contrast, some research sheds light on the overseas steel market (Marukawa 2018; Marukawa and Hattori 2019; Tanaka and Isomura 2020), having important implications for the development of the steel industry. First, understanding the degree of international competitiveness is vital for assessing the development level of the steel industry in a country. For instance, China became the world's largest steel-producing country in 1996, but it had not yet accomplished the catch-up since it was a net importer of steel, and thus not internationally competitive (Tanaka 2008; Tanaka and Isomura 2020). In the twenty-first century, the Chinese steel industry has become a net exporter of steel (Marukawa 2018; Tanaka and Isomura 2020), suggesting that its industry has experienced significant development to become a superpower (Marukawa 2018). Second, the historical development of a specific steel firm could help better understand how the overseas market has played a key role in developing the steel industry in a country. For example, South Korea's largest steel firm, POSCO, established in 1968, had set its export target and focused on exports for various reasons. They included ensuring long runs and full-capacity utilisation for all types of steel and driving a stake in the international market in anticipation of future capacity expansion (Amsden 1989; Shin 1996). Some research assesses the South Korean steel industry as a successful example with export promotion and import substitution from the beginning. The industry had adopted a policy that relied on exports from the initial stage to avoid the domestic market's narrowness. The South Korean steel industry could enhance international competitiveness in the global steel market through POSCO's integrated steelworks that have enjoyed economies of scale (Sato 2014). The South Korean steel industry's case suggests that the importance of exports had been recognised from the initial stage, and that it could not have developed without its export competitiveness in the international steel market. Overall, this study discusses the evolution of non-OECD countries in the twenty-first century by focusing on steel exports, based on the assumption that export competitiveness is a necessary condition for the development of the steel industry in a country.

The concepts of comparative advantage and international competitiveness are important when considering countries' development. However, the key issue lies in how to measure comparative advantage and international competitiveness. For instance, comparing production costs is at the heart of comparative advantage (Fujimoto and Shiozawa 2011), although it is difficult to measure it due to the lack of appropriate data (Balassa 1965). Balassa (1965) considered that trade performance reflects relative costs as well as differences in non-price factors and developed a proxy for measuring comparative advantage called the revealed comparative advantage (RCA) index, which defines a country's export share of each product compared to the world shares of that specific product. After three decades of Balassa's (1965) research, Dalum et al. (1998) and Laursen (1998) developed revealed symmetric comparative advantage (RSCA) index to make the RCA index symmetric.

The economic literature uses the RSCA index to discuss comparative advantage in a country (Dalum et al. 1998; Laursen 1998; Widodo 2009), indicating the country's specialisation in a given product compared to the rest of the world. In contrast, Trade Balance Index (TBI) enables a discussion on international competitiveness in a country (Marukawa 2018; Tanaka and Isomura 2020), suggesting the development level of its steel industry.

Overall, this study assumes that the combination of the RSCA index and TBI enables the assessment of the development of the steel industry in non-OECD countries in terms of comparative advantage and international competitiveness. To shed light on how non-OECD countries have evolved since the early 2000s, the RSCA index and TBI are developed for the whole steel industry and some broad product categories.

Stylised facts

Overview of the steelmaking process

Steel is produced mainly through two routes: the blast furnace-basic oxygen furnace (BF-BOF) route and the electric arc furnace (EAF) route (World Steel Association 2013a; Eurofer 2020). In addition, an outdated open-hearth furnace (OHF) with a BF is used in some emerging/developing countries, and thus, there are multiple routes in technology selection.[5] The steel industry relies on various raw materials in steelmaking (e.g. iron ore, coal, scrap) (Fig. 1). The BF-BOF route mainly uses iron ore and coal, while scrap is a major input in the EAF route (OECD 2014; World Steel Association 2021). The types and amounts of raw materials consumed in steelmaking vary considerably between the BF-BOF and the EAF routes (World Steel Association 2021).

In general, there are three stages in steel production: (i) ironmaking, (ii) steelmaking, and (iii) finishing (ArcelorMittal 2015). In the ironmaking process, oxygen is removed from the iron ore using coking coal to produce liquid iron in a BF, which is then delivered to a steelmaking plant.[6] During the steelmaking process, liquid iron is used to produce steel in a BOF.[7] The EAF route, alternatively, uses scrap as the main input. The casting process involves the transformation of liquid steel into its solid state for the shaping of final steel products. Semi-finished steel products (billet, bloom, and slab) are produced through a continuous casting machine, where steel is poured directly into the machine to create the required shape. Semi-finished products require further processing, treatment, and reshaping. Figure 1 illustrates an overview of the steelmaking process.

Initial investment costs and minimum efficient scales

Initial investment costs of facilities and minimum efficient scales (the rate of output per year at which unit costs reach their minimum) are related to technology selection (Howell et al. 1988; Kawabata 2005; Sato 2009) and vary across production technologies (Table 1).[8] Steelworks based on the BF-BOF technology entails a more significant capital investment than EAF-based steel plants. Thus, a business field's entry

[5] Other technologies, OHF route, are mainly observed in some non-OECD countries such as Russia and Ukraine.

[6] Iron ore can also be directly reduced to solid iron in the direct reduced iron (DRI) route. The DRI method is a process that produces solid iron from iron ore mainly using natural gas as the reductant. It is used as either a replacement or supplement for scrap in the EAF route (Midrex 2018). Generally, DRI production occurs in areas close to abundant natural gas sources and rich iron ore, such as the Middle East.

[7] A BOF is also called a converter.

[8] Apart from investment costs, operating costs affect technology selection. The data from Steel on the Net (2020a, 2020b) indicate a difference in operating costs between the BF-BOF and EAF routes, although operating costs depend on the development of key raw material prices.

Fig. 1 Overview of the steelmaking process. Source: World Steel Association (2013a)

barriers with integrated steelworks based on the BF-BOF route are high for some emerging/developing countries with small economies.

Characteristics of technology and types of steel firms/products

Understanding the steel industry's structure in a country through a steel firm typology framework based on the production system defined by its steel production technology/process is important (Kawabata 2005; Kawabata and Yin 2020). In the steel industry, there are three types of steel firms, namely (i) integrated firms, (ii) EAF firms, and (iii) rolling firms (including surface treatment and pipe and tube making) (Sato 2009).

First, integrated firms have three steel production stages (i.e. ironmaking, steelmaking, rolling, including surface treatment). They require a BF with a BOF to produce steel. The integrated production system is suitable for relatively high value-added steel products mass produced in large lots or for relatively large lots or quantities of high value-added steel products.[9] An integrated production system enables steel firms to enjoy economies of scale by utilising large-sized production facilities, including a BF, BOF, and downstream facility such as a hot strip mill, which is suitable for mass production (Kawabata and Yin 2020). The implication is that the BF-BOF route is an appropriate technology for large expansion if a country aims to grow its steel production.

Second, EAF firms are small-scale steelmaking plants based on EAF technology. EAF firms are generally smaller and simpler to construct and operate than integrated firms based on the BF-BOF route (World Steel Association 2013b). Some EAF firms produce long products (carbon steel) used in civil engineering and construction in medium lots, while others supply special steel in different shapes in small lots (Kawabata and Yin 2020). In addition, the use of an EAF with compact strip production technology has enabled EAF firms to enter the sheet steel market (World Steel Association 2013b). The scrap quality is related to types of steel products (Ruth 2004), and EAF firms need high-quality scrap to produce special steel and flat steel products.

Finally, rolling firms do not have ironmaking/steelmaking facilities. They purchase intermediate inputs such as semi-finished products to produce some steel products (e.g. hot-rolled coils). There are also steel firms that specialise in surface treatment (e.g. galvanising, colour-coating, and tin-coating) or pipe and tube making (Sato 2009). In the steel industry, downstream processes are more fragmented, and production

[9] Integrated firms based on the BF-BOF technology can produce high value-added steel products such as the outer panels of automobiles (Kawabata 2017).

Table 1 Initial investment costs and minimum efficient production scales by production facilities

	Initial investment cost Billion USD	Minimum efficient production scale Million tonnes
Integrated steelworks based on the BF-BOF route	4.0–6.0	3.0
DRI plant	0.1–0.2	1.0
EAF equipped with facilities for long products	0.1	0.3
EAF equipped with facilities for flat products (thin slab caster, compact hot strip mill)	0.3	1.0
Facilities for long products	0.02	0.1
Facilities for flat products (hot strip mill)	0.4	2.0
Facilities for flat products (cold strip mill)	0.1	0.25

Source: Author based on Sato (2013)

facilities are more specialised. Thus, the scale of production is relatively small. Many rolling firms are relatively small and produce small lots (Kawabata and Yin 2020).

Values of steel products

The unit value of steel exports (nominal sales divided by tonnes of steel exported) helps illustrate values across steel products. Figure 2 depicts world export unit values from 2001 to 2018, indicating that steel prices differ widely across types of steel products.[10] Export unit values increase in the order of ingots/semi-finished, long, flat, and pipe and tube products.

The role of exports in the steel industry

As pointed out by the International Trade Administration of the Department of Commerce (2016), 'steel products are a heavily traded commodity' (p. 2). Indeed, large amounts of steel are traded on international markets as inputs for the production of goods and services in various industries; world steel exports increased from 300.4 mmt in 2001 and reached 457.1 mmt in 2018 (World Steel Association 2019b). Generally, around 30% of global steel output (finished steel products) is shipped to trading partners in the form of exports (Fig. 3).

Methodology

Hypothetical model

Generally, the catch-up process of latecomer countries follows this order: (i) import of some goods, (ii) production of goods (import substitution), and (iii) export of goods (export industrialisation) (Suehiro 2008). Latecomer countries have the possibility of a big spurt of industrialisation by exploiting the advantages of backwardness—an opportunity to utilise the knowledge and technologies developed by countries that are already industrialised (Gerschenkron 1962), thus saving time and reducing costs. Technology selection is, therefore, an essential part of the catch-up of latecomer countries. Another critical factor to bear in mind is capability-building efforts for productivity improvement by firms/industries. From the micro perspective of international trade at the industry level, productivity improvement by firms/industries can strengthen their competitiveness (Fujimoto and Shiozawa 2011).

During the industrialisation phase, steel demand rises in response to industrial production growth, rising capital stock, and infrastructure development. The historical pattern observed in the steel industry suggests that when countries undergo industrialisation with growth in steel demand, most of their steel requirements are initially met through imports. After several years of importing steel, steelmaking capacity grows. Steel firms in latecomer countries increase production, reduce import dependency, and initiate exports by improving productivity. Some non-OECD countries could follow this pattern of moving away from imports towards domestic steel production and exports in the long term. As a result, some non-OECD countries are expected to acquire comparative advantage while strengthening international competitiveness in the global steel market.

This study assumes that export competitiveness is a necessary condition for the development of the steel industry in non-OECD countries. Exports have at least two important implications for the analysis of the steel industry. First, the development pattern in the steel industry discussed in the literature review suggests that export could be an indicator of the development of the steel industry. As the flying-geese model (Akamatsu 1962; Kojima 2000) indicates, the industry tends to show three successive patterns: (i) import, (ii) production, and (iii) export. Indeed, this development pattern can be observed in the steel industry in a latecomer country, such as Vietnam (Kawabata 2016b). The implication is that one can

[10] Classification of steel products is presented in Appendix Table 9. The evolution of steel export volume by product is presented in Appendix Table 10.

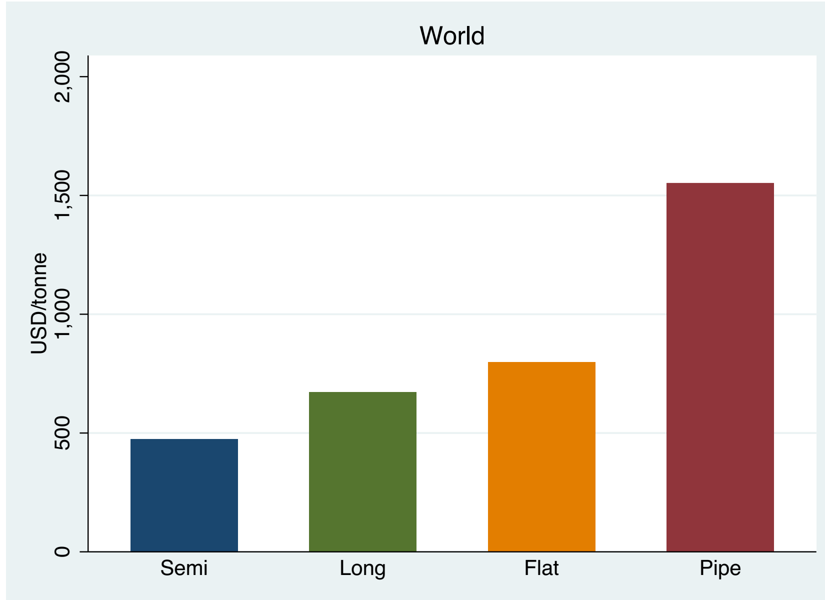


Fig. 2 Export unit values (2001–2018). Source: Author's calculations based on data from ITC (2021)

estimate the level of development of the steel industry in a country by focusing on steel exports.

Second, trade data could provide important insights into the types of steel products in a country. Generally, the steel industry has a product hierarchy in terms of value creation from long products to flat/pipe and tube products (Sato 2013), which has implications for upgrading the steel industry. As the steel industry becomes more sophisticated, a latecomer country tends to change the composition of steel products it produces (Nakaya 2008). While understanding the product mix of countries is essential to assess the development level of the steel industry, it is challenging to obtain steel production data by product.[11] Therefore, trade data can be used as a proxy for production data based on the assumption that export data partially reflects the production system.[12] In addition, the harmonised system (HS) code enables direct comparisons between countries with the same definition.

This study assesses the catch-up of non-OECD countries in the twenty-first century in terms of steel trade. RSCA and the TBI are used as proxies for comparative advantage and international competitiveness in non-OECD countries. The study draws upon multilevel analysis (the combination of macro- and micro-level analyses using RSCA index and TBI) to provide insights into the catch-up dynamics in non-OECD countries since the early 2000s.

The explanations of the RSCA and TBI indices are provided below:

Revealed comparative advantage index and revealed symmetric comparative advantage index

Balassa (1965) introduced the concept of the revealed comparative advantage (RCA) index, which is used to identify products with a comparative advantage in a country. It has been widely used to identify specialisation patterns in international studies (Deardorff 2011; Kowalski and Stone 2011)[13]. If x_{ij} is exports of product j from country i, then the RCA is expressed as follows:

$$RCA_{ij} = \frac{x_{ij}/\sum_j x_{ij}}{x_{wj}/\sum_j x_{wj}}$$

where the subscript w refers to world exports.

The distribution of the RCA index is asymmetric, varying from zero to infinity (Laursen 1998). Dalum et al. (1998) and Laursen (1998) transformed this index to the revealed symmetric comparative advantage (RSCA) index, which ranges from −1 to +1 ($-1 \leq RSCA_{ij} \leq +1$). The index is formulated as follows:

$$RSCA_{ij} = \frac{RCA_{ij} - 1}{RCA_{ij} + 1}$$

[11] The World Steel Association initially revealed production data by product in each country. However, since the scope and definition of reports of each product might have differed from country to country, it appears to have not accurately reflected actual production volumes. In addition, the organisation does not currently publish production data by product.

[12] The United Nations (2013) states that 'the analysis of exports seems to be a good indicator of the production system given that exports make up that part of the production system that is entirely subject to international competition. In other words, exports, for which a country has comparative advantages, in particular, are a genuine demonstration of a country's ability to raise the value of its production system in international markets. Moreover, from a practical viewpoint, export data is often more readily available and more coherent than production data, which enables direct comparisons between countries (p. 1).

[13] See Tamamura (2016) for a detailed discussion of the RCA index, including caveats of the index's interpretation.

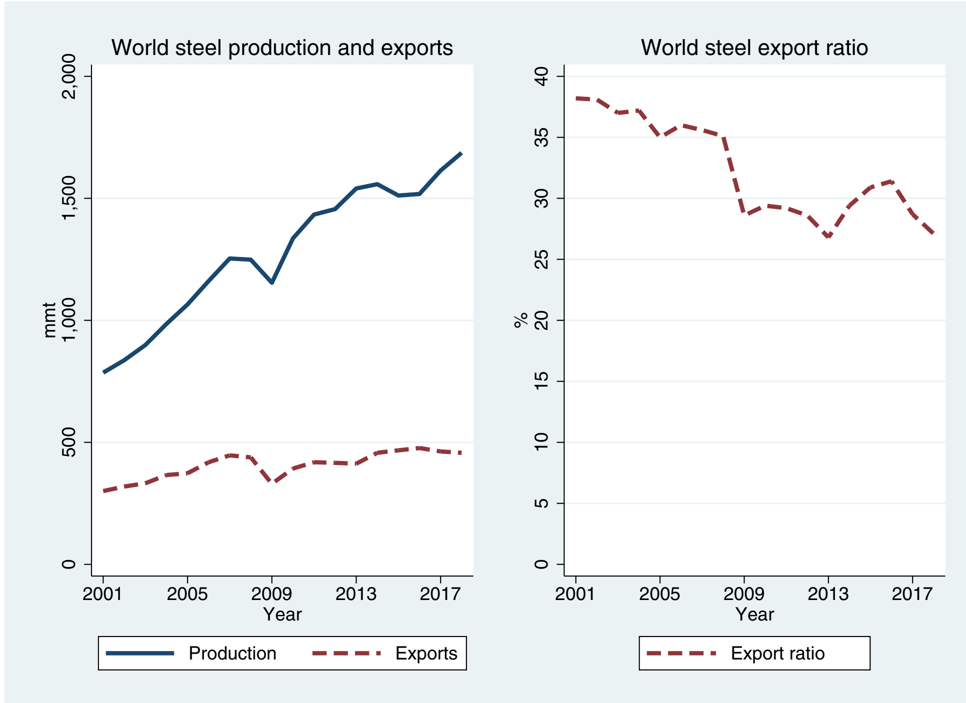


Fig. 3 World steel export ratio (2001–2018). Source: World Steel Association (2019b)

An $RSCA_{ij}$ greater than zero for a given product j indicates that a country reveals a comparative advantage in its exports. Contrarily, an $RSCA_{ij}$ less than zero suggests a comparative disadvantage in the exports of a given product.

Trade balance index

Lafay (1992) introduced the trade balance index (TBI) as a measure to analyse whether a country is a net exporter or a net importer. The index is formulated as follows:

$$TBI_{ij} = \frac{X_{ij} - M_{ij}}{X_{ij} + M_{ij}}$$

where TBI_{ij} represents the TBI of country i for product j and X_{ij} and M_{ij} denote the exports and imports of product j by country i, respectively. The index value ranges from −1 to +1 ($-1 \leq TBI_{ij} \leq 1$). A country is regarded as a net exporter if the TBI value is positive, whereas a negative TBI value indicates a net importer.

Figure 4 illustrates a hypothetical model of the catch-up of latecomer countries in this study. The model assumes that focus on export performance enables assessment of the development level of the steel industry in non-OECD countries.

An explanation of Fig. 4 is provided below:

- Steel imports in a country may increase in response to the growth in steel demand due to high economic growth during industrialisation.
- Steel firms in the country may seek to produce steel products to compete against imported products. Then, they may plan to invest in production facilities and thus select upstream/downstream facilities. As a result of the technology selection, the production system is determined in the country (BF-BOF-based country or EAF-based country). At the same time, the technology choice also defines the product mix in the country.
- After the installation of production facilities, the steel firms begin steel production. They can increase the volume of steel output through capability-building efforts to improve their productivity.
- When productivity is enhanced and production volume increases, the steel firms supply steel products. While they supply steel products to domestic steel-using industries, they may start exporting. As the steel firms increase volumes of steel production and exports, the steel industry in the country may acquire a comparative advantage over other industries in line with improving productivity, thus increasing the RSCA index. The country may substitute imports with domestic production/exports, resulting in an increasing proportion of exports to imports, which leads to TBI improvement. Improvement in its RSCA and TBI values for low value-added products segment may occur at the initial stage. As the steel industry further develops in the country, it may demonstrate high RSCA and TBI values for the high value-added steel products segment.
- The RSCA index suggests the advantages of the country's export of products over its other export items (e.g. Chinese

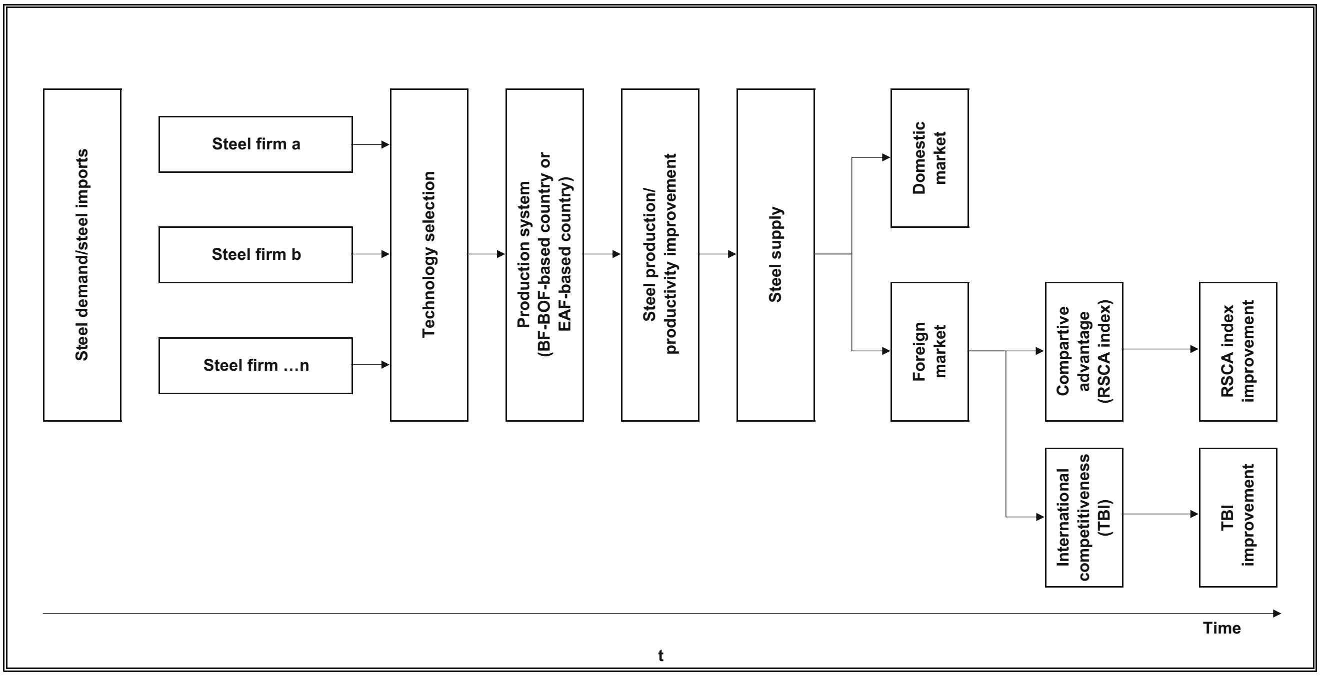


Fig. 4 Hypothetical model of the catch-up of latecomer countries. Source: Author

bars over its apparel). In contrast, the TBI suggests the advantages of the country's product exports over other countries (e.g. Chinese bars over Russian bars). Both the RSCA index and TBI may vary in parallel, but their changes may not necessarily be linked. This is because the TBI considers import data in addition to export data, while the RSCA index is calculated based only on the latter. Therefore, the development of steel demand and imports may significantly affect the evolution of the TBI. Even if the country's RSCA index improves due to the growing comparative advantage over other industries, its steel imports may increase if demand growth is greater than the change in production. In this case, the TBI in the country may not necessarily improve.

This study assumes that countries can supply steel products to domestic and foreign markets if they have a comparative advantage for specific steel products. While supply to the domestic market is also important in the steel industry, this research focuses on the foreign steel market, based on the assumption that steel export is the most reliable indicator for information on latecomer countries' capabilities to catch up, enabling direct comparisons between countries using the HS code.[14]

According to Fig. 4, the interplay of increased steel production/exports leading to growing comparative advantage/international competitiveness and higher steel demand/imports will likely determine the evolution of non-OECD countries in the twenty-first century. Some countries may have already had an interplay in the twentieth century, while others may experience it in the twenty-first century. It is important to examine which among steel production/exports or steel demand/imports have been more significant and whether evolution has occurred in the twentieth or twenty-first century.

This study performs multilevel analysis (the combination of macro-and micro-level analyses). The macro-level analysis sheds light on what technologies have contributed to an increase in steel production for non-OECD countries and how increasing steel production affects export volumes between 2001 and 2018. Next, it shows how the export performance of all non-OECD countries measured by comparative advantage and international competitiveness has evolved since the early 2000s. The micro-level analysis discusses when major non-OECD countries selected what kinds of technologies and how the technology choices have contributed to improving their steel production and export performance i.e. comparative advantage and international competitiveness, since the beginning of the twenty-first century.

Data

This study builds on an international steel trade dataset to shed light on non-OECD countries' evolution. The dataset

[14] Ferrarini and Scaramozzino (2011) argue that 'it is very difficult to measure capabilities directly because of their complex nature. The recent analysis of capabilities and trade rests on the notion that the observed profile of a country's trade specialisation provides indirect information about its productive capacity. … whilst it would prove problematic directly to measure capabilities, the actual trade flows can convey important information on countries' latent capabilities. In particular, export specialisation is seen as the most reliable indicator of a country's underlying capabilities' (p. 1).

Table 2 Summary of key steel-related indicators, 2001, 2008, and 2018

	2001				2008				2018			
	OECD	Non-OECD	China	Non-OECD excl. China	OECD	Non-OECD	China	Non-OECD excl. China	OECD	Non-OECD	China	Non-OECD excl. China
	Tonnage, mmt											
Apparent steel use (finished steel products)	429.1	346.2	158.0	188.2	487.3	744.4	446.9	297.6	472.7	1238.4	836.1	402.3
Crude steel output	471.4	380.6	151.6	229.0	527.4	817.9	512.3	305.6	506.7	1318.8	928.3	390.5
Steel exports	187.9	107.0	7.3	99.7	260.0	178.6	56.3	122.3	252.7	204.9	68.8	136.2
Steel imports	176.5	93.5	25.6	67.9	256.7	174.2	15.6	158.6	258.1	186.1	14.4	171.8
Trade balance	11.4	13.5	−18.3	31.8	3.3	4.3	40.7	−36.4	−5.4	18.8	54.4	−35.6

Note The table above uses the same definition of the OECD from 2001 to 2018 and includes a number of OECD and non-OECD countries whose production data by the process are not available. Source: Author's calculations based on data from the World Steel Association (various years)

provides insights into the global steel industry's dynamics that enable international comparison between countries and how non-OECD countries have evolved in the past 20 years.

The primary trade data comes from ITC's Trade Map, an online database of international trade data (ITC 2021) unless otherwise indicated. While the dataset contains steel products at the six-digit HS code level by source country, trade values, and quantities, trade data in value terms were used to calculate the RSCA index and TBI. This dataset contains trade data for the years 2001–2018. The data were based on approximately 190 steel products covering 88 countries whose production data by the process were available. This study's definition of steel products was based on the International Steel Statistics Bureau (2010). Regarding other key steel-related data, figures for steel production and apparent steel use were taken or calculated from the World Steel Association (various years).

Major non-OECD steel-producing countries were defined as the top 10 non-OECD steel-producing countries in 2018, based on the crude steel output ranking released by the World Steel Association (2019b).[15] Although Taiwan was ranked the sixth largest steel producer in non-OECD countries in 2018, it was excluded from the top 10 in this research because it is an advanced country, according to the IMF (2019).[16] Instead of Taiwan, this study focussed on Indonesia, the 11th largest steel-producing non-OECD country, based on the crude steel output ranking released by the World Steel Association (2019b). In 2018, the combined crude steel output of major non-OECD countries was 1226.5 mmt, accounting for 93.1% of steel production in non-OECD countries.

Macro-level analysis

Overview of steel demand and supply since the beginning of the twenty-first century

To provide an overview of developments since the start of the twenty-first century, Table 2 presents key steel-related indicators for the OECD and non-OECD countries for 2001, 2008, and 2018. Since the early 2000s, non-OECD countries have experienced a significant increase in apparent steel use (a proxy for steel demand), supported by high economic growth and strong demand from steel-using industries. Non-OECD countries have grown faster than OECD countries and have reduced the gap of steel output in the latter since 2001. As a result, the former has surpassed the latter's crude steel output, and their steel exports increased, which was supported by China's tremendous growth. Although non-OECD countries, excluding China, increased steel production and exports since the beginning of the twenty-first century, they have been in a trade deficit.

Technology selection since the beginning of the twenty-first century

Technology selection provides important implications for what technologies have contributed to an increase in steel production for non-OECD countries in the twenty-first century. Figure 5 displays changes in the crude steel output volume by technology and group between 2001 and 2018. The results

[15] An overview of the major non-OECD steel-producing countries is presented in Table 11 within the Appendix.

[16] Taiwan specialises in various steel products, including high value-added products, similar to the OECD countries (Sekiguchi 2017).

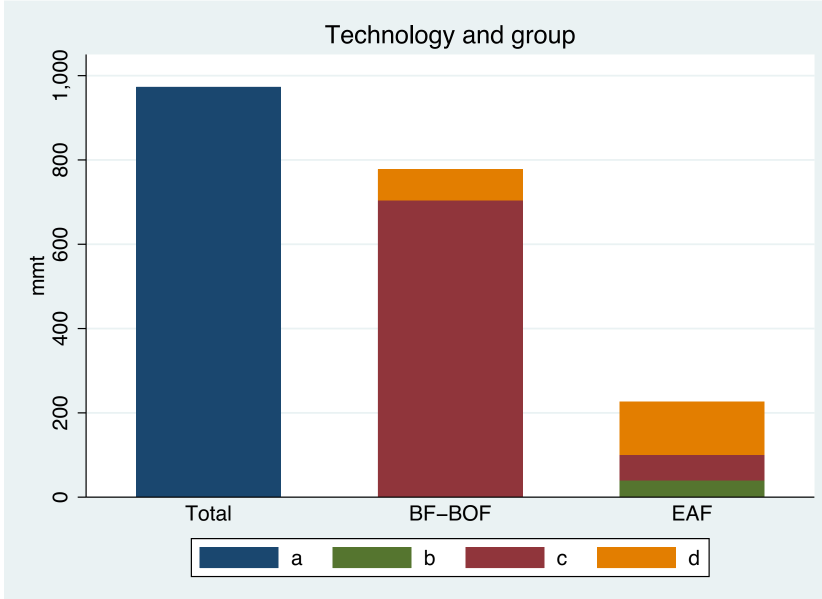


Fig. 5 Changes in crude steel output (2001–2018).Note: (**a**) the world, (**b**) the OECD countries, (**c**) China, and (**d**) non-OECD countries excluding China. Source: Author's calculations based on data from the World Steel Association (various years)

suggest that the expansion of crude steel output in non-OECD countries in the twenty-first century has mainly been due to the rapid increase in steel production via the BF-BOF route in China.[17] Although there were large gaps between the BF-BOF and EAF routes in terms of changes in the volume of crude steel output between 2001 and 2018, steel output via the EAF route in non-OECD countries, excluding China, also contributed to an increase in total crude steel output in the global steel market during the same period.[18] In contrast, the EAF route has played an increasingly important role in OECD countries.[19]

Linkages between steel production and steel exports

This study assumes that steel production is a key driver of steel exports in the international steel market. Some econometric analyses were performed to assess the link between crude steel output and steel exports. The following fixed effects model was employed to assess the heterogeneous link between crude steel output by group and steel exports for OECD and non-OECD countries.

$$ln\ EXP_{ipt} = \alpha_0 + \alpha_1 ln\ CSO_{it} + \alpha_2 ln\ CSO_{it} {*} nonoecd_i + x_i + y_t + \epsilon_{it}$$

where ln EXP_{ipt} is the log exports of steel product group p in volume terms for country i in year t. ln CSO_{it} is the log crude steel output for country i in year t. ln CSO_{it} interacts with a dummy variable non-OECD, which is equal to one if the country is a non-OECD member and zero otherwise. The model includes country and year fixed effects specified by x_i and y_t, respectively. ϵ_{it} is the error term for country i in year t.

Table 3 presents the results of the relationship between crude steel output and steel exports at the product level from 2001 to 2018. This analysis assesses whether the impact of steel output on steel exports differs at the product level across OECD and non-OECD countries. Overall, the results suggest a close relationship between crude steel output and steel exports. The effect of non-OECD countries' status is clarified in Model 1: the estimated magnitudes are far larger in non-OECD countries. It shows that greater volumes of crude steel output are positively and significantly associated with higher steel exports for non-OECD countries, with significance at the 1% level. While the effect of crude steel output is not significant in OECD countries, a 10% increase in crude steel output is estimated to lead to a 4.8% (=1.3% + 3.5%) increase in total steel exports for non-OECD countries.

Nevertheless, the effect of crude steel output appears to differ widely at the product level. Models 2, 3, and 4 reveal that crude steel output in non-OECD countries seems positively linked with greater exports in low value-added products, including ingots/semi-finished products and long products

[17] Between 2001 and 2018, world crude steel output increased from 852.0 mmt to 1825.5 mmt, in other words, by 973.5 mmt during the period. More specifically, globally crude steel output via the BF-BOF route grew by 762.2 mmt, accounting for 78.3% of the global crude output increase between 2001 and 2018. China accounted for 92.4% of the increase of crude steel output through the BF-BOF technology during this period.

[18] The question may arise that why have some non-OECD countries invested in the EAF route, despite their low availability of scrap? At least two patterns seem to exist. For instance, ASEAN countries have invested in the EAF technology utilising imported scrap. In contrast, countries in the Middle East notably Iran have increased its steelmaking capacity through the EAF route, and thus, DRI has been an increasing important feedstock for its producers (OECD 2015a).

[19] Generally, scrap availability is closely related to levels of past steel production (World Steel Association 2021). This appears to be linked to the fact that the share of the EAF route in steel production in some OECD countries has grown steadily for many decades (Laplace Conseil 2012; Sekiguchi 2019).

Table 3 Impact on non-OECD countries on steel exports at product level (2001–2018)

	(1)	(2)	(3)	(4)
	Dependent variables			
Variables	ln total steel exports	ln semi-finished exports	ln long exports	ln bar exports
ln crude steel output	0.132	−0.522	−0.015	−0.371
	(0.10)	(0.37)	(0.19)	(0.25)
ln crude steel output* non-OECD	0.348***	1.005**	0.437**	0.865***
	(0.13)	(0.40)	(0.21)	(0.28)
Fixed effects				
Year	✓	✓	✓	✓
Country	✓	✓	✓	✓
Observations	1469	1469	1469	1469
R-squared	0.901	0.802	0.846	0.822
	(5)	(6)	(7)	(8)
	Dependent variables			
Variables	ln flat exports	ln hot-rolled sheet/coil exports	ln pipe exports	ln high value-added exports
ln crude steel output	0.384***	0.524**	0.229	0.691***
	(0.12)	(0.23)	(0.18)	(0.21)
ln crude steel output* non-OECD	0.038	0.107	0.070	-0.275
	(0.15)	(0.25)	(0.20)	(0.23)
Fixed effects				
Year	✓	✓	✓	✓
Country	✓	✓	✓	✓
Observations	1469	1469	1469	1469
R-squared	0.900	0.895	0.850	0.864

Note: Non-interaction variable reflects OECD countries. Variables are calculated as log + 1 to retain observations with 0 values. All regressions include country and year fixed effects. Robust standard errors clustered at the country year level in parentheses. Significance: ***p < 0.01, **p < 0.05, *p < 0.1. High value-added products are the sum of selected high value-added products, namely rails, electrical sheets, and seamless tubes. Source: Author's calculations based on data from the World Steel Association (various years) and ITC (2021)

(e.g. bars). However, the relationship is not significant for some products such as flat products (e.g. hot-rolled sheets/coils) and high value-added products in non-OECD countries.[20] Conversely, OECD countries appear to have higher coefficients of flat products and high value-added products than non-OECD countries (see Models 5, 6, and 8). Summarily, the relationship between crude steel output and steel exports in non-OECD countries is positive, but only for low value-added products. In contrast, OECD countries have positive associations between crude steel output and flat products/high value-added products.

Another empirical model assesses the relationship between log growth total exports ΔEXP_{it} and ΔCSO_{it} from 1- to 5-year periods to see whether the relationship persists when observing growth rather than levels. Note that log growth in total exports is calculated as the change in log exports between time t and t-1, t-2, t-3, t-4, and t-5, respectively. The following models are employed:

$$\Delta EXP_{it} = \alpha_0 + \alpha_1 \Delta CSO_{it} + x_i + \epsilon_{it}$$

where $\Delta \mathrm{EXP}_{it}$ is the log growth of total steel exports in volume terms for country i in year t. $\Delta \mathrm{CSO}_{it}$ is the log growth of crude steel output for country i in year t. The model also includes the country fixed effects signified by x_i. ϵ_{it} is the error term for country i in year t.

The next analysis seeks to explore the extent to which changes to steel output impact total steel exports over short and medium time periods. Table 4 examines the links between changes in crude steel output on those in total steel exports for non-OECD countries. The results reaffirm the findings that crude steel output is associated with higher export levels and changes over time in non-OECD countries. A 10% increase in crude steel output leads to approximately a 4.2% increase in total steel exports (over the 5-year period) compared to 2.2% (over a 1-year period). For non-OECD countries, the results suggest that changes in crude steel output are more likely to

[20] This study assumes that rails, electrical sheets, and seamless tubes are high value-added products, given that they have high unit values. High value-added products denote the sum of these products.

Table 4 Changes in crude steel output and total steel exports for non-OECD countries (2001–2018)

	(1)	(2)	(3)	(4)	(5)
	Dependent variables				
Variables	Δln total steel exports, t-1 to t	Δln total steel exports, t-2 to t	Δln total steel exports, t-3 to t	Δln total steel exports, t-4 to t	Δln total steel exports, t-5 to t
Δln crude steel output, t-1 to t	0.222***				
	(0.05)				
Δln crude steel output, t-2 to t		0.247***			
		(0.05)			
Δln crude steel output, t-3 to t			0.285***		
			(0.06)		
Δln crude steel output, t-4 to t				0.339***	
				(0.08)	
Δln crude steel output, t-5 to t					0.417***
					(0.09)
Fixed effects					
Year					
Country	✓	✓	✓	✓	✓
Observations	843	789	732	679	625
R-squared	-0.040	-0.010	0.036	0.061	0.131

Note All regressions include country fixed effects. Year fixed effects are excluded from these regressions since variables are calculated as changes. The robust standard errors clustered at the country year level are in parentheses. Significance: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Note that in columns 1 and 2, the R-squared is very small, given that changes in steel production are likely to reveal themselves over longer periods, potentially due to technology catch-up. Thus, the results in the table suggest that assessing the relationship over a longer time is more appropriate. Source: Author's calculations based on data from the World Steel Association (various years) and ITC (2021)

reveal themselves over longer periods. The results indicate that the size of coefficients of non-OECD countries increases with each incremental year increase in the period regressions. This is likely because it takes time for exporters to find new markets. For such countries, it is possible that an increase in crude steel output leads to growing exports, particularly after some time.

Evolution of RSCA and TBI

This study assumes that non-OECD countries can improve RSCA and TBI values as their steel industries develop. Then, a question arises: which specific countries have improved RSCA and TBI values since the early 2000s? Figure 6 a and b illustrate the RSCA and TBI values of total steel products for OECD and non-OECD countries from 2001 to 2003 and 2016 to 2018. Countries that stand closer (farther away from) to the 45° bisection lines are those with RSCA and TBI values that have changed the least, while those below (above) the line have seen the indices decrease (increase).

OECD countries have a more stable structure than non-OECD countries in terms of RSCA value. Compared to their TBI values, slightly more non-OECD countries appear to have improved their RSCA values since the early 2000s. Some non-OECD countries appear to have improved RSCA values (mostly in quadrant 2). Although some non-OECD countries seem to have gradually gained a comparative advantage in steel products, others have not reached a trade surplus between 2001–2003 and 2016–2018.

The structure of the TBI value for OECD countries has been stable since 2001–2003 compared to non-OECD countries. Few non-OECD countries have improved TBI values (quadrant 2), while the gap widened (notably those in quadrant 4) for other countries. Between 2001–2003 and 2016–2018, China and Iran have sharply increased their TBI values, and the two have become net exporters of steel, and major exporters such as Ukraine, Brazil, and Russia have maintained their net exporters' positions since 2001–2003. India also maintained a positive value of TBI between 2001–2003 and 2016–2018. In contrast, some countries (e.g. Argentina, Venezuela) have shown decreased TBI values and turned to net importers of steel between 2001–2003 and 2016–2018.

More insights come from the analysis of the distribution of total steel products for two periods (2016–2018 vs. 2001–2003) using kernel density estimates to provide additional information on the distribution of RSCA and TBI values across countries (Fig. 7).[21]

[21] For details of kernel density estimates, see, for example, Silva and de Carvalho (2016).

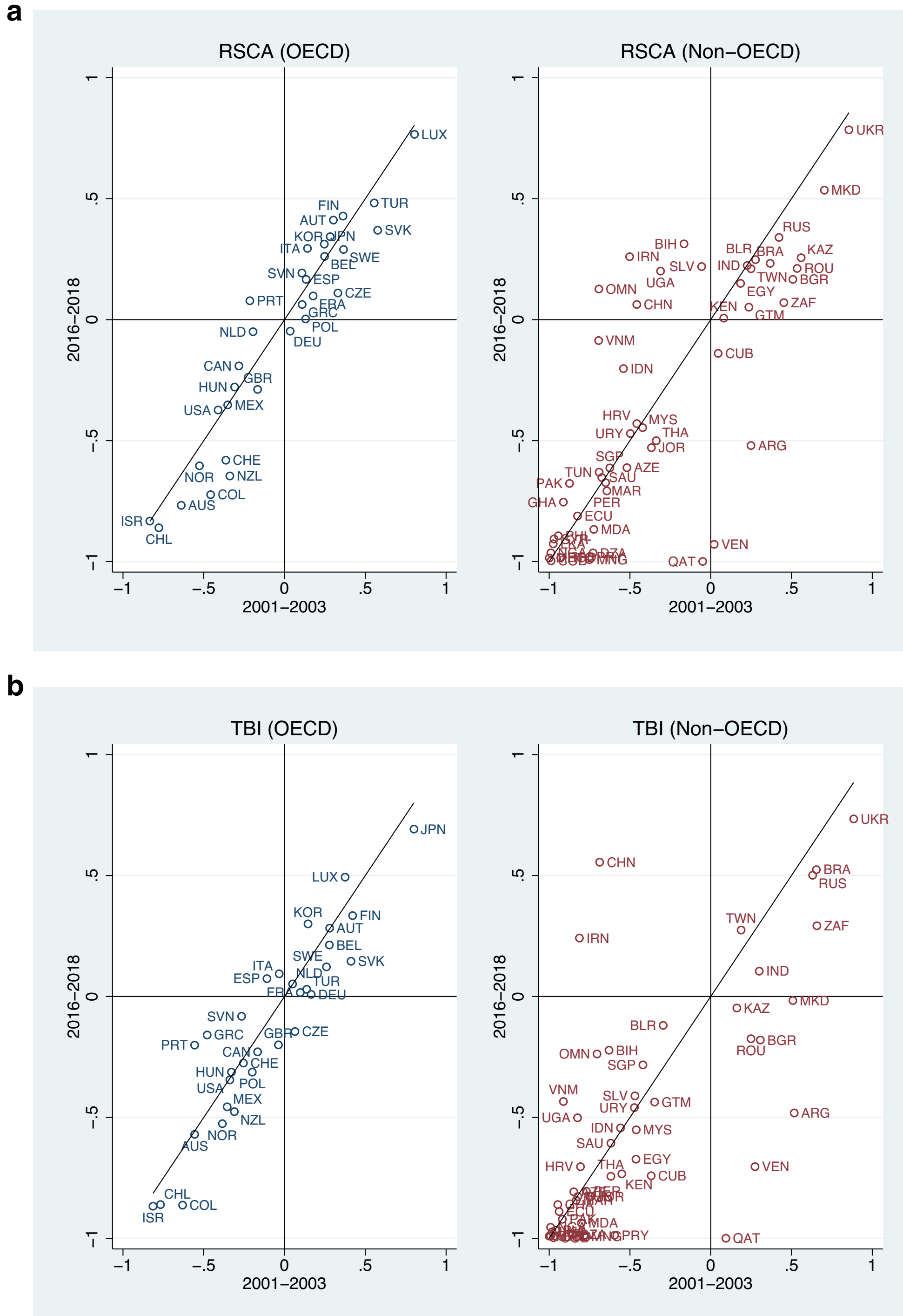


Fig. 6 Evolution of RSCA and TBI values (2001–2003 and 2016–2018). Note: N = 31 (OECD countries) and 51 (non-OECD countries). Countries for which trade data were not available between 2001–2003 and 2016–2018 were excluded. The charts show the value of each of the indices (RSCA and TBI) in each period (2001–2003 and 2016–2018) and for each country (circle and 3-digit ISO code), grouped into OECD and non-OECD countries. The 45° bisection provides an indication of where countries would stand in the charting plot if the value of the indices remained unchanged between the two periods of observation. Source: Author's calculations based on data from ITC (2021)

There are significant differences in the distributions of RSCA and TBI values between OECD and non-OECD countries. The RSCA distribution of non-OECD countries has been bimodal since 2001–2003, suggesting that there have always been two clusters of countries (one with higher values and another with lower values). The RSCA values of OECD countries do not deviate much from a normal distribution.

For OECD countries, the distribution of TBI values seems to be close to a normal distribution (with a mean of around zero) in both periods. For non-OECD countries, the distribution of TBI values was unimodal in 2016–2018, with the majority of countries exhibiting low TBI values. This can be compared to the distribution in 2001–2003 when there was a small cluster of non-OECD countries with relatively high TBI values.

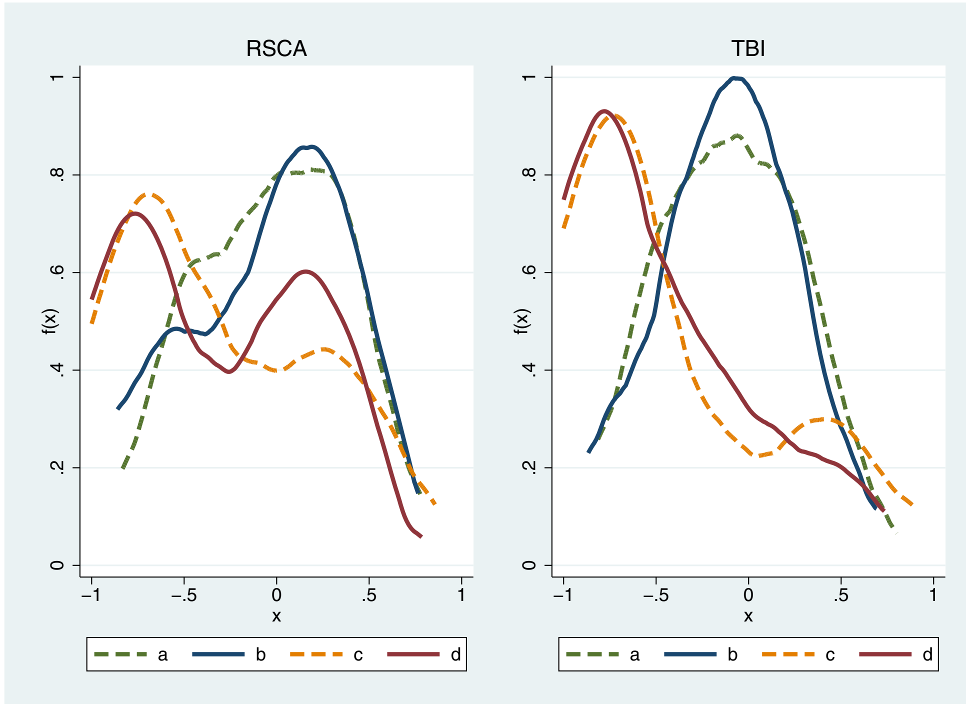


Fig. 7 Distributions of RSCA and TBI values (2001–2003 and 2016–2018). Note: N = 31 (OECD countries), N = 51 (non-OECD countries). Countries whose trade data were not available between 2001–2003 and 2016–2018 were excluded. (a) OECD countries (2001–2003), (b) OECD countries (2016–2018), (c) non-OECD countries (2001–2003), and (d) non-OECD countries (2016–2018). Source: Author's calculations based on data from ITC (2021)

Micro-level analysis

Technology selection in major non-OECD steel-producing countries

To shed light on how non-OECD countries have evolved in the twenty-first century, the micro-level analysis assesses their development through the case of major steel-producing countries. As a first step, it is important to highlight what kind of production technologies major non-OECD steel-producing countries have selected since the early 2000s.

There appear to be diverse patterns of technology selection in steel firms from major non-OECD steel-producing countries. First, some major non-OECD countries had already established production systems based on large integrated steel mills in the twentieth century. Russia, Ukraine, Brazil, and South Africa have been operating integrated steelworks before the early 2000s.[22] Among these countries, Russia and Ukraine have replaced outdated OHFs with new steelmaking facilities (OECD 2015a).

Second, China has heavily invested in large-sized BFs with BOFs since the twenty-first century to meet the strong demand from steel-using industries such as the automobile, home appliance, and construction industries. While China has been operating steelworks based on the BF-BOF technology before the early 2000s, it was in the twenty-first century that the country blew up numerous large-sized BFs (with inner volumes of more than 2000 m^3) (CISA 2015; KOSA 2015). Many Chinese steel firms constructed state-of-the-art steelworks based on the BF-BOF technology in coastal areas since around 2005. For instance, some large integrated steel mill projects (e.g. Ansteel Group's Yingkou Bayuquan, Shougang Group's Caofeidian, and China Baowu Group's Guangdong Zhanjiang) were commissioned in the country's coastal areas between 2008 and 2016; thus, flat products have played an increasingly important role in its steel production.

Third, India has invested heavily in both BF-BOF and EAF technologies in the twenty-first century, along with achieving significant growth in steel demand over the past decade. While it has also employed some large-sized BFs, its major steel firms (e.g. Tata Steel and SAIL) have blown up many large-sized BFs (KOSA 2015; CISA 2015), and several Indian steel firms have heavily invested in the EAF technology.[23] In the twenty-first century, supported by the government's target to increase its steelmaking capacity to 300 mmt in 2030 to 2031, India has made efforts to continue to increase its steelmaking capacity to meet domestic demands (Ministry of Steel of India 2017).

Fourth, Iran and Egypt have selected the EAF route to reduce import dependencies. Many projects entailed DRI plants owing to the abundant natural gas availability in these countries, and thus, EAF technology has played a dominant role in these countries. In particular, Iran has commissioned

[22] For instance, several major steel firms, such as Novolipetsk Iron & Steel (Russia), Metinvest (Ukraine), Usiminas (Brazil), and ArcelorMittal South Africa (South Africa) have been operating integrated steelworks before the early 2000s.

[23] In India, induction furnaces have also played an important role in steel production.

Table 5 Overview of technology selection in major non-OECD steel-producing countries (1991–1993, 2001–2003, and 2016–2018)

	1991–1993					2001–2003					2016–2018				
	Tonnage, mmt			Share, %		Tonnage, mmt			Share, %		Tonnage, mmt			Share, %	
	Total	BF-BOF	EAF	BF-BOF	EAF	Total	BF-BOF	EAF	BF-BOF	EAF	Total	BF-BOF	EAF	BF-BOF	EAF
China	80.5	38.6	17.8	47.9	22.1	185.4	153.7	31.2	82.9	16.8	868.9	788.9	80.0	90.8	9.2
India	17.8	8.1	4.9	45.6	27.6	29.3	16.2	11.2	55.3	38.1	102.1	45.6	56.9	44.6	55.8
Russia	62.7	22.5	9.3	36.0	14.9	60.1	36.6	9.0	60.9	15.0	71.3	47.6	22.0	66.7	30.8
Brazil	23.9	18.8	4.7	78.7	19.5	29.2	22.6	6.0	77.6	20.6	33.9	26.1	7.4	76.8	21.7
Iran	2.9	1.9	1.1	63.0	37.0	7.4	2.2	5.2	29.9	70.2	21.2	2.2	19.0	10.5	89.5
Ukraine	37.2	14.9	2.8	40.0	7.6	34.7	17.0	1.3	48.9	3.8	22.2	15.7	1.6	70.4	7.1
Viet Nam	0.2	0.0	0.2	0.0	82.0	0.4	0.0	0.4	0.0	100.0	11.6	4.9	5.7	41.9	48.9
Egypt	2.6	1.0	1.5	37.8	56.5	4.2	1.2	3.0	27.6	72.4	6.6	0.5	6.0	8.3	91.6
South Africa	9.0	5.6	3.3	62.3	36.7	9.1	5.0	4.1	54.6	45.4	6.3	3.8	2.4	61.0	39.0
Indonesia	3.3	0.0	3.3	0.0	100.0	2.4	0.0	2.4	0.0	100.0	5.4	2.9	2.4	54.8	45.2

Source: Author's calculations based on data from the World Steel Association (various years)

many DRI-based EAF plants over the past few years in line with the government's target to expand its steelmaking capacity to 55 mmt by 2025 (OECD 2015a).

Lastly, Vietnam and Indonesia have invested in EAF technology since the early 2000s, while they have also invested in the BF-BOF technology to meet domestic demand. They have traditionally been large net importers of steel, but growth in steelmaking capacity has gradually increased their steel production self-sufficiency. Since Vietnam had limited steelmaking capacity until the twenty-first century, it installed many EAF facilities to reduce import dependency. In recent years, the two countries have invested in BF-BOF-based integrated steelworks with a corporation of major foreign steel firms. Since 2014, Indonesia's Krakatau POSCO began operating its integrated steel mill, and Vietnam's Formosa Ha Tinh Steel completed its integrated steelworks between 2017 and 2018.

Table 5 summarises the technology selection of major non-OECD steel-producing countries since the early 1990s. In the twentieth century, the BF-BOF route's share was not that high in some countries, such as Russia and Ukraine, because other production processes (i.e. BF-OHF route) also played an important role at that time. In the twenty-first century, several countries have experienced significant growth in steel production. In particular, China has seen tremendous growth in its crude steel output via the BF-BOF route. India steadily increased its crude steel output in the twenty-first century with BF-BOF and EAF technologies, but it shifted its primary production process from the BF-BOF route to the EAF route between the twentieth and twenty-first centuries. Other countries such as Iran, Vietnam, and Egypt saw their crude steel output increase mainly through the EAF route. Meanwhile, countries such as Russia and Brazil witnessed relatively small changes in their crude steel output since the beginning of the twentieth century when compared to other countries. Although crude steel output via the BF-BOF route has increased in Indonesia in recent years, it has witnessed only small changes in its crude steel output.

Changes in steel production/exports in major non-OECD steel-producing countries

It is important to focus on how crude steel output and steel exports have changed since the beginning of the twenty-first century due to technology selection. Figure 8 plots crude steel output against total steel exports for major non-OECD steel-producing countries in 2001–2003 and 2016–2018. Russia, Ukraine, and Brazil were already significant exporters in the international steel market in the early 2000s, and China's steel exports were lower than those of the aforementioned countries from 2001–2003. Because China has significantly increased its crude steel output since the beginning of the twenty-first century, its total steel exports have strengthened considerably, making it the world's largest steel exporter. Aside from China, India, Vietnam, and Iran have also steadily increased their crude steel output since the early 2000s.

Evolution of RSCA and TBI in major non-OECD steel-producing

This study has so far discussed the evolution of major non-OECD steel-producing countries. The key question revolves around how they have developed comparative advantage and international competitiveness since the start of the twenty-first

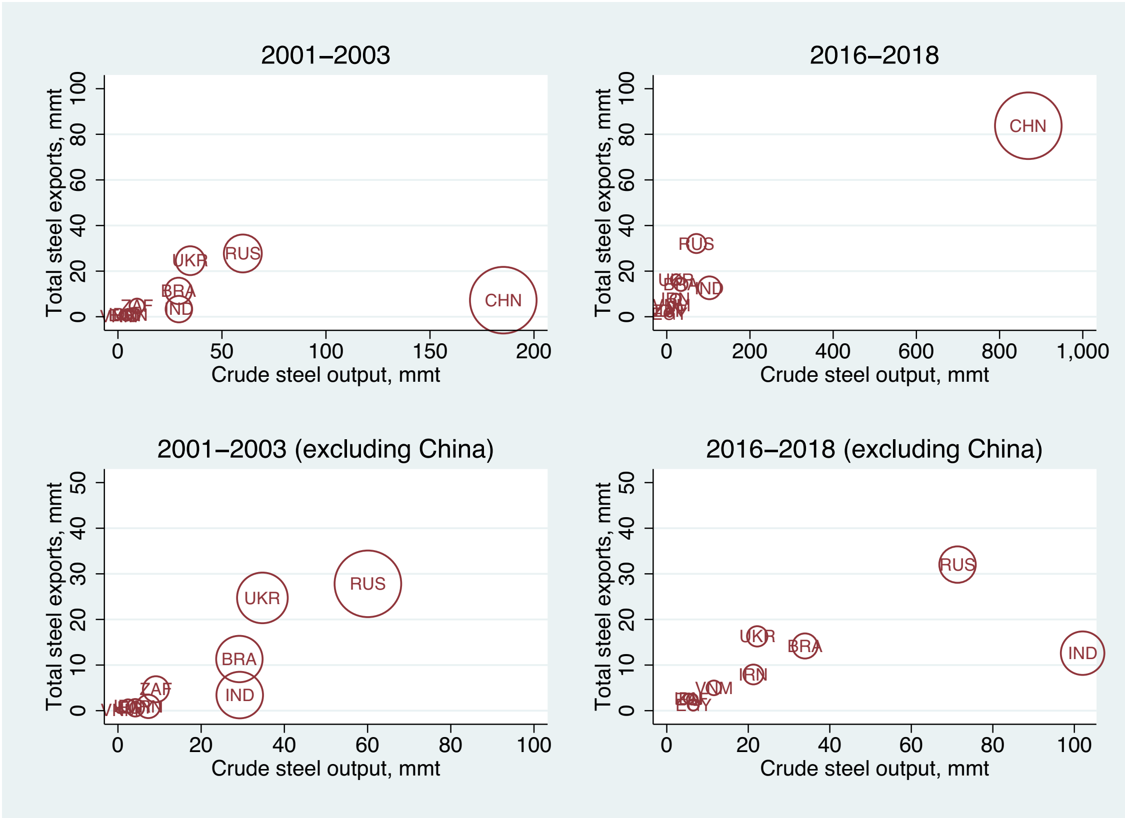


Fig. 8 Evolution of crude steel output and total steel exports for major non-OECD steel-producing countries (2001–2003 and 2016–2018). Note: Bubble sizes represent crude steel output. Source: Author's calculations based on data from the World Steel Association (various years) and ITC (2021)

century. Widodo (2009) introduced an analytical tool called 'products mapping' using the RSCA index and TBI to analyse exported products. This analytical framework is used to better understand the RSCA index and TBI's dynamics for major non-OECD steel-producing countries in the twenty-first century. According to the product mapping, the TBI is on the x-axis, and the RSCA index is on the y-axis (Fig. 9). The upper right quadrants (A) show steel products with comparative advantage and net export positions. The upper left quadrants represent steel products with comparative advantage but are net import positions (B). The lower right quadrants reveal steel products that are net export positions but have no comparative advantage (C). Finally, the lower-left quadrants represent steel products with neither comparative advantage nor net export position (D). Hypothetically, a country's position is expected to shift from D to A if it acquires a comparative advantage and strengthens international competitiveness in the international steel market. The analysis was conducted through six periods (i.e. 2001–2003, 2004–2006, 2007–2009, 2010–2012, 2013–2015, and 2016–2018).

Figure 10 presents a product mapping of the total steel products from 2001–2003 to 2016–2018. China, which has heavily invested in the BF-BOF technology since the early 2000s, showed a marked transformation in RSCA and TBI values since the period 2004–2006. China's position in product mapping shifted from D to A between 2001–2003 and 2016–2018, indicating that it has acquired a comparative advantage and strengthened international competitiveness in the twenty-first century. India, which used both BF-BOF and EAF technologies in the twenty-first century, witnessed small changes in RSCA and TBI values from 2001 to 2018, although it has maintained two indices' positive values since 2013–2015. India has also maintained position A between 2001–2003 and 2016–2018. Countries that established a production system based on the BF-BOF technology in the twentieth century (i.e. Russia, Brazil, Ukraine, and South Africa) have maintained positive values of the RSCA and TBI indices. Those that have selected the EAF technology in the twenty-first century (i.e. Egypt, Vietnam, and Indonesia) have had low RSCA and TBI values since the early 2000s. Iran, which has heavily invested in the EAF route in the twenty-first century, has recorded a significant increase in two indices from 2013 to 2015.

The next key question is as follows: how has product mapping for major non-OECD steel-producing countries evolved at the product level since the beginning of the twenty-first century? Figure 11 a–d present the product mapping of four

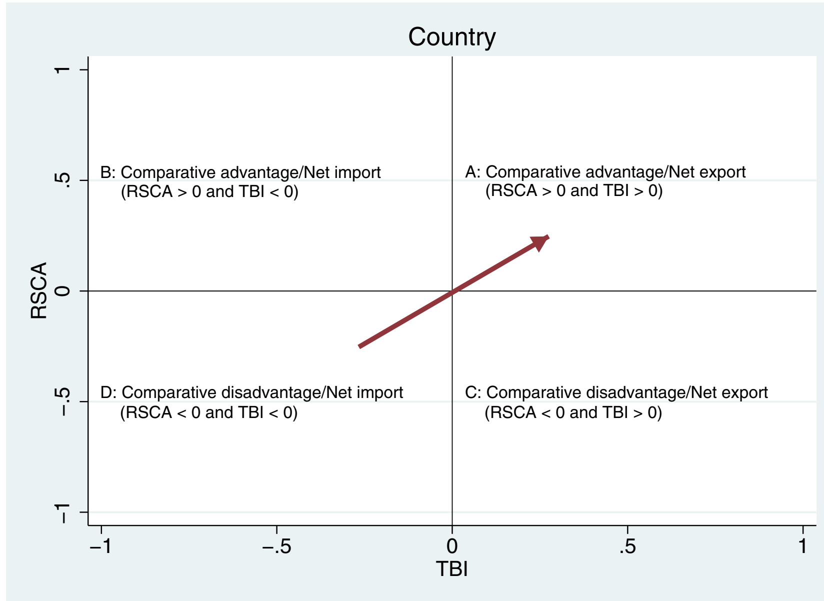


Fig. 9 Products mapping. Source: Author based on Widodo (2009)

broad categories of steel products:(i) ingots/semi-finished products, (ii) long products, (iii) flat products, and (iv) pipe and tube products. Based on Fig. 2, ingots/semi-finished products and long products can be proxied for low value-added

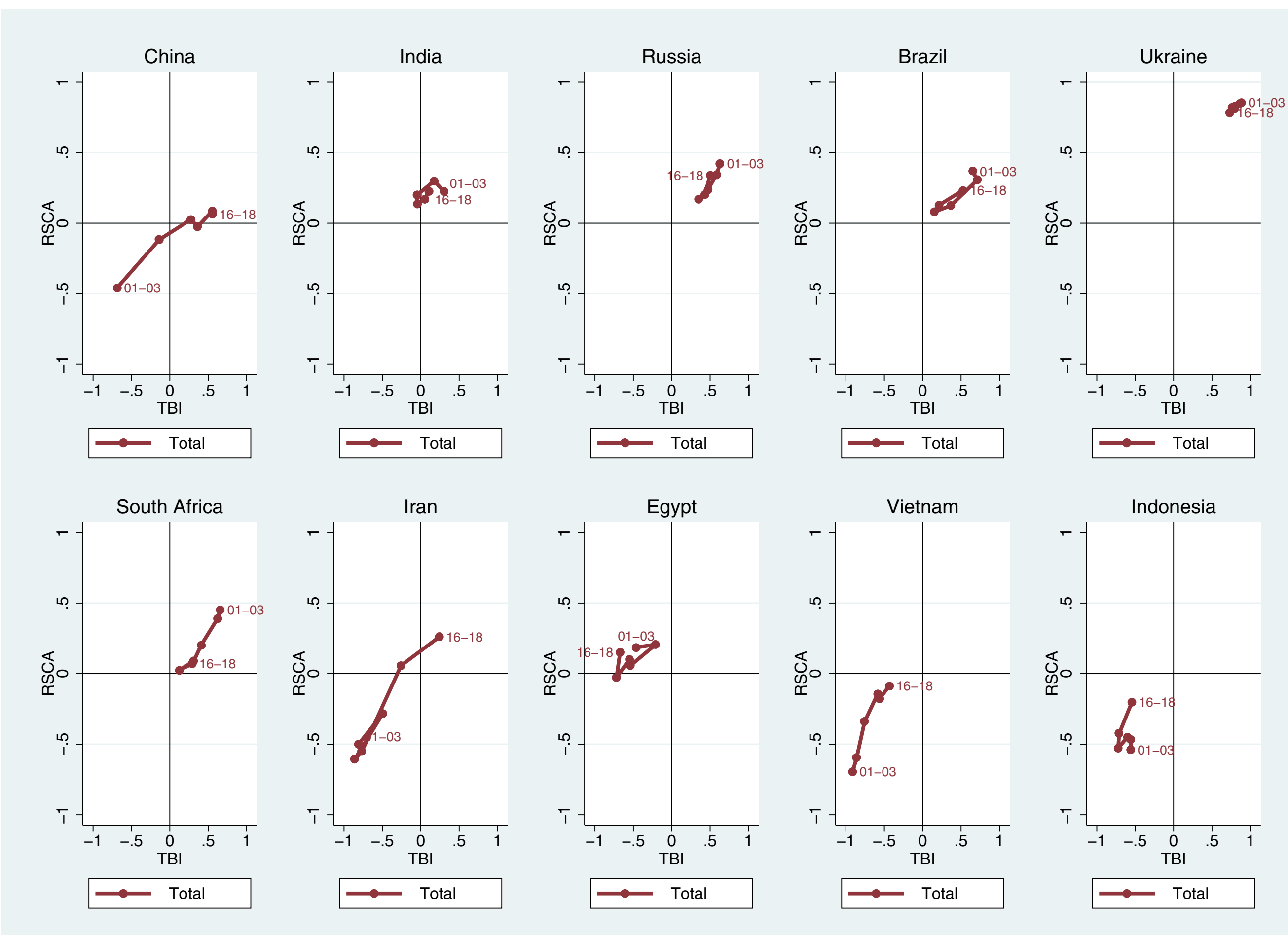


Fig. 10 Product mapping: total steel products. Source: Author's calculations based on data from ITC (2021)

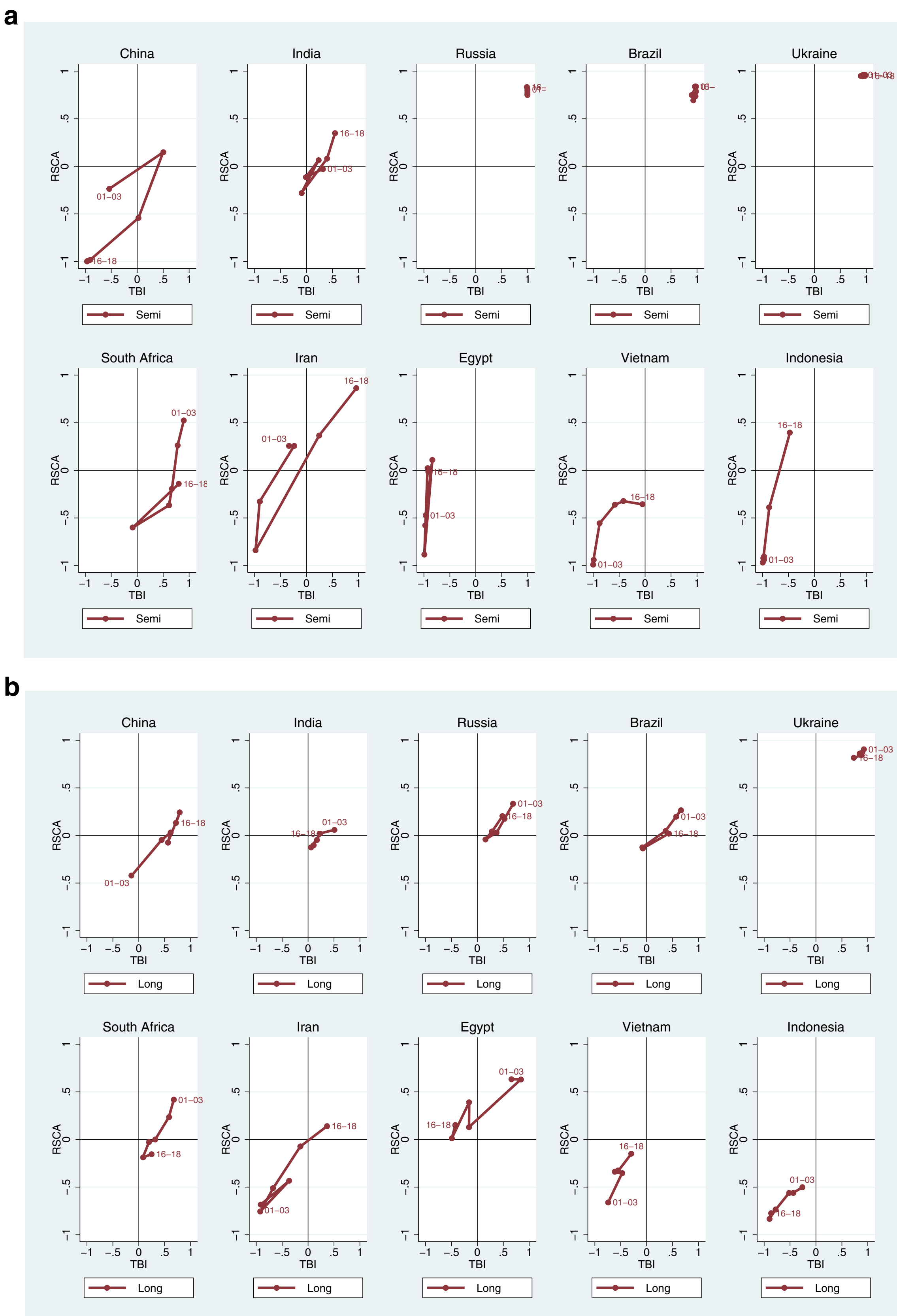
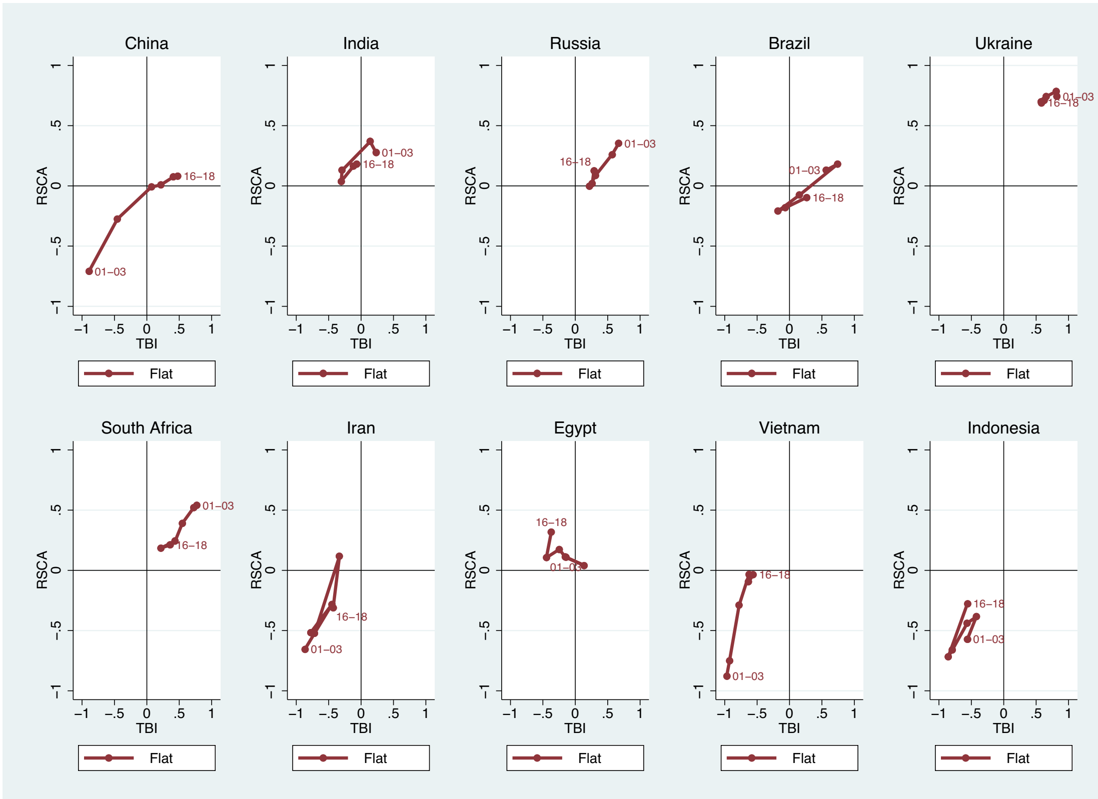


Fig. 11 Products mapping by product. Source: Author's calculations based on data from ITC (2021)

c



d

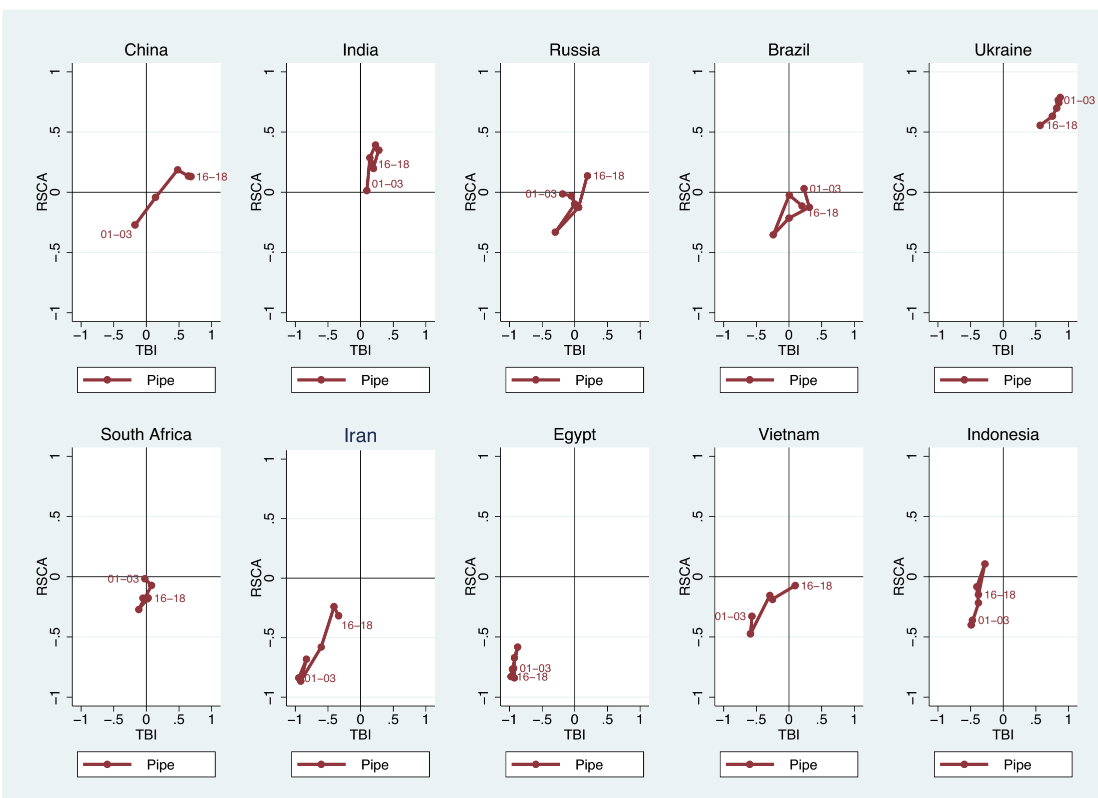


Fig. 11 (continued)

steel products, while flat and pipe and tube products can be proxied for high value-added steel products.

The results suggested that the evolution patterns of product mapping at the product level in the twenty-first century were far from homogenous across major non-OECD steel-producing countries. China has increased RSCA and TBI values for most product categories since 2004–2006. Between 2001–2003 and 2016–2018, China's position in product mapping for ingots/semi-finished products shifted to D, while it turned to A for long products. Moreover, China witnessed an increase in RSCA and TBI values for high value-added segments (i.e. flat, and pipe and tube products) between 2001–2003 and 2016–2018, suggesting that its export structure was becoming more sophisticated. Since 2001–2003, some BF-BOF-based countries such as Russia, Brazil, and Ukraine have maintained high RSCA and TBI values, especially for ingots/semi-finished products since the early 2000s. Between 2001–2003 and 2016–2018, India's position for ingots/semi-finished products reached position A, although its product mapping for each product did not appear to have distinctive features compared to other countries. The positions of product mapping for flat, pipe and tube products in EAF-based countries, such as Egypt, and Vietnam, have not been in position A since 2001–2003, suggesting that they have not gained a comparative advantage and improved international competitiveness for high value-added segments. Nevertheless, Iran has shown a rapid increase in RSCA and TBI values for low value-added segments (i.e. ingots/semi-finished products and long products).

Summary of findings and implications

The results of this study have important implications for the global steel industry in the twenty-first century. The macro-level analysis suggested that non-OECD countries have expanded their position in the global steel industry, having experienced a steady increase in steel production, as well as steel exports and imports in the twenty-first century. While much of the growth in steel production and exports has occurred in China, the results suggested that only a limited number of non-OECD countries have improved TBI values (i.e. international competitiveness). Nevertheless, some seem to have marginally improved their RSCA values. This suggests that they have gradually gained a comparative advantage over other industries. Their steel demand has grown faster than steel production, steel imports have increased, and they have not yet reached a trade surplus. The implication is that the catch-up of non-OECD countries in the international steel market is likely progressing gradually in the twenty-first century, but it is not enough.

The micro-level analysis suggests that technology selection at a certain time is associated with export performance in the twenty-first century. There seem to be considerable differences in technology selection patterns and the evolution of export performance between China and the rest of the major non-OECD countries. Among them, China is the frontrunner in terms of catch-up—it has increased its steel output significantly based on the BF-BOF technology, acquired comparative advantage, and strengthened international competitiveness in the international steel market in the twenty-first century. Steel firms in other non-OECD countries (i.e. Russia, Brazil, Ukraine, and South Africa) seem to have selected the BF-BOF technology in the twentieth century to gain comparative advantage and improve international competitiveness. They have maintained their comparative advantage and international competitiveness in the twenty-first century through BF-BOF technology.

Having selected the BF-BOF and EAF technologies in the twenty-first century, India has not seen a significant improvement in RSCA and TBI values like China has. Along with significant growth in steel demand over the past decade, EAF-based steel firms in India may have contributed to the supply of steel to meet construction demand in the domestic market. India's BF-BOF-based steel firms may have played an important role in maintaining comparative advantage and international competitiveness in the foreign market.

Having heavily invested in the EAF technology in the twenty-first century, Iran has witnessed a steady improvement in comparative advantage and international competitiveness over the past few years. While it has increased RSCA and TBI values for low value-added segments, they have not yet been improved for high value-added segments.

In other major non-OECD countries, Vietnam and Indonesia have selected the EAF route and invested in the BF-BOF route in the twenty-first century but has not shown significant improvements in comparative advantage and international competitiveness. However, these countries may improve in the future, as their steelmaking capacities are likely to grow (Sekiguchi 2019). It may take time for Egypt to select the EAF route in the twenty-first century to improve their export performance.

Conclusion

This study aimed to assess the evolution of non-OECD countries in international steel trade in the twenty-first century in terms of comparative advantage and international competitiveness. It shed light on the linkages between technology selection and steel export performance. The results supported Sekiguchi's (2017, 2019) argument that the selection of the BF-BOF technology in non-OECD countries is a necessary condition for the catch-up of OECD countries; however, the time when steel firms in non-OECD countries selected the BF-BOF technology varied. Chinese steel firms have made this choice in the twenty-first century, representing the entire evolution of the steel industries of non-OECD countries. In sum, Chinese steel firms' technology selection has contributed to developing the steel industries of non-OECD countries since the beginning of the twenty-first century, while steel firms in other non-OECD countries chose the BF-BOF technology to catch up in the twentieth century and have maintained their positions in the twenty-first century. Although the current catch-up of the steel industries of non-OECD countries is limited, the technology selection of some countries in the twentieth century and Chinese steel firms' BF-BOF technology selection in the twenty-first century have impacted their catch-up progress. While this study attempted to provide important insights into the characteristics of non-OECD countries and how they have evolved in the twenty-first century, further research would be necessary to better understand the dynamics of emerging/developing countries, resulting in a few limitations, which have been enumerated as follows.

First, this study did not focus on the domestic market. Since many steel products are used locally by steel-using industries, steel firms in countries are likely to prioritise their domestic markets before starting exports. Given the importance of the flying-geese model of industrial upgrading (Akamatsu 1962; Kojima 2000), it would also be important to focus on the linkages between steel demand, steel imports, domestic steel production, and steel exports more structurally in non-OECD countries.

Second, this research examined non-OECD countries' catch-up based on the statistical analysis, while it did not show specific examples of which specific activities and how steel firms in non-OECD countries have caught up with ones in OECD countries. Case studies based on fieldwork would be needed to illustrate a detailed catch-up movement at the firm level.

Third, this study highlighted the impact of technology selection in international steel trade, but it did not explore factors that affected the steel industry's technology selection. In addition to initial investment costs and minimum efficient scales, what other factors can explain technology selection in the global steel industry? The BF-BOF technology selection appears to have been advantageous in accelerating the catch-up of non-OECD countries in the twenty-first century. However, it is uncertain whether this tendency is sustainable in the global steel industry, given the complexity of the issues on the environment and natural resources. As a crucial CO_2 emitter, the global steel industry has been called on to play an important role in mitigating climate change by reducing CO_2 emissions from steel production (OECD 2015b).

Fourth, this study suggested that technology selection has contributed to the evolution of non-OECD countries in the twenty-first century, but China's unique conditions may have characterised this phenomenon. Whether other non-OECD countries can accelerate their catch-up by selecting the BF-BOF technology in the future may depend on whether they have similar conditions as China does. This provides a direction for future research.

Fifth, if the selection of upstream production technologies (i.e. BF-BOF or EAF routes) affects export performance, what about the impact of downstream technologies (i.e. re-rolling or surface-treating facilities) on the steel trade? There are diverse trade structure patterns in non-OECD countries, even though they selected the BF-BOF technology. Given the significance of the discussion of investment in downstream industries and export sophistication (Ji-mi 2016), it would be important to focus on downstream facilities to analyse the linkages between production technology and steel export performance more structurally. Thus, the findings deserve further investigation for their potential relevance.

Finally, this study analysed the export performance of non-OECD countries with a comparison of OECD countries using detailed trade data. While steel production activities connect different countries through the steel trade, it did not focus on the steel trade by trading partners. The global steel market today is more strongly interconnected than ever (Mattera 2018). Analysis of steel trade by trading partners could offer further insights into how interdependence between OECD and non-OECD countries has changed in the twenty-first century, given the significance of the discussion on the global value chain (Gereffi et al. 2005).

Despite the study's limitations, it provided several insights to better understand the evolution of non-OECD countries in the twenty-first century. Analysing the dynamics of how emerging/developing countries select steel production technology and its impact on steel export performance is an important matter with a wide reach. Its focus on the influence of technology selection for the steelmaking process on export performance should have important implications in the development of the global steel industry, to eventually understand how it can further contribute to the economy. The study's findings can be insightful for industrial development and international trade studies because of its implications on how emerging/developing countries obtain a comparative advantage and strengthen international competitiveness, and how they catch up with advanced countries.

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Appendix

Table 6 Abbreviations of country names

Country (OECD)	Code	Country (Non-OECD)	Code	Country (Non-OECD)	Code
Australia	AUS	Algeria	DZA	Myanmar	MMR
Austria	AUT	Argentina	ARG	Nigeria	NGA
Belgium	BEL	Azerbaijan	AZE	Oman	OMN
Canada	CAN	Bangladesh	BGD	Pakistan	PAK
Chile	CHL	Belarus	BLR	Paraguay	PRY
Colombia	COL	Bosnia and Herzegovina	BIH	Peru	PER
Czechia	CZE	Brazil	BRA	Philippines	PHL
Finland	FIN	Bulgaria	BGR	Qatar	QAT
France	FRA	China	CHN	Romania	ROU
Germany	DEU	Croatia	HRV	Russia	RUS
Greece	GRC	Cuba	CUB	Saudi Arabia	SAU
Hungary	HUN	D.R. Congo	COD	Serbia	SRB
Israel	ISR	Ecuador	ECU	Singapore	SGP
Italy	ITA	Egypt	EGY	South Africa	ZAF
Japan	JPN	El Salvador	SLV	Sri Lanka	LKA
Luxembourg	LUX	Ghana	GHA	Syria	SYR
Mexico	MEX	Guatemala	GTM	Taiwan	TWN
Netherlands	NLD	India	IND	Thailand	THA
New Zealand	NZL	Indonesia	IDN	Tunisia	TUN
Norway	NOR	Iran	IRN	Uganda	UGA
Poland	POL	Jordan	JOR	Ukraine	UKR
Portugal	PRT	Kazakhstan	KAZ	United Arab Emirates	ARE
Slovakia	SVK	Kenya	KEN	Uruguay	URY
Slovenia	SVN	Libya	LBY	Uzbekistan	UZB
South Korea	KOR	Macedonia	MKD	Venezuela	VEN
Spain	ESP	Malaysia	MYS	Vietnam	VNM
Sweden	SWE	Mauritania	MRT		
Switzerland	CHE	Moldova	MDA		
Turkey	TUR	Mongolia	MNG		
United Kingdom	GBR	Montenegro	MNE		
United States	USA	Morocco	MAR		

Note Countries whose production data by the process were available in 2018. Source: Author based on the World Steel Association (2019a)

Table 7 Evolution of steel exports by country in volume terms

Rank	2001		2008		2018	
	Country	Tonnage mmt	Country	Tonnage mmt	Country	Tonnage mmt
1	Japan	29.3	**China**	60.3	**China**	68.6
2	**Russia**	26.4	Japan	37.5	Japan	35.8
3	Germany	23.8	Germany	28.9	**Russia**	33.5
4	**Ukraine**	21.6	**Ukraine**	28.6	South Korea	30.0
5	France	16.6	**Russia**	28.4	Germany	26.3
6	Belgium	15.5	Belgium	20.8	Turkey	19.8
7	South Korea	14.0	South Korea	20.5	Italy	18.2
8	Italy	11.4	Turkey	18.5	Belgium	18.1
9	Turkey	10.6	Italy	18.1	**Ukraine**	15.2
10	United States	9.3	France	16.5	France	14.5
11	**Brazil**	9.3	United States	13.4	**Brazil**	13.9
12	**Taiwan**	7.6	Canada	10.5	**Taiwan**	12.3
13	**China**	7.2	**Taiwan**	10.1	**India**	11.0
14	United Kingdom	6.7	Netherlands	9.9	Netherlands	10.3
15	Netherlands	6.1	Spain	9.6	Spain	9.6
16	Spain	5.7	**Brazil**	9.2	**Iran**	8.8
17	Luxembourg	4.9	United Kingdom	9.0	United States	8.7
18	Austria	4.8	**India**	7.4	Austria	7.5
19	Canada	4.7	Austria	7.2	Canada	6.6
20	Czechia	4.4	Mexico	5.9	Poland	6.1
21	**South Africa**	4.1	Poland	5.6	**Vietnam**	5.9
22	Sweden	3.9	Czechia	5.2	Mexico	5.8
23	Poland	3.7	Slovakia	4.4	Czechia	5.1
24	Slovakia	3.5	Luxembourg	4.1	Slovakia	5.0
25	**Kazakhstan**	3.3	Sweden	4.1	United Kingdom	4.6
26	Mexico	3.1	Finland	3.7	**Indonesia**	3.9
27	Finland	3.0	**Kazakhstan**	3.6	Sweden	3.7
28	**Romania**	2.7	**Romania**	3.2	**Kazakhstan**	3.2
29	**India**	2.4	**South Africa**	2.8	Luxembourg	3.0
30	**Argentina**	2.1	**Malaysia**	2.6	**Romania**	2.9
	World	297.0	World	451.3	World	462.0

Note Non-OECD countries are highlighted in bold. Figures for China and the world in this table are different from Table 2 and Fig. 3, owing to the difference in the source. Source: Author's calculations based on data from ITC (2021)

Table 8 Evolution of top 30 steel firms

Rank	1991			2001			2018		
	Company	Country	Tonnage mmt	Company	Country	Tonnage mmt	Company	Country	Tonnage mmt
1	Nippon Steel	Japan	28.6	Arcelor	Luxembourg	43.1	ArcelorMittal	Luxembourg	96.4
2	USINOR SACILOR	France	22.8	POSCO	South Korea	27.8	**China Baowu**	**China**	67.4
3	POSCO	South Korea	19.1	Nippon Steel	Japan	26.2	Nippon Steel	Japan	49.2
4	British Steel	UK	12.9	Ispat International	Netherlands	19.2	**HBIS**	**China**	46.8
5	NKK	Japan	12.3	**Shanghai Baosteel**	**China**	19.1	POSCO	South Korea	42.9
6	ILVA	Italy	11.3	Corus	UK	18.1	**Shagang**	**China**	40.7
7	Thyssen	Germany	11.1	ThyssenKrupp	Germany	16.2	**Ansteel**	**China**	37.4
8	Kawasaki	Japan	10.9	Riva	Italy	15.0	JFE Steel	Japan	29.2
9	Sumitomo	Japan	10.9	NKK	Japan	14.8	**Jianlong**	**China**	27.9
10	**SAIL**	**India**	9.8	Kawasaki	Japan	13.3	**Shougang**	**China**	27.3
11	USX	USA	9.5	USX	USA	12.8	**Tata Steel**	**India**	27.3
12	Bethlehem Steel	USA	9.1	Sumitomo	Japan	11.7	Nucor	USA	25.5
13	**ISCOR**	**South Africa**	7.4	Nucor	USA	11.2	**Shandong Steel**	**China**	23.2
14	LTV	USA	6.9	**SAIL**	**India**	10.8	**Valin**	**China**	23.0
15	Kobe Steel	Japan	6.5	**Magnitogorsk**	**Russia**	10.3	Hyundai Steel	South Korea	21.9
16	**China Steel**	**Taiwan**	5.8	**China Steel**	**Taiwan**	10.3	**Maanshan Steel**	**China**	19.6
17	BHP Steel	Australia	5.7	**Anshan**	**China**	8.8	**NLMK**	**Russia**	17.4
18	Hoogovens	Netherlands	4.9	**Shougang**	**China**	8.2	**JSW Steel**	**India**	16.8
19	**National Steel**	**Brazil**	4.8	**Severstal**	**Russia**	8.1	**IMIDRO**	**Iran**	16.8
20	Krupp Stahl	Germany	4.5	Bethlehem Steel	USA	8.0	**SAIL**	**India**	15.9
21	Cockerill-Sambre	Belgium	4.4	**Novolipetsk**	**Russia**	7.9	**Benxi Steel**	**China**	15.9
22	Inland Steel	USA	4.2	**Gerdau**	**Brazil**	7.2	**China Steel**	**Taiwan**	15.9
23	Hoesch	Germany	4.2	**Wuhan**	**China**	7.1	**Gerdau**	**Brazil**	15.8
24	Preussag	Germany	4.1	**NISCO**	**Iran**	6.9	**Fangda Steel**	**China**	15.5
25	**USIMINAS**	**Brazil**	4.1	**Krivorozstal**	**Ukraine**	6.9	**Techint**	**Argentina**	15.4
26	Voestalpine	Austria	4.1	Kobe Steel	Japan	6.7	U. S. Steel	USA	15.4
27	Armco	USA	4.1	INI Steel	South Korea	6.6	**Baotou Steel**	**China**	15.3
28	**Sidex**	**Romania**	4.0	**ISCOR**	**South Africa**	6.5	**Rizhao Steel**	**China**	15.0
29	Sidmar	Belgium	3.9	BHP Steel	Australia	6.0	**Liuzhou Steel**	**China**	13.5
30	HKM	Germany	3.9	LTV	USA	5.9	**EVRAZ**	**Russia**	13.0

Note Steel firms in non-OECD countries are highlighted in bold. Source: Author based on the International Iron and Steel Institute (1992, 2002) and the World Steel Association (2019b)

Table 9 Classification of steel products

	Broad detail	Medium level detail	Product description
Total steel products	Ingots/semi-finished products	Ingots/semi-finished products	Ingots
			Semis
	Long products	Wire rods	Bars and rod in coils
		Bars	Deformed reinforcing bars
			Hot-rolled bars and flats
			Cold-finished bars and flats
		Sections	Hot-rolled light sections
			Hot-rolled heavy sections
		Rails	Rails and rolled accessories
	Flat products	Hot-rolled sheets/coils	Hot-rolled wide strip
			Hot-rolled sheets
			Hot-rolled strip
		Plates	Hot-rolled plates
		Cold-rolled sheets/coils	Cold-rolled plates/sheet: coils/lengths
			Cold-rolled strip
		Galvanised sheets	Zinc coated sheets and strip
		Tin plates and tin-free steels	Tinplate and tin free steel
		Other coated sheets	Other coated sheet and strip
		Electrical sheets	Electrical sheet
			Electrical strip
	Pipe and tube products	Welded tubes	Steel tubes, welded
		Seamless tubes	Steel tubes, seamless
		Steel tube fittings	Steel tube fitting
	Other steel products	Other steel products	Wire
			Forged bars
			Forgings
			Tyres, wheels, and axles
			Points/switches/crossings
			Forged/cold finish sections
			Cold formed sections
			Welded structural sections
			Steel castings

Source: Author based on ISSB (2010)

Table 10 Evolution of world steel exports by product in volume terms

	2001		2008		2018	
	Product	Tonnage mmt	Product	Tonnage mmt	Product	Tonnage mmt
1	Ingots/semi-finished products	52.0	Hot-rolled sheets/coils	72.3	Hot-rolled sheets/coils	85.0
2	Hot-rolled sheets/coils	48.6	Ingots/semi-finished products	69.4	Ingots/semi-finished products	63.8
3	Cold-rolled sheets/coils	33.2	Bars	52.3	Galvanished sheets	46.5
4	Bars	28.4	Plates	42.9	Bars	45.3
5	Galvanished sheets	23.0	Cold-rolled sheets/coils	37.7	Cold-rolled sheets/coils	41.9
6	Wire rods	19.5	Galvanished sheets	34.1	Plates	33.7
7	Plates	19.5	Welded tubes	28.0	Wire rods	29.2
8	Sections	17.1	Wire rods	24.9	Welded tubes	27.6
9	Welded tubes	17.0	Sections	24.1	Sections	21.6
10	Other steel products	9.7	Seamless tubes	19.7	Other coated sheets	18.9
11	Seamless tubes	9.6	Other steel products	15.9	Other steel products	17.2
12	Other coated sheets	6.8	Other coated sheets	12.5	Seamless tubes	14.2
13	Tin plates/tin-free steels	6.4	Tin plates/tin-free steels	7.0	Tin plates/tin-free steels	6.9
14	Electrical sheets	2.8	Electrical sheets	4.8	Electrical sheets	4.6
15	Rails	2.3	Rails	3.0	Steel tube fittings	2.8
16	Steel tube fittings	1.3	Steel tube fittings	2.7	Rails	2.8
	Total steel products	297.0	Total steel products	451.3	Total steel products	462.0

Note Figures for total steel products in this table are different from Fig. 3, owing to the difference in the source. Source: Author's calculations based on data from ITC (2021)

Table 11 Overview of the major non-OECD steel-producing countries (2018)

Country	Crude steel output Tonnage mmt	Total steel exports	Export ratio (exports/production) %
China	928.3	68.6	7.4
India	109.3	11.0	10.1
Russia	72.1	33.5	46.4
Brazil	35.4	13.9	39.3
Iran	24.5	8.8	36.0
Ukraine	21.1	15.2	72.1
Vietnam	15.5	5.9	37.9
Egypt	7.8	1.6	20.6
South Africa	6.3	2.8	43.7
Indonesia	6.2	3.9	62.3

Source: Author's calculations based on data from the World Steel Association (various years) and ITC (2021)

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