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Nickel, Steel and Cars

Export Ban and Domestic Value-Added in Indonesia

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Abstract

Nickel is essential for producing iron and steel. Endowed with the world's largest reserve, Indonesia banned nickel exports in 2014 to promote industrialization. This paper studies the impacts of the export ban on downstream steel-using industries. A three-sector model shows that, while the export ban could raise the domestic value-added ratio (DVAR) in exports, the entry of smaller, inefficient firms led to aggregate efficiency losses downstream. Firm-level evidence confirms higher DVAR, smaller firm size, and larger entrant shares in downstream industries post the export ban. A field mission validated these results, while noting the continued heavy reliance on imported steel.

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Nickel, Steel and Cars: Export Ban and Domestic Value-Added in Indonesia [*]

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What we are looking at is to shift our policy from merely exporting raw minerals that will be utilized by other countries to produce higher value products, to developing our processing capabilities. This will result in added value for our minerals-related exports, provide a much-needed boost to our economy and generate employment for our people.

—Philippine Senate President Francis Chiz G. Escudero, Feb 03, 2025

We believe that steel demand in Indonesia is also expected to keep growing in the industries such as automobiles, motorcycles and also in the infrastructure and energy sectors.

—Press release: Establishment of PT. Nippon Steel and Sumitomo Metal Indonesia, Dec 22, 2014

PT Krakatau Nippon Steel Synergy (PT KNSS) will contribute to all of stakeholders and Indonesian automotive Industry by providing high-grade and high-quality cold-rolled steel products, hot-dip galvanized steel products, and galvannealed steel products and service.

—Mission Statement of PT. KNSS, Dec 26th, 2012

1 Introduction

Indonesia has the world's largest reserve of nickel, which is a crucial input to produce iron and steel, and a primary ingredient for batteries that are essential for the production of electric vehicles (EVs). Despite Indonesia's longstanding role as a major exporter of nickel, the Indonesian government banned nickel ore exports in 2014. Industrial deepening by promoting the domestic value-added in the downstream industries, referred to as "*downstreaming*", is part of the stated policy goals. Establishing a domestic production chain for EVs, from ore to cars, is also on the wish list. Can this export ban on nickel jump-start Indonesia's industrialization? Is there any evidence of industrial deepening in Indonesia since the nickel export ban was implemented by the government? What are the hidden costs or unintended tradeoffs to such an industrial policy?

This paper studies the effects of the nickel export ban on the domestic value-added ratio (DVAR) in exports of the downstream iron/steel-using industries of Indonesia. Given that iron/steel products are used widely by firms in industries that produce cars, car parts, metal pipes, machinery, furniture, and construction materials, these firms are collectively referred to as the car firms in this paper for simplicity. To understand the unintended tradeoff, this paper also studies the aggregate allocative productivity of these industries. Besides Indonesia, many countries, such as Zambia and the Philippines, are planning to or have already restricted the export of critical minerals with similar objectives of raising domestic value-added in their exports. Results from this paper may inform these countries of the viability of using an export ban as an industrial policy for development.

To illustrate how the export ban on nickel may affect the domestic value-added of downstream industries, concurrently affecting aggregate allocative efficiency, this paper first presents a three-sector model, consisting of the primary sector producing nickel, the secondary sector using nickel as an input to produce steel, and the tertiary sector using steel as an input to produce cars. The car sector is described as a heterogeneous firm model with a translog material function combining imported steel with domestic steel. The steel sector is a monopsony firm that exercises its market power to depress the domestic price of nickel post the export ban. The nickel sector is operated by a monopoly, choosing between exporting and domestic sales. The model shows that the export ban on nickel creates monopsonistic competition in the nickel market and causes the domestic nickel price to drop, which subsequently leads to a reduction in the domestic price of steel, which uses nickel as the main input of its production. The effect of export ban further cascades down to the car industry. Facing a lower price of domestic steel, profit-maximizing firms switch from imported steel to domestic steel, which increases the DVAR in the car sector. However, the lower price of domestic steel also enables the less productive firms to enter the car sector, which pushes down the aggregate productivity in the equilibrium. Consequently, while the export ban may meet its intended goal of increasing DVAR for the downstream car sector, by depressing the domestic price of nickel and steel, it may also impose unintended costs of harboring inefficiencies in the economy.

To study the empirical impacts of the export ban on nickel on the domestic value-added of downstream industries, firm-level DVAR is first estimated based on a new methodology developed in Kee et al. (2024). This new methodology mainly relies on customs transaction data, without matching with the industrial census, which made it suitable for the current application.[1] Next, based on difference-in-difference reduced form regressions, the estimated DVAR is shown to increase over time within the iron and steel-using industries relative to the other industries after the export ban on nickel. Results show that, from 2011 to 2020, the DVAR of the iron and steel-using industries increased by 5.6%. This implies an increase of 1.1% of the aggregate DVAR,[2] contrasting with the overall decline for the economy. Furthermore, reduced-form regressions on firm size show that post the export ban on nickel, the average firm size of the iron and steel-using industries is significantly lower, with a larger share of smaller entrants. This result is consistent with a lower aggregate productivity in these industries post the export ban, given that smaller firms are less productive (Autor et al., 2020). Finally, new entrants in these industries are found to be smaller than the incumbents, particularly post the export ban, while their DVAR is similar to that of the incumbents, further suggesting that post the export ban, the rising DVAR of these industries is driven by within-firm changes in DVAR, while the falling average firm size within these industries is driven by across-firms changes in firm size. All these results

[1] Due to the lack of a matching industrial census for customs transaction data in Indonesia for the sample period, the method developed in Kee & Tang (2016) to estimate firm-level DVAR is not applicable.

[2] Jointly these industries constituted 19.7% of total exports in 2020, implying a change in aggregate DVAR of $5.6\% \times 0.197 = 1.10\%$

are consistent with the model's predictions, and collaborate well with the subsequent interviews with the industry representatives of nickel mining, steel and metal production, automotive manufacturing, and battery production, as well as researchers from local think tanks and universities, in a field mission to Indonesia in April 2025. The field investigation also found that, despite the increased usage of domestic steel in the downstream industries, the persistent heavy reliance on imported steel to date suggests the capacity for Indonesia to produce high-quality steel products to meet the downstream demand is still quite limited, after more than a decade since the beginning of the export ban on nickel in 2014.

This paper offers important policy implications, not only for Indonesia, but also for other resource-abundant countries that are trying to replicate the Indonesian policy. Overall, the results of this paper suggest that while the export ban on nickel as an industrial policy may have started to increase domestic value-added in the downstream iron and steel-using industries in Indonesia, it comes with some unintended costs. The entry of the smaller and unproductive firms in the downstream industries, shielded by the artificially and distortedly lower domestic price of nickel, iron, and steel, takes resources away from the more productive firms in other industries, leading to an aggregate loss of allocative efficiency. To minimize these unintended negative consequences and to further promote industrialization, it is therefore necessary for the government to implement complementary policies, such as trade and foreign direct investment (FDI) liberalizations in midstream and downstream industries, promoting domestic or international competition to reduce inefficiencies. These complementary policies may also enhance the long-term and broad-based growth prospects of the country. Finally, this paper is completely silent on the possible social and environmental impacts, as well as any political rent-seeking behavior related to the export ban policy, which could be important and requires more comprehensive policy coordination.[3]

This paper contributes to several strands of literature. First, given that the export ban is part of export-related non-tariff measures (NTMs),[4] this paper is related to the growing empirical research on using NTMs as an industrial policy to shape the domestic economy. Juhász et al. (2024) consider industrial policies as government policies that explicitly target the transformation of the economic structure in pursuit of some public goal, such as structural transformation, re-industrialization, decarbonization, good jobs creation, supply chain resilience, and national security. Kee & Xie (2024) show that, against the backdrop of the low tariff and constrained space to increase tariffs due to commitment to trade agreements, more countries resort to imposing NTMs as industrial policies to achieve their domestic goals. Among the industrial policy instruments, the advanced economies focus on subsidies

[3]Using export-related NTMs as industrial policy receives considerably less attention. However, due to the geopolitical tension and the importance of critical minerals, Indonesia's export ban on nickel is a remarkable exception, which raises great interest among mainstream media, industry participants, researchers and other resource-rich governments.

[4]According to UNCTAD (2019), exporter-related NTMs documented in Chapter-P are measures applied by the government of the exporting country on exports, including export taxes, export quotas, export prohibitions, etc.

while developing economies constrained by limited fiscal space have little choice but to concentrate on trade restrictions on import and export (Evenett et al., 2024). For instance, Head et al. (2024) specify the multi-stage supply chain for BEVs to study how governments, such as the US government, purposefully mix taxes and subsidies, tariffs and NTMs (component requirements), to affect the BEV production location choices across the globe. Focusing on Argentina's import licensing requirements, Atkin et al. (2024) study NTMs as discretionary trade policies targeting specific firms and products which affect their market power in international trade, and Bernini et al. (2024) show that the NTMs reduce firms' imports, inducing more exposed firms to reduce exports and employment, leading to losing export markets. A closely related paper that also focused on export bans, Alfaro et al. (2025) study the positive impacts of China restricting export of rare earth elements in the 2010s on the innovation and technological progress of downstream Japanese firms. Our paper adds to this recent literature by studying Indonesia's export ban on nickel. Despite the legality of such a ban being challenged by the European Union (EU) at the World Trade Organization (WTO), many countries have imitated or are planning to imitate Indonesia by imposing similar export restrictions.[5] The findings of these two export ban papers could shed light on the effectiveness of using such an industrial policy to promote industrialization for resource-rich countries, and at the same time highlight the unintended consequences of allocative efficiency loss for downstream industries in their own country or productivity gains for downstream industries in other countries.

This paper is also related to the field of global value chains (GVCs) and value-added trade, by studying the effectiveness of the export ban on nickel in Indonesia based on the DVAR of export in the downstream industries. According to Antràs & Chor (2022), there are two primary approaches in measuring GVCs: macro and micro methods. Papers in the macro approach include Hummels et al. (2001), Antràs & Chor (2012), Johnson & Noguera (2012), Johnson (2014), Koopman et al. (2014), Wang et al. (2022) and Wang et al. (2025), which rely on aggregate World Input-Output tables to assess a country's GVC participation. The advantage of this approach is the comprehensiveness in capturing the input-output linkages of the industries and countries. What could be missing is the rich firm-level heterogeneity in input sourcing and imported input allocation decisions, which could lead to aggregation bias. This macro approach is complemented by the more recent micro approach, with papers such as Kee & Tang (2016), Tang et al. (2016), and Bems & Kikkawa (2021), which construct DVAR from the customs transaction data matching with firm census data. Kee et al. (2024) takes one step further by estimating the export revenue function directly from customs transaction data without matching with the industrial census data to estimate firm-level DVAR. The results are used to study the effects on DVAR in Chinese exports through firm linkages when exporting firms and their domestic potential suppliers are connected by high-speed railways. This export revenue function

[5]In response to Indonesia's export ban on nickel, the EU brought the case to the WTO dispute settlement in November 2019 (DS592, Indonesia — Measures Relating to Raw Materials), the panel report for this case is still under appeal.

approach significantly simplifies the data requirement and broadens the general applicability of the micro approach and is particularly suitable for countries such as Indonesia where there is no matching customs transaction data with industrial census data.

This paper also speaks to the rich theoretical and empirical literature building on the heterogeneous firm model developed in Melitz (2003). Many earlier papers, such as Bernard et al. (2007), Arkolakis et al. (2008),Verhoogen (2008), Bustos (2011), Cherkashin et al. (2015) expanded the classic heterogeneous firm model with product variety, technology choice, product quality, demand shocks and trade policy complications, to name just a few. More recent work focusing on the labor market, with Jha & Rodriguez-Lopez (2021) and Macedoni (2022) incorporate a monopsonistically competitive labor market into models with heterogeneous firms to examine the impact of trade liberalization on wage inequality and profit sharing. Choi et al. (2024) included labor market details in Melitz's model with supporting empirical evidence on the CEO pay based on a comprehensive Dutch dataset. Gurkova et al. (2025) is closest to the current paper, which includes the labor market adjustments in Melitz's model, whereby firms' entry and exit decisions interplay with the equilibrium unemployment leading to delayed aggregate productivity gains with trade liberalization. Instead of labor market imperfection, this current paper develops a three-sector model with input-output linkages and monopsony power in the nickel market, to capture the complex industry structures and dynamics of Indonesia's export ban on nickel.[6] With the help of the translog material function, this paper shows how the DVAR of downstream firms can be affected by the relative price of domestic to imported materials, which is endogenously determined in the model in the presence of the export ban. Careful matching of the empirical data to the theoretical model yields consistent evidence in broad agreement with the heterogeneous firm models whereby the entry of new firms in response to the distorted lower nickel price due to monopsony power and the decrease in the relative price of domestic to imported materials post the export ban directly drags down the aggregate productivity of the downstream industries, despite the within-firm increase in DVAR as a result.

Finally, this paper contributes to the broad range of policy reports examining the impact of Indonesia's downstreaming strategy from various dimensions. Many analyses are from mainstream media, industry experts, policy researchers, think tanks, and other resource-rich governments. Several studies examine the impact of the nickel export ban on value-added creation, greenhouse gas emission, and inward FDI, concluding that the export ban boosts export performance, smelters construction, inward FDI, and local economic growth (Guberman et al., 2024; Rahman et al., 2024; Tritto, 2022). Some mainstream media hailed Indonesia's decision to ban nickel ore export as a success (Lim, 2023). However, Walker & Palaon (2025) find that despite that onshore processing of nickel has increased and

[6]In this regard, our paper is similar to Rubens (2023), which examines the size regulation change in the Chinese tobacco industry that leads to ownership consolidation and finds that consolidation increases oligopsony power in the leaf market and leads to a decline in allocative efficiency.

a large scale of FDI inflow to Indonesia, the limited progress comes with drawbacks. The economic benefits remain geographically localized, failing to translate into broad-based national economic development or substantial improvement in socioeconomic conditions such as poverty reduction and job creation. Broughel (2025) concludes that the stainless-steel industry experiences fast development after the export ban while the battery manufacturing industries exhibit sluggish growth, due to their intrinsically complex and advanced technology and supply chain requirements. Hendrix (2023a;b) further emphasize that both shifting geopolitical environment and potential changes in battery chemistry that rely less on nickel create potential uncertainty and challenges for Indonesia's EV markets. Beyond economic consideration, Castillo et al. (2022) and Myllyvirta et al. (2024) highlight the carbon-intensive and environmentally and healthily damaging characteristics of Indonesia's nickel sector, which further brings environmental, social, and governance pressure to the battery supply chain and undermine the Indonesian government ability to achieve zero emission targets as a pledge to Paris Agreement. This paper complements these qualitative studies by relying on micro-level data-based quantitative empirical analysis based on a three-sector model, narrowly focusing on identifying the impacts of the export ban on nickel on the DVAR and productivity of downstream industries in Indonesia. Our findings suggest that, despite the increasing DVAR in iron and steel-using industries, the unintended aggregate inefficiencies may hinder the long-term growth prospects. This noteworthy result cautions the Indonesian government as well as governments of other resource-rich countries that, as a development strategy, perhaps a quick-fix export ban is not the silver bullet sufficient for economic growth, more broad-based comprehensive and complementary policies with effective implementations, focusing on improving the fundamentals of the economy, are still necessary.

The paper proceeds as follows. Section 2 discusses the policy background of the Indonesian export ban on unprocessed nickel. Section 3 presents a three-sector model. Section 4 discusses the data used in the analysis, and Section 5 presents the empirical specifications and evidence based on both the DVAR estimates and firm size, as well as the findings of a field mission in Indonesia. Section 6 concludes the paper with policy implications. Variable constructions such as DVAR and the relevant industry classification can be found in the appendix.

2 Background of Indonesia's Export Ban on Nickel

This section first presents the global backdrop in which the export restrictions on critical minerals in many resource-rich developing economies, such as Indonesia, have been introduced. We then discuss the importance of nickel and the dominant role of Indonesia in its global supply, followed by the chronological timeline of Indonesian policy changes on restricting the export of nickel products.

2.1 The Commodity Supercycle and the Proliferation of Export Restrictions

Despite the establishment of the WTO and the advocacy for free trade, many commodity-dependent emerging economies find it hard to capture a large fraction of the value-added and reduce their economic dependence on the main commodity.[7] In response, the use of export-restrictive policy instruments has become increasingly pervasive to reshape the division of tasks along the global value chains. According to OECD (2014), against the backdrop of the commodities supercycle in the 2000s, the use of export restrictions on industrial raw materials has surged in recent years, especially since 2007.[8] Among these export restriction practices, the Indonesia's export ban on unprocessed nickel serves as a relevant and informative case.[9] Since Indonesia is the world's largest nickel producer and holds the world's largest nickel reserves, the domestic industrial policy of Indonesia on nickel has far-reaching spillover effects on the global supply of nickel.[10] More importantly, analyzing the impact of Indonesia' export ban on nickel on its downstream industry development, especially in domestic value-added creation, can shed light on understanding the impact of the resource nationalism and commodity-led development strategy and industrial policy (Reed, 2024; Terauds, 2017), and provides references for policy design and implementation of other resource-abundant developing countries.

2.2 The Importance of Nickel and the Dominant Role of Indonesia in Global Nickel Industry

Nickel is an important raw material for the iron and steel industry and the battery industry, and is classified as a critical mineral by the United States Geological Survey in 2022.[11] With the fast-growing demand for EVs due to the need for global green energy transition, the trading of nickel has become increasingly important. There are two forms of nickel deposits: sulphide and laterite, with the latter concentrated in tropical areas such as Indonesia and the Philippines. Nickel smelting is energy-intensive, and the grade of nickel ore is the key determinant of the smelting costs. Higher grade nickel ore can be processed by smaller smelting factories requiring less capital investment and operational expenses.

Indonesia is the world's largest nickel producer and holds the world's largest nickel reserves, mostly in the form of laterite. Compared to other countries with laterite nickel reserves, Indonesia nickel

[7] As noted by Terauds (2017), the commodity-led development strategy is to reinvest the revenues obtained from the strategic commodity sector to other sectors to increase economic sophistication and diversification and drive broader economic growth and structural transformation. Reed (2024) provides a recent survey on export-led industrial policy.

[8] Kowalski & Legendre (2023) and OECD (2024) provide reviews on export restrictions on industrial raw materials.

[9] As emphasized by Terauds (2017), the quantitative export restriction measures only account for a small fraction of all export restriction measures, and Indonesia's export ban on nickel belongs to one of the only three comprehensive bans.

[10] There are huge trade diversions with China from Indonesia to Malaysia and the Philippines on aluminum and nickel.

[11] The EU also initiates the "Critical Raw Materials Act" to ensure a secure and sustainable supply of critical raw materials (CRM), enabling Europe to meet its climate and digital objectives. (Source: https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en). Nickel is included on the CRM list in the CRM act as a strategic raw material.

grades are among the highest (Terauds, 2017). In addition, the laterite nickel ore in Southeast Asia is also rich in iron, which makes it more suitable to produce stainless steel. All these factors lead to Indonesia's prominent and irreplaceable position in the global nickel supply chain, especially for the iron and steel industries, whose output could be used in broad sectors such as automotive, automotive components and frames, two-wheelers, pipes, tubes, and other machinery industries.

2.3 Chronological Timeline of Regulations Concerning the Nickel Export Ban

Driven by the skyrocketed external demand for nickel, mainly from China's rapid urbanization and industrialization, the extraction of nickel in Indonesia increased dramatically during the first decade of the 21st century. This resulted in large export revenues but only limited value-added for the country. During the same period of time, the Indonesian export was dominated by resource-based commodities, while the export share of manufactured goods was falling, reflecting a low GVC participation (Pangestu et al., 2015). To boost downstream processing capacity, build forward linkages along the GVCs, and increase domestic value-added, the Indonesia government resorted to banning the export of nickel ore.[12]

In 2009, the Indonesian Mineral and Coal Mining Law (Law No.4) was introduced, which prohibited the export of raw minerals unless such minerals were processed domestically.[13] Under this law, raw minerals such as copper and nickel would need to be processed by the local smelters before being exported. In the next year, Regulation No.23 was issued, which made it compulsory for mining firms to refine minerals for exporting, with a 5-year buffer period for qualified firms to purchase and install the smelting equipment. In 2014, as part of the implementation and requirement of the 2009 Mineral and Coal Mining Law, the Indonesian government banned the export of nickel ore. Only those firms with smelters built in Indonesia and that paid an export tax were allowed to export a limited amount of nickel concentrates. The export ban caused the Indonesian production of nickel and its share in the global nickel production to drop dramatically in 2014 (Figure 1), implying the downstream industries' processing capability of the nickel was underdeveloped and hard to adapt in such a short period. The world price of nickel increased in 2014, further reflecting a global shortage of nickel supply due to the export ban. About the same time, in addition to the export ban, the "21st Century Maritime Silk Road" initiative proposed by the Chinese President also created huge incentives for Chinese firms to invest in smelting facilities in Indonesia (Tritto, 2022). Chinese firms possessed the technical know-how suitable to mine the Indonesian nickel that is closer to the surface of the earth, together with the large upfront fixed investment, resulting in the smelting sector dominated by a few smelters from

[12]Other policy motives include creating local employment, increasing economic diversification and complexity, slowing down the mining of ore, and reducing the country's economic dependence on exporting raw minerals (Guberman et al., 2024; Pandyaswargo et al., 2021; Terauds, 2017; Tritto, 2022).

[13]The International Energy Agency provides a detailed summary of Indonesia's policies concerning the nickel ore export prohibition, which can be found at https://www.iea.org/policies/16084-prohibition-of-the-export-of-nickel-ore.

China (Dinata et al., 2020; Lederer, 2016). Both technological barriers and financial constraints led to a monopsony scenario in Indonesian domestic nickel market, which will be incorporated in our model below. These large firms with price-setting power suppressed the domestic price of nickel to be lower than the world price, at the cost of undermining the interest of the nickel industry (Dinata et al., 2020; Tritto, 2022).

The export ban on nickel ore caused a plummet in export revenue, compelled the Indonesian government to relax the export ban in 2017, and grant export quotas to firms that could prove practical progress in constructing a smelting facility. In 2018, the Indonesian government announced that the nickel ore export ban would be put into force on January 11, 2022. However, the comprehensive ban on nickel exports became effective two years in advance in 2020, preventing all exports of nickel ores and concentrates.[14]

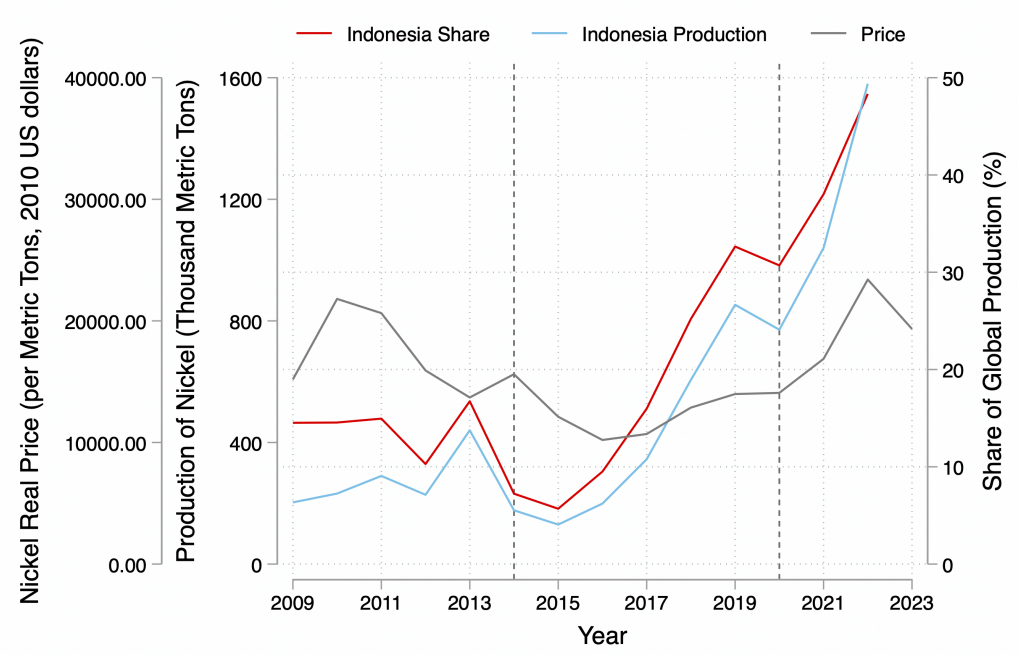

Figure 1: Indonesia Production of Nickel and World Price of Nickel

Notes: The nickel production data comes from Mineral Commodity Summaries provided by U.S. Geological Survey while the nickel price data comes from World Bank Pink Sheet (Commodity Price Data).

In short, despite the fact that the export ban was first initiated in 2014, the scope of Indonesia's export ban on nickel fluctuates and even retrogresses, influenced by the downstream smelter construction progress and the pressure from short-term export revenue loss. According to Guberman et al. (2024), nickel mine production in Indonesia, particularly primary processed nickel production and

[14]One possible reason might be that the smelting industry has already matured and even become oversupply, compelling the Indonesian government to announce the nickel work plan and budget (RKAB), a production quota for nickel ore.

exports of processed nickel, has significantly increased since 2016, with notable growth since 2018. This is because it takes time for firms to build smelters and bring them to operation, due to both technological barriers and financial constraints. The downturn trend of global commodity prices during the second half of 2014 and 2017 further discouraged foreign investment in the smelting industry (Terauds, 2017). In light of these factors, instead of artificially setting the policy shock year at 2014, we study the time series movement of DVAR and firm size from 2011 to 2020 and let the data depict the significant changes without imposing our prior assumptions.

3 A Simple Three Sector Model

In this section, we present a simple model showing how the export ban on nickel may affect the DVAR of downstream car firms that use iron and steel products intensively.

Consider there are three sectors, $\{N, S, C\}$, in this economy. Sector N is the primary good sector, which only has a monopoly firm producing nickel, potentially serving both the domestic market and the world market. Sector S is the intermediate good sector, which consists of a monopoly firm using nickel to produce steel. Sector C is the final good sector, which has infinitely many monopolistically competitive firms using steel as materials in their production. Given that steel is used widely to produce cars, car parts, metal pipes, machinery, furniture, and construction materials, these firms are collectively referred to as the car firms in sector C for simplicity. Firm and sector notations are used interchangeably. Labor is the only factor of production fully employed and free to move across all three sectors, and is assumed to be perfectly elastic with the wage equals one as the numeraire.

The equilibrium is characterized by three concurrent equilibria of the good market of each sector. Before the export ban, the monopoly equilibrium in sector N involves the monopoly firm deciding on the domestic price of nickel, p_N^D, and the overall production, facing an exogenous world price of nickel of p_N^W.[15] After the export ban, the nickel firm can only sell its output to the domestic monopoly steel firm, entering into a Nash bargaining game, which we assume the steel firm dominates and set the domestic price of nickel as a monopsony. The equilibrium of sector S determines the domestic price of steel, p_S^D, facing an exogenous world price of steel of p_S^W. Finally, the monopolistic competition equilibrium of sector C determines the domestic price of cars, p_C^D, facing an exogenous world price of cars of p_C^W.

[15]We assume the exogenous world price of nickel for simplicity. However, before the export ban on nickel, Indonesia was one of the major nickel producers and exporters in the world market. The world price of nickel increased after Indonesia's export ban, as shown in Figure 1. Such an increase might have caused the price of imported steel to increase relative to the domestic price of steel, which might further encourage the substitution of imported steel by domestic steel. It will not offset but reinforce the result of the model.

3.1 Upstream Primary Good Sector Equilibrium

We first start with sector N, the upstream primary good sector, which produces nickel, which is used as an input in sector S for the production of steel. There is only one monopoly firm in this sector. Before the export ban, the monopoly faced a downward-sloping domestic nickel demand curve (11). Labor, L_N, is the only factor of production, and $Y_N = f(L_N)$, with $f'(L_N) > 0$ and $f''(L_N) < 0$. The output can be exported to the world market, Y_N^W, facing a world price of p_N^W, or sold domestically, Y_N^D, at a domestic price of p_N^D. To serve both markets concurrently, the profit-maximizing monopoly will set the domestic price equal to the world price, otherwise the monopoly will either export all the nickel or only serve the domestic market:

$$\begin{aligned} p_N^D &= p_N^W && (1)\\ f(L_N) &= Y_N^D + Y_N^W && (2)\\ \max_{L_N} \pi_N &= p_N^W f(L_N) - L_N. && (3) \end{aligned}$$

The first order condition implies that as the world price of nickel increases, the monopoly will hire more workers:

$$\begin{aligned} \frac{\partial \pi_N}{\partial L_N} = p_N^W f'(L_N) - 1 = 0 \quad &\Rightarrow \quad f'(L_N) = \frac{1}{p_N^W} && (4)\\ &\Rightarrow \quad \frac{\partial Y_N}{\partial p_N^W} = -\frac{f'(L_N)}{f''(L_N)(p_N^W)^2} > 0. && (5) \end{aligned}$$

Thus, when the world price of nickel increases, the nickel firm now produces more nickel, leading to an upward-sloping nickel supply curve as shown in (5).

After the export ban, the nickel monopoly faces the steel monopsony, which sets the price of nickel to maximize the steel firm's profit. In this case, the demand for nickel is a horizontal line, as shown in (18) below. The intersection of this line with the upward-sloping supply curve will determine the equilibrium price of nickel and the corresponding domestic nickel production.

3.2 Midstream Intermediate Good Sector Equilibrium

Now consider the midstream sector, the steel sector, or sector S, which purchases inputs from the nickel sector, sector N, to produce steel used as the material necessary for the downstream car sector, sector C. Given that in reality, firms in this sector faced huge upfront fixed costs to set up smelters and plants, and exert market power in suppressing the domestic price of nickel, we assume that there is only one firm in sector S. Before the export ban on nickel, this steel firm was the only one that needed to compete with exports for domestic nickel, facing the world price of nickel at p_N^W.

This implies that the steel firm was a price taker in the nickel market before the export ban. After the export ban on nickel, this firm is the only buyer of domestic nickel, and is the *de facto* monopsony for the upstream nickel sector. This implies that the steel firm possesses monopsony power in the domestic nickel market, endogenously setting the domestic nickel price to maximize its profits.

On the other hand, there are infinitely many firms in the car sector, the car firms may choose to use domestic steels or imported steels, which are imperfect substitutes. We therefore assume that the steel firm is a price taker in the steel market, facing the world price of imported steel and the demand for steel from the car firms.

Specifically, we assume that the steel firm faces an upward-sloping nickel supply curve, as suggested in (5), with a constant elasticity of $\epsilon > 0$:

$$N_S^D = (p_N^D)^\epsilon. \tag{6}$$

Steel firm uses domestic nickel N_S^D and/or imported nickel, N_S^W and labor, L_S to produce steel output, Y_S following the production function specification as below:

$$Y_S = (N_S^D + N_S^W)^{\theta_S^N} (L_S)^{1-\theta_S^N}. \tag{7}$$

Note that in this production function, domestic nickel and imported nickel are assumed to be perfect substitutes for the production of steel.

3.2.1 Prior to Export Ban on Nickel

We first analyze the equilibrium before the export ban on nickel, where this steel firm is a price taker in the nickel market. Facing the exogenous world price of nickel, p_N^W, the domestic price of nickel, p_N^D, and the wage rate of one for labor, the steel firm maximizes its profits by choosing the input demand for domestic and/or imported nickel and labor:

$$\begin{aligned} \max_{N_S^D, N_S^W, L_S} \quad & \pi_S = p_S Y_S - (p_N^D N_S^D + p_N^W N_S^W) - L_S \\ & = p_S (N_S^D + N_S^W)^{\theta_S^N} L_S^{1-\theta_S^N} - (p_N^D N_S^D + p_N^W N_S^W) - L_S \\ & s.t.\ N_S^D \geq 0, N_S^W \geq 0 \end{aligned} \tag{8}$$

Solving the Kuhn-Tucker first-order conditions implies the following:

$$\begin{aligned} &\text{If } p_N^D \leqslant \ p_N^W \Rightarrow N_S^D \geqslant 0 \text{ and } N_S^W = 0; \\ &\text{If } p_N^D \geqslant \ p_N^W \Rightarrow N_S^D = 0 \text{ and } N_S^W \geqslant 0. \end{aligned}$$

Thus, given that imported nickel and domestic nickel are perfect substitutes in the production of

steel, price-taking steel firm will choose the cheaper one over the other if there is any price difference. If there is no price difference between domestic nickel and imported nickel, let's assume that the steel firm will choose the domestic nickel:

$$\text{If } p_N^D = p_N^W \Rightarrow N_S^D > 0 \text{ and } N_S^W = 0.$$

This implies that the profit maximization problem and the corresponding first-order conditions can be expressed as follows:

$$\max_{N_S^D, L_S} \pi_S = p_S Y_S - p_N^D N_S^D - L_S = p_S (N_S^D)^{\theta_S^N} L_S^{1-\theta_S^N} - p_N^D N_S^D - L_S \tag{9}$$

$$\Rightarrow \frac{\partial \pi_S}{\partial N_S^D} = \theta_S^N \frac{p_S Y_S}{N_S^D} - p_N^D = 0 \tag{10}$$

$$\Rightarrow N_S^D = \theta_S^N \frac{p_S Y_S}{p_N^D}, \tag{11}$$

where (9) re-expresses the profit maximization problem when the domestic price of nickel equals the world price of nickel, (10) is the first-order condition which is used to derive the demand for domestic nickel in (11).

In the equilibrium prior to the export ban, the export of nickel is the difference between the domestic supply and domestic demand of nickel, setting $p_N^D = p_N^W$:

$$Y_N^W \equiv (p_N^W)^\epsilon - \theta_S^N \frac{p_S Y_S}{p_N^W} > 0 \ \ if \ \ p_N^W > \left(\theta_S^N p_S Y_S\right)^{1/(1+\epsilon)}, \tag{12}$$

where the nickel export, facing world price of p_N^W, is positive if p_N^W is high, as shown in (12).

To determine the equilibrium price of steel, assuming that the domestic demand for steel is as follows:

$$Y_S = p_S^\xi, \text{with } -1 < \xi < 0. \tag{13}$$

Then it is clear that the price of steel is positively correlated with the price of nickel. To see this, let $\lambda > 1$, such that in the equilibrium with positive export:

$$p_N^W = \lambda (\theta_S^N p_S Y_S)^{1/(1+\epsilon)} \tag{14}$$

$$\Rightarrow p_S = \left[\left(\frac{p_N^W}{\lambda} \right)^{1+\epsilon} \frac{1}{\theta_S^N} \right]^{1/(1+\xi)}. \tag{15}$$

3.2.2 After the Export Ban on Nickel

Now, we consider the equilibrium after the nickel export ban. The steel firm can now exert monopsony power in the nickel market. Facing the upward sloping nickel supply curve, (6), the

monopsony maximizes profits by setting the domestic price of nickel to be lower than the marginal revenue product of nickel (MRPN),

$$\max_{p_N^D, L_S} \pi_S = p_S Y_S - p_N^D N_S^D - L_S = p_S (p_N^D)^{\epsilon\theta_S^N} L_S^{1-\theta_S^N} - (p_N^D)^{1+\epsilon} - L_S \tag{16}$$

$$\Rightarrow \frac{\partial \pi_S}{\partial p_N^D} = \epsilon\theta_S^N \frac{p_S Y_S}{p_N^D} - (1+\epsilon)(p_N^D)^{\epsilon} = 0 \tag{17}$$

$$\Rightarrow p_N^D = \left(\frac{\epsilon}{1+\epsilon}\theta_S^N p_S Y_S\right)^{1/(1+\epsilon)}, \tag{18}$$

where (16) re-expresses the profit maximization by substituting in the nickel supply curve, (6), and (17) is the first-order condition used to derive the domestic price of nickel in (18), which equals the of marginal revenue product of nickel multiply with a markdown of $\epsilon/(1+\epsilon) < 1$.[16] In addition, comparing (18) to (12), it is clear that after the export ban, the monopsony will set the domestic price of nickel to be less than the world price of nickel before the export ban. Finally, given that the domestic price of nickel drops after the export ban, it is also necessary that the domestic price of steel also drops, according to (18).

3.3 Downstream Final Good Sector Equilibrium

3.3.1 Domestic Market

Now consider the monopolistic competition equilibrium for sector C. Demand of C is governed by a standard constant elasticity of substitution (CES) utility function depending on the aggregate consumption of a continuum of varieties, denoted by ω,

$$U_C \equiv Y_C = \left[\int_\omega y(\omega)^\rho d\omega\right]^{1/\rho}, \quad \text{with} \quad 0 < \rho < 1, \tag{19}$$

with the elasticity of substitution between varieties equals $\sigma = 1/(1-\rho) > 1$. The aggregate price index for cars, p_C, is itself a CES function of the individual prices of the varieties,

$$p_C = \left[\int_\omega p(\omega)^{1-\sigma} d\omega\right]^{1/(1-\sigma)}. \tag{20}$$

The downward sloping demand curve and the revenue for each variety are:

$$y(\omega) = Y_C \left[\frac{p_C}{p(\omega)}\right]^\sigma \tag{21}$$

$$r(\omega) \equiv p(\omega)y(\omega) = R\left[\frac{p_C}{p(\omega)}\right]^{\sigma-1} \tag{22}$$

[16] Markdown is defined as the ratio of the price of nickel to the MRPN, that is markdown $= p_N^D / MRPN$.

where $R \equiv p_C Y_C = \int_\omega r(\omega) d\omega$. There are infinitely many firms with heterogeneous productivity, φ, in this sector. In a symmetric equilibrium, each firm chooses to produce a unique variety with the following constant returns to scale Cobb-Douglas production function:

$$y(\omega) = \varphi {S_C}^{\theta_C^S} {L_C}^{1-\theta_C^S}. \tag{23}$$

In words, (23) shows that firm with productivity φ in sector C, use material which is steel, S_C, and labor, L_C, to produce output of variety ω, which is car, $y(\omega)$. The elasticity of steel material and labor with respect to the output are θ_C^S and $1 - \theta_C^S$, respectively.

Profit-maximizing firms will set the values of marginal product of S_C and L_C equal to the marginal costs, which determines the input demands, with the price of car denoted by $p(\omega)$, the price of steel denoted by p_S, and the wage set to be one as the numeraire:

$$\begin{aligned} S_C &= r(\omega)\theta_C^S / p_S & (24) \\ L_C &= r(\omega)(1 - \theta_C^S) & (25) \end{aligned}$$

We assume that steel material, S_C, is a composite input consisting of imported steel, S_C^W, and domestic steel, S_C^D, and these two types of steel are imperfect substitutes, with a variable elasticity of substitution:

$$S_C = f(S_C^W, S_C^D), \tag{26}$$

Similar to Kee & Tang (2016), facing the prices of imported steel, p_S^W, and domestic steel, p_S^D, without loss of generality, we assume that the unit material cost function of steel material, $p_S\left(p_S^W, p_S^D\right)$, is a translog function that is symmetric and homogenous of degree one. This type of function can provide a second-order approximation to any functional form of the price aggregates (Diewert & Wales, 1988):

$$\begin{aligned} \ln p_S\left(p_S^W, p_S^D\right) &= a_0 + a_{0W} \ln p_S^W + a_{0D} \ln p_S^D \\ &\quad + \frac{1}{2} a_{WW} \left(\ln p_S^W\right)^2 + a_{WD} \left(\ln p_S^W\right)\left(\ln p_S^D\right) + \frac{1}{2} a_{DD} \left(\ln p_S^D\right)^2. \end{aligned} \tag{27}$$

The assumptions of symmetry and homogeneity of degree one imply the following restrictions on the translog parameters:

$$\begin{aligned} a_{WW} &< 0;\ a_{DD} < 0;\ a_{0W} + a_{0D} = 1;\ a_{WW} + a_{WD} = a_{DD} + a_{WD} = 0; \\ \text{and } a_{WW} &= a_{DD} = -a_{WD} < 0 \Rightarrow a_{WD} > 0. \end{aligned} \tag{28}$$

With the translog price function, it can be shown that $\partial \ln p_S / \partial \ln p_S^W$ equals the share of imported steel in total steel material cost, and is a log-linear function of the domestic price of steel relative to the world price of steel:

$$\begin{aligned} \frac{\partial \ln p_S\left(p_S^W, p_S^D\right)}{\partial \ln p_S^W} &= \frac{p_S^W S_C^W}{p_S S_C} > 0 \\ &= a_{0W} + a_{WW} \ln p_S^W + a_{WD} \ln p_S^D \\ &= a_{0W} + a_{WD} \ln \frac{p_S^D}{p_S^W}. \end{aligned} \tag{29}$$

Similarly, $\partial \ln p_S / \partial \ln p_S^D$ equals the share of domestic steel in total steel material cost, and is a log-linear function of the domestic price of steel relative to the world price of steel:

$$\begin{aligned} \frac{\partial \ln p_S\left(p_S^W, p_S^D\right)}{\partial \ln p_S^D} &= \frac{p_S^D S_C^D}{p_S S_C} > 0 \\ &= a_{0D} - a_{WD} \ln \frac{p_S^D}{p_S^W}. \end{aligned} \tag{30}$$

Thus, if p_S^D drops, the unit cost of steel, p_S, will also drop in equilibrium. On the other hand, zero profit condition $p(\omega)y(\omega) = p_S S_C + L_C$ implies that for each firm, the unit cost of production, which is the average cost, must equal to the equilibrium price of variety ω, $p(\omega)$, and the elasticity of each input also equals its share in the total revenue (and total cost):

$$p(\omega) = \frac{1}{\rho} \frac{{p_S}^{\theta_C^S}}{\varphi A_C}, \tag{31}$$

$$\frac{\partial \ln p(\omega)}{\partial \ln p_S} = \theta_C^S > 0 \tag{32}$$

$$\frac{\partial \ln p(\omega)}{\partial \ln p_S^D} = \theta_C^S \left(a_{0D} - a_{WD} \ln \frac{p_S^D}{p_S^W} \right) > 0, \tag{33}$$

where $A_C \equiv (\theta_C^S)^{\theta_C^S}(1-\theta_C^S)^{1-\theta_C^S}$ is a constant term. Equation (31) shows the constant markup rule of firm with productivity φ, where markup equals $1/\rho$, and marginal cost, equals:

$$mc(\varphi) = \frac{{p_S}^{\theta_C^S}}{\varphi A_C}. \tag{34}$$

Equation (31) is also the supply curve of variety ω, which is horizontal and does not depend on the production level, due to the constant returns to scale assumption. Finally, (33) shows that a fall in the domestic price of steel, p_S^D, will cause the price of each variety of car, $p(\omega)$, to drop.

In equilibrium, the output for each variety ω of car, $y(\omega)$, is determined by the intersection of the downward sloping demand curve, (21), and the horizontal supply curve, (31), which is:

$$y(\omega) = Y_C\left(\frac{\rho\varphi p_C A_C}{{p_S}^{\theta_C^S}}\right)^{\sigma} \tag{35}$$

$$\frac{\partial \ln y(\omega)}{\partial \ln p_S} = -\sigma\theta_C^S < 0 \tag{36}$$

$$\frac{\partial \ln y(\omega)}{\partial \ln p_S^D} = -\sigma\theta_C^S\left(a_{0D} - a_{WD}\ln\frac{p_S^D}{p_S^W}\right) < 0. \tag{37}$$

Thus, in equilibrium, the fall in p_S^D will cause the output of each variety of car, $y(\omega)$, to increase, according to equation (37). In addition, the revenue of variety ω in sector C is

$$r(\omega) \equiv p(\omega)y(\omega) = p_C Y_C\left(\frac{\rho\varphi p_C A_C}{{p_S}^{\theta_C^S}}\right)^{\sigma-1}. \tag{38}$$

3.3.2 Domestic Market and Export Market

The analysis up to now only focuses on firms in sector C serving only one market, which is the domestic market (superscript of D omitted for clarity). Now let's consider the export market for each variety ω of C, assuming that the product ω for domestic and export is identical.

The only difference between serving the domestic market and the export market is the variable trade costs, such as transportation costs and foreign tariffs, that firms face when exporting. Assuming a multiplicative iceberg ad valorem variable trade cost, $t > 1$, the marginal cost of exporting for a firm with productivity φ is:

$$mc(\varphi)^W = t\ mc(\varphi) = \frac{t{p_S}^{\theta_C^S}}{\varphi A_C} \tag{39}$$

Thus, given the constant markup rule of profit maximization, for the export market, the equilibrium price, export supply, and export revenue of variety ω are respectively:

$$p(\omega)^W = \frac{t{p_S}^{\theta_C^S}}{\rho\varphi A_C} \tag{40}$$

$$y(\omega)^W = Y_C\left(\frac{\rho\varphi p_C A_C}{t{p_S}^{\theta_C^S}}\right)^{\sigma} \tag{41}$$

$$p(\omega)^W y(\omega)^W = p_C Y_C\left(\frac{\rho\varphi p_C A_C}{t{p_S}^{\theta_C^S}}\right)^{\sigma-1} \tag{42}$$

Correspondingly, the total revenue in the domestic market and export market is expressed as $R(\omega) \equiv p(\omega)^D y(\omega)^D + p(\omega)^W y(\omega)^W$. Taking the ratio of domestic revenue over export revenue by

dividing (38) with (42), and including the superscript D to denote domestic variable, it is clear that the proportion of export revenue in the total revenue of variety ω is a constant that only depends on the iceberg trade cost:

$$\frac{p(\omega)^W y(\omega)^W}{R(\omega)} = \frac{1}{1+t^{\sigma-1}}. \tag{43}$$

Equation (43) shows that as the variable trade cost increases, the share of export revenue in total revenue of variety ω drops. Now consider the domestic value-added of each exporting variety ω in sector C, which is the total revenue of the firm minus the cost of imported steel:

$$\begin{aligned}
DVA &\equiv R(\omega) - p_S^W S_C^W && (44)\\
DVAR &\equiv \frac{DVA}{R(\omega)} = 1 - \frac{p_S^W S_C^W}{p_S S_C}\frac{p_S S_C}{R(\omega)} = 1 - \theta_C^S \frac{p_S^W S_C^W}{p_S S_C} && (45)\\
&= 1 - \theta_C^S\left(a_{0W} + a_{WD}\ln\frac{p_S^D}{p_S^W}\right) && (46)\\
\frac{\partial DVAR}{\partial \ln p_S^D} &= -\theta_C^S a_{WD} < 0, && (47)
\end{aligned}$$

where (44) is the definition of DVA in total revenue. Dividing DVA by total revenue gives us the share of DVA in total revenue, which equals the domestic value-added ratio in export as depicted in (45) under the assumption that the products sold domestically and for export are identical.[17] The right-hand side of (45) is obtained by substituting θ_C^S for $p_S S_C/R(\omega)$. Substituting (29), the share of imported steel in total steel, into (45) to get (46).

Analyzing (46), it is clear that DVAR is negatively correlated with the price of domestic steel, as shown in (47). Any factors that reduce the price of domestic steel increase the DVAR of final goods exporters in the car sector. We will show in the later section how the export ban on nickel may lower the price of domestic steel through empowering steel firms' monopsony power in the nickel market, which thus will lead to an increase in DVAR for exporters. In addition, DVAR presented in (46) is common across all firms in the industry and does not depend on the productivity of the firms. Finally, DVAR is positively correlated with the price of imported steel. Factors such as exchange rate depreciation or tariffs on imported steel may increase the price of imported steel and raise DVAR.

[17] To see this, let DVA^D and DVA^W denote the domestic value-added in domestic sales and exports, respectively, such that $DVA \equiv DVA^D + DVA^W \Rightarrow \frac{DVA}{R(\omega)} = \frac{DVA^D}{p^D(\omega)y^D(\omega)}\frac{p^D(\omega)y^D(\omega)}{R(\omega)} + \frac{DVA^W}{p^W(\omega)y^W(\omega)}\frac{p^W(\omega)y^W(\omega)}{R(\omega)} = DVAR$, given the assumption of identical products for domestic and export markets such that $DVAR = DVA^W/p^W(\omega)y^W(\omega) = DVA^D/p^D(\omega)y^D(\omega)$.

3.3.3 Aggregate Productivity and the Entry of Firms

The analysis here follows the standard heterogeneous firm model (Melitz, 2003). Initially there is a fixed mass, Z, of firms in sector C, with a productivity distribution $\mu(\varphi)$, defined over $(0, \infty)$. The aggregate productivity is the weighted average of firm productivity, with weights reflecting the relative output share of the firms with different productivity:

$$\tilde{\varphi} = \left[\int_0^{\infty} \varphi^{\sigma-1} \mu(\varphi) d\varphi \right]^{1/(\sigma-1)} \tag{48}$$

Note that $\tilde{\varphi}$ also represents the aggregate productivity of the car sector since all aggregate variables are determined by it as follows.

$$p_C = Z^{1/(1-\sigma)} p(\tilde{\varphi}) \tag{49}$$

$$Y_C = Z^{1/\rho} y(\tilde{\varphi}) \tag{50}$$

$$R_C = p_C Y_C = Z r(\tilde{\varphi}). \tag{51}$$

Now consider the entry and exit of firms. Similar to Melitz (2003), we assume that there is a fixed cost of entry to sector C, L_0, a fixed cost of production, L_P, and a fixed cost of exporting, L_E, all expressed in terms of labor costs. Facing the aggregate demand and prices, firms pay L_0 to enter the industry, pay L_P to produce, and pay L_E to export. They will continue to enter the domestic market and the export market until the respective least productive firm makes zero profits in either market. The equilibrium cutoff productivities for the production and export, φ^* and φ^{W*}, are determined by the zero-profit cutoff condition (ZCPC) and the free entry condition (FEC), which also determine the average profit of surviving firms of the domestic market and export market.

With the cutoff productivity, φ^*, whereby firms below this productivity will exit the domestic market, the average industry productivity can be expressed as a function of φ^*:

$$\tilde{\varphi}(\varphi^*) = \left[\frac{1}{1 - G(\varphi^*)} \int_{\varphi^*}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi \right]^{1/(\sigma-1)} \tag{52}$$

$$\frac{\partial \ln \tilde{\varphi}(\varphi^*)}{\partial \ln \varphi^*} = \left(\frac{1}{\sigma - 1} \right) \left(\frac{\varphi^* g(\varphi^*)}{1 - G(\varphi^*)} \right) \left[1 - \left(\frac{\varphi^*}{\tilde{\varphi}} \right)^{\sigma-1} \right] > 0. \tag{53}$$

The assumption that $\tilde{\varphi}$ is finite further implies that $\frac{\partial \ln \tilde{\varphi}}{\partial \ln \varphi^*} < 1$, to ensure a unique equilibrium (see Footnote 18). Using (38), the average revenue of a firm with productivity $\tilde{\varphi}$ in the car sector, can also be expressed in terms of the revenue of the cutoff firm:

$$r(\tilde{\varphi}) = R_C\left(\frac{\rho\tilde{\varphi}p_C A_C}{{p_S}^{\theta_C^S}}\right)^{\sigma-1} = r(\varphi^*)\left(\frac{\tilde{\varphi}}{\varphi^*}\right)^{\sigma-1} \tag{54}$$

In the equilibrium, the profit of the marginal firm with cutoff productivity, $\pi(\varphi^*)$ is its revenue minus variable and fixed costs of production:

$$\begin{aligned}\pi(\varphi^*) &= p(\varphi^*)y(\varphi^*) - y(\varphi^*)mc(\varphi^*) - L_P \\ &= R_C\left(\frac{\rho\varphi^* p_C A_C}{{p_S}^{\theta_C^S}}\right)^{\sigma-1} - \rho R_C\left(\frac{\rho\varphi^* p_C A_C}{{p_S}^{\theta_C^S}}\right)^{\sigma-1} - L_P \\ &= (1-\rho)R_C\left(\frac{\rho\varphi^* p_C A_C}{{p_S}^{\theta_C^S}}\right)^{\sigma-1} - L_P.\end{aligned} \tag{55}$$

Setting (55) equals zero to obtain the ZCPC, which allows us to solve for the cutoff productivity in terms of the price of steel, p_S:

$$\varphi^* = \frac{{p_S}^{\theta_C^S}}{\rho p_C A_C}\left(\frac{\sigma L_P}{R_C}\right)^{1/(\sigma-1)} \tag{56}$$

$$\frac{\partial \ln \varphi^*}{\partial \ln p_S} = \theta_C^S \tag{57}$$

$$\frac{\partial \ln \varphi^*}{\partial \ln p_S^D} = \theta_C^S\left(a_{0D} - a_{WD}\ln\frac{p_S^D}{p_S^W}\right) \tag{58}$$

Given that p_S is positively correlated with the domestic price of steel, p_S^D, (58) shows that when the price of domestic steel falls, the cutoff productivity for the car sector will also fall. Given that $\partial\tilde{\varphi}/\partial\varphi^* > 0$ from (53), (58) implies that:

$$\frac{\partial \ln \tilde{\varphi}}{\partial \ln p_S^D} = \frac{\partial \ln \tilde{\varphi}}{\partial \ln \varphi^*}\frac{\partial \ln \varphi^*}{\partial \ln p_S^D} > 0. \tag{59}$$

Furthermore, the average profit of the industry can be expressed in terms of the cutoff productivity in the equilibrium:

$$\begin{aligned}\pi(\tilde{\varphi}) &= (1-\rho)R_C\left(\frac{\rho\tilde{\varphi}p_C A_C}{{p_S}^{\theta_C^S}}\right)^{\sigma-1} - L_P \\ &= (1-\rho)R_C\left(\frac{\rho\varphi^* p_C A_C}{{p_S}^{\theta_C^S}}\right)^{\sigma-1}\left(\frac{\tilde{\varphi}}{\varphi^*}\right)^{\sigma-1} - L_P \\ &= L_P\left[\left(\frac{\tilde{\varphi}}{\varphi^*}\right)^{\sigma-1} - 1\right].\end{aligned} \tag{60}$$

Equation (60) depicts a downward sloping ZCPC curve in the $(\varphi^*, \pi(\tilde{\varphi}))$ space. When the price of domestic steel drops, the ZCPC curve shifts down and causes $\tilde{\varphi}$ to fall, which leads to a lower average profit, $\pi(\tilde{\varphi})$ for a given φ^*.

The assumption that $\tilde{\varphi}$ is finite and bounded such that $\partial \ln \tilde{\varphi} / \partial \ln \varphi^* < 1$ ensure that the ZCPC curve, (60), is monotonically downward sloping for a unique solution.[18]

In addition to the ZCPC, there is also the positive sloping FEC curve in the $(\varphi^*, \pi(\tilde{\varphi}))$ space, which together pin down the equilibrium average profit and cutoff productivity:

$$\pi(\tilde{\varphi}) = \frac{\delta L_e}{1 - G(\varphi^*)}, \tag{61}$$

where δ is the exogenous death rate of the firms in the industry and L_e is the fixed cost of entering the market. In the equilibrium, both ZCPC and FEC must be met simultaneously.

In the equilibrium, when the price of domestic steel drops, the ZCPC curve shifts downward, leading to a lower φ^* and $\pi(\tilde{\varphi})$ along the FEC curve. A lower φ^* implies a lower average productivity $\tilde{\varphi}$, while a lower $\pi(\tilde{\varphi})$ implies a lower average revenue of the industry, $r(\tilde{\varphi})$ from (60):

$$r(\tilde{\varphi}) = \sigma(\pi(\tilde{\varphi}) + L_P). \tag{62}$$

Furthermore, the equilibrium mass of firms, which is $Z = 1 - G(\varphi^*)$, will increase as a result of a lower φ^*:

$$\frac{\partial \ln Z}{\partial \ln p_S^D} = \frac{\partial \ln Z}{\partial \ln \varphi^*} \frac{\partial \ln \varphi^*}{\partial \ln p_S^D} = \frac{-g(\varphi^*)\varphi^*}{1 - G(\varphi^*)} \left[\theta_C^S \left(a_{0D} - a_{WD} \ln \frac{p_S^D}{p_S^W} \right) \right] < 0. \tag{63}$$

Note that $\partial \ln Z = \Delta Z / Z$, which captures the measure of new entrance (ΔZ) in the total mass of the firm. Equation (63) shows that when the price of domestic steel falls, the share of new entrants in the total mass of firms will increase, and the larger the fall in the price of domestic steel, the larger is the share of new entrants in the car sector.

Likewise, we can derive the cutoff productivity and aggregate productivity for exporting by setting the variable export profit to zero. And the result is the same as the above, that the aggregate export productivity is positively correlated with the cutoff export productivity, and the cutoff exporter's productivity is also positively correlated with the price of domestic steel. Thus, in the equilibrium, when the price of domestic steel falls, the aggregate export productivity also drops, the average size of exporting firms is lower, and more firms will enter the export market, with the share of new exporters

[18] The equilibrium is unique if the ZCPC curve is monotonically downward-sloping. Too see this, from (60), we can obtain $\frac{\partial \tilde{\pi}}{\partial \varphi^*} = -L_P \tilde{\varphi}^{\sigma-1}(\sigma-1)(\varphi^*)^{-\sigma} + L_P \tilde{\varphi}^{\sigma-2}(\sigma-1)(\varphi^*)^{1-\sigma} \frac{\partial \tilde{\varphi}}{\partial \varphi^*} = L_P \frac{\sigma-1}{\varphi^*} \left(\frac{\tilde{\varphi}}{\varphi^*}\right)^{\sigma-1} \left(\frac{\partial \tilde{\varphi}}{\partial \varphi^*} \frac{\varphi^*}{\tilde{\varphi}} - 1\right) < 0$ if $\frac{\partial \tilde{\varphi}}{\partial \varphi^*} \frac{\varphi^*}{\tilde{\varphi}} = \frac{\partial \ln \tilde{\varphi}}{\partial \ln \varphi^*} < 1$.

in the total mass of exporters will be higher.

3.4 Export Ban on Nickel

To analyze the export ban on nickel, we start from sector S, the steel sector. With the export ban, the steel monopsony exercises its input market power to set the price of nickel less than the original world price of nickel before the export ban, comparing (18) to (12). The drop in the domestic price of nickel decreases the overall domestic production of nickel in sector N. However, given that it is no longer exporting, the domestic consumption of nickel is, in fact, higher. The decrease in the domestic price of nickel further pushes down the domestic price of steel in the equilibrium after the export ban on nickel, according to (18).

Finally, for the car sector, C, under the export ban, facing a lower price of domestic steel, p_S^D, the DVAR of firms will be higher, according to (47). This is because firms in sector C substitute imported steel with domestic steel, which also causes the import of firms to decrease. However, the lower price of domestic steel also causes more inefficient firms to enter the car sector, resulting in a lower aggregate productivity of the surviving domestic firms and exporting firms, according to (59). This implies that while the export ban may have achieved the stated objective of industrial downstreaming by improving the domestic value-added of the car industry, it may also have generated unintended inefficiency by allowing the less productive firms to enter and stay in the market, which lowers the aggregate productivity as a side effect.

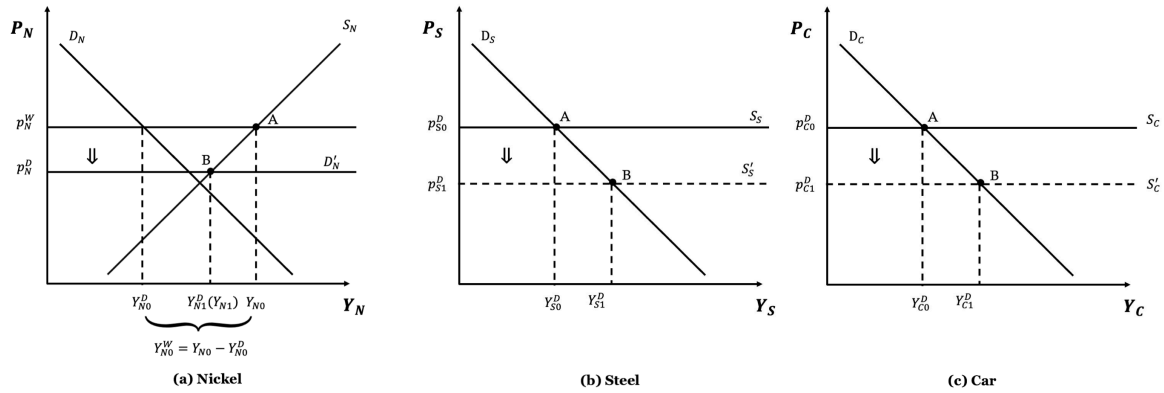

Figure 2: The Impact of Export Ban on Nickel, Steel and Car Industries

Notes: The price and quantity information is qualitative and not comparable across sub-figures.

Figure 2 depicts the equilibrium before and after the export ban on nickel. Before the export ban, the nickel market was characterized by the monopolist's upward-sloping nickel supply curve, S_N, due to diminishing labor productivity ($f''(L_N) < 0$), and the downward-sloping domestic demand for

nickel, D_N. Facing the exogeneous world price at p_N^W, the monopolist produces at Y_{N0}, with Y_{N0}^D for domestic demand, and the difference, $Y_{N0} - Y_{N0}^D = Y_{N0}^W$, is the nickel export. The export ban on nickel causes the nickel producer to face the monopsony steel firm, which sets the domestic price of nickel less than the world price before the export ban, $p_N^D < p_N^W$. The demand curve changes into a horizontal one, denoted by D'_N, with the lower price p_N^D. In equilibrium, the nickel producer only serves the domestic market, such that $Y_{N1} = Y_{N1}^D, Y_{N1}^W = 0$, at a lower domestic price of nickel.

For the monopsony steel market, the initial equilibrium is characterized by the intersection of the horizontal supply curve, S_S, and the downward-sloping domestic demand for steel, D_S, which determines the domestic price of steel, p_{S0}^D, and domestic production of steel, Y_{S0}^D. The fall in the domestic price of nickel in the nickel market decreases the marginal cost of production for steel firms, and causes the steel supply curve to shift down to S'_S, resulting in a lower equilibrium domestic price of steel, $p_{S1}^D < p_{S0}^D$, and a higher domestic production of steel, $Y_{S1}^D > Y_{S0}^D$.

Finally, for the monopolistically competitive car market, the impact of the export ban on nickel is similar to that of the steel market, with the horizontal supply curve of cars shifting downward due to the decrease in the domestic price of steel, resulting in a lower equilibrium domestic price of cars and higher domestic production of cars.

To summarize, the above simple three-sector model shows that post-export ban on nickel, the monopsony steel firm will depress the domestic price of nickel, leading to a lower domestic price of steel. This theoretical result implies the following testable hypothesis for the downstream industries:

Hypothesis 1. *Given the price of imported steel, the export ban on nickel depresses the nickel price due to monopsony power and hence the domestic iron and steel price, inducing firms in the downstream iron and steel-using industries to substitute imported steel with domestic steel, leading to higher industry DVAR.*

Hypothesis 2. *The falling price of iron and steel post the export ban on nickel lowers the cutoff productivity for iron and steel-using industries, resulting in lower industry productivity, manifested as smaller average firm size of the industries.*

Hypothesis 3. *Given the cutoff productivity for iron and steel using industries is lower post the export ban, the size of entrant firms in these industries is smaller, and the share of entrants in these industries is larger.*

The proofs for hypotheses 1 and 2 are according to (47), (59), (62), and (18), comparing the iron and steel using industries to the rest of the industries, pre and post the export ban, while the proof for Hypothesis 3 is based on (59) and (63) further compares the size of entrant firms relative to the incumbent firms within each of these industries.

4 Data

Customs Transaction Data The customs transaction data comes from Indonesian customs. The data records detailed firm-product level transaction information on both import and export for the period of 2015-2022, including trade partners, firm identifier, customs office, trade regime, trade value, and trade quantity.[19] Appendix A shows the details of the data cleaning and variable construction. For DVAR estimation, we estimate the export revenue function by industry to obtain κ_M, the share of imports that is used for production for exports. Industries are defined according to the industry classification proposed by the United Nations based on the HS 2-digit code. Appendix Table A.1 presents the industry classification. As firms may engage in trade for multiple industries, we use only single-industry firms to estimate κ_M and DVAR. A single industry firm is a firm that exports no less than 90% of its total export value within a single industry group.[20]

Large and Medium-Sized Manufacturing Survey The annual survey of large and medium-sized manufacturing (LMM) firms data comes from Statistics Indonesia (Badan Pusat Statistik, BPS), which has been widely used in the literature (Amiti & Konings, 2007; Hallward-Driemeier et al., 2021; Ing & Zhang, 2022; 2024)

The dataset consists of three modules: the main module, the production module, and the raw materials module, from 2009 to 2015. The main module provides information on ownership, employment, wage, capital, raw material, intermediate input, total output, and the percentage of production exported at the firm-year level. The production module and the raw material module break down the data to firm-product-year level.[21] The former provides detailed information on the production value, production quantity, and the export share of each product, while the latter contains detailed information on the domestic input value and quantity, and imported input value and quantity for each product. The identification numbers (IDs) of firms are comparable across these three modules and years. In addition, the BPS also provides a manufacturing firm survey for the period of 2017-2019. However, the product module and raw material module are no longer accessible, and the firm IDs are not comparable across years. As a result, the data for 2017-2019 can only be treated as a repeated cross-sectional dataset instead of a panel dataset.

Matching Customs Transaction Data with Manufacturing Census There is no existing or reliable firm identification code to match the customs data with the manufacturing survey. However, for the empirical specifications below, we only need to identify the industries that use iron and steel as

[19]The Indonesian customs provide information on imports for 2014 as well, but the absence of the corresponding export information prevents us from estimating DVAR for 2014.

[20]We dropped firms belonging to the toy industry (HS 95) due to a lack of sufficient observations, and firms belonging to arms and ammunition (HS 93), miscellaneous (HS 96), and art and collector piece and antique (HS 97) industries.

[21]The product is defined as a unique *Kode Klasifikasi Industri* (KKI) 9-digit code.

inputs. To do so, we rely on the concordance tables, *Korespondensi Dengan KBKI, KKI 1998/1999, KBLI 2009, HS 2012*, published by the Indonesian Department of Statistics, to match the Indonesian product codes (KKI 5-digit) in the manufacturing survey with the HS product codes (HS 2-digit), consistent with the customs data. This matching allows us to identify the industries of the firms in the survey that use iron and steel as inputs, similar to the way we identify firms that import iron and steel in the customs data. Note that KKI product classifications are disaggregated up to 9-digit, but for identifying iron and steel products, which are HS 2-digit, Chapters 72 and 73, KKI 5-digit is sufficient. Any further disaggregation yields no meaningful differences.

5 Empirical Evidence

This section provides empirical evidence to study the effectiveness of the export ban on nickel established in 2014. Firm-level DVAR is first estimated based on a new methodology developed in Kee et al. (2024). Based on the estimated firm DVAR, difference-in-difference reduced form regressions are used to show the time series trend of DVAR and firm size pre- and post the export ban.

5.1 DVAR Estimation

To study the effectiveness of the export ban on nickel in promoting domestic value-added of the downstream industries, it is necessary to have a measure. To this end, we follow the methodology established in Kee et al. (2024) closely for the estimation of firm-level DVAR based on the customs transaction data of Indonesia. This methodology builds on Olley & Pakes (1996) to estimate the export revenue function, controlling for the unobserved productivity using capital good imports.[22]

Specifically, to estimate the export revenue function of a firm, we regress the value of exports on the value of imports, controlling for the unobserved firm productivity based on a polynomial of capital goods imports, capital stock, and exchange rates. The coefficient of imports has a structural interpretation according to the export revenue function, which is the share of imported input used in the production of exports, κ_M:

$$EXP_{it} = \alpha_i + \alpha_t + D(E_{it}, K_{it}) + \kappa^M IMP_{it} + \omega_{it} + \varepsilon_{it}, \tag{64}$$

where the dependent variable, EXP_{it} is the value of export of firm i in year t, and the variable of interest is IMP_{it}, which is the value of import. We assume that domestic value-added of firm i in year t, can be decomposed into the following terms: $D(E_{it}, K_{it})$ is a function of firm exchange rate, E_{it} and capital stock, K_{it}, α_t denotes year fixed effects, α_i denotes firm fixed effects, which captures state variables that are specific to each firm, ω_{it} is the unobserved firm productivity and ε_{it} is either

[22] Kee et al. (2024) estimate the firm-level DVAR of Chinese exporters and show that high-speed railways expansion facilitates firm-to-firm linkages between the exporting firms and their domestic suppliers, driving up DVAR of China.

measurement error or unforeseeable productivity shock. While both ω_{it} and ε_{it} are unknown to the researchers, firm i observes ω_{it} and makes import and investment decisions based on it.

Similar to the production function estimation, estimating the export revenue function without controlling for the unobserved firm productivity, ω_{it}, will cause the least squares estimate of θ^M to have an upward bias, since a higher ω_{it} will increase both EXP_{it} and IMP_{it} simultaneously. Given that a higher ω_{it} also leads to a higher investment, provided that $I^M > 0$, we can invert (65) to form a control function for ω_{it} , similar to the OP approach:

$$I_{it}^M = I(\omega_{it}, E_{it}, K_{it}^M). \tag{65}$$

$$\omega_{it} = I^{-1}(I_{it}^M, E_{it}, K_{it}^M). \tag{66}$$

Here we are assuming that, given (K_{it}^M, E_{it}), the import of capital goods, which can be viewed as the investment, is increasing in productivity. This assumption allows the investment function to be invertible, similar to the original OP approach. Substituting (66) into (64) gives us the following:

$$EXP_{it} = \varphi(I_{it}^M, E_{it}, K_{it}^M) + \kappa^M IMP_{it} + \varepsilon_{it}, \tag{67}$$

with

$$\varphi(I_{it}^M, E_{it}, K_{it}^M) = \alpha_i + \alpha_t + D(E_{it}, K_{it}^M) + I^{-1}(I_{it}^M, E_{it}, K_{it}^M), \tag{68}$$

where $\varphi(I_{it}^M, E_{it}, K_{it}^M)$ can be proxied semi-parametrically using a higher-order polynomial function in the regressions. While we will not be able to separately identify $D(E_{it}, K_{it})$ and ω_{it}, least squares estimation of (67) will give us a consistent estimate of κ_M.

We estimate (67) based on the Indonesian customs transaction data from 2015 to 2022, industry by industry. We expect the coefficient on imports to be significantly no more than one. The results are presented in Tables 1 and 2. The estimated κs, which are the coefficients on imports, are all less than one.

Table 1: Export Revenue Function Estimations

Dependent Variables	(1) EXP	(2) EXP
IMP	0.220***	0.230***
	(0.033)	(0.037)
ϕ(I,E,K)	No	Yes
Firm FEs	Yes	Yes
Year FEs	Yes	Yes
Observations	28,158	17,450
Adjusted R^2	0.770	0.769

Notes: Robust standard errors clustered at the industry level are in parentheses, ***, **, * denote significance at 1%, 5%, 10% level, respectively.

Based on these estimates, we construct the firm-level DVAR as follows:

$$\widehat{DVAR}_{it} = 1 - \frac{\widehat{\kappa^M} IMP_{it}}{EXP_{it}}. \tag{69}$$

Figures 3 and 4 present the DVAR estimates at the industry and national levels, respectively. DVAR is declining across all industries, except for the Metal and Transportation industries, which is exactly the downstream industry of nickel, especially after 2018. The industry trend is also reflected at the national level, where a slight upward tick is detected in the latter part of the sample period, coinciding with the expansion of domestic iron, steel, and car production after the export ban on nickel.

Table 2: Export Revenue Function Estimations by Industries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Industries	Agriculture & Food & Beverage		Chemicals & Allied		Electrical		Furniture & Wood Products		Metals	
Dependent Variable	EXP	EXP	EXP	EXP	EXP	EXP	EXP	EXP	EXP	EXP
IMP	0.270***	0.243**	0.162***	0.181***	0.078*	0.087**	0.618***	0.547***	0.153*	0.150***
	(0.023)	(0.083)	(0.041)	(0.050)	(0.039)	(0.032)	(0.133)	(0.153)	(0.078)	(0.036)
Observations	4,731	2,191	2,890	1,615	1,340	1,130	3,350	1,927	1,919	1,359
Adjusted R^2	0.816	0.848	0.902	0.914	0.905	0.884	0.772	0.792	0.758	0.916
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Industries	Minerals & Stone & Glass		Optical Equipment		Plastic & Rubber & Toys		Textile & Apparel & Footwear & Headgear & Raw hides & Leather		Transportation & Machinery	
Dependent Variable	EXP	EXP	EXP	EXP	EXP	EXP	EXP	EXP	EXP	EXP
IMP	0.065	0.595	0.414***	0.523***	0.305***	0.314***	0.532***	0.639***	0.299***	0.325***
	(0.192)	(0.373)	(0.076)	(0.121)	(0.047)	(0.048)	(0.073)	(0.101)	(0.051)	(0.083)
Observations	1,870	1,154	414	342	2,822	1,855	3,881	2,068	4,115	3,149
Adjusted R^2	0.751	0.759	0.930	0.936	0.897	0.882	0.909	0.904	0.782	0.779
ϕ(I,E,K)	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors clustered at the industry-year level are in parentheses, ***, **, * denote significance at 1%, 5%, 10% level, respectively.

Figure 3: DVAR Trend by Industry

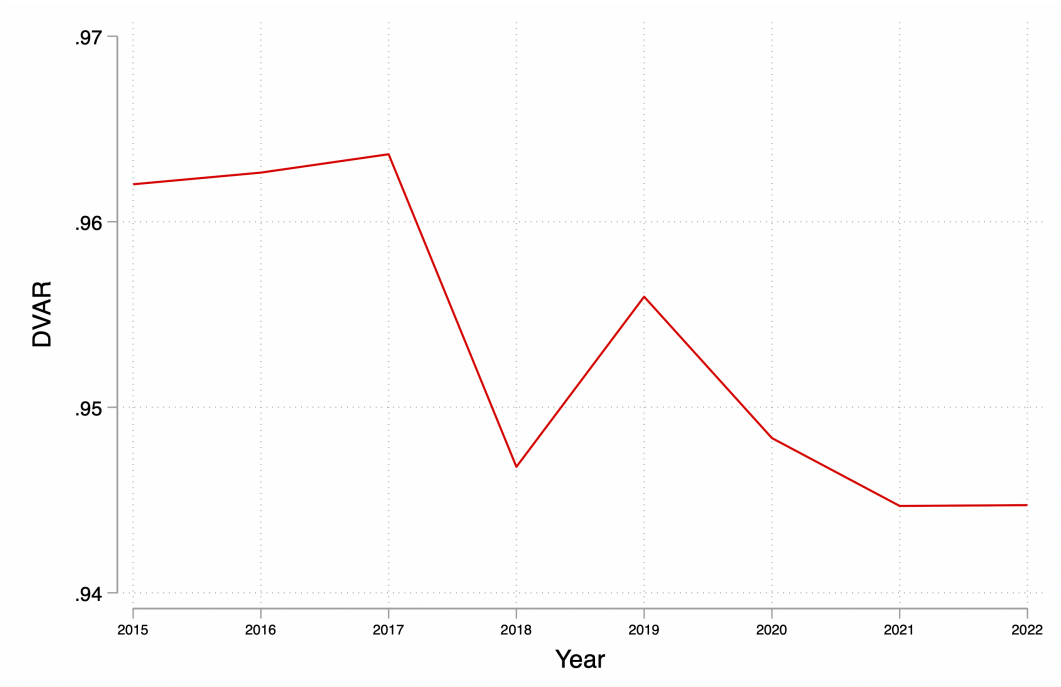

Figure 4: National DVAR Trend

5.2 Regression Analysis Focusing on All Firms in the Iron and Steel Using Industries

In this section, we study the impact of the nickel export ban on DVAR and firm size of the downstream industries to provide evidence for Hypothesis 1 and 2. The sample period covers 2011 to 2019 or 2022, with the Indonesian government announcing the export ban on nickel in 2014. The regression specification is as follows:

$$DEP_{it} = \eta_j + \eta_t + \sum_{k=2012}^{2019/2022} \left(\eta_k \times \mathbb{1}_{\{k=t\}} \times C_j \right) + \boldsymbol{X}\boldsymbol{\eta} + v_{it}, \tag{70}$$

where the dependent variable, DEP_{it}, denotes firm-level DVAR or firm size, measured as the log of total revenue and the log of total employment of firm i in year t. η_j denotes the KBLI 2-digit industry fixed effects (FE), capturing the average DVAR, revenue, or employment of all firms within industry j, while η_t denotes year FE, capturing the average DVAR, revenue, or employment of all firms in year t. The indicator variable, $C_j = 1$, corresponding to sector C in the model, denotes the KBLI 2-digit industry-level industries that use iron and steel intensively, with the proportion of iron and steel inputs in total inputs more than 5%, identified using the 2011-2013 average input structure from the LMM survey data.[23] The control variables included in $\boldsymbol{X}$ are KBLI 2-digit industry-year level input tariffs and import weighted exchange rate when DEP_{it} is firm-level DVAR, as suggested in (46), since both tariffs and exchange rate may affect the price of imported steel. On the other hand, industry total revenue is used as the control variable when DEP_{it} is firm size, as suggested in (38). Finally, v_{it} is the classical regression error, and standard errors are clustered at the KBLI 2-digit industry-year level.

The data on total revenue and total employment come from the LMM survey data and the sample coverage is from 2011 to 2019, with 2011 as the base year, while the data on firm-level DVAR is estimated based on the export revenue function approach from Kee et al. (2024) using the customs transaction data of Indonesia from 2015 to 2022.[24] Firm-level DVAR for 2011-2014 is constructed based on the LMM survey data, using the estimated import share κ^M from the customs data. The effectively applied import tariff data of Indonesia comes from World Integrated Trade Solution, with missing tariff data for 2014 and 2015 replaced by the moving average of the adjacent years, while the exchange rate data comes from Penn World Table and the World Bank.

The coefficients of interests are η_k, with k denotes each year for the period 2012-2022, when DEP_{it} is firm DVAR, and for the period 2012-2019, when DEP_{it} is firm size. Given that η_k is the

[23]The raw input module enables us to identify iron and steel input using the concordance table between HS and KKI provided by the BPS. Appendix A Table A.2 presents the industries that use iron and steel intensively.

[24]For customs data, we only keep manufacturing exporters and single KBLI industry exporters, using the concordance table between ISIC Rev4 and HS to match the relevant iron and steel using industry indicators, since the KBLI 2-digit code is the same as the first 2 digits of the ISIC Rev4 code. Both the manufacturing exporters and single KBLI industry exporters are defined as those firms with a share of exports larger than 90% in the corresponding industry.

coefficient of the interaction term between the dummy variable for year k and the iron and steel using industry indicator, C_j, η_k captures the additional changes to DEP_{it} in year k for those firms in the iron and steel using industries, over and beyond the common year k FE, η_t, besides any differences capture by industry FE, η_j. When DEP_{it} is firm DVAR, we expect η_k to be not statistically different from 0 for the years before the export ban (2012-2014), but that it turns positive post the export ban on nickel (2015-2022), consistent with a higher average DVAR for firms in the iron and steel using industries, over and beyond the changes in firm DVAR in the other industries. In contrast, when DEP_{it} measures firm size, while η_k is still expected to be not statistically different from 0 for year before the export ban, it would turn negative post the export ban, consistent with a smaller average firm size only in the iron and steel using industries, over and beyond the changes in firm size in the other industries.

Figure 5 presents the coefficients of the interaction term, η_k of regression (70) when the dependent variable is firm-level DVAR. The results indeed show that before the export ban, which was established in 2014, there is no statistically significant difference in the average DVAR for industries that use iron and steel versus the other industries, beyond what was captured by their respective industry FE. However, post the export ban, the average DVAR in those industries that use iron and steel more intensively is statistically significantly higher than before and is over and beyond changes in the other industries. This is consistent with our model prediction that the export ban on nickel causes the DVAR of those downstream industries that used iron and steel as inputs to be higher, driven by the fall of domestic price of iron and steel post the export ban and the consequent substitution of the imported steel with the domestic steel for firms in these industries. Thus, Figure 5 provides supportive evidence that the export ban on nickel may have achieved its intended goal of promoting domestic value-added in the downstream industries. Based on the results, from 2011 to 2020, the DVAR of industries that used iron and steel as inputs increased by 5.6%, which could lead to the aggregate DVAR to increase by 1.10%, given that these industries together account for about 19.7% of Indonesia's exports in 2020. This is against the backdrop of aggregate DVAR decline in Figure 4.[25]

[25]It should be noted that the export ban on nickel was temporarily removed in 2017 and reinstated in 2020, which explained the drop in DVAR in 2017 and the subsequent rise in 2020 as shown in Figure 5.

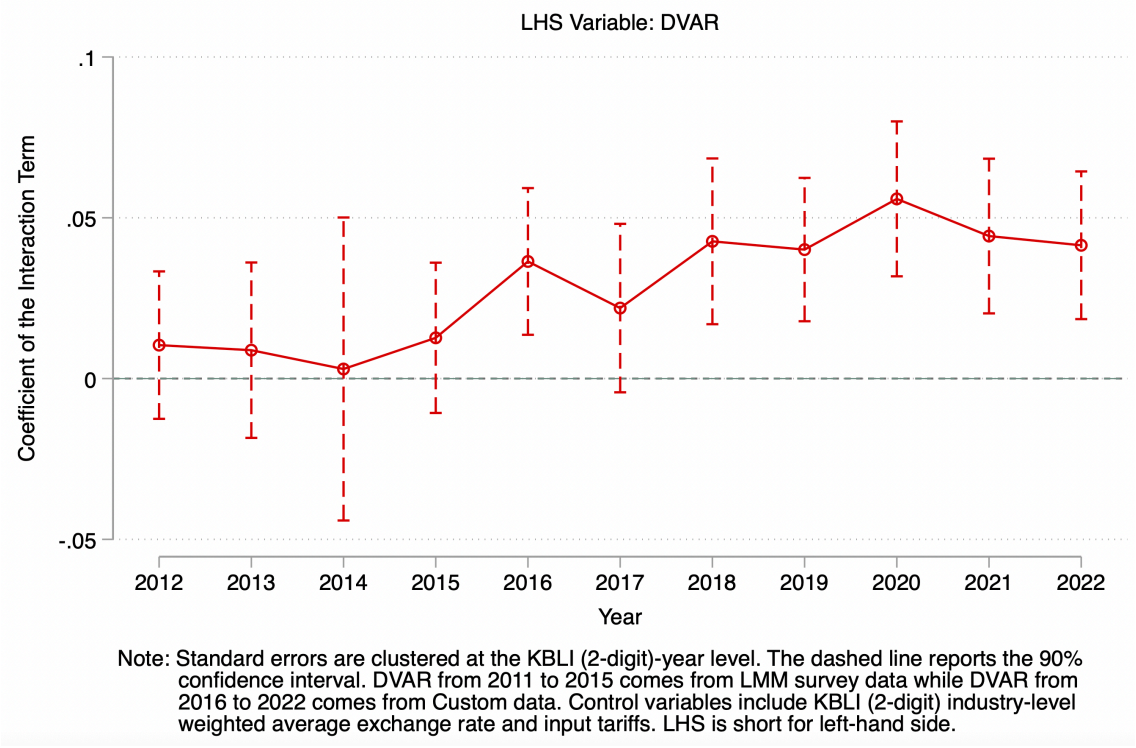

Figure 5: The Average DVAR of Iron and Steel Using Industries (Relative to Other Industries)

There could be other factors that raised firm DVAR for the industries that used iron and steel as inputs, besides the export ban on nickel. One such factor is the local content requirement (LCR) of Indonesia, which specifically targets the car industry. According to Fernando & Ing (2022), the current LCR regime in Indonesia can be traced back to 2006 when the government introduced Minister of Industry Regulation No. 10 of 2006 regarding the Use of Domestic Production Machineries to obtain Facilities on Import Duties for Goods and Materials. Indonesia's efforts to implement the LCR regulations were reinforced in 2018 when President Joko Widodo issued Presidential Decision No. 24 of 2018 to promote the use of domestic products. A similar ambition is also reflected in the Strategic Plan of the Ministry of Industry 2020–2024. Thus, throughout our sample period of 2011-2022, LCR was in place and no significant changes occurred around 2014, when DVAR is observed to be increased. The presence of LCR that are not targeting specific industries could therefore be absorbed by the year FE and cannot explain the result presented in Figure 5. However, for the LCR regulations introduced in 2018 with a specific focus on the car industry, the increase in DVAR presented in Figure 5 could be partially attributed to this. To rule out this confounding factor, we remove the automotive industry from the iron and steel-using industry and re-run the regression. Results are almost identical to Figure 5, confirming that the rise in DVAR for the iron and steel using industry is not driven by the automotive industry, which is targeted by the LCR implemented around 2018.

In contrast, Figure 6 presents the coefficients of the interaction term, η_k of regression (70), where

the dependent variable is firm size, measured as both the log of firm revenue and the log of firm employment. The results also show that before the export ban, which was established in 2014, there was no statistically significant difference in the average firm size for industries that use iron and steel versus the other industries, beyond what was captured by their respective industry FE. However, post the export ban, the average firm size in those industries that use iron and steel more intensively is significantly smaller than before, over and beyond changes in the other industries. This is consistent with our model's prediction. Given that firm size maps one on one to firm productivity in the model, Figure 6 provides the evidence that the iron and steel using industries suffer allocative productivity loss post the export ban on nickel, driven by smaller and lower productivity firms enter and stay in the industries, facilitated by lower domestic prices of nickel, iron and steel.

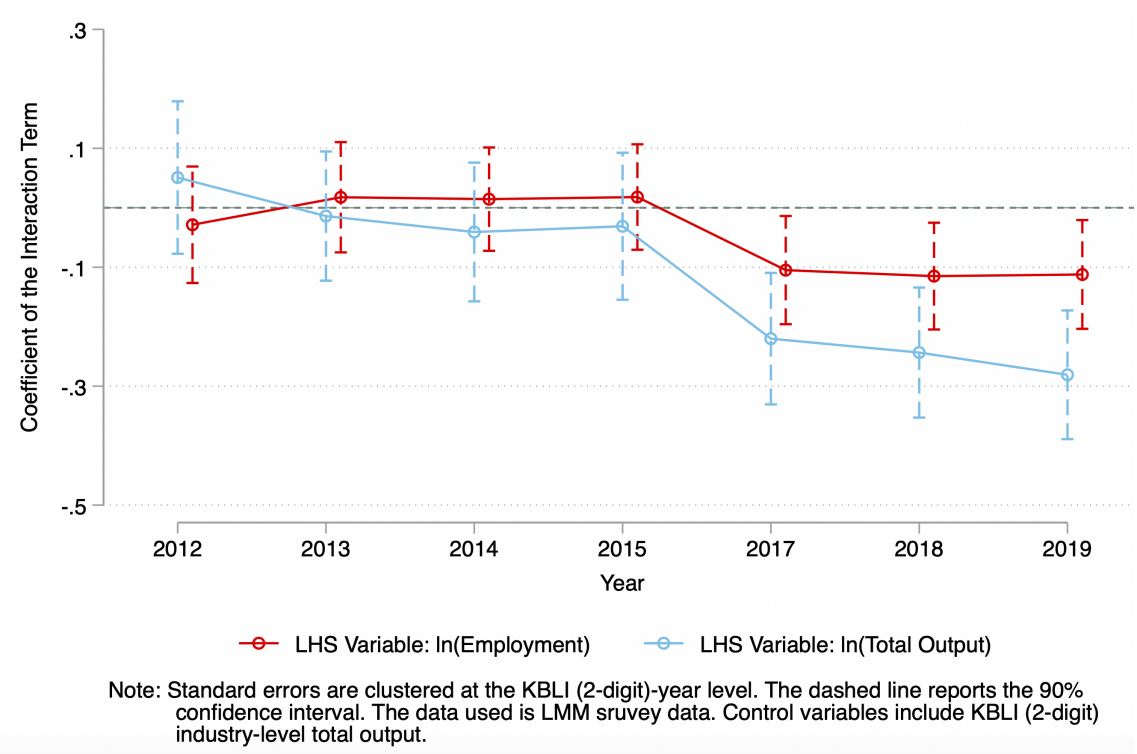

Figure 6: The Average Firm Size of Iron and Steel Using Industries (Relative to Other Industries)

Overall these regression results support hypotheses (1) and (2) that the export-ban on nickel has improved the domestic production capacity of iron and steel, which allows the exporting firms to substitute imported steel with domestic steel, hence concurrently pushing up the DVAR in exports, while depressing the average productivity and firm size in these industries.

5.3 Regression Analysis Focusing on Entrants in the Iron and Steel Using Industries

According to the model, the channel via which the average productivity and firm size of the downstream industries that use iron and steels are affected by the export ban on nickel is mainly through the entry of smaller and inefficient firms, as a result of the falling domestic price of iron and steels which pushed down the cutoff productivity in these industries (See 58), while firm DVAR is not affected by the new entrants (See 46). This section provides this collaborative evidence in support of Hypothesis 3, by comparing the DVAR, firm size, and the share of new entrants relative to the existing firms in the iron and steel using industries, pre and post the export ban. This is done by introducing an indicator variable, $E_{it} = 1$, if firm i is a new entrant in year t to (70), as specified as follows:

$$DEP_{it} = \eta_j + \eta_t + \sum_{k=0,2016}^{2019} \left(\eta_k \times \mathbb{1}_{\{k=t\}} \times C_j + \eta_k^{CE} \times \mathbb{1}_{\{k=t\}} \times C_j \times E_{it} \right) + \boldsymbol{X}\boldsymbol{\eta} + u_{it}. \quad (71)$$

Similar to (70), in this specification (71), the dependent variable, DEP_{it}, denotes firm-level DVAR or firm size. The industry FE, η_j, captures the average size of firms in each industry j, the year FE, η_t, captures the average firm size of all firms in year t, and η_k captures the additional changes for firms in the iron and steel using industries over and beyond firms in other industries in each year k. Unlike (70), here in (71), period 2011-2014 is combined to form year 0, which denotes the period before the export ban on nickel, with $k = 0$. This is because of there is only a small number of entrants in these industries, causing a very limited degree of freedom to estimate the coefficients for each year.

For LMM survey data from 2011 to 2014, entrant firms are defined as those firms with the year of establishment equal to the calendar year, with 2015 dropped from the sample due to missing establishment year information. For custom data from 2015 to 2019, entrant firms are those that first appeared in the sample, with 2015 dropped from the sample since it is the first available year of export data.

The coefficients of interests in (71) are η_k^{CE}, which are the coefficients of the interaction terms between the dummy variable for year k, the iron and steel using industry indicator, C_j, and the entrant indicator, E_{it}. η_k^{CE} thus captures the additional changes to DEP_{it} in year k for those entrant firms in the iron and steel using industries, over and beyond the incumbent firms in these industries. When DEP_{it} is firm-level DVAR, we expect η_k^{CE} to be not statistically different from 0 pre or post the export ban, because all firms in the same industries faced the same relative prices of domestic to imported steels and will have the same DVAR, despite the entrant status (see (46)). The finding of no distinguishable differences between the DVAR of the entrants and the incumbent in the iron and steel using industries would be suggestive that the upward trend in DVAR post the export ban in nickel for the iron and steel using industries in Figure 5 is not driven by the composition effect with higher DVAR entrants, but is driven by within firm changes in DVAR responding to the change in the price

of domestic iron and steel that are common across all firms in the same industries.

In contrast, when DEP_{it} measures firm size, η_0^{CE} is expected to be negative since younger firms are often smaller in size even for years before the export ban, and the magnitude of η_k^{CE} increases (more negative) post the export ban, consistent with the composition effect with even smaller average entrants in the iron and steel using industries relative to the incumbent firms due to the drop in the cutoff productivity driven by the fall in the domestic price of iron and steel. Note that in this specification, firm size is only measured by the log of firm revenue for 2011-2014, and the log of firm export for 2016-2019 due to data constraints. Nevertheless, given that other industries are included in the regression, any changes to firm size due to switching data sets have been controlled for. This is in addition to the argument that export revenue is proportional to total revenue in the model.

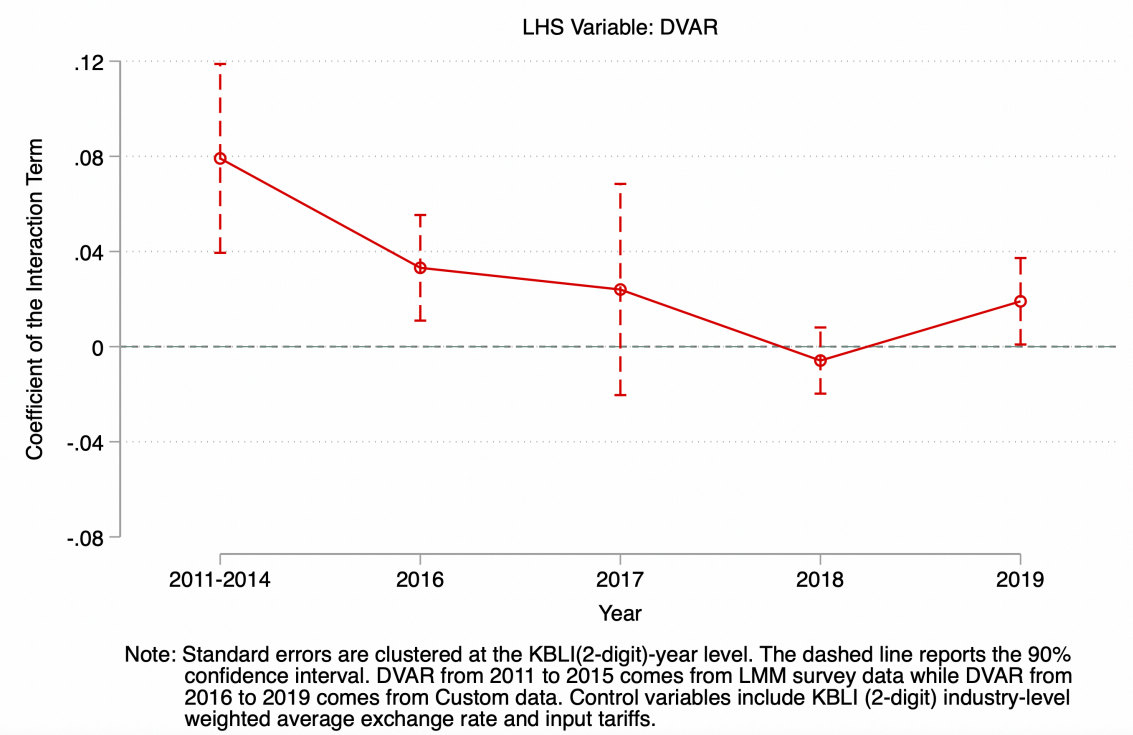

Figure 7: Average DVAR of Entrants Relative to Incumbents In Industries that Used Iron and Steel

Figure 7 presents the coefficients of the interaction term, η_k^{CE} of regression (71), where the dependent variable is firm-level DVAR, to show the time series changes in firm-level DVAR of entrants relative to the incumbent firms in the iron and steel using industries. While the results show that pre the export ban on nickel, entrants have higher DVAR relative to the incumbent firms in the iron and steel using industries, the differences vanish post the export ban. These results suggest that the upward trend observed in Figure 5 is not driven by the entrants with high DVAR post the export ban.

Figure 8 presents the coefficients of the interaction term, η_k^{CE} of regression (71), where the dependent variable is firm size, to show the time series changes in firm size of entrants relative to the

incumbent firms in the iron and steel using industries. As predicted, pre the export ban, entrants are smaller than the incumbents in the iron and steel using industries because they are younger, and the size differences enlarged post the export ban, indicating that entrants are even smaller in the iron and steel using industries. These results provide the collaborative evidence supporting the result presented in Figure 6, that post the export ban on nickel, the entry of smaller inefficient firms in the iron and steel using industries driven by the fall in the price of domestic iron and steel cause an allocative efficiency loss in these industries, manifest with a reduction in the average firm size.

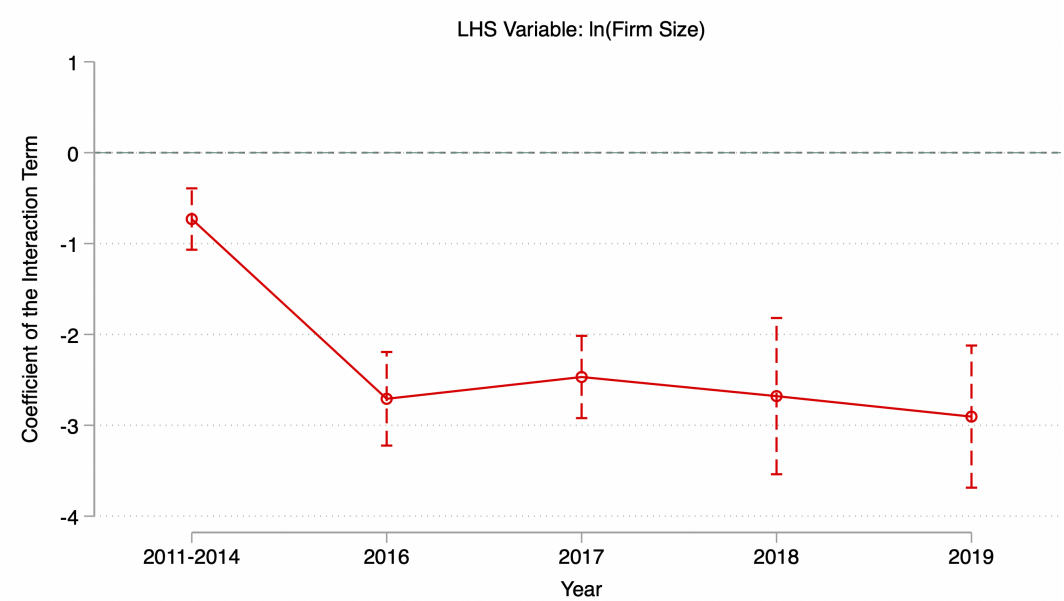

Figure 8: Average Size of Entrants Relative to Incumbents In Industries that Used Iron and Steel

Finally, we compare the share of new entrants in the iron and steels using industries to the other industries, pre and post the export ban according to the following firm level regression:

$$E_{it} = \eta_j + \eta_t + \sum_{k=0,2016}^{2019} \left(\eta_k^{ES} \times \mathbb{1}_{\{k=t\}} \times C_j \right) + \boldsymbol{X}\boldsymbol{\eta} + \mu_{it}, \tag{72}$$

where the dependent variable in (72) is now, E_{it}, the new entrance firm indicator variable. Given that E_{it} only takes on $\{0, 1\}$, the industry FE, η_j, captures the average E_{it}, which is the average share of firms that are new entrants in industry j. Likewise, the year FE, η_t, measures the average share of firms that are new entrants in year t. The coefficient of interests is η_k^{ES}, which shows the difference in the share of new entrants between industries with $C_j = 1$, which are the iron and steel-using industries, and the other industries. The results will be consistent with the model if η_k^{ES} is only positive and

significant post the export ban.

Figure 9 presents the coefficients of the interaction term, η_k^{ES}. As expected, before the export ban on nickel, the share of entrants in the iron and steel-using industries was not statistically significantly different from the other industries. However, after the export ban, the share of entrants in the iron and steel-using industries is significantly higher than that in the other industries, indicating that more entrants in the industries that used iron and steel, which is consistent with the model.

Overall all the results presented in this subsection is supportive of the Hypothesis 3 of the model that while the export ban on nickel pushes up the DVAR of the downstream industries that use iron and steel as inputs, it also decreases the cutoff productivity of these downstream industries, attracted smaller firms to enter the industries which led to a lower average firm size and a larger share of entrants which are smaller than the incumbents of these industries.

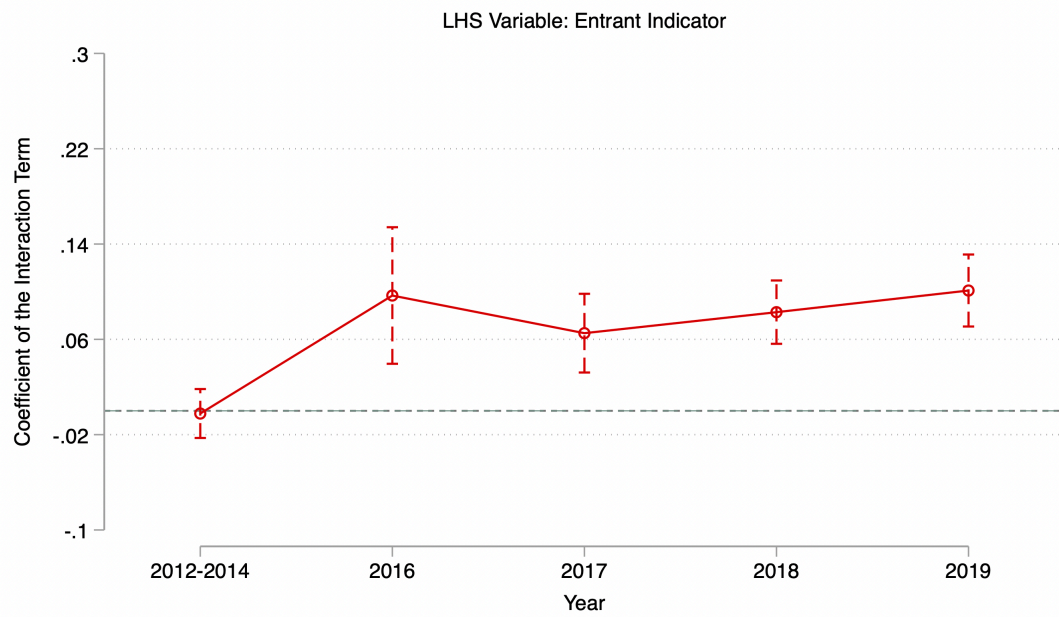

Figure 9: The Share of Entrants in the Industries that Used Iron and Steel Relative to Other Industries

Finally, all the above analysis hinges on the assumption that the export ban on nickel caused the domestic price of iron and steel to drop. Figure 10 presents the evidence based on the published statistics of the BPS. The domestic price of iron started falling in 2015 and continued to fall until July 2017. From 2016 to 2019, Indonesia's Rupiah depreciated by more than 6%, which led to higher prices across all products, including domestic iron and steel. Thus, it is important to control for year FE as well as the exchange rate in the analysis to remove the influence of currency depreciation.

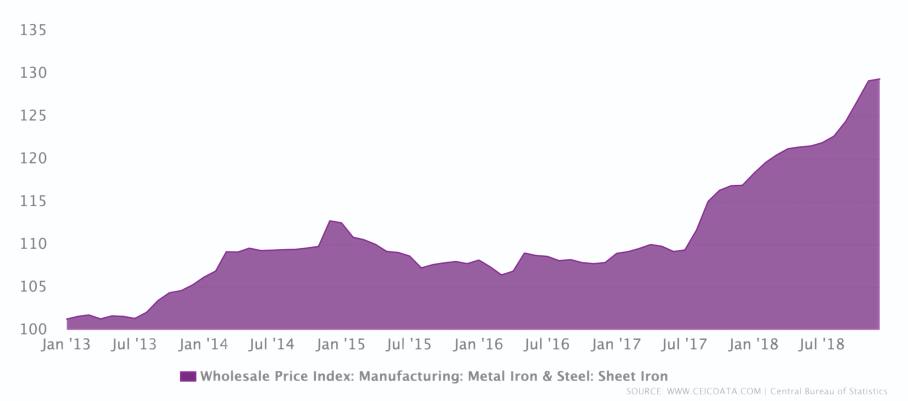

Figure 10: Domestic Price of Iron

5.4 Field Mission

A field mission was conducted in April 2025 in Indonesia. We interviewed and engaged with private sector stakeholders involved in the export ban on nickel, including representatives in various related industries such as nickel miners, iron and steel firms, automotive and automotive parts manufacturers, and battery makers, as well as researchers in think tanks and universities. The purpose of the mission is to gain a better understanding of the local environment and structure of the Indonesian nickel-related industries, as well as to listen to the on-the-ground opinions on the export ban, to share our empirical findings, and to gather collaborating or contradictory evidence.

The main findings of the field mission are threefold. First, following the implementation of the export ban on nickel in 2014, the domestic price of nickel declined, attributable to the monopsony power exercised by the midstream smelting sectors that benefited from the significant entry barriers and technological requirements.[26] Second, as aforementioned, nickel reserves in Indonesia predominantly consist of laterite with high iron content, which is suitable for producing stainless steel and carbon steel. Stainless steel is used domestically to make bolts, nuts, wires, mufflers (for both automotive and two-wheelers), seatbelt buckles, metal pipes, electric wiring, and furniture, while carbon steel is mainly used in the construction sector as well as to produce any structural components of vehicles, such as automotive seat frames. Currently, there is no local demand for nickel to produce batteries, due to the absence of nickel-based battery production in Indonesia. Third, despite progress in the development of nickel smelting and processing sectors, the consensus is that the positive economic benefits in terms of jobs and growth are rather localized and not widespread, and there are no spill-overs to unrelated industries or geographical areas.

Overall, the findings of this field mission collaborate well with our empirical findings.

[26]Note that the Indonesian Nickel Miners Association (APNI) was established in 2017 to counterbalance the monopsony power of midstream smelting sectors and regulate transaction terms between the mining sector and the smelting sector. After 2020, the APNI has gradually gained substantial influence over domestic nickel pricing. In light of this structural shift and limitations in post-2020 data availability, our analysis primarily focuses on the period ending in 2019.

6 Conclusions

This paper studied the impacts of the export ban on nickel in Indonesia on the domestic value-added of downstream industries and the potential unintended effects of the export ban. We first presented a three-sector model showing how the export ban on nickel in the upstream industry may have affected the domestic value-added of the downstream iron and steel using industries through a midstream monopsony in the iron and steel industry that uses nickel as inputs to produce iron and steel. The export ban on nickel enabled the monopsony steel firm to depress the domestic price of nickel to produce domestic iron and steel at a lower cost, leading to a lower domestic price of iron and steel, which subsequently reduced the material cost for downstream iron and steel using industries, attracting smaller and inefficient firms to enter the downstream industries, resulting in a higher domestic value-added in exports and lower average productivity. Thus, while the export ban on nickel may have achieved its intended objective of raising domestic value-added of the downstream industries, it also concurrently generated allocative inefficiency in those industries and incurred productivity loss.

To support the model empirically, this paper combined the customs transaction data of Indonesia from 2015 to 2022, with the survey data of manufacturing firms from 2011 to 2015, and from 2017 to 2019. Results show that DVAR of the iron and steel using industries increased by 5.6% from 2011 to 2020, together with around 19.7% of their share in total exports in 2020, implying that the DVAR of aggregate exports rose by 1.10%. Concurrently, these industries also observed a decline in the average firm size, which is a proxy for industry productivity. In addition, the DVAR of the entrants in the iron and steel using industries was not different from the incumbent firms, while their firm size was significantly smaller, with a large share of entrants in the iron and steel using industries post the export ban. These results are consistent with the model. In addition, the findings obtained from the field investigation in Indonesia involving industry participants and researchers also echoed our model framework and empirical findings, offering more external credibility to our results.

Overall, the results of this paper suggest that although implementation of the export ban on nickel may have had a positive impact on Indonesia in increasing domestic value-added in exports, the policy also generated distortions through lowering the cost of nickel and consequently reducing the production costs for the downstream industries, which led to inefficient firms entering the market and pushing down the aggregate productivity. In addition, the high entry costs of the midstream industry along the nickel supply chain empowered the incumbent steel firms to possess monopsony power in the nickel market, which implies that the gain in DVAR of the downstream sector was also at the expense of the upstream sector, if the downstream market was not competitive enough.

In light of this, it is important to emphasize that in addition to the export ban on nickel to promote downstream industrialization, it is necessary to implement complementary policies to address the plausible allocative inefficiencies due to insufficient competition caused by the export ban. One

such complementary policy would be to liberalize the downstream industries such that market forces through imports may reduce allocative inefficiencies. Another complementary policy would be to promote exporting, allowing global competition to trim the inefficiencies in domestic production.

Finally, this paper did not consider any social or environmental impacts of the export ban on nickel, or the political rent-seeking of various parties. Could Indonesia do better than the export ban? How to define "do better"? These outside dimensions missing from this paper may be equally important for the consideration of the development strategy for the country, in the short or long run.

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Appendix A Industry Classification, Data Filtering, and Variable Construction

Table A.1: Industry Classification Based on HS 2 Code

Industry	Sub-Industry	HS 2 Code
Agriculture, Food and Beverage	Agriculture	1-15
	Foodstuffs and Beverage	16-24
Plastic and Rubber	Plastic and Rubber	39-40
Furniture and Wood Products	Wood Products	44-49
	Furniture	94
Mineral, Stone, Glass, Chemicals and Allied	Chemicals and Allied	28-38
	Mineral	25-27
	Stone and Glass	68-71
Textile, Apparel, Footwear, Headgear, Raw Hides and Leather	Raw hides and Leather	41-43
	Textiles	50-60, 63
	Apparel-Knitwear	61
	Apparel-Woven	62
	Footwear and Headgear	64-67
Metals and Transportation	Metals	72-83
	Transportation	86-89
Machinery and Electrical	Machinery	84
	Electrical	85
Optical Equipment	Optical Equipment	90-92
NA	Toys	95
	Arms and Ammunition	93
	Miscellaneous	96
	Art and Collector Piece and Antique	97

Data Filtering We clean the Indonesian customs transaction data using the following steps. First, in terms of trade regime, we keep ordinary exports and imports for sale. Second, we remove export and import transactions with Indonesia itself. Third, we dropped zero trade values in exports and imports. Fourth, we remove capital imports from firm-year-level imports and use firms' capital imports as the proxy variable for investment, which is used to control unobserved productivity in export revenue

function estimation. The capital goods are identified from the Broad Economic Category (BEC), the correspondence tables between HS 2012, HS 2017 and BEC 4 come from UN.[27] Finally, we drop observations with missing HS product codes and only keep firms engaging in both import and export.

Table A.2: KBLI 2-digit Level Industries that Use Iron and Steel Intensively

KBLI	Industry Description	Indicator
10	Food Industry	No
11	Beverage Industry	No
12	Tobacco Processing Industry	No
13	Textile Industry	No
14	Ready-made Garment Industry	No
15	Leather Industry, Leather Goods, and Footwear	No
16	Wood Industry (Excluding Furniture) and Products Made from Bamboo, Rattan, and Similar Materials	No
17	Paper and Paper Products Industry	No
18	Printing and Reproduction of Recorded Media Industry	No
19	Coal and Crude Oil Processing Industry	Yes
20	Chemical and Chemical Product Industry	No
21	Pharmaceutical Industry, Chemical Drugs, and Traditional Medicines	No
22	Rubber Industry, Rubber and Plastic Products	No
23	Non-Metallic Mineral Industry	No
24	Basic Metals Industry	Yes
25	Other Non-Machinery and Equipment Metal Product Industry	Yes
26	Computer, Electronic, and Optical Equipment Industry	No
27	Electrical Equipment Industry	No
28	Machinery and Equipment Industry, etc.	Yes
29	Motor Vehicle, Trailer, and Semi-Trailer Industry	Yes
30	Other Transport Equipment Industry	Yes
31	Furniture Industry	No
32	Other Processing Industries	Yes
33	Machinery and Equipment Repair and Installation	Yes

Notes: Indicator denotes whether the industry use iron and steel intensively, with Yes corresponds to iron and steel using industries.

[27] As pointed out by Levinsohn & Petrin (2003), a large fraction of firms in developing countries does not invest. For our final sample, nearly 1/3 firms do not import capital goods.