The role of iron and nickel smelters for the Indonesian steel industries

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Abstract. The iron and steel industries play a crucial role in supporting national development. The high dependence on imported raw materials causes Indonesia to suffer US $ 2.11 billion steel trade deficit per year. This study identifies the role of iron and nickel smelters in supporting the development of steel industries. The methodology used is descriptive statistics and regression models. Ferronickel and nickel pig iron as the primary raw materials for stainless steel have been produced in Indonesia, but only 23.05% and 47.77% are sold domestically. According to the linear regression models, it is expected that steel production and consumption will grow. Indonesia will become an independent steel producer and even export it by 2050. However, the supply chain is weak and poorly integrated as the local raw materials do not meet the domestic steel industry's specifications. By 2050, 44 million tonnes of scrap, 19 million tonnes of sponge iron, 16 million tonnes of nickel, and 10 million tonnes of other raw materials will be needed annually. Hence, to reduce the national steel trade deficit, Indonesia must increase the smelters capacity and optimize local iron resources by increasing Fe content to meet the specifications of the national steel industry.

1. Introduction
Infrastructure is one of the drivers for the Indonesian economy to improve the quality of life and the national welfare indicators [1]. The growth of national infrastructure development has increased quite significantly, and this can be seen from the contribution of the construction and building sector, which is the fourth largest contributor to the gross domestic product structure at 10.75%. The success of Indonesia's infrastructure development impacted on Indonesia's ranking index in 2018 ease of doing business from 61.52 to 66.47, so the ranking has increased from rank 91 to rank 72 [2,3]. The growth of the construction and building sector in infrastructure development cannot be separated from the role of the steel industry in Indonesia. It absorbed around 51% of the global steel products. The role of the steel industry can be seen from the diversity of industrial users, such as ships, railways, automobiles, oil drilling, road construction, bridges, housing, and other public facilities.

The Indonesian Government has committed to support national strategic projects, especially construction using domestic steel. The high domestic demand for steel has encouraged iron mining in Indonesia to market their products domestically and at the same time improves the balance of the national steel trade. As a result, in 2020, Indonesia succeeded in reducing the import of steel raw materials such as slab, billet, and bloom by 25.78% compared to 2019. Indonesia's steel raw material production increased to 11.58 million tonnes in the same year, or 30.25% higher than in 2019. This increase shows that the demand for steel in the country is still growing, and the productivity of the
domestic steel industry is increasing. Every year, Indonesia's steel demand is expected to rise along with the growth of Indonesia's population. Therefore, efforts are needed to balance production with demand.

The development of the domestic steel industries cannot be separated from the role of iron and nickel mining in Indonesia. Both iron and nickel resources are abundant in Indonesia. In 2020, The Centre for Mineral, Coal, and Geothermal Resources Geological Agency Republic of Indonesia recorded that Indonesia's laterite iron ore reserves were around 1.54 billion tonnes, primary iron 1.47 billion tonnes, and iron sand 986.97 million tonnes. Meanwhile, nickel ore reserves are about 1.1 billion tonnes, 722 million tonnes of which have a grade of ≤ 1.7% Ni and 363 million tonnes of > 1.7% Ni [4]. This paper aims to study the role of iron and nickel commodities to support the development of the steel industries in the country. The paper reviewed the iron and steel market, with an approach based on economic data, not experiment. The related data is secondary data obtained from a variety of sources.

2. Materials and Methods

2.1. Materials
The materials of this research used secondary data collected and available from a variety of sources. The variables and data sources used in this research are shown in Table 1.

| No | Variables                                                                 | Sources                                           |
|----|---------------------------------------------------------------------------|---------------------------------------------------|
| 1  | Production capacity, production, consumption, export, and import of Indonesian basic steel | Ministry of Industry                               |
| 2  | Production, consumption, export, and import of Indonesian steel, 2015-2019 | - Ministry of Industry - Central Bureau of Statistics |
| 3  | Indonesia's iron trade (2019 and 2020)                                    | - Central Bureau of Statistics - Directorate General of Mineral and Coal, Ministry of Energy and Mineral Resources |
| 4  | Production, export, and domestic sales of nickel matte, ferronickel, and nickel pig iron in Indonesia, 2015-2020 | Directorate General of Mineral and Coal, Ministry of Energy and Mineral Resources |

2.2. Methods
This research used a quantitative approach, and the data analysis methods used were descriptive statistics and regression models.

2.2.1. Descriptive statistics. Descriptive statistics are used to describe and summarize the characteristics and distribution of a set of data through numerical calculations, graphs, and or tables. This method helps to understand the tendency and variation of values in the data series [5].

2.2.2. Regression model. Multiple regression is one of the tools used to forecast and identify the variable influence of steel consumption as an independent variable and time on Indonesian steel production as a dependent variable [6]. The estimated values can be used to predict the number of iron and nickel ores and determine the strategies to fulfill the ores. The general form of multiple regression with two variables of free consumption of Indonesian steel and time can be seen in the equation (1) below:

\[ Y_t = \beta_0 + X_t + t + \varepsilon_t \]  

in this case:
\( Y_t \) = dependent variable total production of Indonesian steel at time \( t \),
\( X_t \) = independent variable total consumption of Indonesian steel at time \( t \)
t = independent variable of time, \( t = 2010\text{-}2019 \)
\( \beta_0 = \text{constant} \)
\( \beta_1 = \text{regression coefficient of Indonesian steel consumption variable} \)
\( \beta_2 = \text{regression coefficient of time variable} \)
\( \varepsilon_i = \text{the residuals/error of time, that is independent and has a normal distribution (0, } \sigma_2). \)

The data used for estimation are the Indonesian steel production and consumption from 2010-2019, published by the Central Bureau of Statistics. Analysis of data, processing, and calculation of coefficients \( \beta_0, \beta_1, \text{ and } \beta_2 \) in equations (1) was done using IBM SPSS Statistics Package for Social Science (SPSS) version 20 for further interpretation of consumption factors and time that affects the production [7–9].

3. Results and Discussions

3.1 Results

3.1.1. Indonesian steel industries development. The Ministry of Industry Republic of Indonesia stated that there is only one steel factory in Indonesia that produces sheet steel with a capacity of 1.85 million tonnes [10]. In addition, there are 40 companies producing billets, ingots, and blooms with a total capacity of 8.77 million tonnes and two hot-rolled coil (HRC) companies with a total capacity of 2.55 million tonnes. According to Setiadharmaji [11], the largest steel production capacity in 2019 was steel bar, which is 8.48 million tonnes, and HRC steel is 4.9 million tonnes. But, steel bar and HRC steel only produced 2.7 million tonnes and 2.0 million tonnes, respectively (Table 2).

Table 2. Production capacity, production, consumption, export, and import of Indonesia's basic steel in 2019 (thousand tonnes) [11,12].

| Product                | Capacity | Consumption | Production | Utilization | Export | Import |
|------------------------|----------|-------------|------------|-------------|--------|--------|
| Hot rolled coil        | 4.900    | 3.759       | 2.047      | 42%         | 190    | 1.902  |
| Plate                  | 2.760    | 1.508       | 1.813      | 66%         | 778    | 473    |
| Cold Rolled Coil       | 2.380    | 2.736       | 751        | 32%         | 1      | 1.986  |
| Wire Rod               | 2.155    | 1.612       | 965        | 45%         | 43     | 690    |
| Bar                    | 8.478    | 3.165       | 2.746      | 32%         | 101    | 520    |
| Section                | 1.727    | 1.088       | 833        | 48%         | 4      | 259    |
| Coated Sheet           | 2.240    | 1.997       | 1.043      | 47%         | 10     | 964    |
| Pipe                   | 2.392    | 1.352       | 884        | 37%         | 195    | 663    |
| Total                  | 27.032   | 17.217      | 11.082     |             | 1.322  | 7.457  |

Based on the data from Table 1, the utility of these two industries (steel bar and HRC) was only 32% and 42%. At the same time, the demand for both types of steel reached 3.2 million tonnes and 3.8 million tonnes. Therefore, Indonesia had to import 520,000 tonnes of reinforced steel and 1.9 million tonnes of hot rolled steel to fulfill domestic demand. From several types of steel production, the total capacity of the Indonesian steel industry was 27.0 million tonnes. However, the utilization rate was only 32%-66% which was the cause of the low output of national steel production. From 2008 to 2019, imports of Indonesian steel were greater than exports, causing a deficit of US $ 5.80 billion or the equivalent to IDR 84.16 trillion per year [13]. The contribution of steel imports to fulfill the domestic demand for steel products reached 43.31%. Currently, the domestic steel production capacity is 27.03 million tonnes per year, and with this amount, there is no need to import steel. However, this did not happen due to several
reasons, such as the high cost of steel raw materials and a flood of steel products from China [14], whose prices were lower than domestic products.

Although Indonesia is not yet fully able to meet domestic demand, the national steel production continues to experience a significant increase (Table 3). The growth of Indonesian steel production in the last five years (2015-2019) which was calculated using the compound annual growth rate or CAGR [15], shows a significant increase, about 12.35%. In the same period, Indonesia's exports did not increase, domestic consumption rose 8.57%, and imports increased by an average of 2.9% per year. Indonesia's steel production in 2019 reached 11.1 million tonnes. However, this amount had not been able to meet the domestic consumption of steel, which amounted to 17.2 million tonnes, so Indonesia had to import 7.5 million tonnes of steel.

Table 3. Production, consumption, export, and import of Indonesian steel, 2015-2019 (million tonnes) [11–13].

| Year | Production | Import | Export | Consumption |
|------|------------|--------|--------|-------------|
| 2015 | 6.2        | 6.5    | 1.3    | 11.4        |
| 2016 | 6.6        | 6.9    | 0.8    | 12.7        |
| 2017 | 7.9        | 7.1    | 1.3    | 13.6        |
| 2018 | 10.0       | 7.6    | 2.6    | 15.1        |
| 2019 | 11.1       | 7.5    | 1.3    | 17.2        |

3.1.2. Development of steel industry raw materials in Indonesia

3.1.2.1. The development of the iron trade. Iron is used as the main raw material in producing steel. In 2019, Indonesia exported 2.88 million tonnes of iron ore and concentrate, valued at US $ 76.71 million, while in 2020, the exports increased by 25.70% to 3.62 million tonnes with a value of US $ 98.3 million. Export of sponge pig/sponge iron in 2020 increased by 148.36% compared to 2019, which amounted to 112.486 tonnes (Table 4).

Table 4. The development of Indonesia's iron trade in 2019 and 2020 [13,16].

| Types of trading commodities | 2019 | 2020 |
|-----------------------------|------|------|
|                            | Volume (ton) | Value (US$ thousand) | Volume (ton) | Value (US$ thousand) |
| **EXPORT**                 |            |                   |            |                   |
| Iron ores and concentrates | 2,879.790  | 76.706            | 3,619.905  | 98.331            |
| Spiegel pig/sponge iron    | 112.486    | 73.952            | 279.375    | 161.414           |
| Total                      | 2,992.276  | 150.658           | 3,899.280  | 259.744           |
| **IMPORT**                 |            |                   |            |                   |
| Iron ores and concentrates | 4,902.965  | 430.500           | 6,875.902  | 681.927           |
| Spiegel pig/sponge iron    | 1,058.876  | 1,143.891         | 1,008.414  | 990.194           |
| Scrap                      | 2,614.133  | 924.476           | 1,420.456  | 449.586           |
| Total                      | 8,575.974  | 2,498.867         | 9,304.772  | 2,121.708         |

The high domestic demand for steel had caused the increase in imports of iron ore and concentrates by 40.24% million tonnes in 2020 compared to 2019, which amounted to 4.90 million tonnes. Indonesia also imported 1.01 million tonnes of sponge iron in 2020, close to the same number as the previous year. Meanwhile, scrap imports in 2020 amounted to 1.42 million tonnes, a significant decline of almost 50%
compared to 2019. The total import value of the three types of commodities (ore, sponge iron, scraps) for the domestic steel industries reached the US $2.1 billion. Meanwhile, the export value for the same three types of commodities reached the US $259.7 million. This amount means that the trade balance for Indonesia, considering the three types of steel raw material, experienced a trade deficit of US $1.8 billion even though this number decreased by 20.7% compared to 2019.

Indonesia will always experience a deficit in iron trade if the potential of iron resources for the domestic steel industries is not maximized. The steel trade data in Table 2 shows that domestic steel production in Indonesia was 12.4 million tonnes. To produce that number, Indonesia must import about 4.9 million tonnes of iron concentrates, 1.1 million tonnes of spiegel pig/sponge iron, 2.6 million tonnes of scrap, and the rest was supplied from domestic scrap. Spiegel pig iron is a pig iron that contains 10%-20% manganese [17]. Meanwhile, the domestic demand for ferronickel and NPI for stainless steel production was only 66,000 tonnes and 562,259 tonnes. Currently, there are no iron pellets for pig/iron sponges, so Indonesia must import them [18,19].

Meanwhile, the production of iron concentrates in Indonesia reached 2.5 million tonnes [16]. Unfortunately, those iron concentrates was exported (Table 3). Domestic iron ore/concentrate production cannot be used directly in the steel industry because it contains laterite, which cannot be used directly by the domestic steel industry. The steel industry has been using iron ore containing hematite as raw [20]. The iron used in the steel industry must have at least 60% Fe content in fine or lump form [21,22]. If it is in the form of pellets, the iron content must be with at least of 65% [23]. The beneficiation process of laterite iron ore from Sebuku Island, South Kalimantan, increased Fe content only up to 53.03% [24]. One domestic smelter company processed laterite iron to meet the needs of the local steel industry. However, the continuity of supply did not last long [25]. The required specifications were not met, and the resources were not evenly distributed [26,27].

3.1.2.2. Scrap. Many steel companies use scrap steel as raw material to ensure their business continuity and increase the competitiveness of the Indonesian steel on the global market. Besides being easy to obtain, scrap also has a higher value than material from iron ore extraction [28]. Unfortunately, of the total national scrap needs, only 30% can be met from within the country [29]. The rest still rely on imports from South Africa, the United States, Singapore, and Australia. One of the factor affecting the procurement of imported scrap raw materials is the issuance of Regulation of the Minister of Trade Number 84 of 2019 concerning Provisions for the Import of Non-Hazardous and Toxic Wastes as Industrial Raw Materials in October 2019 [30]. Scrap, which is included in non-hazardous and toxic waste products, must follow special provisions that make it difficult to import scrap. However, with the issuance of Government Regulations No. 28 of 2021 concerning the implementation of the industrial sector, domestic steel entrepreneurs can import steel scrap as raw material to support steel industries. Through Government Regulations No. 28 of 2021, it is stipulated that policies in the steel industry, including steel import licensing, will be decided based on the steel commodity balance. Government policies of importing scraps will be based on the capability of the national steel industry. In addition, the determination of the national steel commodity balance will also encourage the use of national steel products in national projects through the application of the Domestic Content Level. This regulation is expected to increase the competitiveness of the development of steel industries in the country and reduce steel imports.

3.1.2.3. The development of the nickel trade. Stainless steel is one of the most widely used materials in the industry. The raw materials for manufacturing stainless steel are nickel, ferrochrome (Fe-Cr), ferromanganese (Fe-Mn), ferrosilicon (Fe-Si), ferromolybdenum (Fe-Mo), and low carbon steel scrap. The composition of the stainless steel is 71% iron (Fe), 18% nickel (Ni), and 0.2% carbon (C) with the addition of other elements such as titanium, manganese, silicon, molybdenum in smaller amounts [31]. Nickel is used around 46% for the manufacturing of stainless steel, 34% as an alloy (superalloy), electroplating material (14%), and the remaining nickel is used as casting material, batteries, and catalysts [32]. The nickel element in the stainless steel as an alloy is more valuable [33]. Also, ductility,
strength, and weldability are better than ordinary steel without nickel [34]. Indonesia has three products from pyrometallurgical processing and refining of nickel ore: nickel matte, ferronickel, and nickel pig iron (NPI). However, only ferronickel and NPI can be utilized by the domestic steel industry. Total ferronickel production was 1.46 million tonnes, only 23.05% of which were sold domestically. Meanwhile, the NPI production was 860,470 tonnes, but only 47.77% were sold domestically, and the rest was exported. NPI is made from low-grade laterite nickel ore, Ni <1.7%, which is widely available in Indonesia [34]. Meanwhile, nickel matte, which uses high-grade saprolite laterite with a Ni content ≥ of 1.7% [35], all nickel matte was exported during 2015-2019 (Table 5). Some of ferronickel and NPI were sold and utilized domestically during 2015-2020, and the rest were exported. This shows that the nickel processing and refining industries in Indonesia have not been able to support the domestic steel industry.

### Table 5. Production, export, and domestic sales of nickel mate, ferronickel, and nickel pig iron in Indonesia, 2015-2020 (tonnes) [16].

| Type of Production | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
|--------------------|-------|-------|-------|-------|-------|-------|
| **Production**     |       |       |       |       |       |       |
| Nickel mate        | 82.440| 78.748| 78.007| 75.708| 72.015| 91.692|
| Ferronickel        | 97.056| 89.429| 314.630| 573.159| 1,151.741| 1,462.255|
| Nickel pig iron    | 271.111| 770.685| 542.131| 323.989| 781.017| 860.470|
| **Export**         |       |       |       |       |       |       |
| Nickel mate        | 81.916| 78.974| 76.743| 75.708| 71.342| 71.548|
| Ferronickel        | 92.617| 89.429| 243.422| 573.159| 1,080.661| 1,239.002|
| Nickel pig iron    | 271.111| 770.685| 192.561| 323.989| 167.014| 291.938|
| **Domestic Sales** |       |       |       |       |       |
| Nickel mate        | -     | -     | -     | -     | -     | -     |
| Ferronickel        | 4.439 | -     | 71.209| -     | -     | 337.014|
| Nickel pig iron    | -     | -     | 349.570| -     | 435.947| 411.049|

Exports of Indonesian nickel and its derivatives in 2019 reached US$5.30 billion from sales (exports) of 34.16 million tonnes. Meanwhile, the import volume of nickel and its derivatives reached 345.9 thousand tonnes with a US$378.9 million purchase value. The export volume of nickel and its derivatives reached 32.28 million tonnes, dominated by nickel ore and concentrate, and nickel ferroalloy reached 1.6 million tonnes. The value of Indonesia’s nickel exports in 2019 was greater than the value of its imports. This shows that the Indonesian nickel trade balance and its derivatives produced a positive trade balance or a significant surplus of US$4.92 million. The largest export value from this trade came from sales of nickel ferroalloys with a value of US$2.6 billion. Meanwhile, nickel ore and concentrate, which had the largest export sales volume, only generated an export value of 1.10 billion. The volume of imports of Indonesian nickel and its derivatives, the largest of which was 169,000 tonnes of nickel ore and concentrate with a value of around US$4 million.

### 3.2 Discussions: prospect of the development of the Indonesian steel industry

#### 3.2.1 Steel demand projection and steel industry development plan in Indonesia.

Based on Indonesian steel production and consumption data for 2015-2019, in line with the population growth and the improvement in the national economy after the pandemic, it is expected that steel production and consumption will grow according to the linear regression model. In 2020, the national demand for steel is estimated to increase by 18.2 million tonnes. The amount of steel consumption cannot be matched by domestic production. Domestic producers were only able to produce 12.3 million tonnes of steel, so
Indonesia must import 5.9 million tonnes of steel. However, if the maximum production capacity is 27.03 million tonnes per year, Indonesia will not import steel until 2026. Entering 2027, Indonesia must prepare to increase steel factory capacity or add new steel factories to meet the demand of domestic steel of 28 million tonnes. This demand will continue to increase until 2030 by 32.2 million tonnes. By 2050, Indonesia will consume 60.2 million tonnes of steel (Figure 1). To anticipate the high demand for national steel in the future, the Government through the Ministry of Industry, is preparing a steel factory development program for eight domestic companies with a total production capacity of 39.85 million tonnes until 2027 [35]. If this steel capacity development goes according to plan, by 2050 the steel demand estimated at 60.2 million tonnes can be fulfilled by the national steel production, which produces 64.6 million tonnes. Because of limited raw materials, the current production capacity during 2022-2025 will give an average percentage of 8.14%. This means that Indonesian steel production in 2025 will only reach 18.9 million tonnes or only about 74.87% of the total national steel demand of 25.2 million tonnes. In 2025, the Indonesian Government instructs the eight steel companies in Indonesia to increase their steel production capacity by 39.85 million tonnes so that Indonesia will stop importing steel by 2026. However, the production adjusts domestic steel demand to maintain market balance.

![Figure 1. National steel production, consumption and import projections, 2020-2050](image)

Note:
Linear regression model estimation of time (t) against consumption (k), $k = 9.8 + 1.4 \times t$
Linear regression model estimation of consumption (k) and time (t) against production (p), $p = 0.57 + 0.39 \times k + 0.77 \times t$

a dan b calculated by equation (1).

The increase in steel production in 2026-2030 is estimated at 13.97%. The total demand for Indonesian steel in 2026 will be 26.6 million tonnes, which will be met by the supply of the existing steel industries and production of new steel companies, to a total of 27.2 million tonnes. The increase in steel production due to national project development will be adjusted to the steel demand in that year. Steel consumption in 2030 will reach 32.2 million tonnes, so Indonesia's steel production must be in the range of 35.6 million tonnes.

Production growth in 2031-2040 will increase by an average of 4.18% per year. Steel production in 2040 will reach 53.2 million, sufficient to meet domestic demand for steel, which is estimated to reach 46.2 million tonnes. Domestic steel producers will fulfil the demand for steel of 60.2 million in 2050 by
65.0 million tonnes. The increase in production is adjusted to the increase in the national steel demand. By 2050, Indonesia will become an independent steel producer and even be able to export it.

3.2.2. Projection of raw material demand for the Indonesian steel industry. As previously explained, the most dominant raw materials in steel making include iron, scrap, and nickel. Some of the postulates [31] used to estimate raw material requirements are:

a. Every steel production requires double the raw material.

b. 71% use iron, 70% of the iron is scrap and 30% pig iron.

c. 18% of the total raw material is nickel.

d. The rest is other elements such as titanium, manganese, silicon, and molybdenum.

Based on the development of steel production in Figure 1, until 2050, the demand for scrap raw materials will require an average of 44 million tonnes per year. Other raw materials for pig/sponge iron are needed on average 18.9 million tonnes per year, nickel 15.9 million tonnes per year, and other elements 9.7 million tonnes per year. In detail, the demand for raw materials for the domestic steel industry can be seen in Figure 2. The total scrap demand by the steel industry from 2022-2050 is estimated to reach 1.3 billion tonnes, for pig/sponge iron at 547 million tonnes, and nickel at 462 million tonnes.

Some of the iron raw material will be supplied by several companies that will be built in Indonesia, which are expected to operate by 2024 [36]. The companies are Sumber Baja, SILO, Rusan, and Sumbar Mas, which will produce ferroalloy sponge, nugget iron, pig iron, and cold bricket iron. Each product will produce 2.21 million tonnes annually, 165,000 tonnes, 120,000 tonnes, and 36,367 tonnes, respectively. The total need for iron ore is 6.92 million tonnes per year [16]. In 2022, 14 NPI smelters will be built with a capacity of 2.3 million tonnes per year and 11 ferronickel smelters with a total capacity of 2.2 million tonnes per year. However, only 1.2 million tonnes will be projected for the domestic market. Likewise, ferronickel and all its products are planned for export. This means that the presence of ferronickel smelters and NPI will not contribute significantly to the development of the domestic steel industry.
4. Conclusions
Every year, domestic steel industries need iron as raw material significantly in line with the increasing domestic steel demand. In anticipation of the high demand for national steel in the future, until 2027, the Government, through the Ministry of Industry, is preparing a steel factory development program for eight domestic companies with a total production capacity of 39.85 million tonnes. With this capacity, by 2050, the demand for steel, which is estimated to reach 60.2 million tonnes, will be met by the national steel production of 64.6 million tonnes.

However, the supply chain for the steel industry in Indonesia is still weak and not well integrated. This is reflected in the raw material for steel, namely iron ore, which is still imported from other countries because the local iron raw material does not meet the domestic steel industry's specifications. Apart from that, the unequal availability of existing iron resources is an obstacle to ensuring continuity and consistency of the supply of iron raw materials for the domestic steel industry. Efforts that can be made to support the independence of the national steel industries, are by obtaining the information of iron reserves location and technology that can improve the quality of Indonesian iron to meet the specifications required by the domestic steel industry.

The presence of a nickel smelter in the country has not fully met the demand of the domestic stainless-steel industry. This is reflected in the composition of ferronickel and NPI exports compared to domestic sales. Every year, the demand of stainless steel in the country continues to increase. This increases the demand of ferronickel and the NPI in the country. Therefore, efforts must be made by the smelter's productions to encourage the independence of the domestic steel industry and to be able to compete in the world steel trade.

There is a limitation of this study that future research could address. This paper only uses production and consumption data to obtain the projection of the smelter role. However, some parameters could be added to improve the model based on historical data and future assumptions, such as investment and world steel prices. So, the relation may be seen as exponential, not only a linear relationship. The analysis can also be added using pessimist and optimist projection.

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