The (Un)intended Consequences of Export Restrictions: Evidence from Indonesia

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Abstract

An increasing number of developing countries are restricting non-renewable natural resource exports to encourage domestic processing, move up the global value chain, and spur local development. This paper studies the local labor-market effects of Indonesia's voluntary export ban on unprocessed nickel and bauxite in 2014, previously a major source of export revenue. Exploiting plausibly exogenous variation in the timing of the ban, the opening of new processing facilities, and the location of Indonesia's mineral deposits, we find that—after an initial dip—major investments in nickel processing increased employment in nickel mining districts. New smelters drove structural change, shifting jobs from agriculture to mining and manufacturing. In sharp contrast, the ban only led to very limited investment in bauxite processing, causing bauxite production and local employment to fall. We also find that nickel processing raised mining employment in Indonesia's coal districts, which provide the main source of energy for nickel processing.

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1 Introduction

Industrial raw materials such as nickel, cobalt and rare earths are critical inputs in countless production processes, including renewable energy, lithium batteries, and permanent magnets. Globalization has allowed advanced economies to source raw materials worldwide and specialize in the higher value-added segments of global supply chains. In contrast, developing countries often merely act as suppliers of raw materials and struggle to move up the global value chain, such as by establishing domestic industries further downstream.[1] To address imbalances such as these, political leaders in developing countries have long experimented with import substitution and industrial policy more generally. These policy experiments—including import tariffs, subsidies, tax incentives, deliberate neutrality towards markets, and the targeted export promotion of promising industries—have typically produced mixed and highly context-dependent results (Harrison & Rodríguez-Clare, 2010; Juhász, Lane, & Rodrik, 2024; Reed, 2024). Lately, another form of industrial policy has grown in popularity among developing and emerging economies: export restrictions on industrial raw materials (OECD, 2025). Among 80 countries surveyed, covering 97% of the world production of minerals and metals, the number of export restrictions increased five-fold between 2009 and 2023, with 34 countries applying full export bans on at least one industrial raw material by 2023. While their stated goal is typically to promote downstream processing industries, boost local employment, and accelerate structural transformation, little is known about their effectiveness for development.

In this paper, we provide novel evidence on whether such policies can indeed promote (local) economic development. To do this, we exploit detailed, locally-representative data from the annual labor force survey of Indonesia, a leading raw material producer whose government has targeted manufacturing as the national economy's principal growth engine. In 2014, Indonesia banned the export of raw nickel and bauxite, and several other minerals that are comparatively less relevant for the country. The aim was to stimulate domestic mineral processing and, later, manufacturing sectors as far downstream as battery and EV production (MINERBA, 2021, p. ii-iii). Moreover, a stated goal was to

[1] For recent developments in the critical-minerals industry, see IEA (2025). For projected mineral demand as a result of the energy transition to renewable energy sources, see IMF (2021).

promote local economic development in its, often economically lagging, mining regions—not only by generating employment in the processing sector but also by creating jobs in supporting industries and services (MINERBA, 2021, p. 59).[2] With Indonesia being the world's largest exporter of nickel ore and bauxite (the main input for aluminum production) before the ban, industry analysts considered the export restrictions "the biggest supply risk facing base metals in a long time, particularly nickel and aluminum" (Financial Times, 2014). This was not least because the policy came as a surprise—despite being announced as early as 2009—due to widespread skepticism that Indonesia would indeed forego the substantial revenue accrued by mineral ore exports.

A priori, the effects of export restrictions on raw materials are unclear. Absent prior development of domestic processing capacity, mining output is bound to decline following the restrictions, negatively affecting export revenue and employment. Conversely, investment into mineral processing can (at least partly) offset this decline, promote manufacturing employment in processing areas, and potentially generate spillovers into other local sectors or regions supplying inputs. However, adding processing capacity also carries the risk of negative environmental effects, which could harm agricultural employment and/or local living standards. For substantial investment into domestic processing to actually occur after restricting the export of raw materials, two crucial factors must be in place: (i) a sufficiently large wedge between domestic and international raw material prices following the export restrictions (which hinges on pre-restriction market shares and the ability of previous foreign buyers to switch to other suppliers and/or material substitutes in their production processes), and (ii) cheap domestic access to the other inputs that the processing industry requires for production.

By one simple measure, a back-of-the-envelope calculation suggests that the policy was very successful for nickel: the total export value of all nickel-containing ores and derivatives increased from US$ 3.1 billion in 2013 to US$ 19.2 billion in 2023, while nickel ore prices appreciated only 46%. Of this, raw ore smelted into processed nickel products

[2] Indonesia's president during 2014-2024, Joko Widodo, stated the following (in the context of building mineral processing plants): "We hope that the people living around this industry will feel the benefits, both in terms of employment and new business opportunities for small and medium enterprises and others, thereby increasing economic growth in the provinces and districts where this industry is located." (for the original quote in Bahasa Indonesia, see https://setkab.go.id/resmikan-smelter-di-konawe-presiden-jokowi-akan-tingkatkan-nilai-tambah-nikel/).

represented only US$ 1.3 billion in 2013 but the entire US$ 19.2 billion in 2023. This was a result of Indonesia attracting substantial investment into domestic nickel processing after the ban. In contrast, (investment in) the processing of bauxite into alumina did not increase markedly after 2014. The main reason was that previous buyers of Indonesian bauxite could easily switch to alternative suppliers, sharply reducing incentives to invest in Indonesian bauxite processing plants. As a result, the export value of all bauxite-containing ores, alumina, and aluminum decreased from US$ 2.4 billion in 2013 to US$ 1.6 billion in 2023, despite bauxite prices appreciating by 11%.

However, how did these aggregate effects translate into local employment, another key goal of the policy? We combine detailed and representative labor-market survey data over 2009-2023 with district-level data on mineral-specific endowments and processing capacity to identify the effects of the export ban on local labor market outcomes. In separate subsections, we focus on these effects in mining districts, processing districts, and districts supplying the crucial energy source (coal) to the processing industry, respectively. We do so using a shift-share, as well as an event-study type, empirical design. Both exploit plausibly exogenous variation in the timing of the export restrictions, the opening of new processing facilities, as well as in the spatial distribution of Indonesia's mineral deposits.

We find positive employment effects of the export ban in nickel districts. Specifically, in the average nickel-endowed district, the export ban led to a sustained increase in aggregate employment by 3.0%, corresponding to 3,400 jobs in the average nickel district. This positive effect is primarily driven by a rise in manufacturing and service sector employment. Mining employment falls immediately after the imposition of the export ban, but recovers as domestic nickel processing capacity picks up a few years later. By contrast, agricultural employment initially rises and later drops, consistent with idle mining workers initially moving into agriculture but later moving back as the mining sector rebounds. These effects are present regardless of whether the district hosts one of the new nickel smelters or not.

In sharp contrast to nickel, the export ban on bauxite did not have the intended consequence of stimulating local employment. With (new) investment in domestic bauxite processing largely lacking and bauxite output thus remaining below pre-ban levels, we find that the ban actually had a lasting negative impact on employment in bauxite-endowed districts. In terms of magnitude, the employment reduction amounted to roughly 2,500 lost jobs in the average bauxite district compared to before the ban. This is primarily driven by mining workers losing their job, with only few of those workers finding a new job in the mining districts' agriculture, services or manufacturing sector.

In a second step, we study the local impact of nickel smelter openings. For identification, we exploit two factors. First, observing the actual locations of smelters that were newly built after the ban, it is very unlikely that smelter location decisions were made based on (unobserved) time-varying local trends in sectoral employment. They are rather based on local time-invariant characteristics, notably the ex-ante availability of nearby nickel endowments, and transportation infrastructure such as ports. Second, the exact timing of a smelter opening is also very unlikely to be related to local labor market trends. This is because planning and construction are done by large companies without ties to the specific district, and because the most relevant permits for these projects of national strategic importance are typically granted at higher administrative levels of government than the local district. We find that a district's manufacturing employment rises upon the opening of a new smelter, but this increase is entirely offset by a reduction in agricultural employment. On the one hand, this can be explained by agricultural workers finding a new job in the nickel mining or processing industry, either in their own or a neighboring district. On the other hand, media and policy reports suggest that local agriculture production suffers significantly from the negative environmental and health effects of nickel processing and mining. New smelter openings thus contribute to a district's structural transformation, but add little in terms of overall employment.

In our final set of results, we identify the potential spillovers of Indonesia's nickel processing boom to the labor markets of coal-endowed districts, even though coal was completely left out of Indonesia's export restrictions. Coal is important because nickel processing requires vast amounts of energy, which are provided by off-grid coal power plants that are built in close vicinity of nickel processing plants and whose large coal demand sparked a marked increase in Indonesian coal production.[3] We find that while total employment is

[3]Considering that burning coal emits vast amounts of CO2 and other (local) pollutants relative to all other sources of energy, this boom in coal mining (and burning) is an interesting side-effect of a policy that ultimately aims to produce inputs into renewable energy, such as batteries for electric cars.

unaffected, mining employment significantly rises in coal districts following the expansion of Indonesia's nickel processing capacity with suggestive evidence that these workers are primarily coming from the local services sector.

From a policy perspective, our findings provide a strong message to other countries considering the use of export restrictions on raw materials with the aim of moving up the global value chain: such restrictions must be accompanied by a swift increase in domestic processing capacity to promote local development, while failing to do so implies foregone export revenue and local job losses. In anticipating the commodity-specific effects of an export ban, and thus for deciding the set of commodities to include in the ban, policymakers must carefully consider commodity-specific factors such as ex-ante domestic processing expertise and capacity, the expected response of pre-ban buyers and international markets to a ban, the domestic availability of other (crucial) inputs into the processing industry, and the likelihood of attracting foreign direct investment into processing. In the Indonesian case, these factors differed markedly across nickel and bauxite, explaining the mixed fate of its different mining regions after 2014.

Our paper contributes to several strands of literature. First, we add to the body of work analyzing the impact of voluntary export restrictions. Most of this literature has focused on export restrictions on manufactured goods, whose production depends less on local endowments and can therefore be relocated more easily across space. For example, Dei (1985) uses a two-country model to study how export restrictions abroad affect the domestic production of the same good, while Takacs (1978) compares how equilibrium prices, production and trade differ across tariffs, import quotas, and export restrictions. Other studies focus on export restrictions on final goods that apply towards a specific trade partner who favors the restriction to protect domestic industry.[4] We contribute to these studies by focusing on the domestic effect of export restrictions that function as industrial policy and are undesirable for trade partners (as evidenced by a formal complaint

[4]For example, Berry, Levinsohn, and Pakes (1999) analyze the impact of restrictions on Japanese car exports to the US resulting from US political pressure; and Rosendorff (1996) and Konishi, Saggi, and Weber (1999) theorize under which circumstances it is preferable to pressure the trading partner to introduce export restrictions rather than impose a tariff.

to Indonesia's export ban at the WTO[5]). Recently, export restrictions on raw materials have been studied in other contexts. Alfaro, Fadinger, Schymik, and Virananda (2025) study export restrictions on rare earths by China and the effect of these on downstream innovation by trade partners. Garred (2018) documents how China used such restrictions after its 2001 accession to the WTO to partially restore pre-WTO trade policy, finding positive effects of these upstream export restrictions on downstream product exports. We contribute to these studies by focusing on the local labor market effects in raw material-producing and -processing regions as well as on the spillovers along the supply chain, rather than on aggregate downstream product exports. Moreover, our context differs markedly in that Indonesia's motivation for export restrictions on raw materials was to significantly expand its underdeveloped processing sector, while China was already a key player in global mineral processing when it imposed export restrictions on the associated raw materials.

Second, our paper adds to a set of descriptive policy reports that specifically discuss (the impact of) Indonesia's 2014 export ban (Guberman, Schreiber, & Perry, 2024; UNCTAD, 2017; USGS, 2016). As the first paper to provide plausibly causal evidence on the labor market effects of Indonesia's export ban, we add substantial value to this largely qualitative literature.

Third, our paper is related to a large body of work on the local economic effects of natural resource-related shocks (e.g. Allcott & Keniston, 2018; Aragón & Rud, 2013; Caselli & Michaels, 2013; De Haas & Poelhekke, 2019; Pelzl & Poelhekke, 2021). We contribute to this literature by providing novel evidence on the effects that nationwide export restrictions on natural resources have on the local economies that extract these resources, process them, or provide relevant inputs to the processing sector.

Finally, we speak to the literature studying the local labor-market effects of trade liberalization in emerging economies (e.g. Dix-Carneiro & Kovak, 2017; Erten, Leight, & Tregenna, 2019; McCaig & Pavcnik, 2018; Topalova, 2010). We add to these papers by studying the effects of a trade policy that instead creates substantial *barriers* to trade,

[5] The complaint was brought forward by the European Union in 2019 and was supported by many third parties such as the US and China. The outcome is still uncertain: the case is under appeal as of December 2022 but suspended since 2023 because of the current non-operational situation of the Appellate Body (WTO, 2022, accessed Oct. 2025).

which is increasingly popular among resource-rich developing countries.

The rest of the paper is structured as follows. Section 2 provides a brief conceptual framework. Section 3 describes the Indonesian context, where we discuss the specifics of the export restrictions, their timing, investment in the processing industry, other policies, and the spatial scope and structure of mining and labor markets that inform the interpretation of results. Section 4 documents our data sources and key variables. Section 5 presents our empirical strategy and results. Specifically, Section 5.1 analyzes the effect of the export ban on labor market outcomes in nickel and bauxite mining districts; Section 5.2 studies the local effects in districts hosting Indonesia's rapidly expanding nickel *processing* industry; and Section 5.3 analyzes the labor market spillovers to districts providing a crucial input to nickel processing: coal. Finally, Section 6 presents robustness checks and Section 7 concludes.

2 Conceptual framework

In this section, we build the intuition on how an export ban on raw materials can affect local labor markets and the establishment of a downstream processing industry.

To fix ideas, suppose an export ban is imposed unexpectedly.[6] First, no longer able to serve foreign demand, domestic mining companies are left with the domestic processing industry as the only possible buyer of their output. As a result, at least in the short run, an oligopsony emerges, driving down domestic raw material prices compared to global markets. Lower demand for raw materials reduces labor demand in the mining sector, leading to a decline in its employment and to downward pressure on wages. This increases the supply of labor to non-mining sectors (if labor can freely switch between sectors), also lowering wages and raising employment in non-mining sectors. The more limited migration is, the more concentrated these effects are in the mining regions themselves. The deepest mining slumps, and associated labor market effects, likely occur in regions that produce export restricted minerals for which Indonesia has limited or no processing capacity at the time of the export ban.

Second, lower input prices increase the profitability of processing plants, which may at-

[6]We discuss the timeline of the Indonesian export ban in the next section.

tract investment into the domestic processing sector, increasing capacity in the medium term. One decision criterion for domestic or foreign investors is the extent (and duration) to which the export ban drives a wedge between international and domestic prices of a specific raw material. With foreign demand for global raw materials unchanged, global prices will rise (increasing the wedge), particularly when the country imposing the export ban holds a large share of the pre-ban global market. This effect may be only temporary if the price increase leads to higher mine capacity utilization and/or investment in mining capacity in other countries; however, recent evidence documenting an average duration of 18 years between discovery and mine production (S&P Global, 2024) imply that adding extra capacity offers little immediate relief from export restrictions. Moreover, technological substitution between different minerals is often very costly or infeasible, due to the distinctive properties brought by each mineral to its downstream applications (Graedel, Harper, Nassar, & Reck, 2013). Beyond raw material prices, another decision criterion for potential investors is the competitiveness of the domestic processing industry in terms of other inputs, such as labor, energy, or infrastructure.

If a boom in the domestic processing sector materializes, it will increase local employment in manufacturing and potentially other industries such as services, unless processing plants displace other economic activity (for instance by causing environmental damage). At the same time, such a boom would raise demand for raw materials, leading to a rebound in mining activity in mineral-endowed districts. The spatial distribution of these positive effects depends on the location choices of the processing industry. If most new plants are built near mines, then mining districts may benefit most from the ban—unless mining output drops well below pre-ban levels despite increased processing capacity. While factors such as transportation costs or pre-existing trade infrastructure favor co-location of mines and processing plants, other factors such as the cost and skill composition of labor might induce the processing industry to locate in non-mining districts. Besides the opportunity of hosting new processing plants, non-mining districts could also benefit from the export ban by supplying inputs to such plants. For example, an expanding processing industry could raise labor demand in coal mining districts—and thus employment and wages, since mineral processing is very energy-intensive (and in some cases also requires coal as primary input).

Eventually, other industries even further downstream of mining might also benefit from the export ban on raw materials. Specifically, lower domestic prices for raw mineral ores can lower domestic prices for processed minerals, lowering input costs for downstream industries as long as (i) processed minerals are not (entirely) shipped abroad, and (ii) the decrease in domestic raw material prices push the domestic price of processed minerals below the price on world markets. If industries downstream of processing indeed face lower input costs following the export ban on raw materials, labor demand in districts that are able to attract these downstream industries will increase, raising employment and wages.

3 Background

Context. Indonesia has very large mineral reserves. The share of (non-oil and gas) mining in GDP ranged from about 4% to 8% annually between 2000 and 2023. During 2003-13, Indonesian mineral ore exports increased considerably, raising the country's share in the global nickel ore market from 36 to 55%, and its bauxite share from 5 to 47%. As more and more unprocessed minerals were shipped overseas, mainly to China, Indonesian policymakers became concerned that these finite resources were generating too little revenue, offering limited benefits to Indonesia's overall economic development (Warburton, 2017).[7] This led to the adoption of Mining Law 4/2009 in 2009, which proposed imposing restrictions on the export of a variety minerals in their raw form, starting in 2014. The goal of the export restrictions was to stimulate domestic mineral processing and industries further downstream, and promote local employment in mining regions (MINERBA, 2021).

Restrictions by mineral and over time. The stringency of the export restrictions and their implications varied by mineral (see also Warburton, 2017). Nickel ore and bauxite, two of the most important minerals mined in Indonesia—with most of pre-2014 output being exported—were subject to a strict export ban from 2014 onward. Indonesia's other two major minerals—copper and iron ore (see Figure OA3)—faced less

[7]See Online Appendix Section OA1.6 for an overview of China's role in Indonesia's export market for raw and processed nickel and bauxite in the period 2007-2023. All data on mineral export volumes are sourced from Comtrade. Data on the share of mining in GDP are sourced from Indonesia's national statistical agency Budan Pusat Statistik (BPS).

stringent restrictions, with exports still permitted conditional on a sufficiently high metal content (15% for copper, 62% for iron ore; see PwC, 2014), subject to an export tax.[8] Other (quantitatively less important) minerals such as gold, manganese, or tin were also subject to a strict export ban, but this had limited consequences since virtually all output was already processed domestically before 2014.

The stringency of the export restrictions also varied over time. In 2017, having faced substantial export revenue losses as a result of the export restrictions, Indonesia temporarily relaxed the policy for multiple minerals including nickel and bauxite. The new regulation again allowed unprocessed ore exports, but only on the important condition that individual companies construct processing facilities and regularly document their progress against pre-approved milestones to the Ministry of Energy and Mineral Resources. However, in 2020 Indonesia reinstated the full ban on nickel exports (to "accelerate the development of smelters"), and in 2023 it did the same for bauxite (to "stimulate domestic bauxite processing").[9] Given the importance of nickel and bauxite in Indonesia's mineral production and exports and the stringency of the export restrictions on these two minerals, we focus on nickel and bauxite from now on.[10]

Were the export restrictions unexpected? After the announcement of the export ban in 2009, there were strong doubts in the mineral industry that the government would indeed follow up and forgo the substantial revenue from nickel ore and bauxite exports (Warburton, 2017). The actual imposition and strict enforcement of the ban on 12 January 2014 then came as a surprise, as highlighted by industry experts at the time. For example, base metals analyst Gayle Berry stated in December 2013, when the evidence

[8]These (last-minute) exemptions from the ban have been attributed to lobbying of Indonesia's copper industry dominated by US mining giants Freeport and Newmont (Clifford Chance, 2014; Reuters, 2014d). Besides lobbying against the ban, these two companies have also been described as influential in bringing down the export tax from an initial 25% to below 10% (conditional on reaching smelter development milestones) by mid-2014, following disputes with the government (Reuters, 2014c). In contrast, the Indonesian nickel and bauxite industry have been described as more fragmented, and thus not having sufficient bargaining power to successfully lobby for changes in export regulations (Warburton, 2018).

[9]The full ban on nickel exports was announced in September 2019. The cited statement about nickel was made by Bambang Gatot Ariyono, Director General of Minerals and Coal at Indonesia's Ministry of Energy and Mineral Resources; see https://www.esdm.go.id/id/media-center/arsip-berita/bijih-nikel-tidak-boleh-diekspor-lagi-per-januari-2020. The full ban on bauxite exports was announced in December 2022. The cited statement was made by then-President Joko Widodo; see https://setkab.go.id/en/govt-to-impose-export-ban-on-bauxite-ore-june-next-year.

[10]See Section OA1 for a detailed description of the export restrictions, production, exports, value, and location of all minerals. In our empirical analysis, we account for the export restrictions imposed on the other minerals.

was mounting that the ban would actually be implemented: "The market up until now had been pretty complacent about the ban. A lot of people were of the view that in the past the Indonesians haven't gone ahead with regulation and bans that they'd spoken about, so [*they*] didn't believe that it would happen." (The Wall Street Journal, 2013). Moreover, industry specialist Andy Home emphasized that this belief partly persisted right until the ban's actual implementation in early 2014, stating that "[*r*]ight up until the Jan. 12 deadline the consensus view was that the Indonesian authorities would fudge the issue, most likely in the form of wide-ranging exemptions" (Reuters, 2014b). Global nickel ore and bauxite prices increased markedly right after the export ban went through (Reuters, 2015; Wall Street Journal, 2014), further corroborating the surprise element in the ban implementation. Nonetheless, China and other pre-2014 buyers of Indonesian nickel ore and bauxite did preemptively increase imports towards the end of 2013, in case the ban would indeed go ahead as announced back in 2009 (see e.g. Reuters, 2013; USGS, 2016). This helps explain the large nickel and bauxite production and export volumes in 2013 shown in Figure 1 (USGS, 2016). The implication is that while the actual implementation and enforcement of the export ban largely came as a surprise, there was some degree of anticipation shortly before the ban, which may have affected (mining) employment in nickel and bauxite districts in 2013. We explicitly account for this when interpreting our findings, also conducting several robustness checks to verify the sensitivity of our findings to any possible (last-minute) anticipation.

Pre-ban investment in downstream processing capacity. Consistent with the widespread and long-lasting doubts about the actual implementation of the export ban, Indonesia's domestic processing industry did not experience much investment over 2009-13. In fact, nickel and bauxite processing capacity remained virtually unchanged throughout this period (see Figure 2). In 2013, the country had only two (small) operational nickel smelters on Sulawesi (one dating back to the 1970s, the other opened in 2010), and one new smelter opened that year on Java. These three smelters jointly processed 11% of domestic nickel ore production into ferronickel and nickel matte, two distinct processed nickel products.[11] Domestic capacity for processing bauxite into alumina (which can be further processed into aluminum) was entirely absent in 2013, with all bauxite ore being exported.[12] Due to the lack of domestic processing capacity, most nickel and bauxite mines were thus left without a market for their output when the export ban was suddenly implemented in 2014. This led to an immediate 79% reduction in Indonesian nickel ore production and a 96% decrease in bauxite production between 2013 and 2014 (see Figure 1).

Post-ban investment in downstream processing capacity. In the years *following* the export ban, Indonesia's nickel processing industry did gain momentum. Between 2013 and 2023, the number of smelters increased from 3 to 54 (see Figure 2). Processed nickel production rose from 94,000 to 1.68 million tons of nickel content (see Figure 1 for corresponding gross weights), turning Indonesia into the world's largest nickel processor. This was mainly due to Chinese investments, as China—which had imported around 80% of Indonesia's nickel output between 2009-13—sought to maintain access to Indonesian nickel ore, motivated by its lower processing costs due to the ore's higher metal content versus other suppliers such as the Philippines (UNCTAD, 2017).[13] In fact, 74% of Indonesia's 2023 nickel smelter capacity is Chinese-owned (and 85% is foreign-owned), as revealed by smelter-specific ownership data which we hand-collect for all 54 smelters active in 2023.[14] That said, even smelters that are majority Chinese-owned employ mostly Indonesian workers, with reported Chinese worker shares ranging between 7 and 13% across various smelters, years, and sources.

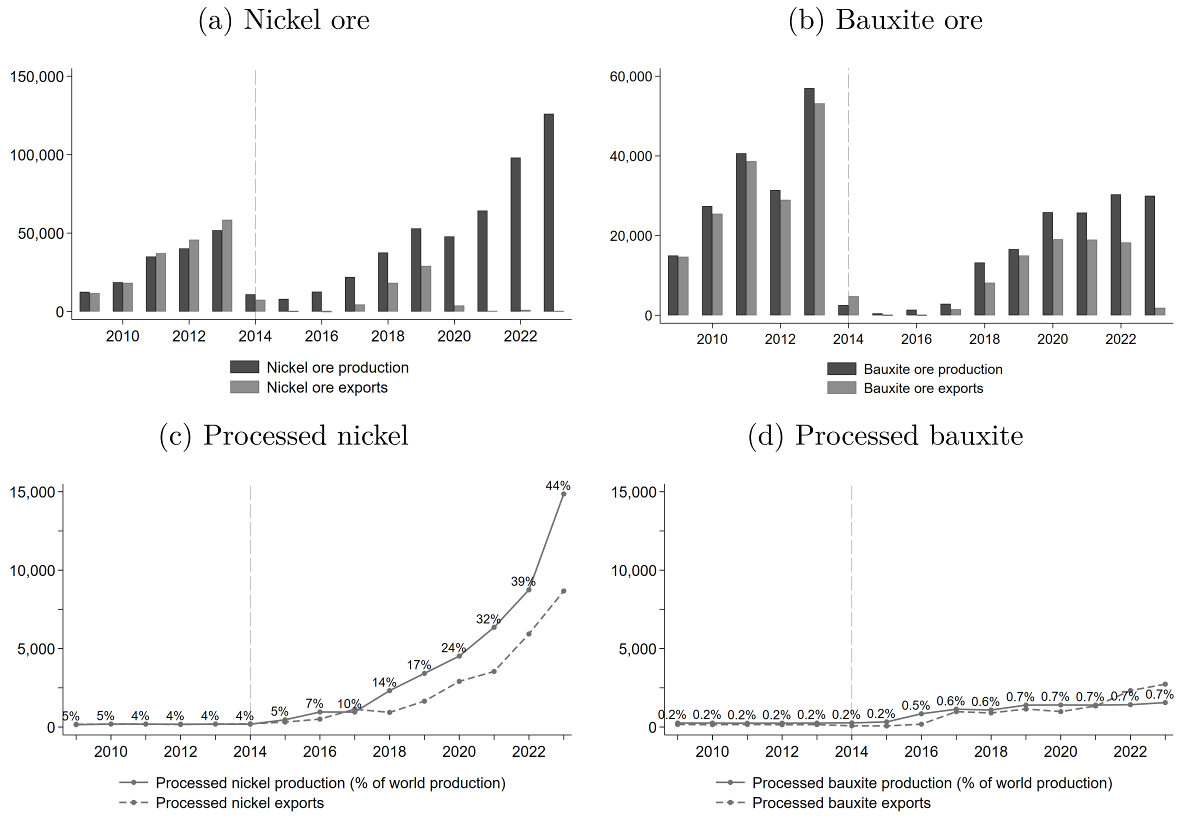
[11]Source: USGS. Domestic nickel ore production amounted to 834,200 tons of nickel content in 2013, while ferronickel production equaled 18,249 tons of nickel content (1% of global production) and nickel matte production amounted to 75,802 tons of nickel content (26%). Ferronickel is an iron-nickel alloy containing typically 20-40% nickel which is mainly used in stainless steel production. Nickel matte is an intermediate product that can be further refined into nickel sulfate used for lithium-ion batteries, or can be refined into high-purity nickel metal which is used for stainless steel production, for instance (Crundwell, Moats, Ramachandran, Robinson, & Davenport, 2011).

[12]There was one aluminum smelter operating in 2013, located in North Sumatra. This smelter operated, and still operates, on *imported* alumina and accounted for 0.5% of global aluminum production in 2013. The first alumina factory, PT ICA, achieved sustained commercial operations by the end of 2018 (`https://www.pt-ica.com/our_history`).

[13]Sources: USGS, Comtrade. See also Figure OA7 in the Online Appendix for an overview of Indonesia's role in China's import market for raw and processed nickel and bauxite in the period 2007-2021.

[14]We use various sources, such as corporate annual reports. We compute a weighted average of Chinese (or foreign) ownership, using a smelter's capacity as weight. We account for indirect ownership, such as through foreign shares in Indonesian firms and vice versa. Online Appendix Section OA2 details our methodology, and Figure OA8 shows shares in ownership by country.

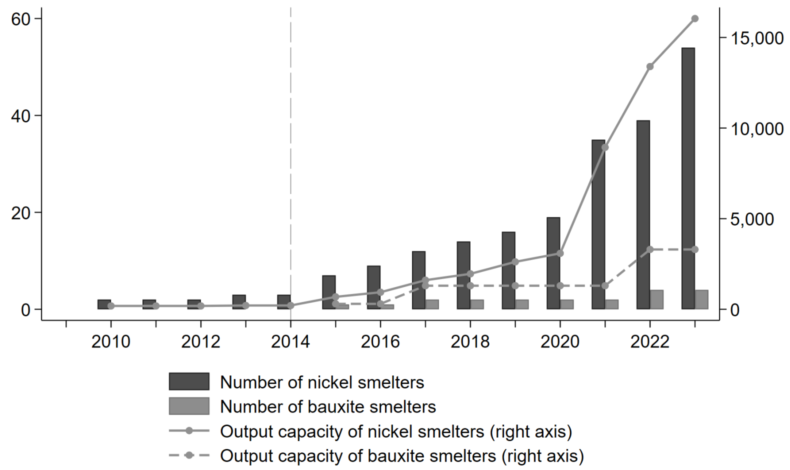
Figure 1: Production and export of nickel and bauxite in Indonesia (2009-2023)



Notes: The data are reported in gross weight (1,000 metric tons), rather than nickel/aluminum content. Processed nickel (including ferronickel/nickel pig iron, nickel matte and mixed hydroxide precipitate) is made from nickel ore; processed bauxite (including alumina and aluminum) is made from bauxite ore. Production data come from the United States Geological Survey (USGS), while export data come from Comtrade. Export figures are based on the following HS-6 codes: nickel ore (260400), ferronickel (720260, which includes nickel pig iron), nickel matte (750110), mixed hydroxide precipitate (282540), bauxite ore (260600), alumina (281820) and aluminum (760110). The percentages refer to Indonesia's share of annual world production, where both Indonesian and global production are measured in terms of nickel content. In the raw data, nickel products are reported in terms of nickel content rather than gross weight. To make production data comparable to export data, we convert their reported nickel content to gross weight using the following average nickel content of Indonesian products: 1.61% for nickel ore (Dalvi, Bacon, & Osborne, 2004), 10% for nickel pig iron (USGS, 2023), 20% for ferronickel (USGS, 2021), 78% for nickel matte (Bizteka, 2023), and 35% for mixed hydroxide precipitate (see Figure OA4 for production figures with nickel content). As a result, nickel content of extracted nickel ore can make exports exceed production in the figure, as observed over 2011-13 (nickel ore imports never exceed 10 metric tons, and therefore do not co-explain this phenomenon).

In terms of processing costs, domestic nickel ore prices were indeed substantially lower than world prices, so low that they triggered complaints by nickel miners (Reuters, 2019). In response, the government issued a mineral ore benchmark price (HPM) in 2020, which is not to be undercut and has been about 40-60% lower than international prices (Putraindo News, 2022).[15]

Figure 2: Development of processing industry (2009-2023)



Notes: Output capacity is reported in gross weight (1,000 metric tons). Over 2007-09, the number of smelters and output capacity are zero, rather than missing. Sources: CREA & Celios, MINERBA and USGS.

Most of Indonesia's (new) nickel smelters use the so-called Rotary Kiln Electric Furnace (RKEF) method, which turns nickel ore into Nickel Pig Iron (NPI) (Figure OA9 in the Online Appendix shows a stylized depiction of the nickel supply chains). As a result, the production of NPI rose rapidly over our sample period (see Figure OA4). NPI is a low-cost processed nickel product that serves as the main input for producing certain types of stainless steel. Initially, all of Indonesia's NPI was exported to stainless steel plants in China, but after 2016 the increasingly available (cheap) domestically produced NPI also paved the way for domestic stainless steel production (see Figure OA5). In recent years, five stainless steel plants have opened, adding an additional stage to the domestic nickel supply chain. However, virtually all of Indonesia's stainless steel output has been exported rather than used in domestic industries further downstream (MINERBA, 2021).

Beyond stainless steel, other applications such as batteries typically require nickel prod-

[15]Note that large-scale miners often process their output "in-house" post-2014, partly because government policy requires it. This vertical supply chain integration can help explain why Indonesia's current nickel ore output substantially exceeds pre-ban levels, despite sales prices being considerably lower than world prices after the ban.

ucts of higher quality than NPI. Indonesia does produce comparatively small but increasing amounts of these higher-quality nickel products, such as nickel matte and Mixed Hydroxite Precipate (MHP) (see Figure OA4). Several nickel smelters using the High Pressure Acid Leach (HPAL) method—which is technologically more demanding than the RKEF method—were opened for MHP production since 2021. These recent developments are part of Indonesia's ambitious strategy to create a complete EV supply chain on domestic soil (The Economist, 2025). Moving closer to this goal, Hyundai and LG opened Indonesia's first battery cell factory in 2024 (Financial Times, 2024).

In contrast to nickel, Indonesia's export ban triggered only limited investment in the domestic bauxite processing industry. Although China had imported 93% of Indonesian bauxite production between 2009-13, Chinese alumina refineries could adapt to the ban by sourcing more bauxite domestically and from other countries such as Malaysia, Australia and Guinea, rather than investing in processing capacity in Indonesia (see USGS, 2016, and Figure OA7). Domestic investment in bauxite processing was moreover deterred by high construction and operating costs, also compared to nickel smelters (Indonesia Business Post, 2023b). According to industry expert Michael Komesaroff in 2014, "It's not economic to construct an (alumina) refinery in Indonesia. The costs are too high, [and] the bauxite deposits are too scattered to supply an in-situ refinery" (Reuters, 2014a). As a result, only four new bauxite processing plants opened until 2023—with the two largest only opening in 2022. These four refineries produce less than 1% of global alumina output, despite Indonesia hosting 10% of global bauxite reserves (USGS, 2025a).[16] Virtually all domestic alumina production is exported, rather than used in Indonesia's only aluminum smelter in North Sumatra.

Other policies aimed at stimulating processing capacity. Beyond the export restrictions, domestic nickel and bauxite processing was also promoted by various policies of the Indonesian government (Tritto, 2023). Importantly, these policies applied to nickel and bauxite processing alike.[17] They include tax incentives such as tax holidays for the new processing facilities built over the period 2014-2016 (Indonesia Business Post, 2023a),

[16]The construction of seven additional smelters have been announced but face severe funding issues, such that leading industry representatives have called for substantial government funding (Indonesia Business Post, 2023b).

[17]One exception are royalty rates, which were not lowered for processed bauxite after the export ban (MINERBA, 2012, 2019).

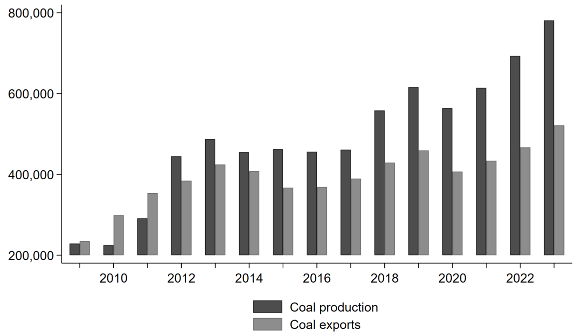
a reduction of the royalty rates on processed nickel introduced in 2019 (USGS, 2023), a US$70/ton ceiling on the domestic price of coal (PwC Indonesia, 2018) that became effective as of 2018, the designation of large processing projects such as the Indonesia Morowali Industrial Park (IWIP) as "National Strategic Project" (a designation created in 2016), which facilitates and accelerates access to various types of licenses (Cabinet Secretariat of Indonesia, 2016), and relaxed environmental regulations, such as an exception for the processing industry to the 2022 moratorium on the construction of new coal-fired power plants (Rahman, Larasati, Putri, & Rosifah, 2024). None of these policies would have been sufficient to substantially promote domestic mineral processing in the absence of the export ban—in fact, in the case of bauxite processing, they were not even sufficient in the presence of the ban. However, they were deemed necessary by policymakers at the time to augment the export ban's impact, and were partly revoked once policymakers considered them ineffective or no longer necessary for attracting smelter investment (see e.g. Reuters, 2023).

Effects on coal mining. The newly developed nickel smelters, as well as the stainless steel plants that use the NPI produced by these smelters, require vast amounts of power to operate. Virtually all of this is supplied by captive (off-grid) coal power plants located close to the smelters and/or steel plants. This is because on-site coal power is by far the cheapest and most reliable energy source for the downstream nickel industry, given the lack of suitable conditions for substantial hydropower generation and insufficient infrastructure for delivering power to the nickel smelters.[18]

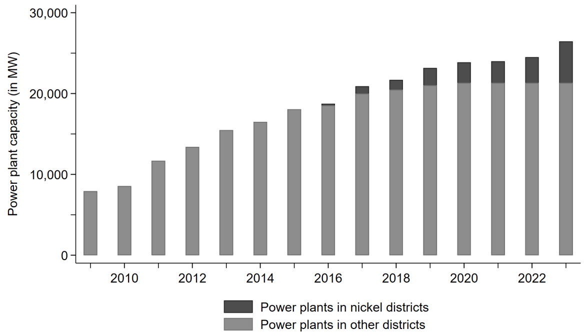
Indonesia has vast coal reserves and is the world's third largest coal producer, implying that the increased coal demand from the processing industry could be met domestically. Figure 3a shows that while Indonesia's coal exports remained roughly constant over 2013-2023, domestic coal *production* increased substantially starting from 2018, which is largely explained by the rapid expansion of processed nickel output during 2018-2023. In part to facilitate meeting the processing sector's increase in coal demand, in 2018 the Indonesian government started strictly enforcing a Domestic Market Obligation (DMO) for coal producers that had been introduced in 2009, mandating coal producers to sell at least 25% of their output domestically. Figure 3b further demonstrates the impact of increased

[18] (Coking) coal is also a direct input in making NPI and stainless steel.

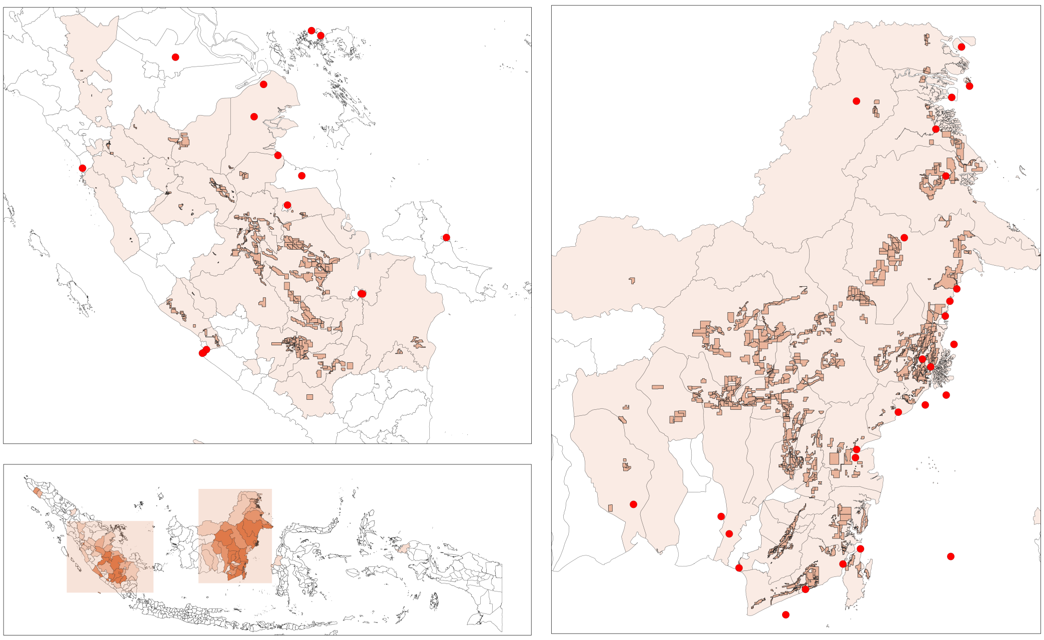
Figure 3: The coal sector in Indonesia (2009-2023)



(a) Production and export of coal



(b) Coal power plant capacity



(c) Geography of coal endowments and ports

Notes: In Figure (a), units are expressed in gross weight (1,000 metric tons). Export data are based on HS-6 codes 270111, 270112, 270119, 270210, and 270220. Figure (b) reports power plant capacity in megawatts (MW). All power plants located in nickel districts are captive plants, meaning they are operated by industrial or commercial users to meet their own energy needs. Figure (c) illustrates the geographic distribution of coal endowments and coal-exporting ports across Indonesia's 497 districts. Shaded areas indicate districts with at least one endowment. Red dots represent coal-exporting ports. Sources: USGS, Comtrade and MINERBA.

nickel processing on the domestic coal sector by showing that from 2017-18 onward, the increase in national coal power plant capacity was almost entirely driven by (new) power plants in nickel districts. This is partly explained by strategic policy decisions: while Indonesia's government imposed a moratorium on the construction of new coal power plants in 2021 to help curb CO_2 emissions, it made an explicit exception for captive coal power plants supplying its mineral processing industries. Aided by this exception, overall coal power plant capacity in nickel-processing districts surged from 295 MW in 2014 to 6,090 MW in 2023.[19] The total amount of coal used in these power plants accounts for roughly 10-15% of total Indonesian coal consumption.

Geographic dispersion. Nickel, bauxite and coal mining occur in very different parts of the Indonesian Archipelago. Indonesian nickel endowments are concentrated in 17 districts in (primarily) Southeast Sulawesi, Central Sulawesi and North Maluku, while bauxite endowments are found in 9 districts, located in West Kalimantan and to a smaller extent on the Riau Islands (see Figure 4 and Table OA3). Also, almost all processing plants are located in—or very close to—these mining areas. In fact, 47 out of 54 nickel smelters are located in districts with nickel endowments, and three out of four alumina refineries are located in districts with bauxite endowments. Six districts process nickel but do not mine it, while one district processes bauxite but does not mine it. Indonesia's coal endowments are found across 66 districts in Southern Sumatra, and Eastern, Central, and North Kalimantan (see Figure 3c).

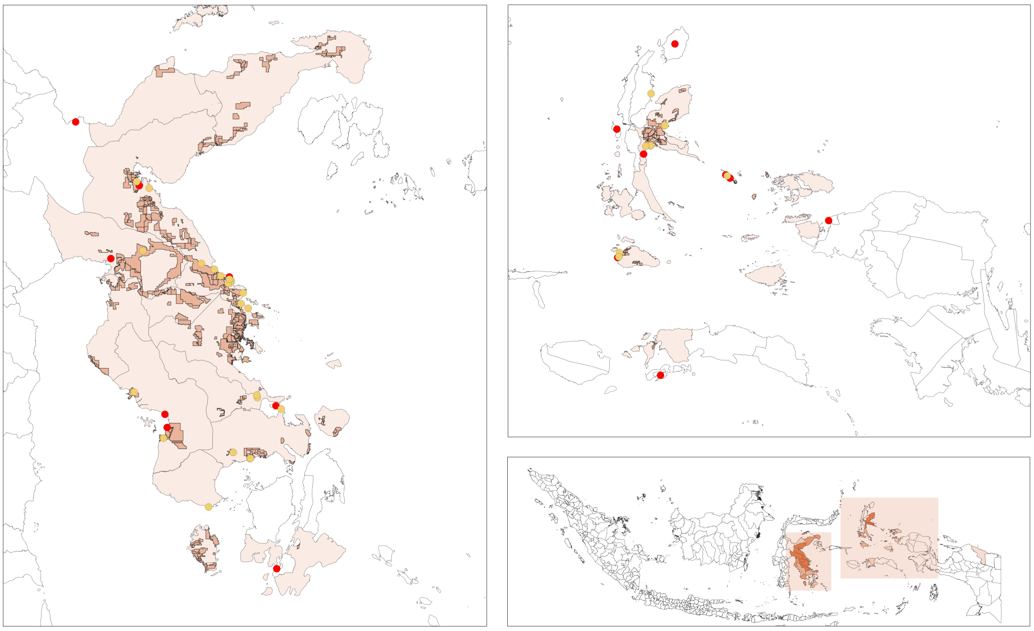
Local labor markets. In this paper we define local labor markets as Indonesia's districts, of which there are two types: *kabupaten* (rural district) and *kota* (city). An important reason for this choice is that migration between districts is not very common. In the 2020 population census, 95% of people reported living in the same district as five years before—whether or not we are looking at nickel, bauxite or non-nickel/bauxite districts. Only 5% moved in from another district, with about half of these people moving in from a nearby district in the same province, and the other half moving in from another, usually nearby, province.[20] Urban-rural migration within districts is much more common, as is inter-sectoral labor mobility, with many people switching sectors in any particular

[19] In bauxite-producing districts, coal power plant capacity remained at 0 MW over 2014-2023.

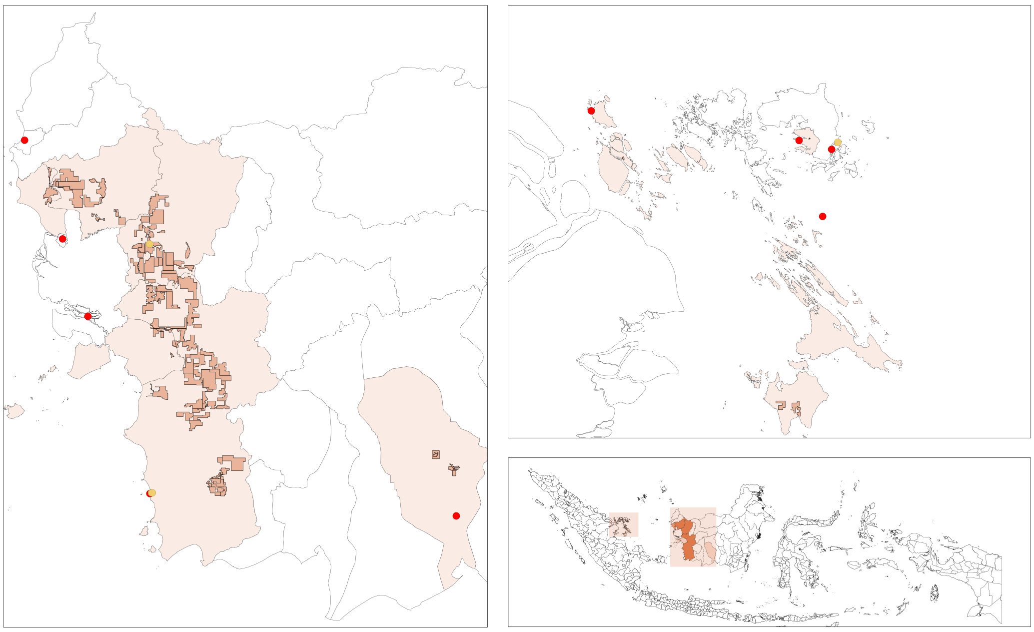
[20] Also temporary migrant workers (or commuters) are very few: only 1.5-2.5% of workers working in a bauxite or nickel district report living in another districts.

Figure 4: Geography of nickel and bauxite endowments, smelters, and ports

(a) Nickel



(b) Bauxite



Notes: This figure illustrates the geographic distribution of nickel and bauxite endowments, smelters, and ports, across Indonesia's 497 districts. Shaded areas indicate districts with nickel or bauxite endowments. Yellow dots represent nickel or bauxite smelters as of 2023, and red dots represent nickel- or bauxite-exporting ports. Sources: MINERBA & Comtrade.

year—especially in the more informal occupations (in agriculture, the number of people switching to another sector the next year is typically over 30%, and in mining and services this number is 43% and 22%, respectively). Besides limited migration, another reason to define local labor markets as districts is that labor market regulation is very often set at the district level. Notably, districts set their own minimum wages, and workers, especially in the mining and manufacturing sectors, organize themselves into unions.

Local economic structure. In terms of the structure of the local economy, the nickel, bauxite and coal mining districts are quite comparable. On average, mining, agriculture, manufacturing, and services accounted for 4%, 55%, 4%, and 22% of total employment, respectively, in these districts in 2013 (see Table OA3 for details). In Indonesia's other districts, these average sector shares were 1%, 33%, 15%, and 37%, respectively, showing that the local economy of the average (nickel, bauxite or coal) mining district is much more focused on agriculture and mining and not as industrialized as other parts of Indonesia. However, these differences are to a large extent driven by Java, where Indonesia's manufacturing and service industries are most developed. When excluding Java from the sample of non-mining districts, the sectoral shares are much more comparable to those in the average mining district (see Table OA3).[21] It is also important to mention that, throughout Indonesia, a large share of the labor force is informal and thus not regulated. This is especially the case in agriculture and (low-skilled) services, where only 8% and 27%, respectively, are formal employees. Mining and manufacturing are much more formalized sectors, with 54%, respectively 47%, of workers being formal employees.[22]

4 Data

Our primary data sources include information on nationwide export restrictions and district-level data on mineral endowments and labor market outcomes. Descriptive statistics are provided in Tables A1 and A2 in the Appendix.

[21] In robustness checks, we verify the sensitivity of our findings to the inclusion of Java in the sample.

[22] Source: Authors' own calculations based on the labor force survey (Sakernas) data used in this paper. We define formal workers as those having a written indefinite term, or fixed term, employment agreement. Informal workers instead are those with either no, or an oral employment agreement.

Export restrictions. Data on export restrictions are primarily sourced from the OECD Inventory of Export Restrictions on Industrial Raw Materials (OECD, 2025). This dataset lists export restrictions imposed by the Indonesian government between 2007 and 2023 on various raw materials at the 6-digit HS code level. The dataset also specifies the type of export restriction, such as "export prohibition", "export tax", or "licensing requirement". We corroborate these data with information from the annual PwC publication *Mining in Indonesia: Investment and Taxation Guide* (PwC Indonesia, 2025), to ensure correctness and comprehensiveness. Taken together, these datasets provide us with information on the the timing and the types of export restrictions applied to nickel and bauxite, as well as other natural resources.

Mining activity. We follow the recent natural resource literature (Allcott & Keniston, 2018; Pelzl & Poelhekke, 2021) by proxying local resource activity with a measure of endowments, considering that endowments are largely a function of geology and therefore much less related to local developments than production. Specifically, we capture district-level mineral endowment using novel data on the share of a district's surface area under mineral extraction license. The license data are provided by the Indonesian government's Directorate General of Minerals and Coal (MINERBA), and provide more comprehensive coverage than aggregating commercially available endowment data across individual mines and deposits.

A mining license in Indonesia is an official permit issued by the government that authorizes a company to conduct specific mining-related activities within a designated area. We exclude the few exploration licenses in the data, thereby focusing on production licenses. Since bauxite and nickel are typically extracted using open-pit mining, the surface area under mining production license correlates positively with the scale of endowments.[23] Nickel production licenses are found in 17 districts, while bauxite licenses are located in 9 districts, out of a total of 497 districts that existed in 2009 (see Figure 4).[24] To aggregate the original license-level data to the district level, we calculate the total area covered by licenses for a specific resource within each (2009) district and then divide by the district's

[23] Using a subsample of districts which both have land licensed to nickel (bauxite) mining and positive nickel (bauxite) endowments based on commercial endowment data, we find for both nickel and bauxite a positive and statistically significant correlation between license area and reserves.

[24] To account for changes in district borders over time, we aggregate all district-level data to 2009 districts.

total surface area, as shown in the formula below:

$$R_d^m = \frac{\sum_l r_{ld}^m}{Area_d} \tag{1}$$

where r_{ld}^m represents the area (in square meters) of license l for resource m in district d and $Area_d$ (in square meters) represents the total area in district d.

Processing industry. A key purpose of the export restrictions has been to establish more domestic production of valuable refined materials. For nickel, our primary source of processing data is CREA & Celios (2024), which provides broad geographic coverage, commercial operation start years, and capacity data at the facility level. We supplement this with data from MINERBA (2021) and the United States Geological Survey (USGS, 2025b), and obtain complementary information from various sources for cases where MINERBA and USGS do not report capacity or start year data. We identify a total of 54 nickel smelters as of 2023, 46 from CREA & Celios and eight additional ones from USGS and/or MINERBA, including five smelters which are located in areas outside of CREA & Celios' geographic scope. For bauxite, no data are available from CREA & Celios, so we rely entirely on USGS and MINERBA and complementary sources, and identify four smelters that are operational as of 2023. Using these data, we construct a novel annual district-level panel of resource-specific smelter activity, which we compute as the sum of output capacity across active smelters:

$$C_{dt}^m = \sum_s c_{sdt}^m \tag{2}$$

where c_{sdt}^m denotes the output capacity of smelter s processing resource m in district d in year t. As alternative measures, we also consider the *number* of active resource-specific smelters in a district, or a simple dummy variable indicating the presence of at least one resource-specific smelter in the district.[25]

Coal industry. The newly established nickel smelters require substantial amounts of electricity, almost entirely supplied by coal power plants. Our coal power plant data are

[25] We mainly source smelter location data from `https://betahita.id/news/detail/10567/indonesia-tanah-nikel-china.html?v=1726060353`.

drawn from the Global Coal Plant Tracker (GCPT) by Global Energy Monitor, which records all coal-fired power units in Indonesia with a capacity of 30 megawatts (MW) or more. The GCPT provides detailed information on the operating status and capacity (in MW) of each unit. Using these data, we construct an annual series of power plant capacity in nickel districts, computed as the sum of capacities across all relevant power plants:

$$P_t^n = \sum_p p_t^n \tag{3}$$

where p_t^n denotes the capacity of coal power plant p in a nickel district n in year t.

Labor market. To study the effect of the export restrictions on local labor markets, we draw on Indonesia's annual labor force survey, Survei Angkatan Kerja Nasional (Sakernas). For the years of our sample period (2009-2023), the August round of this repeated cross-section survey is representative at the district-level.[26] We are unable to include the year 2016 since the data are not available at the district level in this particular year. The total number of respondents ranges from 507,713 in 2012 to 963,172 in 2010. The data provide detailed information on the labor market situation of the respondents, including employment status, sector and earnings, as well as individual characteristics such as age, gender, education, current district of residence, as well as residence five years ago.

In our analysis we distinguish labor outcomes across four broadly defined sectors: mining, agriculture, manufacturing and services; see Table OA3. We do not study more disaggregated sectors because the sampling in Sakernas is stratified at the district-level, so that using a finer-grained sectoral decomposition runs a much higher risk of substantial measurement error.[27] We do not consider the public sector, given that hiring and firing as well as wage-setting are much more rigid and institutionalized in this sector.

We calculate the number of individuals working in a specific sector in a given district-year

[26] Our sample includes all districts as of 2009, except for certain missing observations: 26 districts are missing in 2009, 6 in 2011, 4 in 2012, 11 in 2013, 6 in 2014, 2 in 2015, and 1 in 2018. The number of observations differs across sectors, as some district–years lacked respondents in certain sectors and were therefore excluded.

[27] Mining is typically the smallest of the four sectors that we consider, making it most vulnerable to measurement error. There is no reason to believe this measurement error is non-random, so that it will only affect the precision of our estimates.

as follows: first, we compute the sector's share in the total number of Sakernas respondents who are working (i.e., those who either worked last week or temporarily do not work but have a job); and then we multiply this share with total district-year employment. The latter is computed as the ratio of working respondents to the total number of respondents, multiplied by the district's most recent population estimate.[28]

To measure earnings, we calculate each sector's hourly wage premium based on Dix-Carneiro and Kovak (2017). We prefer this measure over simply using each sector's average hourly wage because it reflects average district-level earnings *controlling for the composition of the district's workforce*, which may well change in the aftermath of the export restrictions. Specifically, we estimate the following specification year-by-year to measure this wage premium:

$$\ln(w_{ijdt}) = X_{it}\gamma_t + \lambda_{jdt} + \varepsilon_{ijdt}$$

where w_{ijdt} denotes the hourly nominal wage[29] of individual i working in sector j in district d in year t. X_{it} is a vector of individual worker characteristics, including overall workforce experience (age, age squared), tenure in the current job in years (and its square), the worker's highest completed level of education,[30] and a set of dummy variables capturing employment status[31] in year t. γ_t captures the year-specific impact of these worker characteristics on wages. The included industry-district-year fixed effects (λ_{jdt}) capture the wage premium specific to each district-sector-year. Subsequently, we use the estimated $\hat{\lambda}_{jdt}$ as our measure of each district-sector-specific wage premium when studying the effect of export restrictions on earnings.[32]

[28] Indonesia's national statistical agency Budan Pusat Statistik (BPS) produces district-level population data across the entire country via its population census (2000, 2010, 2020) and inter-census population surveys (2005, 2015). We supplement these data with annual BPS population estimates obtained from districts' local BPS websites, and use interpolation to fill the (few) remaining gaps.

[29] Sakernas reports monthly earnings in both cash and in-kind. We follow Bosker, Park, and Roberts (2021) and calculate hourly wages as: (monthly income/ (365/12)) × (7/hours worked last week). Unless otherwise specified, we use cash income only to calculate monthly income.

[30] We distinguish between four categories of education: (i) did not finish primary school (ii) finished (vocational) junior high school (ii) finished (vocational) senior high school and (iv) completed education beyond (vocational) senior high school, such as university.

[31] Sakernas distinguishes between (i) own-account worker (ii) self-employed assisted by temporary worker/unpaid worker (iii) employer assisted by permanent worker (iv) employee (v) casual employee in agriculture (vi) casual employee not in agriculture (vii) unpaid worker.

[32] To ensure reliable estimates of the district-sector-year specific wage premia, we restrict the sample to district–sector–year cells with at least five individual respondents.

Migration. We complement our main analysis with information from the 2010 and 2020 Population Census on migration flows between districts. Based on province-level reports we know for each district how many people, in the previous five years, migrated to the district from (i) each other district in the same province, as well as (ii) from the five other origin provinces of most migrants to the district. Using these data we can provide some evidence on the extent to which any of the labor market effects that we find, could (partly) be explained by differences in in- or out-migration before and after the imposition of the export ban. Moreover, we can provide a picture of the origin (destination) of the migrants moving to (out of) Indonesia's bauxite and nickel districts.

5 Empirical strategy and results

In this section we present evidence on the effects of Indonesia's export restrictions on local labor markets in nickel- and bauxite-endowed districts (Section 5.1), as well as in the districts where the nickel processing industry is located (Section 5.2). Moreover, we study (un)intended spillover effects to Indonesia's coal mining districts, which provide the vast amounts of coal needed as input in the nickel processing industry (Section 5.3). In each of these three subsections, we first describe our specific empirical strategy before presenting our findings. Throughout the section, our evidence is based on both straightforward pre-post-ban regressions, and on event-study specifications, allowing us to capture the timing and dynamics of effects.

Our sample period starts in 2009 and ends in 2023, the most recent year for which we observe local labor market outcomes. 2009 is the year in which the Indonesian government adopted Mining Law 4/2009, which specified 2014 as the year in which Indonesia would start imposing its mineral export restrictions. Moreover, by starting our analysis in 2009, we avoid including the global financial crisis years. This matters because the crisis led to a sharp drop in demand for both nickel and bauxite (as well as many other minerals), which likely affected nickel and bauxite districts differently than others. At the time of data collection for the 2009 round of Sakernas (i.e., August), Indonesia had largely recovered from the crisis (World Bank, 2009).

5.1 The effect of the export restrictions on mining districts

5.1.1 Empirical strategy

To establish how Indonesia's ban on raw nickel and bauxite exports affected labor markets in the districts endowed with these minerals, we estimate the following shift-share specification, over the period 2009-2023:

$$Y_{dt} = \beta_1 \left(NI_d \times ER_t \right) + \beta_2 \left(BX_d \times ER_t \right) + X_{dt}\zeta + \alpha_d + \alpha_t + \varepsilon_{dt} \tag{4}$$

where Y_{dt} is outcome variable Y in district d in year t; NI_d and BX_d equal district d's nickel and bauxite endowment, respectively, as defined in Equation (1); and ER_t is a dummy variable equal to one in the years 2014-2023. β_1 and β_2 are our coefficients of interest. They tell us whether and to what extent the post-2013 export restrictions had differential effects on districts depending on the extent of their nickel or bauxite endowments, respectively. For ease of interpretation of these coefficients, we always scale a district's nickel (or bauxite) endowment by the average endowment across all nickel- (or bauxite-) endowed districts. X_{dt} denotes a vector of time-varying district characteristics. In our baseline specification, these characteristics include a district's iron and copper endowment, respectively—defined in Equation (1)—interacted with ER_t, as well as the share of a district's area under palm oil licenses interacted with the world market price of palm oil.[33] For more detail on this choice of control variables, see our discussion on identification below. Finally, α_d and α_t are district and year fixed effects, respectively. We always cluster standard errors at the district level.

In addition to Equation (4), we estimate the following event-study type specification, where we allow the effect of a district's nickel and bauxite share to vary over the years in our sample relative to 2013 (the year before the export restrictions were imposed):

$$Y_{dt} = \sum_{\tau \in \mathcal{T}} \beta_{1,\tau} \left(\mathbf{1}\{t = \tau\} \times NI_d \right) + \sum_{\tau \in \mathcal{T}} \beta_{2,\tau} \left(\mathbf{1}\{t = \tau\} \times BX_d \right) + X_{dt}\zeta + \alpha_d + \alpha_t + \varepsilon_{dt},$$

where $\mathcal{T} = \{2009, \ldots, 2012, 2014, \ldots, 2023\}$. (5)

[33] We use Global Forest Watch data to compute the current and planned palm oil license concessions as of 2023 at the district level.

This specification allows us to see, on a year-by-year basis, whether and to what extent employment and earnings developed differently in nickel and bauxite districts (precisely: depending on their nickel and bauxite endowments) after the export ban imposition.[34] This can reveal interesting temporal dynamics in the effect of the export restrictions that remain hidden when estimating a simple before-after specification as in Equation (4). Importantly, it also allows use to assess whether prior to the export ban, employment and earnings followed parallel trends in nickel and non-nickel districts, and in bauxite and non-bauxite districts.

Identification. Given that our shift-share design considers only one shift, i.e. the imposition of the export restrictions in 2014, our identification crucially relies on share-exogeneity (see Borusyak, Jaravel, & Spiess, 2024). We therefore need to assume that in the absence of the export ban, our district-level outcomes of interest would have followed similar trends in districts with different nickel and bauxite endowments. In that respect, results from our event study specifications are reassuring, as they show little evidence of differential pre-trends in total and sectoral employment or earnings across districts with different nickel or bauxite endowments (see Figures 5-7).

Nevertheless, several concerns could still be raised that would threaten identification. First, the export restrictions imposed in 2014 did not only apply to the exports of unprocessed nickel and bauxite ore but included other minerals as well, in varying degrees (see Section 3). Although these minerals either did not face a strict export ban (e.g. copper) or were quantitatively much less important than nickel and bauxite (e.g. tin), our estimates would partly pick up the effect of those minerals' export restrictions if their endowments were concentrated in the same districts as nickel and bauxite. However descriptive Table OA2 and Figure OA1 indicate that these other minerals are typically found in different parts of the country than nickel and bauxite. For example, only small amounts of gold and manganese are found in nickel districts. In Equation 4 we include our post-2013 dummy interacted with each district's copper and iron share, respectively (the two most important other minerals for Indonesia in terms of production and exports, see Figure OA2), while in our event study specifications we interact these shares with a

[34]Note that we cannot estimate coefficients for $\tau = 2016$ because district-level labor force survey data are unavailable in that year.

full set of year dummies.

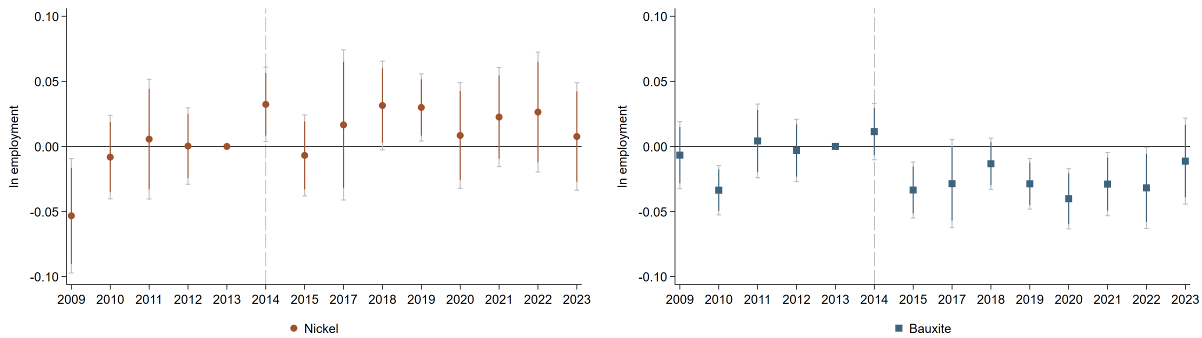
Second, and related, there could be other shocks that coincide with the imposition of the export restrictions and that differentially affected nickel and bauxite districts. Other demand or supply shocks on world nickel or bauxite markets immediately come to mind here. However, with endowed districts no longer able to export raw nickel and bauxite starting from 2014, the export ban effectively shielded endowed districts from such shocks. This leaves Indonesia-specific events as potential threats to identification, notably the co-occurrence of other domestic policies of the Indonesian government that affected nickel and bauxite districts differently than others. While such policies existed, their timing does not coincide with the imposition of the export ban. Moreover, they should be considered complementary to the export ban rather than of influence on outcomes in nickel- or bauxite-endowed districts even in the absence of the ban (see Section 3).

Finally, there might have been developments in Indonesia around the time of the ban which are unrelated to mineral endowments, markets, or policies, but that still affected nickel or bauxite districts differently than others. This could occur if nickel and/or bauxite districts not only systematically differ from other districts in terms of mineral endowment, but also along other dimensions. As briefly discussed in Section 3, Indonesia's nickel and bauxite districts (as well as its coal districts) differ from the other districts in terms of their sectoral make up. The agricultural and mining sector are more important in these districts, whereas they are lagging behind in terms of manufacturing and services employment—especially compared to districts on Java.

In that respect, one relevant development during our sample period is the fast expansion of the area under palm oil cultivation in Indonesia, notably on Kalimantan and Sumatra (see Figure OA1). Bauxite mining is also heavily concentrated on Kalimantan, resulting in a strong correlation between a district's area share under bauxite mining licenses and a district's area share under palm oil cultivation licenses (see Table OA2). During our sample period, global palm oil prices fell until 2018 after which they saw a sharp increase. To make sure that our bauxite results are not driven by developments in Indonesia's palm oil sector, we always include a district's area share under palm oil cultivation licenses, interacted with the yearly world price of palm oil in our regressions. Last, but not least, to make sure that our findings are not driven by developments in the more industrialized

Figure 5: Timing of effects on total employment (2009-2023)

(a) nickel (b) bauxite



Notes: The results are based on Equation (5). The dependent variable is the total number of people employed (in ln). 'nickel (bauxite)' is a continuous variable measuring the share of nickel (bauxite) licenses of the district's surface area in district *d*, scaled by the average endowment across all nickel (or bauxite-) endowed districts. All specifications include a vector of control variables, including the copper and iron share interacted with year dummies, as well as the palm share interacted with the palm oil price (in ln), as well as year fixed effects and district fixed effects. Standard errors are clustered at the district level. Dots represent point estimates; orange/blue (grey) lines indicate 95% (90%) confidence intervals. The year 2013 is the reference year.

parts of Indonesia (which are largely in our control group), in robustness checks we (i) exclude districts on Java, (ii) remove districts with no—or very little—mining employment, (iii) remove the most densely populated (urban) districts, or (iv) include a district's ex-ante manufacturing or agricultural employment share interacted with a full set of year dummies as additional controls.

5.1.2 Results

Total employment. We first turn to the impact of the export ban on *total* employment in mining districts. Table 1 shows the average effect across the post-ban years 2014-2023 as estimated using Equation (4), while Figure 5 plots the two vectors of year-specific effects $\hat{\beta}_{1t}$ and $\hat{\beta}_{2t}$ from estimating Equation (5). We find that the effect on total employment is very different in nickel versus bauxite districts, although both minerals faced the same export ban and virtually the same other domestic policies. In the average nickel district, the export ban leads to a 3.0% increase in total employment, which corresponds to 3,400 jobs. Figure 5 show that this increase is consistently found (although sometimes not precisely estimated) in all years after the imposition of the ban. In contrast, employment in bauxite districts in negatively affected by the export ban. While the Table 1 coefficient on changes in employment across 2009-13 and 2014-23 statistically significant with 90% confidence.[35] Figure 5 shows a more significant employment drop of around 1.5% (∼2,600 jobs) in the average bauxite district after the ban (compared to districts without nickel or bauxite endowment).

Sectoral employment. Table 1 also reports results by sector, in columns 2-5: agriculture, mining, manufacturing, and services. In nickel districts, the post-ban employment increase is mainly driven by the manufacturing and services sector. In the average nickel district, the export ban raises employment in these two sectors by 19.3% and 6.7%, respectively, corresponding to an additional 1,100 manufacturing and 2,000 services jobs. Mining and agricultural employment are not significantly affected by the ban based on our our pre-post specification, but the results from our event study specifications (see Figure 6) show that these insignificant average effects hide very interesting temporal dynamics. Mining employment drops abruptly in 2014 but then gradually recovers by 2018. The near opposite occurs for agricultural employment, with a strong rise over 2014-19 which is then partly reversed in later years. This suggests that workers who initially lost their mining job move into agriculture, and as the development of the nickel processing industry picks up (see Figure 1), some of these workers return to the mining industry, or to a new job in manufacturing or services.[36]

In bauxite districts, the largest employment decrease is found in the mining sector, with Table 1 indicating a 17.5% (∼1,300 jobs) post-ban decrease. While this coefficient is not statistically significant, the event-study results in Figure 6a show that mining employment declines upon the imposition of the export ban in 2014, recovers somewhat after the government relaxes the export restrictions in 2017, and decreases again after 2020 when the outright export ban is reinstated. In 2023, mining employment was still around 40%

[35] The much lower agricultural employment in bauxite districts in 2009 and 2010 is responsible for this (see Figure 6). Excluding these years from the sample yields a more significantly negative post-export ban effect on total employment in bauxite districts. The much lower agricultural employment in 2009/2010 is likely related to the aftermath of the crash in palm oil markets during the financial crisis. Fewer palm oil plantations were established and existing plantations expanded significantly slower up until 2009-2010, affecting agricultural employment in bauxite districts that are very often home to palm oil plantations. This is imperfectly picked up by our included palm oil control.

[36] In fact, the individual-level data on sectoral switches from Sakernas (be it very sparse) shows that 76% of the interviewed workers in 2014 that were employed in mining in 2013 switched to another sector in 2014 (up from 46% the year before), with the majority moving to agriculture, and services. At the same time, the percentage of interviewed agricultural workers transitioning from agriculture to mining fell from 13% in 2013 to only 3% 2014. When the processing industry gathers steam, and the nickel mining sector recovers, we then see an increase in the percentage of interviewed workers that switch from agriculture to a mining, manufacturing or service-sector job.

lower in the average bauxite district compared to 2013 (corresponding to about 2,900 lost mining jobs). There is no robust evidence that the outflow of mining workers led to a significant increase in employment in any of the other three sectors.

These findings in bauxite districts call for further discussion along two dimensions. First, Figure 6a is suggestive of some anticipation in the bauxite mining sector: compared to pre-2013, mining employment shows a small, one-off spike in 2013, which matches the increase in overall Indonesian bauxite production and exports in that year (see Figure 1). However, in robustness checks where we drop 2013 from the sample (Table OA4) or use 2012 as our base year instead (Figure OA15), we find similar—only slightly less pronounced—effects. Second, the question arises why the immediate negative effect of the export ban on mining employment is less stark in bauxite than in nickel districts (see Figure 6a). Here, it is important to note that many bauxite districts, unlike nickel districts, are also endowed with other minerals (iron, tin, gold and zirconium)—see Table OA2. The Sakernas data do not distinguish mining workers by the mineral that they extract, so that the less abrupt decline in mining employment in bauxite districts can (partly) be explained by workers moving from a bauxite mining job to another mining job.[37]

[37] The Indonesian Bauxite and Iron Ore Entrepreneurs Association reported that the ban on bauxite exports resulted in the layoff of 40,000 miners (corresponding to an average of 4,400 lost jobs per bauxite district) between December 2013 and February 2014. This corroborates that the ban did lead to an abrupt decline in bauxite mining employment, similar to the evidence for nickel in Figure 6a. Source: `https://finance.detik.com/energi/d-3031009/40-000-pekerja-tambang-bauksit-kena-phk-sejak-2013`.

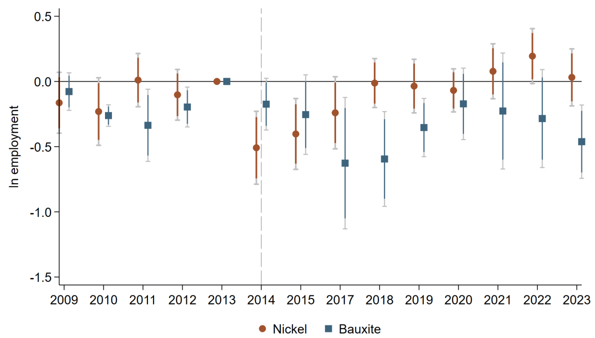
Table 1: Export restrictions and sectoral employment

dependent var	ln employment				
	(1) total	(2) mining	(3) agriculture	(4) manufacturing	(5) services
nickel endowment × ER	0.030***	-0.010	-0.001	0.193*	0.067**
	(0.010)	(0.062)	(0.021)	(0.104)	(0.032)
bauxite endowment × ER	-0.015*	-0.175	0.020	0.086	0.055
	(0.008)	(0.136)	(0.021)	(0.104)	(0.045)
N	6902	6087	6897	6747	6866

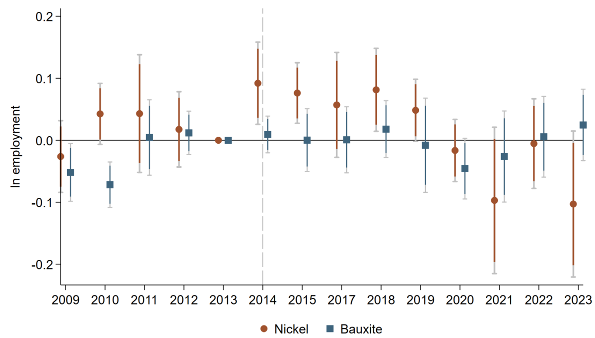
Notes: In this table we study how export restrictions on raw materials impact sectoral employment in districts where these resource deposits are located. The sample period is 2009-2023. ‘ln employment’ is the number of people employed in a specific sector (in ln). ‘nickel (bauxite) endowment’ is a continuous variable measuring the nickel (bauxite) endowment as a share of the district’s surface area in district d, scaled by the average endowment across all nickel (or bauxite-) endowed districts. ‘ER’ is a dummy variable which takes the value one if there is an export restriction active for this specific resource in year t. All columns include a full set of control variables, including interaction terms of the copper and iron endowment with the export restriction and the palm share with the palm oil price (in ln), as well as year fixed effects and district fixed effects. Standard errors are clustered at the district level and shown in parentheses. $^{***}p < 0.01,^{**} p < 0.05,^{*} p < 0.1$.

Figure 6: Export restrictions and sectoral employment

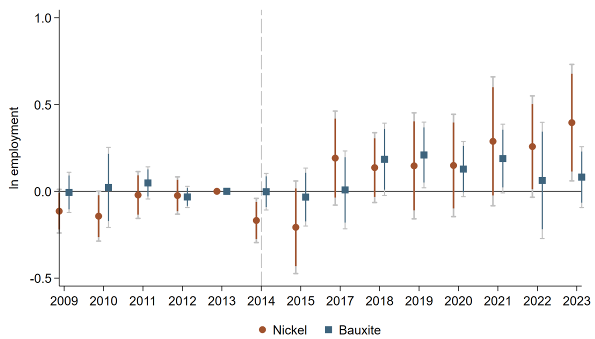
(a) mining



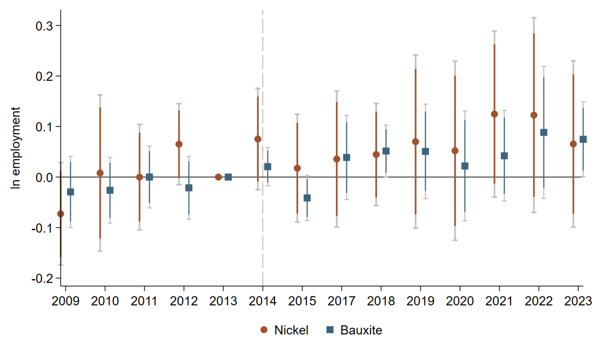
(b) agriculture



(c) manufacturing



(d) services



Notes: The results are based on Equation (5). The dependent variable is the total number of people employed in a specific sector (in ln). ‘nickel (bauxite)’ is a continuous variable measuring the share of nickel (bauxite) licenses of the district’s surface area in district d, scaled by the average endowment across all nickel (or bauxite-) endowed districts. All specifications include a vector of control variables, including the copper and iron share interacted with year dummies, as well as the palm share interacted with the palm oil price (in ln), as well as year fixed effects and district fixed effects. Standard errors are clustered at the district level. Dots represent point estimates; orange/blue (grey) lines indicate 95% (90%) confidence intervals. The year 2013 is the reference year.

Earnings. Are employment growth and the reallocation of workers between sectors accompanied by changes in wages? To complete our analysis of how local labor markets adjusted to the export ban, we next turn to earnings. We study earnings using information on district-level and sector-specific wage *premia*, as defined in Section 4. This approach allows us to study export ban-induced changes in earnings for workers with a fixed set of characteristics (education, experience, etc.), thus holding constant the composition of a district's workforce (see Dix-Carneiro & Kovak, 2017). The results are presented in Table 2 and Figure 7, respectively.[38]

[38] Results using simple nominal wages instead can be found in Table OA12 and Figure OA22.

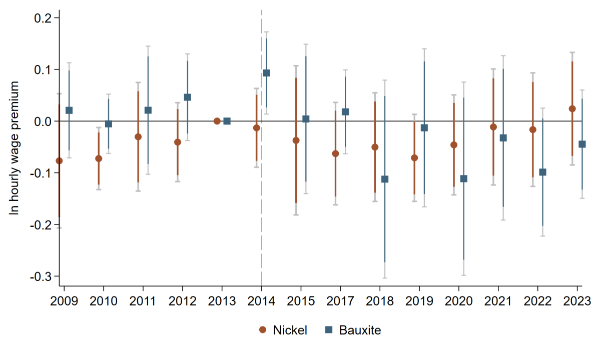
Table 2: Export restrictions and sectoral earnings

dependent var	ln hourly wage premium				
	(1) total	(2) mining	(3) agriculture	(4) manufacturing	(5) services
nickel endowment × ER	-0.016	0.014	-0.036	-0.000	-0.046**
	(0.033)	(0.045)	(0.045)	(0.047)	(0.019)
bauxite endowment × ER	-0.025	-0.054	-0.042	0.010	-0.023
	(0.025)	(0.058)	(0.028)	(0.040)	(0.022)
N	6871	3459	6722	6393	6791

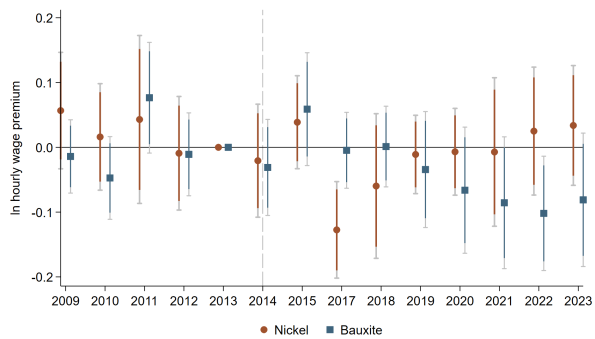
Notes: This table examines how export restrictions on raw materials impact sectoral hourly wage premiums in districts where these resource deposits are located. The sample period is 2009-2023. 'ln hourly wage premium' is the sectoral hourly wage premium (in ln) (see Section 4 for more details). We only include district-sector-years with at least five wage records. 'nickel (bauxite) endowment' is a continuous variable measuring the nickel (bauxite) endowment as a share of the district's surface area in district d, scaled by the average endowment across all nickel (or bauxite-) endowed districts. 'ER' is a dummy variable which takes the value one if there is an export restriction active for this specific resource in year t. All columns include a full set of control variables, including interaction terms of the copper and iron endowment with the export restriction and the palm share with the palm oil price (in ln), and year and district fixed effects. Standard errors are clustered at the district level and shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Figure 7: Export restrictions and sectoral earnings

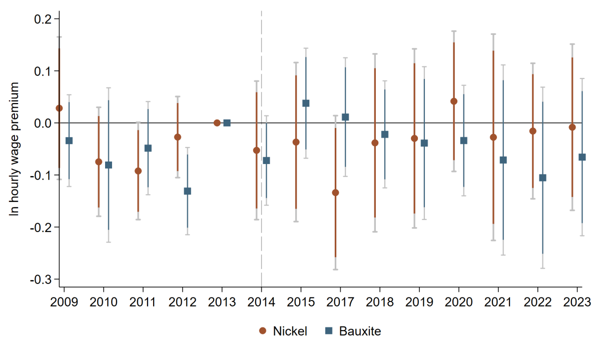
(a) mining



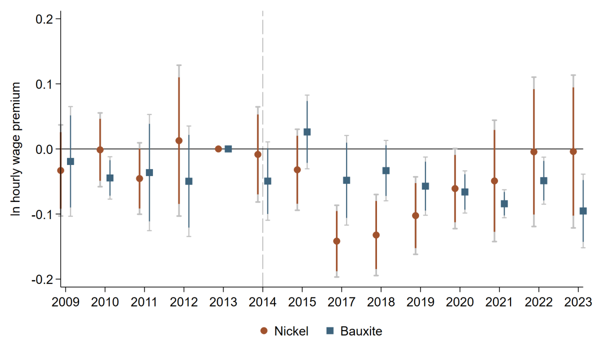
(b) agriculture



(c) manufacturing



(d) services



Notes: The results are based on Equation (5). The dependent variable is the hourly wage premium in a specific sector (in ln). We only include district-sector-years with at least five wage records. 'nickel (bauxite)' is a continuous variable measuring the nickel (bauxite) endowment as a share of the district's surface area in district d, scaled by the average endowment across all nickel (or bauxite-) endowed districts. All specifications include a vector of control variables, including the copper and iron endowment interacted with year dummies, as well as the palm share interacted with the palm oil price (in ln), and year and district fixed effects. Standard errors are clustered at the district level. Dots represent point estimates; orange/blue (grey) lines indicate 95% (90%) confidence intervals. The year 2013 is the reference year.

In the mining sector, we find no statistically significant change in earnings following the imposition of the export restriction, neither in nickel nor in bauxite districts. In view of the post-ban mining employment decrease in nickel districts and bauxite districts indicated in Figure 6a, these results suggest that reduced labor demand in the mining sector primarily led to lay-offs rather than also wage reductions. This is consistent with mining being one of the most formalized sectors, with sector-specific minimum wages putting a constraint on the extent to which firms can lower workers' wages (see Section 3).[39]

Earnings in the manufacturing sector also do not change significantly following the export ban in either nickel or bauxite districts. In nickel districts, manufacturing employment gradually and substantially increased in the period after 2014, but earnings do not match this trend. This suggests that there was a sufficiently large supply of workers—possibly from other sectors in the district, the pool of unemployed, or to a limited extent from other districts—to hire more workers without substantially raising wages. In bauxite districts, the fact that both manufacturing employment and wages did not rise despite lay-offs in mining suggests that mining workers find it difficult to switch to a manufacturing job.[40]

In agriculture and services, wage premia do show more pronounced dynamics following the export ban. In nickel districts, earnings in both sectors decline substantially (up to 10%) in the first few years after the export ban imposition, consistent with downward pressure on wages due to an inflow of workers who lost their mining jobs. However, as local employment in mining and manufacturing pick up again around 2017-18 when Indonesia's nickel processing industry gains momentum, earnings in agriculture and services recover—consistent with increased competition for workers from the manufacturing and recovering mining sectors that gives rise to upward wage pressure. In bauxite districts, the export ban has a negative effect on earnings in both agriculture and services. Figure 7 shows that these effects gradually increase over time and are never offset in the later years of

[39]When considering nominal wages (see Table OA12), we do see a significant decline in mining wages immediately following the imposition of the export ban. Compositional changes can explain this decline: it suggests that mining workers leaving the sector are relatively better skilled, more experienced, than their counterparts that remain in the sector.

[40]When considering nominal wages (see Table OA12), we do see an eventual increase in manufacturing wages. This suggests that the new manufacturing workers added to the processing industry are relatively better skilled than those that were already working there.

our sample period. In 2023, wages in agriculture and services are still about 7-8% lower than in 2013. The outflow of workers from bauxite mining did not lead to a significant increase in agricultural or service-sector employment in bauxite districts, but it did put significant downward pressure on earnings in these sectors.

Are the effects solely explained by increased processing in mining districts? Following the export ban, substantial investment flowed into the nickel processing sector, with new smelters primarily locating in nickel-producing districts (see Section 3). This raises two important questions.[41] First, are the observed employment effects in nickel districts solely driven by the opening of the new nickel smelters, or do they extend to mining districts *without* any processing facilities? We answer this question below. Next, in Section 5.2, we document the local labor market effects of the newly opened processing facilities themselves.

To assess the first of the above two questions, we replicate our main analysis after excluding *all* districts that ever host a nickel smelter. The treatment group thus comprises districts with nickel endowments but no processing, while the control group includes districts with neither nickel endowment nor nickel smelters. Table 3 and Figure 8 show that the results are very similar to our baseline results in Table 1 and Figure 6 when only considering these "nickel-mining only" districts. Employment in these districts rises through increased demand for nickel from the processing sector located elsewhere. This drives the recovery of nickel mining employment and leads to an associated increase in local services employment. The manufacturing sector is the important exception here: we no longer find an increase in manufacturing employment following the export ban—the estimated coefficient is much smaller and no longer significant. This clearly shows that the rise in manufacturing employment in nickel districts is entirely driven by those nickel districts that receive the new processing plants.[42]

Summing up, we find that employment in nickel districts increased following the imposition of the export restrictions, driven by an expansion of jobs in manufacturing, services,

[41] From now on we focus entirely on nickel processing since Indonesian bauxite processing capacity remained at very low levels after 2014, certainly compared to nickel (see also Figure 2 and the discussion in Section 3).

[42] The results on wage premia are also very similar to those in Table 2 and Figure 7 when dropping nickel-endowed districts hosting nickel smelters (see Online Appendix OA4.1, Table OA11 and Figure OA21).

as well as in the mining sector—which recovered after an initial drop in employment occurring right after the ban. With the exception of the increase in manufacturing jobs, these effects are present regardless of whether the district hosts nickel processing facilities or not. In sharp contrast, we find a much less favorable picture in bauxite districts: mining employment significantly and persistently declines following the imposition of the export ban, with some evidence that this also led to downward wage pressure in agriculture and services as a result of the increased labor supply in these districts. These findings clearly show that the success of imposing export restrictions in stimulating local economic development crucially relies on the restrictions actually spurring the successful creation of a domestic processing industry, be it in the mining districts themselves or not.

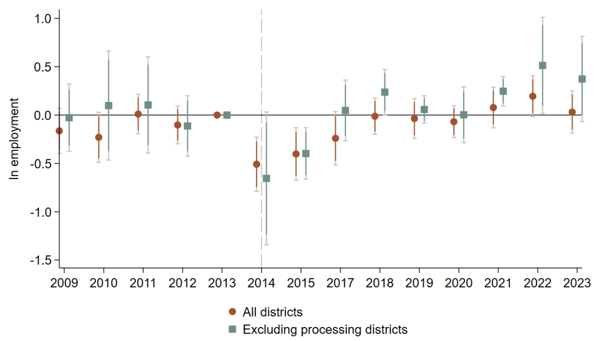
Table 3: Accounting for the processing industry

sample	excluding processing districts				
dependent var	ln employment				
	(1) total	(2) mining	(3) agriculture	(4) manufacturing	(5) services
nickel endowment × ER	0.032**	0.035	0.010	0.045	0.067***
	(0.013)	(0.114)	(0.025)	(0.082)	(0.024)
bauxite endowment × ER	-0.015*	-0.173	0.018	0.088	0.055
	(0.008)	(0.136)	(0.021)	(0.105)	(0.045)
N	6692	5877	6687	6537	6656

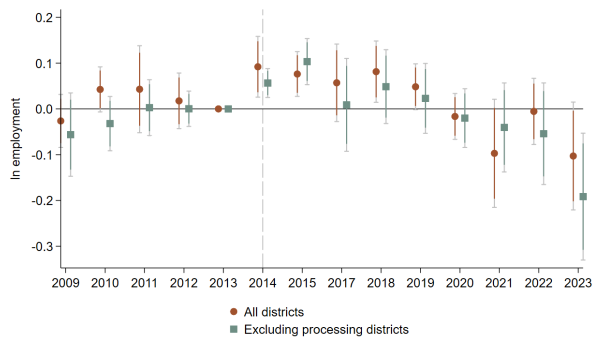
Notes: In this table we study how export restrictions on raw materials impact sectoral employment in districts where these resource deposits are located, but which never got a nickel smelter. The sample period is 2009-2023. This table excludes all 15 districts that ever had a nickel smelter. This leaves us comparing the 6 districts with mining but no smelters to the 476 districts with neither mining nor smelters. 'ln employment' is the number of people employed in a specific sector (in ln). 'nickel (bauxite) is a continuous variable measuring the nickel (bauxite) endowment as a share of the district's surface area in district d, scaled by the average endowment across all nickel (or bauxite-) endowed districts. 'ER' is a dummy variable which takes the value one if there is an export restriction active for this specific resource in year t. All columns include a full set of control variables, including interaction terms of the copper and iron endowment with the export restriction and the palm share with the palm oil price (in ln), as well as year fixed effects and district fixed effects. Standard errors are clustered at the district level and shown in parentheses. $^{***}p < 0.01,^{**} p < 0.05,^{*} p < 0.1$.

Figure 8: Accounting for the processing industry

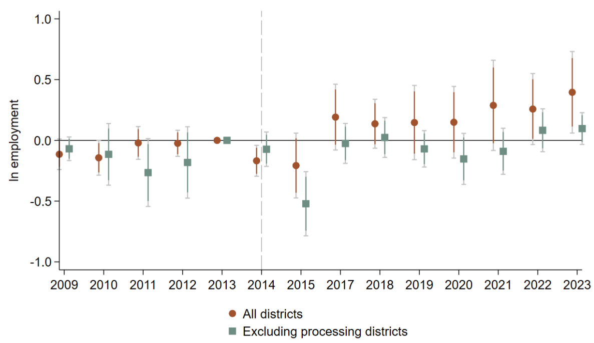
(a) mining



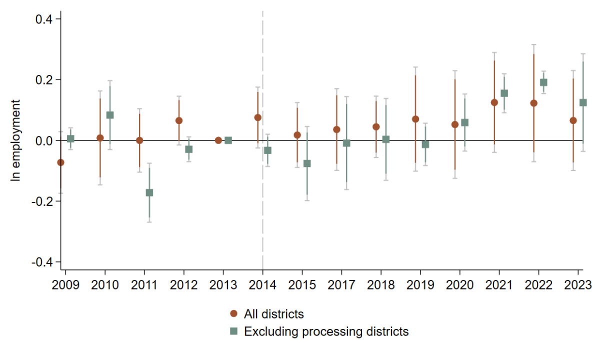
(b) agriculture



(c) manufacturing



(d) services



Notes: The results are based on Equation (5), but we only show nickel point estimates. The dependent variable is the number of people employed in a specific sector (in ln). 'All districts' includes all districts. 'Excluding processing districts' excludes all 15 districts that ever had a nickel smelter. 'nickel' is a continuous variable measuring the nickel endowment as a share of the district's surface area in district d, scaled by the average endowment across all nickel endowed districts. All specifications include a vector of control variables, including the copper and iron endowment interacted with year dummies, as well as the palm share interacted with the palm oil price (in ln), as well as year fixed effects and district fixed effects. Standard errors are clustered at the district level. Dots represent point estimates; orange/green (grey) lines indicate 95% (90%) confidence intervals. The year 2013 is the reference year.

5.2 Local effects of downstream nickel processing

Section 5.1 documented largely positive effects of the export ban on local employment in nickel mining districts, even in those without nickel smelters. We attributed these effects (and the very different experience of Indonesia's bauxite mining districts) to the successful expansion of Indonesia's nickel processing industry post-2014. In this section we follow up on this by documenting the local labor market effects of the newly developed nickel processing industry itself.

In doing so, we focus on the new nickel smelters, and do not study potential labor market effects of stainless steel production further downstream. The reason is that virtually all of the new steel production is located in the district of Morowali, which—given that it also hosts nickel processing—prevents us from distinguishing the local effects of processing from those of steel production. Moreover, Indonesia's stainless steel production is exported abroad, with no evidence to date of Indonesian firms taking advantage of its domestically produced stainless steel (see e.g. MINERBA, 2021). Any labor market effects even further downstream (from nickel processing) in the nickel supply chain are therefore very unlikely, and if even present, would be extremely hard to pick up in our data. That said, we do assess the sensitivity of our findings to the inclusion of Morowali (see Section OA3).

5.2.1 Empirical strategy

Establishing the local labor market effects of the new smelters is challenging, since smelter placement may be endogenous to local conditions. If smelter placement is systematically geared to districts that were already on different (sectoral) employment trends, it would be hard to distinguish the effects of the smelter from the effects of the drivers of these trends. However, the actual location choices of the new smelters, built on Sulawesi and Maluku (see Figure 4), strongly suggest that smelter location is primarily based on other factors than pre-existing district-specific employment trends. These factors are: (i) the availability of nearby nickel deposits, given the high costs of shipping the raw ore to the smelter—all smelters are indeed found close to existing nickel deposits; (ii) the presence of a sufficiently large port, in order to ship the processed nickel out and the relevant inputs for nickel smelting (most importantly coal) in—all smelters are found along the coast and in close vicinity to a port; and (iii) sufficient distance to the densest populated areas, minimizing the direct (immediately noticeable) impact of pollution caused by nickel smelting—only one (relatively small) smelter is located in an urban district (*kota*).[43]

All of the above factors are district characteristics that can be considered time-invariant over our sample period. This alleviates the concern that smelter location decisions were made based on district-specific unobserved trends that also influence labor market outcomes. Another concern could be that among the districts where a smelter opens after 2013, the specific *timing* of the smelter opening is endogenous to underlying local employment trends. However, this concern is largely invalidated by two factors. First, smelters are built by large companies which have limited or no ties to the district. Second, given the large scale, complex engineering, and strategic importance, these smelters typically use skilled labor from outside the district for construction and obtain relevant permits from administrative layers above the district level.

Considering that a smelter's location and opening date are thus very plausibly unrelated to local trends in employment, the opening of a smelter in a given year can be considered an exogenous shock from the district's perspective. We exploit this by estimating the following specification:

$$Y_{dt} = \gamma Smelter_{dt} + X_{dt}\xi + \alpha_d + \alpha_t + \varepsilon_{dt} \tag{6}$$

where Y_{dt} is labor market outcome variable Y in district d in year t. $Smelter_{dt}$ is defined as either a dummy variable indicating the presence of at least one operational smelter, the log number of operational smelters, or the log capacity of all operational smelters, in district d in year t.[44] X_{dt} is a vector containing the same set of control variables as included in Equation (4), as well as our main nickel and bauxite variables, NI_d and BX_d, interacted with our export restrictions dummy, ER_t. ξ is a coefficient vector capturing the effect of these control variables on Y_{dt}. γ is our coefficient of interest; its estimate tells

[43] The availability of sufficient freshwater (from rivers, springs and groundwater wells) for cooling, ore separation, dust suppression, and waste treatment and disposal, is another important prerequisite for smelter placement, but this is abundantly available throughout Sulawesi and Maluku.

[44] We always add 1 to these numbers before taking the log to avoid dropping districts without any smelter from the sample. Moreover, when simply using the total number of smelters or total smelter capacity instead, results are heavily dependent on the inclusion of the Morowali district, a clear outlier in terms of the number and joint capacity of smelters (23 smelters, with a joint capacity of 6.5 million metric tons), into the sample. When using the log instead, this is not the case (see also Section OA3).

us whether and to what extent nickel processing affects our outcome variables. α_d are district fixed effects and α_t are year fixed effects. We cluster standard errors at the district level. Finally, we always exclude the three districts that were already home to a (small) nickel smelter before 2014. As a result, our control group consists of districts without nickel smelters during our entire sample period, while our treatment group consists of the 12 districts that opened a nickel smelter after 2013.

Identification. The above-outlined empirical strategy relies on the exact timing of the opening of a new smelter, and its associated processing capacity, to be exogenous. As discussed above, it is very unlikely that other local events affecting a district's labor market are systematically occurring at the same time as smelter openings. However, there could be anticipation effects, such as workers and/or firms moving to the district with the expectation of securing a job or benefiting from increased local demand. If present, such effects would most likely lead us to underestimate the labor market effects of the smelter opening (and subsequent presence). Figure OA24 in the Appendix mitigates this concern, as it shows no significant employment pre-trends in the years leading up to a district's first smelter opening, compared to districts that do not have a smelter (yet).[45]

5.2.2 Results

Smelter openings and sectoral employment. Table 4 shows our findings. Regardless of the way we define $Smelter_{dt}$ in Equation (6), we do not find statistically significant effects of newly opened nickel smelters on total employment. However, this hides important differences in the employment effects in specific sectors. Defining $Smelter_{dt}$ as a dummy variable that equals one if at least one smelter is operational in the specific year (Panel A), we find that the opening of a district's first smelter increases manufacturing employment by 40% on average, which is equivalent to 2,300 jobs in the average nickel smelting district. This increase aligns well with actual employment at Indonesian nickel smelters, which usually ranges between 2,000 and 4,000 workers (but can exceed 10,000 at the country's largest facilities).

[45] The figure also shows employment trends in the years *after* the opening of a district's first smelter. Note that these results are not straightforward to interpret. They confound any dynamics in the effect of this first smelter in the years after its opening, with that of more smelters opening, or the smelter adding further capacity in later years.

Table 4: Downstream effect on employment in processing districts

dependent var	ln employment				
	(1) total	(2) mining	(3) agriculture	(4) manufacturing	(5) services
Panel A					
nickel smelter	-0.018	0.112	-0.116**	0.402*	-0.048
	(0.013)	(0.142)	(0.048)	(0.210)	(0.056)
Panel B					
ln # nickel smelters	-0.005	0.235***	-0.105**	0.393*	0.008
	(0.010)	(0.090)	(0.045)	(0.214)	(0.053)
Panel C					
ln nickel smelter capacity	0.008	0.344**	-0.107*	0.504	0.017
	(0.010)	(0.150)	(0.061)	(0.323)	(0.063)
N	6860	6045	6855	6705	6824

Notes: In this table we study how active nickel smelters impact sectoral employment in districts where these smelters are located. The sample period is 2009-2023. Starting from the full list of districts, the used sample excludes 3 districts that had a smelter before the export ban. This implies that we compare the 12 districts with post-ban nickel smelters to the 482 districts with no nickel smelters. 'ln employment' is the number of people employed in a specific sector (in ln). 'nickel smelter dummy' is equal to one if there is at least one nickel smelter active in the district, zero otherwise. 'ln # nickel smelters' is the number of nickel smelters in a district (in ln). 'ln nickel smelter capacity' is the total nickel smelter capacity (in 1,000,000 metric tons) in a district (in ln). All columns include a full set of control variables, including interaction terms of the nickel, bauxite and copper endowment with the export restriction and the palm share with the palm oil price (in ln), as well as year fixed effects and district fixed effects. Standard errors are clustered at the district level and shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

These positive effects of a smelter opening on manufacturing employment corroborate our conclusion that the overall post-ban rise in manufacturing employment in nickel-endowed districts is driven by those with a smelter.[46] Agricultural employment instead significantly decreases by 12% after a nickel smelter opens, corresponding to an average loss of about 7,100 workers. Some of those workers may be attracted by the (better-paying) jobs at the new nickel smelter or in nickel mines. However, the smaller absolute increase in manufacturing and mining employment suggests that such movements cannot fully explain the negative effect on agricultural employment. An important possible explanation for this loss of agricultural jobs are deteriorating employment conditions in the sector due to the negative environmental externalities of nickel processing and the associated coal power plants. Specifically, nickel processing in Indonesia has been linked to decreased land productivity, depletion or pollution of freshwater resources, and diminished fish stocks (CRI, 2024; Eco-Business, 2022), while evidence from the US and

[46] Additional results shown in Figure OA25 in the Online Appendix further confirm this. When including a simple smelter dummy (as in Panel A of Table 4) as an additional control to our event study specification in Equation (5), we no longer find the positive effect of a district's *nickel endowment* on manufacturing employment in the sample of smelter districts.

India shows that coal power plants reduce local crop yields (Burney, 2020; Singh, Lobell, & Azevedo, 2025).

In Panel B of Table 4, we allow the employment effects of local processing to depend on the *number* of active smelters in a given year. The results show that more smelters lead to more pronounced employment effects.[47] Doubling the amount of smelters in a district results in a 24% and 39% increase in mining and manufacturing employment, respectively, and leads to a 11% decline in agricultural employment. Finally, in Panel C, we use the joint processing capacity of all operational nickel smelters in a district and year, as our main explanatory variable. The results indicate that receiving more processing capacity results in larger employment effects, but the coefficients are less precisely estimated compared to Panel B. This is not unexpected: nickel processing is very capital-intensive, implying that a doubling of processing capacity translates into a smaller labor demand increase by the local processing sector than a doubling in the number of smelters (all of which need a minimum amount of workers to be operational).

In contrast to our employment findings, we find no significant effect of the expanding nickel smelter industry on sectoral wage premia (see Online Appendix OA4.2). The main adjustment mechanism of labor markets to a nickel smelter opening thus operates through changes in employment rather than earnings. Mining and manufacturing firms do not have to raise their wages to attract new workers. Our finding that agricultural wages do not change despite many workers leaving the sector (even more than taken up by the manufacturing sector), suggests that many (informal) agricultural workers are already earning subsistence wages with little room for further wage reductions. Moreover, there appears to be no scope for agricultural wage increases to keep workers from moving to the mining and manufacturing sector—again possibly due to reduced agricultural productivity as a result of the environmental damage from nickel processing.[48]

Summing up, smelter openings drive up local manufacturing (and mining) employment, but this comes at the expense of job losses in agriculture. This reflects structural trans-

[47] In the years following the imposition of the export ban, six districts opened one smelter, two districts opened two smelters, and four districts opened more than two smelters—with Morowali being the absolutely outlier, opening 23(!) smelters.

[48] We do find an increase in nominal manufacturing and mining wages upon the opening of a new smelter—see Table OA4.1.2. Again suggestive of the nickel processing boom resulting in the manufacturing sector attracting relatively better skilled people.

formation, which is one of Indonesia's key economic goals. In terms of magnitude, the effects are sizable: Table OA13 shows that a smelter opening increases the manufacturing employment share by around four percentage points (and a comparable reduction in agricultural employment), which implies a doubling of the manufacturing share in the average nickel mining district (see Table OA3). However, it is unclear whether the district benefits from these developments: a smelter opening does not raise total employment, and the decrease in agricultural employment does not solely reflect labor movements into manufacturing or services, but arguably also negative environmental effects of smelter activity (and the associated captive coal power plants) on agriculture.

5.3 Local effects in upstream coal districts

The newly developed nickel processing plants require vast amounts of power. This power is provided by nearby off-grid coal power plants, which contributed to a strong increase in Indonesian coal production starting from 2018. Besides creating negative (unintended) environmental effects in smelter districts, these coal power plants may have created positive (and again unintended) spillover effects on employment and wages in upstream coal mining districts. In this section we identify the existence of such effects.

5.3.1 Empirical strategy

We do not expect any effects on the labor market in *coal*-producing regions right after the export ban on raw nickel in 2014. If anything, such effects would only materialize once the new nickel smelters and their associated captive coal power plants start to be operational. Therefore, we restrict our sample to the period following the export ban (2014-2023), and estimate the following shift-share specification:

$$Y_{dt} = \rho\left(Coal_d \times NPC_t\right) + X_{dt}\psi + \alpha_d + \alpha_t + \varepsilon_{dt} \tag{7}$$

where Y_{dt} is outcome variable Y in district d in year t. $Coal_d$ is a district's area share under coal mining licenses, and NPC_t is the joint capacity of all operational nickel smelters in nickel districts in year t. X_{dt} is a vector of control variables, specified in more detail below, with ψ a coefficient vector capturing the effect of these control variables on Y_{dt}. ρ is our coefficient of interest: its estimate tells us whether and to what extent the expansion of Indonesia's nickel processing industry significantly affects labor market outcomes in Indonesia's coal districts. α_d and α_t are district and year fixed effects, respectively. As always, we cluster standard errors at the district level.

Identification. The important identification assumption warranting the causal interpretation of our estimates is, again, the parallel trends assumption. This assumption posits that in the absence of the newly developed nickel processing industry, and the associated boom in captive coal power plant construction, our labor market outcomes of interest would have followed similar trends in districts with different coal endowments. In Figure OA26, we show that there is little evidence of differential *pre*-trends in (sectoral) employment in coal-mining districts.

Nevertheless, several concerns could still be raised that imply a violation of the parallel trends assumption. We address these by always including a fixed set of control variables when estimating Equation (7).[49] First, we always include a district's coal share interacted with (i) a post-2018 dummy (i.e. post strict enforcement of Indonesia's Domestic Market Obligation in coal production) as well as with (ii) the total capacity of coal power plants outside of Indonesia's nickel districts. These two controls capture other important drivers of domestic demand for Indonesia's coal during our sample period which are also likely to disproportionately affect labor market outcomes in coal mining districts.

Second, if a district's coal endowment is correlated with other local factors which—due to coinciding events—became more relevant around the same time as the rise of the nickel processing industry, this could result in a violation of the parallel trend assumption. One particular concern here could be that Indonesia's coal districts are also (disproportionally) endowed with minerals that were (unlike coal) subject to the export restrictions starting from 2014. However, districts with coal endowments—which are found on East Kalimantan and Southern Sumatra (see Figure 3c)—hardly ever host other endowments of other minerals (see Table OA2). Nonetheless, we always include a district's nickel, bauxite, copper and iron endowments, respectively, interacted with a full set of year dummies, as controls to our regressions.

[49] Again, our results do not hinge on the inclusion of any of these control variables. We find the same results when not including them to our regressions.

Contrary to minerals, the location of Indonesia's coal endowments does show considerable overlap with palm oil plantations (compare Figure 3c to Figure OA1). Moreover, the production of palm oil strongly increases over our sample period. Therefore, we always include a district area's share under palm oil licenses interacted with the world price of palm oil as one of our controls. Finally, shocks on global coal markets could, if occurring at the same time as the expansion of Indonesia's nickel processing industry, confound our results. The most relevant events during our sample period are the fall in coal demand at the start of the Covid-19 crisis in 2020, a subsequent recovery, and a further price increase after Russia's invasion of Ukraine in early 2022. To address this, we also always add a district's coal endowment interacted with Australia's total coal exports to our set of control variables. Australia is the world's second largest exporter of coal after Indonesia, implying that Australia's exports arguably capture global coal market trends well.

5.3.2 Results

Table 5 shows our findings. Panel A shows results when estimating Equation 7. Panel B shows results when interacting a district's coal share with the *total capacity of all captive coal power plants in nickel districts*, instead of interacting with the total processing capacity of all operational nickel smelters in Indonesia. This specification arguably captures the demand for coal in the nickel processing industry even more directly.

Table 5: Employment in upstream coal mining districts

dependent var	ln employment				
	(1) total	(2) mining	(3) agriculture	(4) manu-factur-ing	(5) services
Panel A					
coal endowment × nickel smelter capacity	-0.0001 (0.0001)	0.0030*** (0.0009)	0.0001 (0.0004)	-.0011* (0.0006)	-.0005* (0.0003)
Panel B					
coal endowment × nickel power plant capacity	-0.0004 (0.0003)	0.0078*** (0.0023)	-0.0003 (0.0013)	-.0036** (0.0017)	-.0014** (0.0006)
N	4464	3968	4462	4377	4451

Notes: In this table we study how the increase in total nickel smelter capacity impacts sectoral employment in districts where coal deposits - a key input for the downstream processing industry - are located. The sample period is 2014-2023. 'ln employment' is the number of people employed in a specific sector (in ln). 'coal endowment' is a continuous variable measuring the coal endowment as a share of the district's surface area in district d, scaled by the average endowment across all coal endowed districts. 'nickel smelter capacity' is the total output capacity of nickel smelters in 1,000,000 metric tons, scaled by the mean smelter capacity in nickel districts (297,000 metric tons). 'nickel power capacity' is the total capacity in 1,000 MW of captive power plants in nickel districts, scaled by the mean power plant capacity (171 MW). All columns include a full set of control variables, including interaction terms of the nickel, bauxite, copper and iron endowment with the export restriction and the palm share with the palm oil price (in ln), and interaction terms with coal share with a post-2018 dummy, with aggregate Australian coal exports and with the total capacity in MW of power plants in non-nickel districts. Moreover, we also include year fixed effects and district fixed effects. Standard errors are clustered at the district level and shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

We find that an expansion of the domestic nickel processing sector positively affects mining employment in coal-mining districts. Adding an additional nickel smelter of average capacity increases mining employment in the average coal-mining district by 0.30%, corresponding to 25 mining workers (or about 1,650 mining workers in total in Indonesia's 66 coal mining districts). At the same time, employment in services and manufacturing falls by an average of 0.05% (23 service-sector workers) and 0.11% (9 manufacturing workers), suggesting that at least some workers leave the service and manufacturing sector to take up jobs in the expanding mining sector. Consistent with these results, we find no statistically significant change in total employment.

Panel B shows that the results are similar when interacting districts' coal endowment with the total capacity of all captive coal power plants in nickel districts. Adding one additional captive coal power plant of average capacity increases mining employment in the average coal-mining district by 0.78%, decreases manufacturing and service-sector employment by 0.36% and 0.14%, respectively, and does not lead to a significant change in total employment.[50]

6 Robustness

Our results in Sections 5.1-5.3 are robust to a wide range of robustness checks. While in this section we only provide a broad overview, in Online Appendix Section OA3 we carefully motivate and explain every robustness check and the corresponding results.

First, the results are robust to different ways of making the control and treatment group more homogeneous, such as (i) excluding districts on Java, the most developed and industrialized island of Indonesia; (ii) excluding districts without, or with very low levels of, mineral or coal endowments; (iii) excluding district with no, or very little, mining employment; (iv) adding additional control variables;[51] or (v) including a full set of island-year dummies to our regressions (which comes at the cost of losing a lot of variation and thus power). Second, our results are not purely driven by the districts with the largest nickel endowments or most processing activity (notably the Morowali district, home to 23 nickel smelters and most of Indonesia's stainless steel plants), but hold more generally. Third, we find qualitatively the same results when using simple endowment dummies indicating whether or not a district has any nickel or bauxite (or coal) endowments, instead of using our continuous endowment measures.

7 Conclusion

This paper identifies the local labor market effects of Indonesia's export ban on raw bauxite and nickel, introduced in 2014. Exploiting plausibly exogenous variation in the timing of the export restrictions, the opening of the new smelters, and in the location of

[50] Note that in total about 15 million metric tons of nickel processing capacity, and 5 thousand MW of coal power plant capacity, are added in nickel districts over our sample period (thus 0.33 thousand MW per 1 million metric tons of added nickel processing). This can explain the usually roughly three times larger coefficients in Panel B of the Table compared to those in Panel A. For completeness, our earnings results are provided in Online Appendix OA4.3. They show very small, near-zero, mostly insignificant, wage effects in coal districts.

[51] As additional controls, we include interactions of our post-export-ban dummy (or a full set of year dummies) with (i) a district's endowments of other minerals (than nickel, bauxite, copper and iron ore) which are quantitatively much less relevant but were also subject to the 2014 export ban; (ii) a district's ex-ante employment share in manufacturing or agriculture; or, in case of our smelter regressions, with respective dummy variables indicating whether or not the district (iii) is a city (*kota*), or (iv) has a mineral-handling port, both of which are important inputs in determining smelter location.

Indonesia's bauxite and nickel endowments, we show that the ban on raw nickel exports increased aggregate employment in nickel-endowed districts by about 3.0%, corresponding to 3,400 jobs (or 51,000 jobs across all nickel districts). This effect is mostly driven by gains in manufacturing and services, as well as the recovery of the mining sector as a result of the increased demand from a rapidly expanding domestic nickel processing industry. In sharp contrast, the bauxite export ban—unsupported by commensurate bauxite processing investment—reduced local employment in bauxite districts. On average, a bauxite district loses 1.5% of jobs compared to before the ban, most of them in mining, corresponding to 2,600 jobs (or 23,000 jobs across all bauxite districts), also putting significant downward pressure on earnings in agricultural and services. Finally, we also document an increase in mining employment in Indonesia's coal-endowed districts that provide the vast amounts of energy needed in nickel processing.

These findings provide a more nuanced picture than aggregate production or export statistics suggest. Yes, the export restrictions led to the (rapid) development of domestic nickel processing capacity, spurring the creation of new jobs as well as structural transformation in the districts attracting the new nickel smelters and stainless steel factories. However, in bauxite districts nothing like this happened. Many mining workers lost their job, which also substantially reduced wages in other sectors. Moreover, in the nickel processing districts, agricultural employment falls even more than the observed increase in manufacturing jobs. The negative environmental externalities on agricultural are an important possible explanation for this. Future research should aim to carefully identify these externalities.

Future research should also look at the longer-run effects of the export ban on industries even further downstream, such as stainless-steel making, higher-quality nickel products, and batteries. For now, there is little scope for substantial effects: stainless steel production has started in recent years but most of the output is exported, while domestic battery production only started in 2024 at one factory. As these domestic industries develop further and produce at competitive prices, other manufacturing industries further downstream may also benefit in future years. Moreover, future research should study to what extent nickel processing revenue remains in Indonesia and benefits its population, considering the high foreign ownership share and policy-induced tax and royalty revenue losses in the processing industry.

Our results offer valuable insights for other resource-rich developing countries contemplating similar export restrictions. Malaysia, for instance, plans to ban exports of rare earth raw materials in a similar bid to boost the high-value domestic processing industry. Our findings stress that export bans only translate into local development when matched with timely investment in domestic processing. Where such capacity fails to emerge, as in the case of Indonesian bauxite, lost export revenue can undermine employment and economic activity. Policymakers should therefore weigh commodity-specific factors—such as processing know-how, expected investor response, and market conditions—before imposing export restrictions.

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Appendix

Table A1: Summary statistics

variable	N	mean	sd	min	max
ln employment	6,902	12.153	1.041	7.889	15.27
ln hourly wage premium	6,871	0.000	0.266	-1.286	1.487
nickel endowment	6,902	0.034	0.234	0	2.444
bauxite endowment	6,902	0.018	0.187	0	2.411
coal endowment	6,902	0.133	0.529	0	6.004
nickel endowment (unscaled)	6,902	0.002	0.016	0	0.157
bauxite endowment (unscaled)	6,902	0.001	0.010	0	0.126
coal endowment (unscaled)	6,902	0.010	0.039	0	0.439
nickel smelter	6,902	0.014	0.118	0	1
ln # nickel smelters	6,902	0.134	0.127	0	3.178
# nickel smelters	6,902	0.030	0.452	0	23
ln nickel smelter capacity	6,902	0.004	0.060	0	2.019
nickel smelter capacity	6,902	11.949	17.269	0	54.023
nickel power capacity	6,902	7.497	9.177	0	30.029

Notes: See the main text for variable definitions. *unscaled* refers to resource endowment variables not scaled by the average endowment across all resource-endowed districts.

Table A2: Resource endowments, processing industry and coal power plants by district

		resource endowment		processing industry		coal power plants	
resource	district	#	share	#	capacity	2014	2023
nickel ↓	*Jawa Timur*						
	Gresik	0	0	1	21,601	0	0
	Banten						
	Serang	0	0	2*	59,500	295	780
	Kota Cilegon	0	0	1	57,500	4025	4065
	Sulawesi Tengah						
	Banggai	25	0.063	0	0	0	0
	Morowali	112	0.131	23	6,533,291	0	3785
	Tojo Una-Una	1	0.016	0	0	0	0
	Sulawesi Selatan						
	Bantaeng	0	0	1	500,000	0	0
	Luwu Timur	19	0.139	1*	94,300	0	0
	Sulawesi Tenggara						
	Buton	4	0.014	0	0	0	0
	Konawe	25	0.084	2	3,200,000	0	530
	Kolaka	18	0.049	4*	640,523	0	60
	Konawe Selatan	18	0.041	3	92,000	0	0
	Bombana	13	0.065	1	200,000	0	0
	Kolaka Utara	23	0.072	0	0	0	0
	Konawe Utara	86	0.157	0	0	0	0
	Kota Kendari	0	0	1	62,000	0	0
	Maluku						
	Seram Bagian Barat	1	0.007	0	0	0	0
	Maluku Utara						
	Halmahera Tengah	22	0.155	7	2,237,500	0	760
	Halmahera Selatan	15	0.026	4	521,951	0	0
	Halmahera Utara	0	0	1	1,600,000	0	0
	Halmahera Timur	29	0.157	2	224,655	0	0
	Papua Barat						
	Raja Ampat	2	0.008	0	0	0	0
	Papua						
	Jayapura	0	0	0	0	0	0
	Sarmi	1	0.006	0	0	0	0
bauxite ↓	*Kepulauan Riau*						
	Karimun	1	0.002	0	0	0	0
	Bintan	0	0	1	1,000,000	0	0
	Lingga	2	0.019	0	0	0	0
	Kota Tanjung Pinang	1	0.003	0	0	0	0
	Kalimantan Barat						
	Landak	12	0.109	0	0	0	0
	Pontianak	2	0.069	0	0	0	0
	Sanggau	22	0.126	1	300,000	0	0
	Ketapang	32	0.118	2	2,000,000	0	0
	Kayong Utara	4	0.017	0	0	0	0
	Kalimantan Tengah						
	Kotawaringin Timur	8	0.007	0	0	0	0

Notes: Endowments data comes from MINERBA. # refers to the number of licenses for a specific resource. Share refers to the share of the license area relative to the district's surface area. Data on the processing industry comes from CREA Celios, MINERBA & USGS. # refers to the number of processing plants in 2023 (* indicates one processing plant existed before the ban). Capacity refers to the output capacity of a processing plant in metric tons in 2023. Coal data comes from the Global Energy Monitor and refers to the capacity of power plants in MW. It is included only when corresponding figures exist in other columns.