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Abstract

The macroeconomic natural resource curse literature has identified volatility as a potential contributor to lower economic growth in resource-rich countries. We provide microeconomic evidence on how fluctuations in monthly mine-level copper production propagate through domestic production networks using 22 million domestic transaction and customs import records in Zambia. The 10 large copper mines account for approximately one-fifth of the annual value of VAT-reported domestic transactions, highlighting their centrality to Zambia's economy. A 1% increase in copper production is associated with a 0.516% increase in mines' domestic procurement. Mines' imports also respond to production changes, but less elastically. Chinese-majority-owned mines have lower domestic procurement levels but stronger procurement responses to production fluctuations. Tier 1 suppliers' domestic procurement and imports increase by 0.07% and 0.1%, respectively, in response to a 1% increase in their mining customers' production. The results are robust to instrumenting the monthly mine copper production with a shift-share copper price instrument. Mining volatility can generate substantial fluctuations in demand faced by domestic firms: a one-standard-deviation decline in mine-level copper production predicts a 23.4% contraction in mines' domestic procurement, equivalent to 4.7% of total VAT-reported domestic B2B transaction value if all mines experience such a decline simultaneously. As countries endowed with critical mineral deposits seek to expand mineral production and strengthen backward linkages, mitigating exposure to the sector's inherent volatility must be a policy imperative.

Critical Minerals; Copper Mining; Backward Linkages; Firm-to-Firm Transactions; Production Networks; Imports; Production Volatility.

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1 Introduction

The scramble for critical minerals to fuel the green energy transition and the expansion of artificial intelligence has heightened the strategic importance of the mining sector, particularly for resources such as copper, cobalt and lithium, designated as 'critical'. Many natural-resource-rich countries therefore aim to attract foreign direct investment (FDI) to unlock the potential of their mineral sectors, hoping that these industries will drive economic development (Adam *et al.*, 2026). Yet the perils of such an industrial strategy are well documented in the natural resource curse literature, which provides evidence of Dutch disease effects and increased corruption and conflict following mineral booms (Sachs and Warner, 2001; van der Ploeg, 2011; Berman *et al.*, 2017).

One important macroeconomic channel identified in the natural resource curse literature is volatility (Van der Ploeg and Poelhekke, 2009; Koren and Tenreyro, 2007). Mining is an intrinsically volatile industrial sector, partly because of fluctuations in international commodity prices (Guzmán and Silva, 2018; United Nations, 2024). This paper provides microeconomic evidence on how fluctuations in mining production propagate through domestic production networks via direct and indirect backward linkages. Backward linkages have long been viewed as crucial for translating mineral wealth into sustained economic development, by generating employment beyond the mining sector's inherently low labor-to-capital ratio and fostering firm growth through technology transfers, know-how, and economies of scale (Fessehaie and Rustomjee, 2018).[1] However, the same backward linkages that transmit the benefits of mining activity to domestic firms may also transmit its volatility.

Developing economies are particularly exposed to economic volatility because they tend to concentrate economic activity in a small number of sectors and specialize in industries characterized by high intrinsic volatility (Koren and Tenreyro, 2007). Moreover, the negative indirect effect of natural-resource dependence on economic growth through increased volatility can outweigh its

[1]This policy emphasis on backward linkages persists despite mining's reputation as an 'enclave' industry, characterized by weak integration into the domestic economy, an argument generally attributed to Hirschman (1958). An alternative strategy is to promote forward linkages through the downstream use of minerals in domestic industrial production, such as battery plants and copper wire manufacturing (Eggert, 2001). However, forward linkages often remain elusive in mineral-rich low- and middle-income countries because of limited industrial capacity and unfavorable geographic conditions for international trade. Mining locations are determined by geological rather than economic geography (Eggert, 2001), a challenge particularly relevant for landlocked countries such as Zambia.

positive direct effect (Van der Ploeg and Poelhekke, 2009). In addition, idiosyncratic shocks to sufficiently large firms need not average out in the aggregate (Gabaix, 2011).

Zambia exhibits all three sources of risk: (i) concentration in a particular sector, (ii) specialization in a high-volatility sector, and (iii) dominance by a few large firms. Copper alone accounts for more than 70% of export earnings (International Monetary Fund, 2025), with production dominated by ten major copper mines (and additional mines beginning production at the end of or after the data period). Our data confirm that these ten copper mining firms account for approximately one-fifth of the annual value of VAT-reported domestic business-to-business purchases.[2]

Against this background, Zambia's planned expansion of copper production from 800 thousand metric tons per year to 3 million metric tons per year(Mutesa and Meyns, 2024), raises important questions about the transmission of mining volatility to the domestic economy. Using monthly firm-to-firm transaction data reported to the Zambia Revenue Authority (ZRA), we move beyond conventional input-output analysis to estimate the elasticities of backward linkages with respect to copper production and quantify the implications of mining volatility for domestic demand.

We combine 10.8 million domestic firm-to-firm transactions with 10.7 million transaction-level import records and monthly mine-level copper production data. The domestic transaction data cover 2013–2022, while the import and production data extend through 2023.[3]

The analysis proceeds in four steps. In the first step, we show that Zambian copper production responds to short-term fluctuations driven by the volatile international copper price. In a second step, we explore mines' demand for domestic and foreign goods and services. We demonstrate that copper mines procure more goods and services from domestic firms—driven by both higher value and more transactions—in months and quarters when they produce more. We find that mines' imports also respond to contemporaneous production changes. We complement the analysis with a 2SLS shift-share analysis, which confirms the monthly co-movement of copper production and

[2]Additional research shows the propagation of shocks through production networks: Acemoglu *et al.* (2012) show how production networks can transmit shocks beyond their origin. Carvalho *et al.* (2021) provide empirical evidence of such propagation through firm-level supply-chain relationships.

[3]The transaction data were collected by the Zambia Revenue Authority (ZRA) for value-added tax (VAT) and import duty administration. As with other tax datasets, these data do not capture (1) transactions between informal firms and (2) transactions that are not reported to avoid taxes or import duties. The Zambian firm-to-firm transaction data have previously been used to study the effects of tax audits on compliance (Adu-Ababio *et al.*, 2023) and the local economy of Kitwe, a city in the Copperbelt Province (Benshaul-Tolonen and Fernandez Musso, 2025).

procurement, although the coefficients are different in magnitudes.

Third, we turn to Tier-1 suppliers to the large copper mines, defined as firms that have sold directly to a mine on at least one occasion, although we carefully test robustness to alternative definitions. We repeat the baseline OLS analysis for the Tier-1 suppliers, with some methodological adaptations demanded by the data structure: the main treatment variable (copper production) is now defined as the sum of total production of its copper mine customers (ever) at the monthly level. This variable takes into account the dynamic nature of this relationship, where firms become Tier-1 suppliers during our time period; thus, from the first month of supplying a mine, it will add this mine's copper production to its treatment variable. We find that Tier-1 suppliers increase their purchases from both domestic and international firms when the copper production of their customer rises.

We explore several heterogeneous effects and mechanisms. First, a geographic decomposition reveals that mines' domestic procurement is concentrated among suppliers registered in the Copperbelt Province (60% of procurement value), Lusaka Province (35%), and, to a lesser extent, North-Western Province (approximately 5%), which hosts several greenfield copper mines. Linkages to the remaining seven provinces are negligible. At the same time, Tier 1 suppliers increase their own imports as production rises at their mining customers, suggesting that some of the additional demand generated by mining is transmitted abroad. Second, a heterogeneity analysis for the Chinese-majority-owned mines show that these mines procure less on average, controlling for production, but are more responsive to changes in production. Third, Using a more sparse employment dataset, we calculate monthly direct employment elasticities for a subset of the time period; the best quality data for 2022-2023 find a modest contemporaneous link between mine production and contract employment.

Taken together, our findings challenge the traditional enclave hypothesis by documenting substantial backward linkages between copper mines and domestic firms, while highlighting the importance of imported inputs in these production networks. An important qualification is that gross domestic procurement does not necessarily translate into equivalent domestic value added. Many mine suppliers are themselves importers, suggesting that some of the demand generated by copper

mining may ultimately be transmitted abroad through imported inputs. However, limited domestic value added does not imply limited economic vulnerability to mining fluctuations if importing firms face uncertainty over future orders and demand. Thus, the domestic value added generated by backward linkages and the exposure of domestic firms to mining volatility need not be proportional.

To illustrate the magnitude of this exposure, we examine the volatility of monthly mine-level copper production after accounting for mine, year, and calendar-month fixed effects. The residual standard deviation of log production is 0.516. Combined with our estimated domestic procurement elasticity of 0.516, a one-standard-deviation negative production fluctuation is associated with a 23.4% reduction in domestic procurement, while an equivalent positive fluctuation is associated with a 30.5% increase. Given that copper mines account for approximately one-fifth of the annual value of VAT-reported domestic business-to-business transactions, these fluctuations represent potentially substantial changes in demand faced by domestic firms. Moreover, the responses of Tier-1 suppliers suggest that the effects of mining volatility extend beyond mines' direct purchases and propagate through domestic production networks.

We build on a rich literature examining the relationship between foreign direct investment (FDI) and economic growth (Alfaro *et al.*, 2004; Borensztein *et al.*, 1998), and spillovers to domestic firms (Alfaro *et al.*, 2010; Aitken and Harrison, 1999; Javorcik, 2004; Markusen and Venables, 1999; Setzler and Tintelnot, 2021). More closely, we are contributing to a growing literature on firm-to-firm transaction network (Alfaro-Ureña *et al.*, 2022; Amiti *et al.*, 2024; Balboni *et al.*, 2024; Chacha *et al.*, 2024; Dhyne *et al.*, 2021; Demir *et al.*, 2024). We focus on arguably one of the most critical—and most contested—industrial sectors: mining. For this purpose, Zambia is the perfect case study: copper has constituted around 70% of the country's exports on an annual basis over the past decades. Additionally, Zambia produces around 5% of global copper, making it a price taker, rather than a price setter, allowing us to exploit the fluctuations in the rather volatile international copper price as an exogenous source of variation in domestic copper production (corroborated naively by a positive correlation between the copper price and the Zambian copper output). As the country seeks to expand its annual copper output from 800 thousand metric tons per year to 3 million metric tons (Mutesa and Meyns, 2024), the question is timely.

This article proceeds as follows. Section 2 describes the study context. Section 3 provides a detailed overview of the database, while Section 4 introduces our empirical strategy. Section 5 presents results, Section 6 shows heterogeneity for subgroups, including Chinese-owned mines, and heterogeneous results by sector and geography. Section 7 discusses the volatility implications of the results. Section 8 concludes.

2 Background

2.1 The Economics of Mining

Previous research on backward linkages from the mining industry has largely relied on input-output tables (Fessehaie and Rustomjee, 2018) or firm surveys. In comparison to a thriving literature on the local welfare impacts of mining, for example, (Aragón and Rud, 2013; Benshaul-Tolonen, 2019; Cust and Poelhekke, 2015; Kotsadam and Tolonen, 2016; Mamo *et al.*, 2019; Von der Goltz and Barnwal, 2019), including studies on copper mining (Narantungalag, 2025) and research from Zambia (Wilson, 2012; Zabré *et al.*, 2021),[4] the literature on firms is more limited.

One relevant study examines the effects of mining on firms located near mining sites using standardized geocoded firm surveys, allowing the authors to define a specific "capture area" (e.g., within a 20 km radius of a mine) (De Haas and Poelhekke, 2019). Moreover, Allcott and Keniston (2018) find that oil and gas booms in the United States increase local upstream demand, while a study from Sweden documents increased entrepreneurship following a recent mining boom (Rodríguez-Puello and Kekezi, 2025). Using firm-level data from Chile, Atienza and Modrego (2019) show that mining service suppliers located in mining municipalities benefited more during the copper price super-cycle.

Our paper differs from this literature by measuring spillovers through observed firm-to-firm transactions within production networks, rather than defining spillovers based on Euclidean proximity to mining sites. We make an additional contribution by examining how natural resource

[4]In addition, a substantial literature uses qualitative methods. Two recent studies from Zambia document community perceptions of insufficient spillovers and employment benefits, alongside substantial environmental burdens (Benshaul-Tolonen *et al.*, 2026; Kolala and Bwalya Umar, 2019).

booms affect imports, an aspect of the natural resource curse literature that has received considerably less attention than exports (Arezki *et al.*, 2025a,b).

At the opposite side of the mining supply chain—where the critical minerals are used as inputs—a growing literature is exploring the impacts of critical mineral price and supply shocks on the macroeconomy (Ho *et al.*, 2026), innovation (Alfaro *et al.*, 2026), propagation into firm networks (Nguyen-Tien, 2026; Panon *et al.*, 2026), and firm valuation on stock markets (Ostry, 2026). Therefore, our research also contributes to this literature on the effects of critical mineral price shocks by focusing on the firm network in the producer rather than the consumer market.

2.2 Zambia's Position as a Global Copper Producer

Copper mining is central to Zambia's economy: the sector accounts for approximately 86% of foreign direct investment, 80% of export earnings, and roughly one quarter of government revenue (Sikamo *et al.*, 2016). Historically, mining activity was concentrated in the Copperbelt Province, along the border with the Democratic Republic of the Congo (DRC), and has spread westward along the border into the North-Western Province over the last decades, supported by greenfield investments.

Despite the outsized role that copper plays in the domestic economy, Zambia remains a relatively small actor in the global production landscape. Major producers—Chile, Peru, the DRC, and China—far exceed Zambia's output. With a 4–5% share of global production, Zambia is the second-largest producer in Africa and among the top ten worldwide, yet its scale remains modest relative to global leaders, positioning the country as a price taker in international commodity markets. Nevertheless, Zambia's macroeconomic performance has long been tightly linked to copper price movements: GDP growth closely tracked international copper prices from independence in 1964 through 2010 (Sikamo *et al.*, 2016).

A strong dependence on copper has persisted into the modern era. Anticipating continued growth in global demand, the Zambian government has set an ambitious target of raising annual copper production to 3 million tonnes by 2031—up from roughly 800,000 tonnes in 2021 (Mutesa and Meyns, 2024). This expansion reflects rising global demand for copper, projected to increase by approximately 30% between 2024 and 2040, driven by its high electrical and thermal conductiv-

ity and its critical role in renewable energy technologies and electrification (International Energy Agency, 2025).

As Zambia seeks to expand copper production to capitalize on a potential price super-cycle, the question of whether and how the sector can foster broader economic growth becomes increasingly important. Existing research often finds that backward linkages in mining are generally weak (Teka, 2011; Fessehaie, 2012), typically limited to low-value services and basic goods, with little scope for value addition or long-term industrial development (Robbins, 2013). In Zambia, low domestic demand and intense competition from low-cost imports have further constrained supplier development (Caramento, 2020; Benshaul-Tolonen and Fernandez Musso, 2025).

2.3 Chinese Ownership in Zambia's Copper Mines

The global race for critical minerals has heightened geopolitical competition between China and Western economies. China has established a dominant position in several critical-mineral value chains, raising questions about the implications of Chinese investment for economic development in mineral-producing countries. In Zambia, four of the copper mines in our sample were majority-owned by Chinese firms during the study period.

Chinese investment in the mining sector has attracted considerable scrutiny. Survey evidence suggests that Chinese mining FDI is perceived less positively than investment from other foreign investors (Shi and Seim, 2021), reflecting concerns about weaker employment spillovers (Wegenast *et al.*, 2019), greater vertical integration and fewer domestic backward linkages (Li *et al.*, 2022; Fessehaie and Morris, 2013), and the concentration of existing linkages in relatively low-technology sectors (Li *et al.*, 2022). Interviews conducted in the beginning of our study period with local suppliers and mining firms in the Copperbelt revealed that while neither Chinese-majority-owned nor non-Chinese-majority owned mines were content with the quality of locally sourced goods and services, Chinese-majority-owned mines did not consider local supply chain development as part of their corporate strategies in contrast to other mines who emphasized it as part of corporate social responsibility (CSR) activities (Fessehaie and Morris, 2013).

3 Data

We use a unique combination of data sources to construct the novel database that merges monthly firm-level procurement of goods and services domestically and internationally, copper production at the mine level, and international copper prices. The individual datasets and how they are linked are described in the following section.

3.1 Firm-to-Firm Transaction Data

The first dataset is derived from forms submitted to the Zambia Revenue Authority (ZRA) for VAT reporting purposes.[5] The dataset contains the near universe of firm-to-firm transactions, recorded at the goods and services level across the Zambian economy between 2013 and 2022.

We exclude six observations with pretax values exceeding ZMW 5 billion, which the ZRA flagged as erroneous entries, resulting in an initial sample of more than 10.85 million observations. Within this dataset, we identify 13,999 unique purchasers and 34,916 unique suppliers, noting that 12,811 firms operate in both capacities (see Table 1).

Informal and unregistered firms are unlikely to be captured in the VAT data; however, prior research finds that most informal enterprises in Zambia are rural, agricultural operations (Shah, 2012), and that mine suppliers are more likely registered with the tax authorities (Benshaul-Tolonen and Fernandez Musso, 2025). Moreover, because copper mines are export-oriented and subject to a zero-rate on exports, they are entitled to refunds on the VAT paid on their inputs, which provides strong incentives to report transactions accurately (Arezki *et al.*, 2025c).

3.2 Customs Records

The second dataset consists of the universe of imports[6] between 2013 and 2023 as reported to the ZRA. To exclude individuals importing for personal use and ensure firm-level comparability,

[5] According to Zambia's 2021 VAT guide, a supplier must be registered and VAT compliant if the value of taxable supplies exceeds ZMW 800,000 in any twelve consecutive months or ZMW 200,000 in any three consecutive months. Suppliers with turnover below the statutory registration threshold may still opt to register voluntarily.

[6] According to Zambia's 2021 VAT guide, an importer—whether a private individual or a business, and regardless of VAT registration status—is liable for VAT on eligible imports.

we restrict the dataset to importers registered in the domestic economy, identified through their presence as purchasers or suppliers in the domestic VAT dataset. This restriction yields more than 10.73 million import observations. Across these observations, we identify 14,751 unique importing firms, with imports originating from 233 distinct countries (see Table 1).

3.3 Linking to ZEITI Database

We subsequently merge in identification information derived from Payment Flows for mining and quarrying firms from 2013 to 2023, as published by the Zambia Extractive Industries Transparency Initiative (ZEITI), to flag the ten copper mines, as well as other mining and quarrying firms—including the export-oriented emerald mines, and firms producing for example gold, nickel and manganese.[7] Additional linking of ZRA administrative records allows us to incorporate (i) province of registration and (ii) information on ISIC business sectors for domestic purchasers, domestic suppliers, and importers.

3.4 Tier-1 Suppliers

To map upstream linkages, we exploit the dyadic structure of the data to identify the Tier-1 mine suppliers, defined in the baseline as non-mining and non-quarrying firms (per ZEITI) that supplied at least once to any of the ten copper mines within the domestic economy. We also consider more stringent definitions, including thresholds requiring a firm to supply (i) at least five times to any of the ten copper mines over the sample period and (ii) at least five times within a single month.

Beyond identifying these suppliers through purchaser–supplier linkages, we also observe the year and month in which a firm first becomes a Tier-1 mine supplier, enabling a dynamic definition of supplier status. We further track subsequent expansions in a Tier-1 supplier's customer base by observing the number of copper mine clients it serves over time. We leverage supplier identifiers to map these firms into the purchasing position within the dataset, allowing us to trace the domestic

[7] While the Zambian exports are dominated by copper, the country has a globally significant emerald production too. Gem stones, like emeralds, are not traded similarly to industrial metals and therefore do not have a traded market price like copper. These fundamental differences between emeralds and copper led to our restriction to copper mines.

inputs they procure. Because the structure of the import data does not permit direct identification of Tier-1 supplier, we carry over the list of domestic Tier-1 suppliers to track their import behavior. Using this approach, we identify 2,438 and 2,270 Tier-1 suppliers in the domestically purchasing and importing roles, respectively (see Table 1).[8]

[8]Out of 3,212 Tier-1 supplier, 2,438 show up as buyers of goods and services locally, and 2,270 import goods and services. In addition, 283 Tier-1 suppliers show up only as importers, not as domestic buyers.

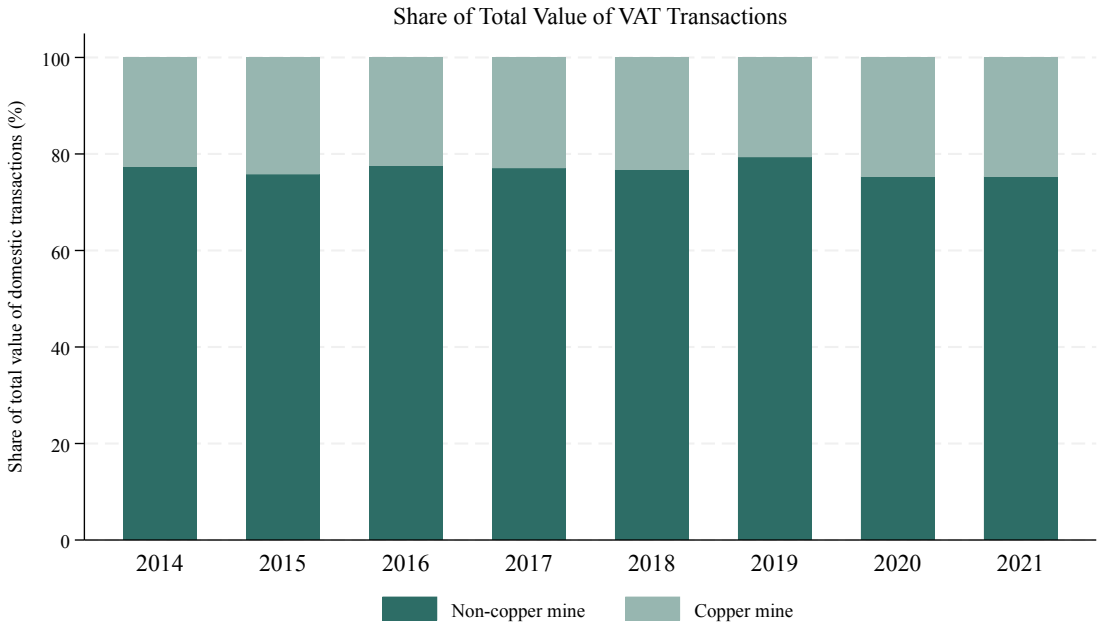


Figure 1: Share of Total Value of VAT Transactions by Copper Mines and Non-Copper Mines by Year

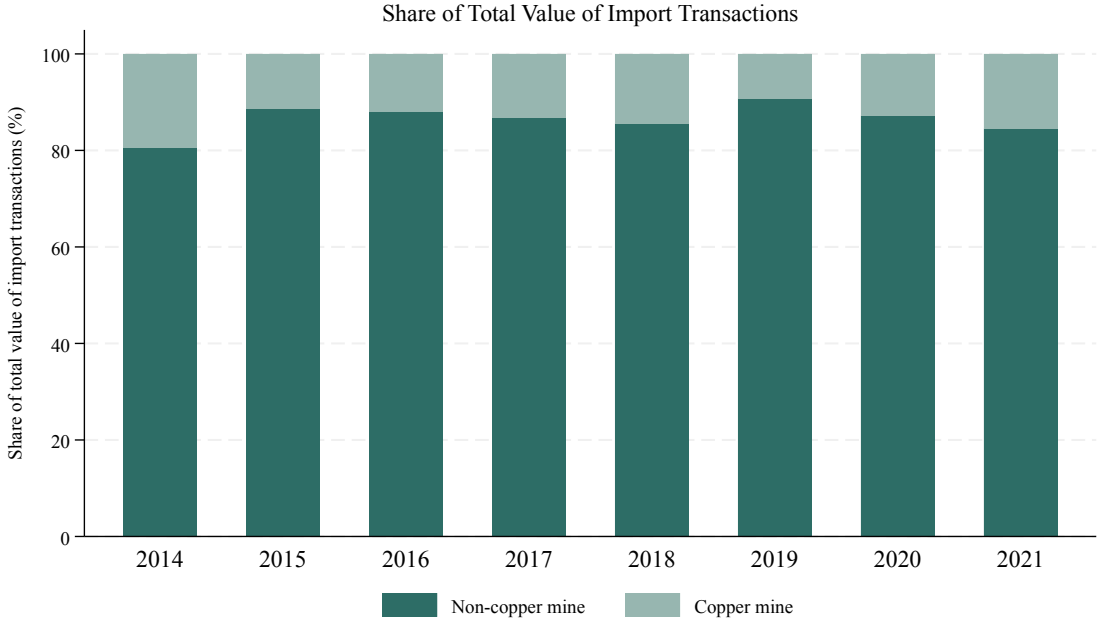


Figure 2: Share of Total Value of Imports by Copper Mines and Non-Copper Mines by Year

Notes: The Figures show the share of VAT and Import transactions reported in the data, split by copper mining firms and non-copper mining firms, defined as all other firms in the economy.

3.5 Copper Production Data

Drawing on a range of historical records maintained by the Zambia Ministry of Mines and Mineral Development, we construct a harmonized production dataset covering monthly copper output (measured in metric tons) for eleven Zambian mining firms from January 2013 to December 2023, with the eleventh firm entering the sample in the final year. The dataset exclusively reflects own-source production—comprised primarily of copper concentrates and, to a lesser extent, copper cathodes—and excludes output obtained through the smelting or refining of imported copper. Over the sample period, an individual copper mine produced an average of 6,594 metric tons monthly, with monthly output peaking at 26,833 metric tons for some firms (see Table 1). To ensure a consistent panel structure suitable for analysis, we standardized the historical data to account for changes in ownership, mergers, and firm renaming.

3.6 International Copper Price

In addition, we incorporate the international copper price series published by the World Bank for use as an instrument for copper production in our instrumental variables analysis. The global copper price is well suited for this purpose because it is highly volatile and driven by a combination of complex real and financial forces. Gilbert (2024), examining the notion of copper "super-cycles," finds that—unlike earlier periods of persistently high prices (e.g., those surrounding the world wars)—contemporary copper prices respond to a wide array of economic variables beyond supply and demand. Non-fundamental factors, including financial speculation, may influence the global price of copper more strongly than fundamental factors, making future copper price movements particularly difficult to predict (Gilbert, 2024; Guzmán and Silva, 2018). Moreover, copper markets are not characterized by effective cartelization, although historical failed attempts to form copper cartels have been observed.[9]

[9]Examples include the Copper Export Association (1918–1924) and the International Copper Cartel (1935), which coordinated production and pricing among major producers. Despite their influence, these cartels were voluntary, lacked legal enforcement, and were ultimately undermined by market pressures and competition from non-compliant firms (Walters, 1944). While copper production is concentrated among a handful of major producers, it remains economically and geographically dispersed—Chile, the DRC, China, the United States, and Zambia among them. The economic and political costs of coordination across this diverse set of producers likely explain the absence of modern cartelization efforts, even though models suggest that cartelization would substantially reduce output and

Figure 3 shows a positive correlation between copper prices and Zambian copper production, with a temporary deviation in early 2020 coinciding with the onset of the COVID-19 pandemic. Regression analysis supports this relationship: a 1% increase in the international copper price is associated with a 0.139% increase in production (statistically significant). Over the sample period, the average international copper price was USD 6,908 per metric ton, with fluctuations ranging from a low of USD 4,472 to a high of USD 10,231, highlighting price volatility (see Table 1).

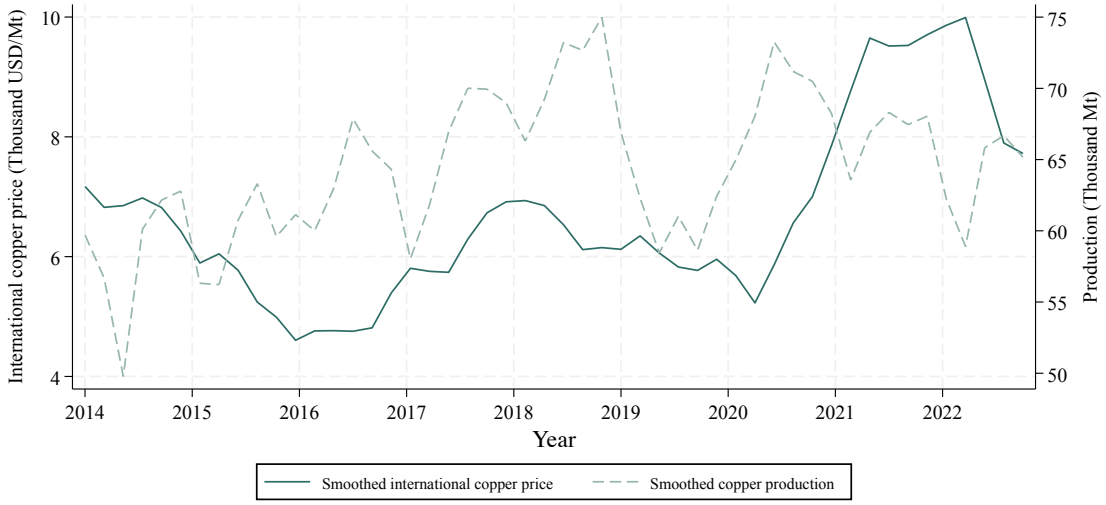


Figure 3: International Copper Price and Copper Production

Notes: Monthly series, January 2014 to October 2022. Copper production is the total monthly production of the large copper mines in Zambia, as reported to the Ministry of Mines and Mineral Development, in thousand metric tons (right axis). The international copper price is the World Bank monthly copper price, in thousand USD per metric ton (left axis). Smoothed trends were generated using local polynomial regression (lpoly) with a bandwidth of 1, corresponding to a ± 1 month window.

4 Empirical Strategy

In what follows, we set out our baseline empirical strategies used to assess how changes in copper production affect the domestic procurement and import behavior of mines and their suppliers.

increase producer profits (Romani *et al.*, 2025).

Owing to differences in the structure of the underlying datasets, the empirical approaches necessarily vary. We first describe the specifications used to estimate backward linkages from mines and address potential endogeneity concerns through an instrumental variables framework. We then turn to Tier-1 supplier, for which we employ a dynamic design that tracks firms as they enter the Tier-1 supplier network.

4.1 Baseline Empirical Strategy

During the study period, a total of ten large copper mines operated in Zambia, with an eleventh mine entering production in the final year. The domestic procurement dataset contains 252,006 purchases made by these mines. Using mine-level production and procurement data, we estimate the following specification:

$$\log Purchase_{it} = \beta_0 + \beta_1 \log Q_{it} + \phi_i + \phi_y + \phi_m + \varepsilon_{it} \tag{1}$$

where $Purchase_{it}$ denotes the domestic procurement of mine i producing copper at time t; Q_{it} is the copper production of mine i at time t; ϕ_i, ϕ_y, ϕ_m represent mine, year, and month fixed effects; and ε_{it} is the error term. The coefficient of interest is β_1, while β_0 captures a constant term. Standard errors are clustered at the Year-Month level; when indicated, we include Year-Month $\times$ Mine clustering, or wild cluster bootstrapped standard errors following Cameron *et al.* (2008).

The outcome variable is estimated in three forms: (i) average transaction value, (ii) number of transactions, and (iii) total transaction value. The first is computed using the raw goods-and-services-level dataset, while the latter two stem from the firm-month aggregated data. Total procurement value is our primary outcome of interest, with average transaction value and the number of transactions providing insight into the margins along which any estimated effects operate.

Our baseline domestic procurement regressions use a sample that excludes (i) intragroup transactions among the copper mines[10] and (ii) intercompany transactions involving a particular mine and its subsidiaries.[11] These exclusions remove copper sold for downstream processing, as well

[10] N = 2,454.
[11] N = 5,899.

as large and irregular entries—such as those arising from mergers, acquisitions, and internal asset transfers—that do not represent genuine backward linkages and would otherwise distort the analysis. Nevertheless, we demonstrate in robustness checks that our results are not sensitive to the inclusion of these transactions.

We replicate the domestic procurement analysis using the import records, identifying 465,944 import transactions made by copper mines.

4.2 Instrumental Variables Analysis

Our baseline OLS specifications for both domestic procurement and imports may suffer from endogeneity, as mine-level production is determined by a plethora of factors. To address potential endogeneity in copper production, we employ two instrumental variables strategies using the international copper price. Because Zambia is a relatively small producer in the global copper market, international copper price fluctuations are plausibly exogenous to individual mines' production decisions. The validity of the instruments additionally requires relevance and the exclusion restriction, namely that international copper prices affect mines' procurement only through their impact on copper production, conditional on the included controls. A comparison of the OLS and 2SLS estimates allows us to examine how estimated procurement responses differ when exploiting variation in production associated with international copper prices.

First, we instrument production with the contemporaneous international copper price. The exclusion restriction requires that international copper prices affect mines' inflation-adjusted procurement only through their impact on copper production in the very short-term, rather than through other channels such as revenues, liquidity, or investment decisions. Crucially, this assumption does not require international copper prices to be irrelevant for the broader Zambian economy; it pertains specifically to the procurement decisions of mining firms. The instrument varies at the year-month level but not across mines, and therefore cannot be combined with year-month fixed effects.

Second, we implement a shift-share instrumental variables strategy that interacts each mine's baseline share of total copper production in 2013 with the international copper price. Unlike the first

specification, this instrument varies across both mines and time, allowing us to include mine and year-month fixed effects. The year-month fixed effects absorb common price movements and other aggregate shocks, while the interaction exploits differential production responses to international copper price fluctuations across mines with different baseline production shares. This specification therefore provides an alternative source of identifying variation, although the exclusion restriction additionally requires that baseline production shares do not predict differential procurement responses to copper prices through channels other than production.

4.3 Copper Mine Suppliers

Subsequently, we shift our focus to upstream firms. In the baseline specification, a firm is classified as a Tier-1 supplier beginning in the first month in which it supplies any of the ten copper mines. This definition may introduce endogeneity, as firms begin supplying mines for non-random reasons. In particular, more productive or better-connected firms may be more likely to become Tier-1 suppliers, raising concerns that unobserved differences reflect selection rather than causal spillovers, a challenge emphasized in the literature on supplier linkages (e.g., Alfaro-Ureña *et al.*, 2022; Amiti *et al.*, 2024). Our empirical strategy partially addresses this concern by exploiting within-firm variation over time and tracking firms as they enter supplier relationships, allowing us to relate changes in procurement behavior to changes in exposure to mining activity. However, we cannot fully rule out selection into supplier status, and therefore interpret our results as capturing a combination of demand-driven effects and selection.

In addition, some firms may have been supplying mines prior to the start of our dataset, resulting in the misclassification of such firms as new entrants during the study period. Nevertheless, under this definition we identify 3,212 Tier-1 suppliers, each serving an average of 2.1 mines over the study period. Leveraging the dyadic structure of the data, we identify more than 3 million purchases made by 2,438 of these suppliers, and estimate the following model:

$$\log Purchase_{it} = \beta_0 + \beta_1 \log\left(\sum_{j \in \mathcal{J}_{it}} Q_{jt}\right) + \phi_i + \phi_y + \phi_m + \varepsilon_{it} \tag{2}$$

where $Purchase_{it}$ denotes the domestic procurement of Tier-1 suppliers i in month t; $\mathcal{J}_{it}$ is the set of mines that supplier i has supplied at least once up to and including month t; and $\sum_{j \in \mathcal{J}_{it}} Q_{jt}$ captures the total copper production of all copper mine customers of supplier i in month t. The terms ϕ_i, ϕ_y, ϕ_m denote firm, year and month fixed effects respectively, and ε_{it} is the error term. Again, the outcome variable is estimated in its three distinct forms: (i) average transaction value, (ii) number of transactions, and (iii) total transaction value.

We vary this specification to measure the intensive margin by replacing the treatment variable with (i) the number of copper mine customers, (ii) the log of the international copper price, or (iii) an interaction of copper mine customers and the log copper price. The second approach, which relies solely on copper-price variation, helps mitigate concerns related to the endogenous timing of a firm's entry into Tier-1 supplier status. Additionally, we test the robustness of our results to more stringent definitions of Tier-1 supplier status.

We extend the analysis to the import dataset, identifying 2,270 Tier-1 suppliers engaged in more than 6 million import transactions.

5 Results

5.1 Domestic Procurement by Copper Mines

Figure 4 shows visual evidence of a similar temporal pattern between copper production and copper mine procurement of goods and services. The OLS regression estimates corroborate this pattern: copper production is positively associated with the average value of transactions, both contemporaneously and with a one-quarter lag (Table 3, Columns 1 and 2 respectively). In months with higher copper output, the CPI-adjusted average transaction value increases. Higher production is also linked to a greater volume of purchasing activity, as reflected in the number of transactions (Table 3, Columns 4 and 5). Naturally, the total value of goods and services increases when the copper production increases: a 1% increase in the copper production is associated with a 0.516% increase in total procurement value (Table 3, Column 7). Taken together, these findings indicate a robust and positive relationship between copper production and domestic procurement, consistent

with the presence of backward linkages.

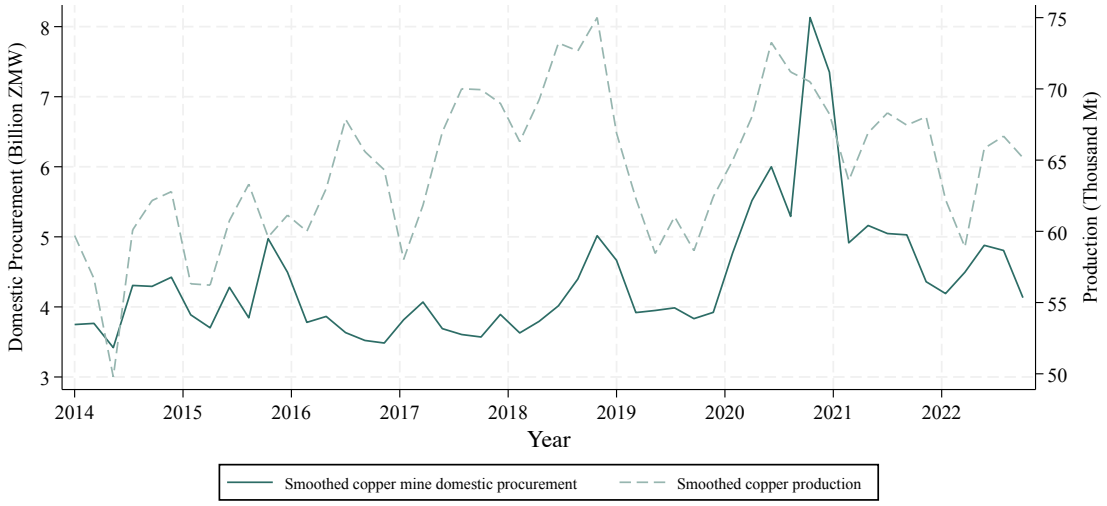


Figure 4: Copper Production and Domestic Procurement by Copper Mines

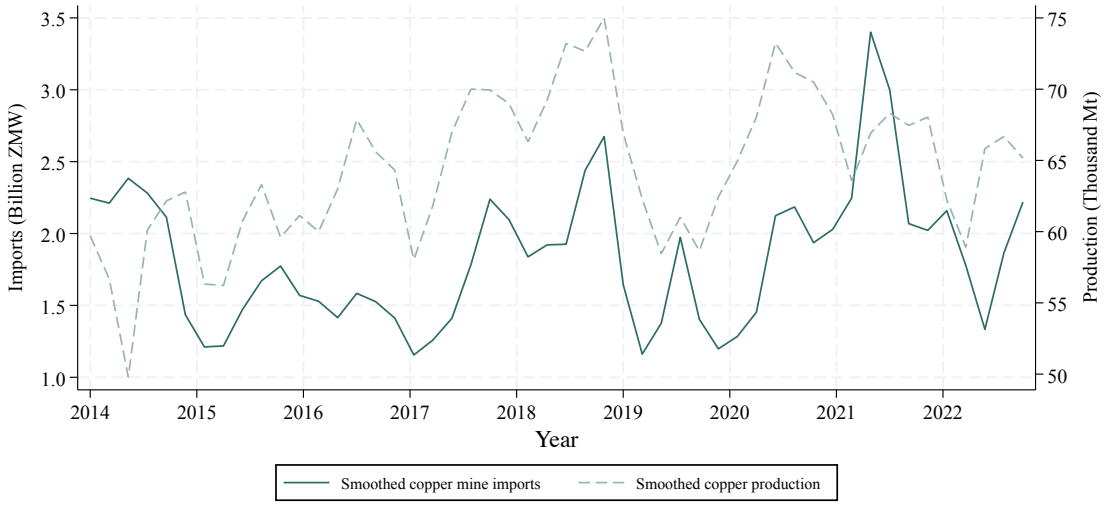


Figure 5: Copper Production and Imports by Copper Mines

Notes: Monthly series, January 2014 to October 2022. Copper production (right axis) is the total monthly production of the large copper mines, in thousand metric tons. Figure 4: total domestic procurement of the copper mines in billion ZMW, inflation-adjusted with the monthly CPI; the sample is that of Table 3 (excluding six transactions above ZMW 5 billion, 810 records with unreadable amounts, transactions between copper mines, and transactions among one mine and its subsidiaries), and negative values (credit notes) are excluded before summing. Figure 5: total imports of the copper mines in billion ZMW, inflation-adjusted with the monthly CPI. Smoothed trends were generated using local polynomial regression (lpoly) with a bandwidth of 1, corresponding to a ±1 month window.

We conduct a series of robustness checks that vary the fixed-effects structure, time trends, and standard-error specifications, and we expand the sample to include transactions among copper mines and between a multinational mine and its subsidiaries. Across all specifications, the results remain largely consistent and statistically significant (Table 4, Columns 1–3 and 5–6). Additionally, we investigate the pronounced spike in Figure 4 toward the end of 2020. Contemporary accounts suggest that delays in procurement earlier that year were linked to the COVID-19 pandemic, which severely restricted the flow of goods and services. To ensure that this disruption does not bias our estimates, we re-estimate the models excluding the COVID-19 period (Table 4, Column 4). The results remain consistent and statistically significant.

5.2 Instrumental Variables Estimation

The IV results reported in Table 3 (Columns 3, 6, and 9) show that production shocks instrumented with the contemporaneous international copper price lead to an increase in the number of transactions, albeit accompanied by a reduction in their average size. This contrasts with the OLS estimates, which associate higher production with both more frequent transactions and larger average transaction values. The divergence suggests that the OLS coefficients reflect a mix of short-run operational fluctuations and longer-run, planned production changes—such as investment cycles or major contracting decisions—that scale both the volume and the value of procurement. By contrast, the IV estimates isolate short-run, exogenous production responses to copper-price shocks, which mines can accommodate through operational adjustments such as increasing shift intensity, processing accumulated ore stockpiles, deferring minor maintenance, or drawing on higher-grade sections of existing pits. These adjustments tend to rely on smaller, recurrent inputs (e.g., fuel, reagents, spare parts), generating more frequent but lower-value purchases. Despite these differing margins of adjustment, the resulting total effect (Column 9) remains similar in magnitude to the baseline OLS estimate (Column 7).

Next, we conduct a shift-share 2SLS analysis, where the international copper price is interacted with each mine's share of total copper production in 2013, with the analysis starting in 2014. The estimated elasticity of total domestic procurement is larger, at 1.340, driven by higher transaction

values rather than more transactions (Table 5). The shift-share specification has a substantially stronger first stage (effective F-statistic of 80.06, compared with 17.16 in the price-only IV specification). By interacting international price fluctuations with baseline production shares, the model exploits differential responses across mines while controlling for mine and year-month fixed effects. Interestingly, the first-stage coefficient is negative, indicating that mines with larger baseline production shares exhibit weaker production responses to increases in copper prices relative to smaller mines.

The larger shift-share estimate suggests that the procurement response to price-induced production changes may be stronger than indicated by the baseline OLS and price-only IV estimates. The contrasting adjustment margins—transaction values versus transaction frequency—may reflect heterogeneity in procurement responses across mines of different sizes. However, because the specifications also differ in their identifying variation, fixed effects, and estimation samples, these differences cannot be attributed solely to mine size.

5.3 Direct Imports by Copper Mines

To provide the necessary counterfactual for interpreting the magnitude of backward linkages within the domestic economy, we turn to mines' import behavior, which captures the portion of input demand met outside Zambia. Figure 5 shows that copper mine import patterns closely track copper production over time, and because the import values are deflated using monthly CPI, this co-movement is unlikely to be driven by general price changes. These imports come from a wide range of origins, with the most frequent countries (by transaction count) being (1) South Africa, (2) China, and (3) the United States; imports from the neighboring DRC are also frequent.[12]

We find that copper production is negatively associated with the average value of import transactions (Table 6, Columns 1 and 2), consistent with the interpretation that higher production leads to more—but smaller—imports within the same month. This pattern is driven by a significant increase in the number of import transactions (Table 6, Columns 4 and 5). As a result, the total value

[12]Some of these transactions may reflect imports of copper for further refining, although the mine production numbers reflect own mine production, not processing of imported copper concentrates. Therefore, this issue would bias our effects downward.

of imports rises, with estimates indicating that a 1% increase in copper production is associated with a 0.188% increase in the value of imports (Table 6, Column 7).

Sensitivity analyses underscore the robustness of these findings (Table 7, Columns 1–3). Given the slight divergence in trends observed in 2020, followed by a catch-up in early 2021—likely a result of the COVID-19-related border closures, which reduced import traffic by roughly 25%—we also re-estimate the results excluding the year 2020 and find that the results remain robust (Table 7, Column 4).

Furthermore, the IV estimates—exploiting variation in production induced by international copper prices—corroborate the OLS results: exogenous, price-driven increases in production lead to a higher frequency of import transactions and an expansion in total import value, but not to larger individual transactions. Overall, the extensive margin (number of transactions) dominates the intensive margin (average value per transaction), resulting in a larger estimated effect on total import value. This pattern is consistent with the view that large, infrequent capital imports—such as mining trucks or other heavy machinery—are not closely tied to short-run production or price fluctuations, leaving higher production months characterized by a larger number of smaller imports. Nonetheless, while both OLS and IV estimates show that total import value rises with production, their magnitudes diverge substantially: the OLS coefficients are modest (0.188–0.285), whereas the IV estimate is much larger (2.233), suggesting that price-driven production shocks induce stronger import responses than anticipated production changes.

5.4 Domestic Procurement by Tier-1 Suppliers

Tier-1 suppliers are defined in the domestic procurement data as non-quarrying, non-mining firms that engage in at least one transaction with any of the ten copper mines during our study period. Although this definition is time-varying, a substantial share of firms are already classified as Tier-1 suppliers at the start of the observation period. Visual evidence indicates that these Tier-1 suppliers increase their procurement of goods and services from domestic firms when the copper production of their corresponding copper mines clients is high (Figure 6), underscoring their potential role in generating domestic demand. Because Zambian Tier-1 suppliers are unlikely to exert a meaningful

influence over the production decisions of foreign-owned, large-scale copper-exporting mining firms, the patterns documented in Figure 6 plausibly reflect demand effects driven by mining activity rather than the reverse. Regression results corroborate this interpretation: a 1% increase in copper production is associated with a 0.069% increase in total procurement value (Table 8, Column 5). The main explanatory variable, log(Cu production), captures the total output—measured in a given month—of all mines with which a supplier has ever transacted up to that point.

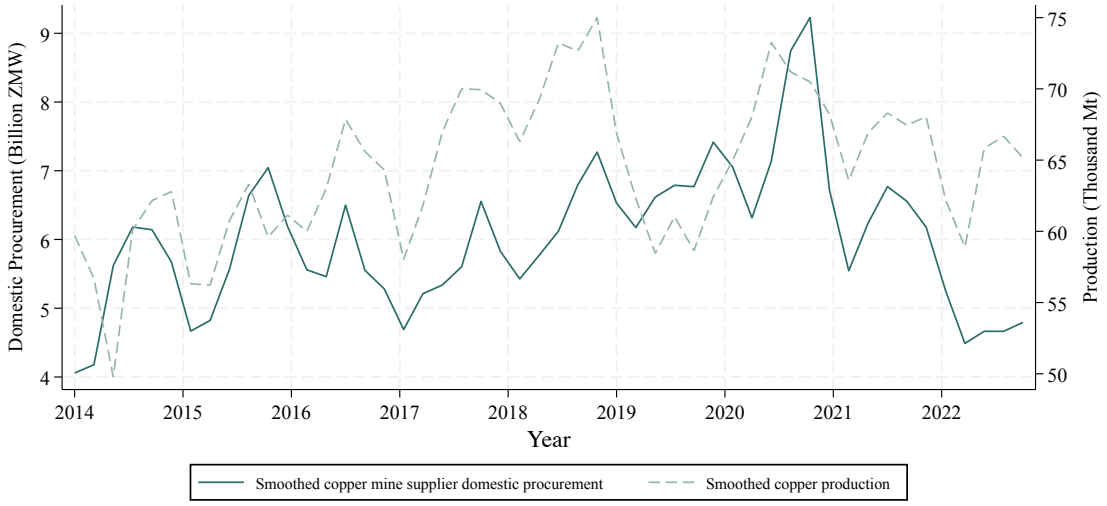


Figure 6: Copper Production and Domestic Procurement by Copper Mine Suppliers

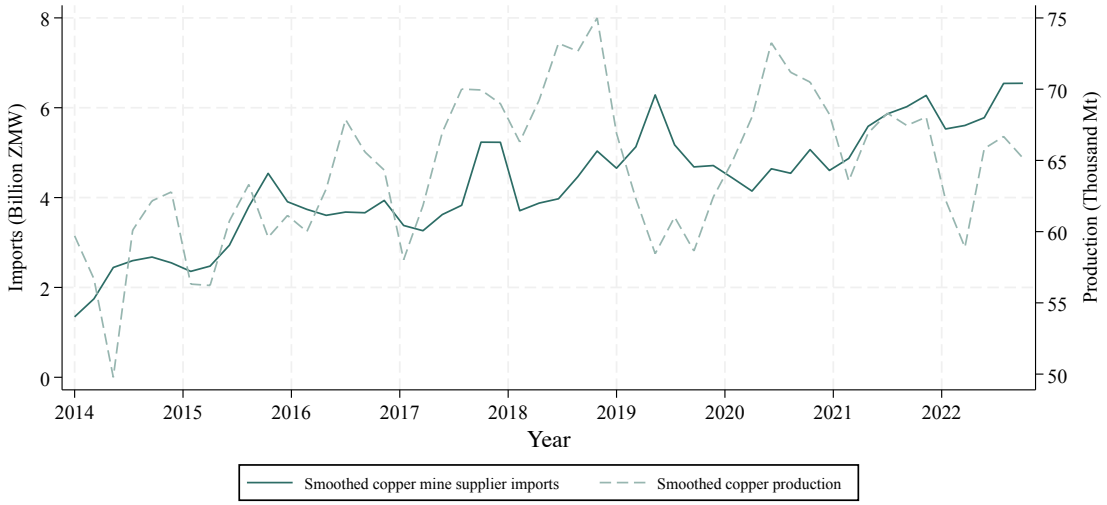


Figure 7: Copper Production and Imports by Copper Mine Suppliers

Notes: Monthly series, January 2014 to October 2022. Copper production (right axis) is the total monthly production of all large copper mines, in thousand metric tons (not only the mines supplied by each firm). Figure 6: total inflation-adjusted domestic procurement of copper mine suppliers, in billion ZMW, from the month of their first sale to a copper mine onward; negative values (credit notes) are excluded before summing. Figure 7: total inflation-adjusted imports of copper mine suppliers, in billion ZMW, from the month of their first sale to a copper mine onward. Smoothed trends were generated using local polynomial regression (lpoly) with a bandwidth of 1, corresponding to a ± 1 month window.

5.5 Imports by Tier-1 Suppliers

Turning to the import behavior of Tier-1 suppliers, we find a similar pattern—albeit of larger magnitude. A 1% increase in copper production is associated with a 0.099% increase in the total value of imports (Table 9, Column 5). These findings suggest that Tier-1 suppliers may at times function primarily as intermediaries, importing goods on behalf of the mines with limited domestic value addition. Calculating the total share of import, direct (mines) and indirect (Tier-1 mine suppliers), or even further upstream the value chain, would require the assumption that mine suppliers have similar import share in their sales to mines as to other customers, in line with previous literature (Dhyne *et al.*, 2021, 2023). However, given the idiosyncratic nature of the large copper mines in Zambia in ownership, sector and size, it is unclear if this assumption would hold.

5.6 Tier-1 Supplier Definition

To assess the sensitivity of our results to the choice of treatment intensity—measured in the baseline as the sum of customers' copper production—we vary this definition in two ways. Using the number of copper customers as an alternative measure of exposure (intensive margin) yields consistent results (Table 10, Columns 1, 4, and 7, and Table 11, Columns 1, 4, and 7). Moreover, interacting this customer count with the international copper price similarly produces stable estimates (Table 10, Columns 2, 5, and 8, and Table 11, Columns 2, 5, and 8).

We then conduct a broader set of robustness tests on our baseline empirical specifications for domestic procurement and imports by Tier-1 suppliers. The results remain robust across alternative fixed-effects structures and clustering choices (Table 12, Columns 1–4, and Table 13, Columns 1–4, respectively). We next vary the definition of a Tier-1 supplier, raising the threshold from at least one transaction with any of the ten copper mines during the study period to at least five transactions overall, and then to at least five transactions within a single month. As expected, as the classification criterion for Tier-1 suppliers becomes more stringent, the estimated coefficients for both domestic procurement and imports increase in magnitude (Table 12, Columns 5–6, and Table 13, Columns 5–6).

6 Sensitivity and Heterogeneity Analysis

6.1 Chinese Majority-Owned Mines

To better understand the nature of these domestic linkages, we examine the suppliers of Chinese-majority-owned copper mines. To examine whether procurement patterns differ systematically by mine ownership, we include an ownership indicator reflecting the ownership structure prevailing during the study period, and interact it with copper production.

Chinese-majority-owned mines are associated with smaller average transaction values, fewer procurement transactions, and lower total procurement, conditional on production and time fixed effects (columns 1, 4, 7 in Table 14). Despite less domestic procurement, the interaction between the Chinese ownership dummy and copper production is positive and statistically significant for total procurement value, both contemporaneously and with lagged production. The contemporaneous interaction coefficient of 0.264 implies that a 10% increase in copper production is associated with approximately 2.6 percentage points greater growth in domestic procurement among Chinese-owned mines than among non-Chinese mines. This difference is driven by a stronger response in average transaction values rather than transaction frequency. Together, these findings suggest that Chinese-owned mines' demand is weaker and more responsive to production changes compared to other mines.

Chinese-majority-owned mines are associated with significantly lower total imports, while the interaction between Chinese ownership and copper production is statistically insignificant (Table 15, Columns 8 and 9). Thus, although import levels differ substantially across ownership groups, we find no statistically significant difference in their import elasticities.

6.2 Sector Heterogeneity

Although the domestic VAT dataset lacks detailed goods and services descriptions for much of the study period, the ISIC classification indicates that nearly 50% of Tier-1 suppliers operate in wholesale and retail trade, about 10% in professional, scientific and technical activities, about 9% in construction, and around 7.5% in manufacturing (see Table 16). We use this firm-level sector

classification to re-estimate the main model and obtain industry-specific elasticities. Table 17 reveals substantial heterogeneity across sectors. The largest elasticities are estimated for mining and trade and distribution, at 0.72 and 0.66, respectively, implying that a 1% increase in the explanatory variable is associated with approximately a 0.7% increase in the outcome. Manufacturing, business and professional services, construction, and social and other services exhibit intermediate elasticities, ranging from 0.23 to 0.46. Transport is considerably less elastic, with an elasticity of 0.17, although the estimate remains statistically significant at the 5% level. The estimated elasticity for utilities is small (0.065) and statistically indistinguishable from zero. Agriculture is the only sector with a negative point estimate (-0.247), but the estimate is imprecise and not statistically significant.

6.3 Geography of Linkages

We continue by exploring the spatial distribution of the linkages. We use provincial-level data, which, although less granular, are more reliable and less prone to misclassification. All ten copper mines are concentrated in the North-Western and Copperbelt provinces, which are well known for their copper-cobalt resource deposits.

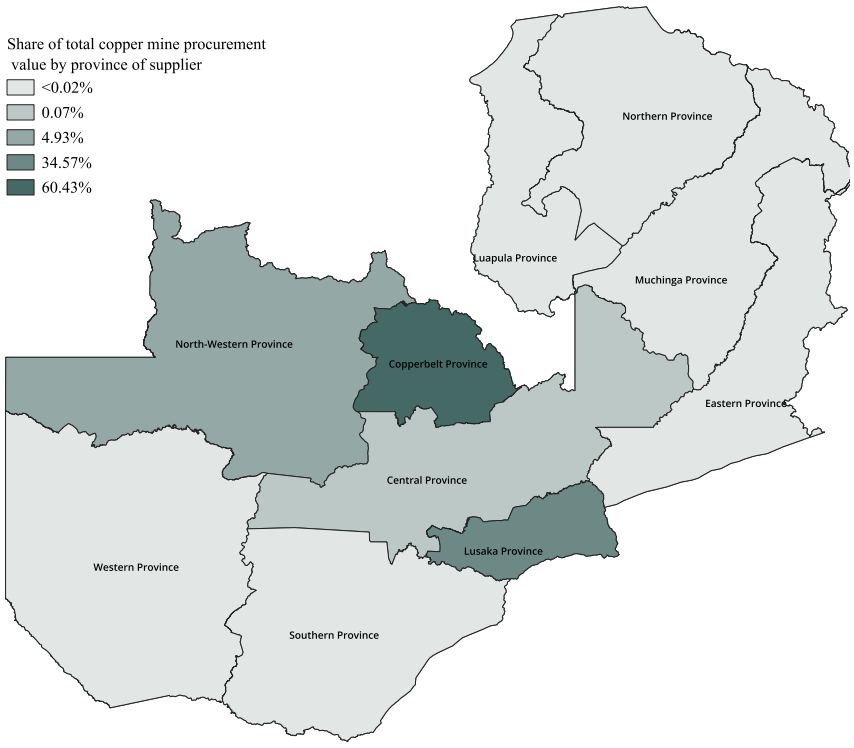


Figure 8: Share of Total Copper Mine Procurement Value by Province of Copper Mine Supplier

Notes: Share of the copper mines' total inflation-adjusted domestic procurement value (September 2013 to November 2022) by the province in which the supplier is registered with ZRA, with the same exclusions as in Table 3; transactions with suppliers without province information are excluded. The ten copper mines are located in the North-Western and Copperbelt Provinces. The capital, Lusaka, is in Lusaka Province.

Copper mines' domestic procurement is highly concentrated: 60% of total transaction value in our study period originates in the Copperbelt Province and 35% in Lusaka, less than 5% in Northwestern Province, and the remaining provinces together accounting for less than 1% (Figure 8). Similar patterns emerge when considering transaction counts rather than value. These results indicate that linkages are geographically concentrated in the Copperbelt Province—close to the mines themselves—and functionally concentrated in the capital Lusaka—where specialized services and skilled labor are clustered. North-Western Province, which is less economically developed and

has more greenfield copper mine development, has not yet tapped into the mining value chain in a significant way. These patterns highlight strong agglomeration forces that leave much of the country outside the copper supply network. Geography has been identified as a barrier for entry into global mining value chains for SMEs in Zambia (Siachinji *et al.*, 2026), especially those in rural areas with poor road and electricity infrastructure (Kanyinji and Tembo, 2019).

To better understand if these patterns vary over time, we decompose the time series data by the three main provinces. Figure 9 provides visual evidence of the evolution of supplier patterns over time: It suggests that the Copperbelt Province and Lusaka Province have retained similar shares of backward linkages in the study period, whereas suppliers in the Northwestern Province begin supplying mines in 2020.[13]

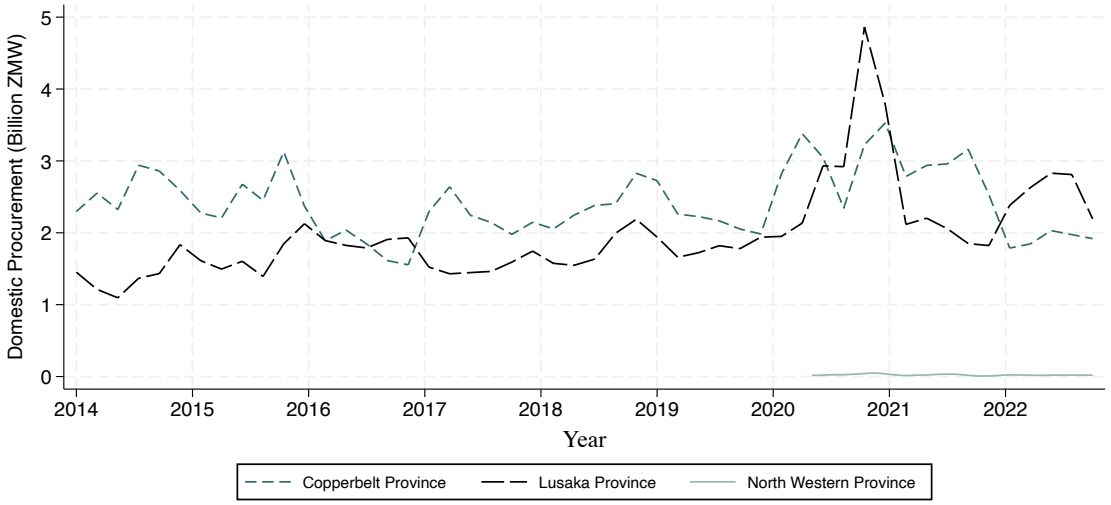


Figure 9: Monthly Total Procurement Value by Copper Mines by Province of Copper Mine Supplier

Notes: Monthly series, January 2014 to October 2022. Total domestic procurement of the copper mines in billion ZMW, inflation-adjusted with the monthly CPI; the sample is that of Table 3 (excluding six transactions above ZMW 5 billion, 810 records with unreadable amounts, transactions between copper mines, and transactions between one particular mine with registered subsidiaries), and negative values (credit notes) are excluded before summing, split by supplier region of registration (Copperbelt Province, Northwestern Province and Lusaka Province).

[13] Allowing for a different scale, illustrates that NW follows a similar pattern albeit at a much lower level (Appendix Fig. 11).

6.4 Mining Employment Elasticities

Linkages to the domestic economy can arise through direct and indirect employment, as captured by employment multipliers (Moretti, 2010). We complement our main analysis by examining the relationship between copper production and direct employment at the mines. Monthly mine-level employment data were provided by the Mines Safety Department of Zambia's Ministry of Mines and Minerals Development for 2019–2020 and 2022–2023.[14] The data distinguish between permanent and contract workers. We estimate the following specification:

$$\ln L_{it}^{k} = \alpha_i + \beta^{k} \ln Q_{it} + \gamma_y + \delta_m + \varepsilon_{it}^{k}, \tag{3}$$

where L_{it}^{k} denotes employment of type k (total or contract) at mine i in month t, and Q_{it} denotes monthly copper production. The regression models include mine fixed effects, with year and calendar-month fixed effects added in some specifications. Standard errors are clustered at the year-month level.

Table 18 reports positive total employment elasticities ranging from 0.150 (statistically significant at the 10% level) to 0.173 (not statistically significant) across specifications. Including lagged production yields a cumulative elasticity of 0.154 ($p = 0.054$) in the longer sample.

For the time period 2022–2023, a 10% increase in copper production is associated with approximately 0.6% higher contract employment, with a cumulative elasticity of 0.088 ($p = 0.075$) when including lagged production. The relationship between copper production and contract employment is weaker in the full time period (2019-2023), which may reflect pandemic-related disruptions, differences in reporting coverage, or sample composition.

These estimates suggest that direct employment constitutes a relatively modest adjustment margin for fluctuations in copper production. Across 2022–2023, our sample of ten mines employed approximately 53,746 workers on average, calculated using the observations included in the employment regression. Using the total employment elasticity of 0.173 estimated over the same period,

[14] We lack employment data for Tier-1 suppliers and therefore cannot estimate indirect employment effects. Monthly mine employment data are unavailable for 2021, and coverage in 2020 is incomplete. Employment data for 2016–2018 are available only at annual frequency and are therefore excluded from this analysis.

a hypothetical 10% increase in copper production across all ten mines would be associated with approximately 1.7% higher employment, equivalent to roughly 900 additional workers. Relative to Zambia's 3.98 million employed persons in 2023 (Zambia Statistics Agency, 2024), this represents only approximately 0.02% of national employment. The employment effects may nevertheless be concentrated in mining-dependent communities, where the adjustments may be large. In addition, further volatility may stem from Tier-1 suppliers' employment adjustments, a margin we were unable to explore due to data access.

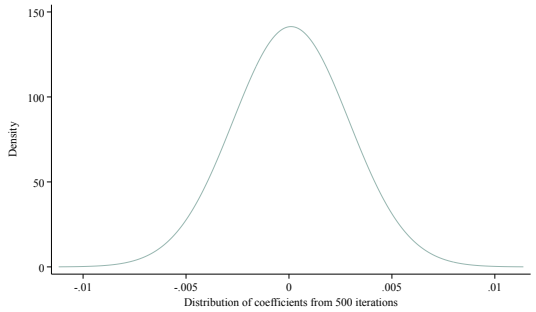
6.5 Falsification Test

To assess whether the patterns observed for Tier-1 suppliers are driven by broader economic trends or firm-level dynamics unrelated to mining activity, we conduct two falsification tests on their domestic procurement and import behavior.

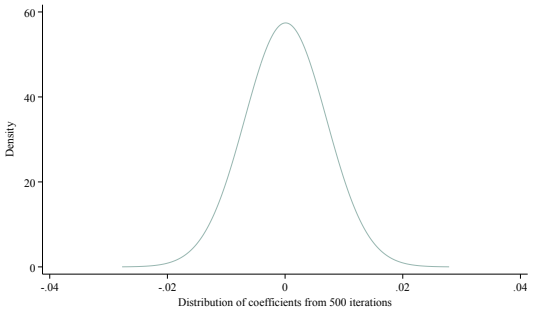
In the first strategy, we reassign the monthly mine production associated with each Tier-1 supplier to a randomly selected subset of non-mine-supplying domestic firms. For example, if in Year-Month t, we observe 10 Tier-1 suppliers—each with a production value equal to the copper output of their copper mine customers in that period—we take those 10 production values and randomly reallocate them to 10 non-mine-supplying firms present in the same Year-Month t. This approach preserves the original Year-Month structure of the data and the number of firms observed in each period, varying only the identity of the firm. In the second exercise, we randomize the monthly production within a Tier-1 supplier. Specifically, we randomly permute the monthly copper production series of each Tier-1 supplier i across the months in which it is observed, so that production in Year-Month t is reassigned to a randomly drawn Year-Month.

Subsequently, we use the modified data to re-estimate the baseline econometric specification. Across 500 iterations, the distributions of coefficients for domestic procurement in Figure 10 (a) and (b) are centered around zero. Repeating the same procedures for the import levels of Tier-1 suppliers—shown in panels (c) and (d)—likewise yields distributions centered on zero. For both domestic procurement and imports, the baseline estimates are sufficiently large relative to the placebo distributions that they do not appear on the same x-axis. Taken together, these results

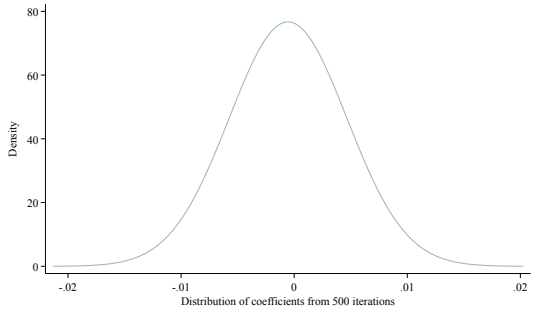
indicate that neither underlying time trends nor firm-specific but time-invariant patterns are driving our results on domestic procurement and imports of Tier-1 suppliers.



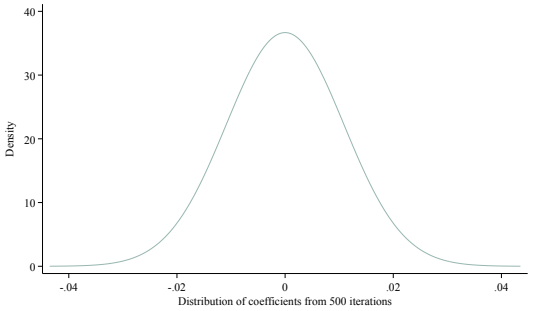
(a) Domestic Procurement: Falsification Strategy 1



(b) Domestic Procurement: Falsification Strategy 2



(c) Imports: Falsification Strategy 1



(d) Imports: Falsification Strategy 2

Figure 10: Falsification Tests for Domestic Procurement and Imports of Copper Mine Suppliers
Notes: Each panel shows a normal density with the mean and standard deviation of the coefficients from 500 placebo estimations of the baseline specification (Table 8, Column 5, and Table 9, Column 5). Strategy 1 (panels (a) and (c)) reassigns, within each month, the copper production values of the mine suppliers to randomly selected firms that are neither copper mines nor mine suppliers. Strategy 2 (panels (b) and (d)) randomly permutes each mine supplier's monthly copper production values across the months in which it is observed. In both strategies, the placebo coefficients are centered around zero. The baseline estimates are 0.069 for domestic procurement (panels (a) and (b)) and 0.099 for imports (panels (c) and (d)).

7 The Economic Implications of Volatility

To better understand the implications for the elasticity results on domestic volatility in demand, we calculate the inferred volatility in demand by copper mines.

Following Equation (1), Q_{it} denotes copper production at mine i in month t, and $Purchase_{it}$

denotes its domestic procurement. We first remove mine, calendar-year, and calendar-month fixed effects from $\log Q_{it}$ using the auxiliary regression:

$$\log Q_{it} = \gamma_0 + \phi_i^Q + \phi_y^Q + \phi_m^Q + \eta_{it}, \qquad \sigma_Q = SD(\hat{\eta}_{it}), \tag{4}$$

where the superscript Q distinguishes these fixed effects from those in Equation (1). Given the estimated elasticity $\hat{\beta}_1$, a positive one-standard-deviation movement in residual log production implies the following predicted percentage change in procurement:

$$\%\Delta\widehat{Purchase}(+1\,\text{SD}) = 100\left[\exp(\hat{\beta}_1\sigma_Q) - 1\right]. \tag{5}$$

The preferred within-mine, fixed-effects-residual standard deviation is $\sigma_Q = 0.516$ log points (Table 19). Combined with the baseline domestic procurement elasticity $\hat{\beta}_1 = 0.516$, this corresponds to a predicted 30.5% increase in domestic procurement following a positive one-standard-deviation production movement. Conversely, a negative one-standard-deviation movement corresponds to a 23.4% contraction.

The economic importance of these demand fluctuations reflects the unusually large footprint of copper mining in Zambia's domestic economy. Although the ten mines represent only a small number of enterprises, they account for approximately one-fifth of the annual value of VAT-reported domestic business-to-business purchases (Figure 1). As an illustration, if the mines accounting for 20% of that value all experienced a simultaneous negative one-standard-deviation production movement, the associated 23.4% contraction in mine procurement would amount to 4.7% of baseline nationwide VAT-reported transaction value.

The economic consequences of mining volatility may extend considerably beyond these direct transactions. The direct procurement estimates do not capture all subsequent adjustments by Tier 1 suppliers or the employment adjustments explored in this analysis. In addition, mining production fluctuations also affect public finances through mineral royalties (Ericsson *et al.*, 2026), corporate income taxes, and VAT receipts, as well as employment in mining-dependent communities. The aggregate economic consequences of volatility in the sector is thus plausibly larger than estimated

here.

8 Conclusions

The designation 'critical mineral' reflects these minerals' scarcity relative to expected global demand, their irreplaceability in the production processes of modern technologies, and the geopolitical conflicts in which they are entangled. Although the term 'critical' is generally associated with downstream use, many of these minerals are equally 'critical' to the economies in which they are extracted—particularly in low- and middle-income countries with smaller and less diversified economies. However, the natural resource curse literature highlights the challenges of translating subsoil natural capital into economic growth. Using microeconomic evidence, we examine one channel of the natural resource curse: volatility.

Using a novel database containing the near-universe of VAT-registered domestic firm-to-firm transactions in Zambia, combined with customs records and monthly mine-level copper production, we directly measure backward linkages between the mining industry and domestic firms. Our findings reveal the substantial importance of copper mining for domestic economic activity. Ten major copper mines account for approximately one-fifth of the annual value of VAT-reported domestic business-to-business purchases, demonstrating that a relatively small number of mining firms generate a considerable share of demand for domestic goods and services.

We estimate a domestic procurement elasticity with respect to copper production of 0.516 (OLS) for these large mining firms. Although this implies a less-than-proportional response, it suggests considerably stronger domestic linkages than those implied by traditional theories of mining as an economic enclave. Our 2SLS shift-share specification, which exploits baseline copper share of production interacted with monthly international copper price to instrument for mine production, yields a larger elasticity of 1.340. Imports also respond to mine production (elasticity of 0.188 for the OLS model, 2.233 for the price only IV model).

These linkages also expose domestic firms to fluctuations originating in the mining industry. A one-standard-deviation negative fluctuation in residual mine-level production is associated with a

23.4% reduction in domestic procurement. Given the substantial share of domestic transactions attributable to copper mines, such fluctuations can represent economically significant changes in demand faced by domestic suppliers.

Moreover, these estimates capture only direct procurement by mines. We also document responses among Tier-1 suppliers, whose own domestic procurement and imports vary with production of their mining customers. Mining volatility can therefore be identified in the production network.

The extent to which backward linkages translate into domestic value added may, however, be more limited than gross procurement values suggest. Approximately 71% of Tier-1 mine suppliers import goods, compared with 38% of other VAT-registered firms (naive comparison, not accounting for sector and firm size). Moreover, Tier-1 suppliers' imports respond more elastically to their mining customers' production than their domestic procurement, with elasticities of 0.099 and 0.069, respectively. These findings suggest that some mining demand may be transmitted abroad through imported inputs, potentially limiting the domestic value added generated by backward linkages. Nevertheless, the economic costs of mining volatility may remain substantial even when domestic value added is relatively limited, as uncertainty over future orders can discourage investment, increase liquidity requirements, and affect employment decisions. The domestic value added generated by backward linkages and the economic vulnerability they create need not be proportional.

For mineral-rich developing countries, the policy challenge is therefore not simply to increase local procurement, but to translate mining demand into sustained domestic productive capacity. This requires attention to the sectors in which linkages emerge, the ability of domestic suppliers to expand and diversify their customer base, and the extent to which the tax system facilitates rather than discourages domestic transactions. As Zambia plans a substantial expansion of copper production, policies that strengthen domestic supplier capabilities while reducing vulnerability to mining fluctuations will be important for translating mineral wealth into broader economic development.

References

Acemoglu, D., Carvalho, V. M., Ozdaglar, A. and Tahbaz-Salehi, A. (2012). The network origins of aggregate fluctuations. *Econometrica*, **80** (5), 1977–2016.

Adam, C., Arezki, R. and van der Ploeg, F. (2026). The scramble for critical minerals. *Oxford Review of Economic Policy*, **42** (1), 1–13.

Adu-Ababio, K., Koivisto, A., Lungu, E., Mwale, E., Msoni, J. and Musole, K. (2023). *Estimating tax gaps in Zambia: A bottom-up approach based on audit assessments*. WIDER Working Paper 2023/25, UNU-WIDER, Helsinki.

Aitken, B. J. and Harrison, A. E. (1999). Do domestic firms benefit from direct foreign investment? evidence from venezuela. *American Economic Review*, **89** (3), 605–618.

Alfaro, L., Chanda, A., Kalemli-Ozcan, S. and Sayek, S. (2004). FDI and economic growth: the role of local financial markets. *Journal of international economics*, **64** (1), 89–112.

—, —, — and — (2010). Does foreign direct investment promote growth? Exploring the role of financial markets on linkages. *Journal of development Economics*, **91** (2), 242–256.

—, Fadinger, H., Schymik, J. and Virananda, G. (2026). The rare-earth footprint of the global economy: Input-output evidence. *AEA Papers and Proceedings*, **116**, 103–108.

Alfaro-Ureña, A., Manelici, I. and Vasquez, J. P. (2022). The effects of joining multinational supply chains: New evidence from firm-to-firm linkages. *The Quarterly Journal of Economics*, **137** (3), 1495–1552.

Allcott, H. and Keniston, D. (2018). Dutch disease or agglomeration? The local economic effects of natural resource booms in modern America. *The Review of Economic Studies*, **85** (2), 695–731.

Amiti, M., Duprez, C., Konings, J. and Van Reenen, J. (2024). FDI and superstar spillovers: Evidence from firm-to-firm transactions. *Journal of International Economics*, **152**, 103972.

Aragón, F. M. and Rud, J. P. (2013). Natural resources and local communities: evidence from a Peruvian gold mine. *American Economic Journal: Economic Policy*, **5** (2), 1–25.

Arezki, R., Fernandes, A., Merchán, F., Nguyen, H. and Reed, T. (2025a). Natural resource dependence and monopolized imports. *Review of Economics and Statistics*, pp. 1–36.

—, Nguyen, H. and van der Ploeg, R. (2025b). *Easy money, easy spending: Evidence from commodity export windfalls*. CESifo Working Paper 12088, CESifo, Munich.

—, van der Ploeg, R., Rota-Graziosi, G. and Lê, V. Đ. (2025c). *The VAT paradox in resource dependent economies*. CESifo Working Paper 11967, CESifo, Munich.

Atienza, M. and Modrego, F. (2019). The spatially asymmetric evolution of mining services suppliers during the expansion and contraction phases of the copper super-cycle in Chile. *Resources Policy*, **61**, 77–87.

Balboni, C., Boehm, J. and Waseem, M. (2024). Firm adaptation in production networks: Evidence from extreme weather events in pakistan. *London School of Economics working paper*.

Benshaul-Tolonen, A. (2019). Local industrial shocks and infant mortality. *The Economic Journal*, **129** (620), 1561–1592.

— and Fernandez Musso, P. (2025). Mine suppliers: Understanding backward linkages in Kitwe, Zambia. *Resources Policy*.

—, —, Ndhlovu, O., Gebreyohannes, M. and Nyanza, E. C. (2026). Dust, discoloration, and distrust: Lived experiences in Zambia's copper mining communities. *Available at SSRN 7537764*.

Berman, N., Couttenier, M., Rohner, D. and Thoenig, M. (2017). This mine is mine! how minerals fuel conflicts in Africa. *American Economic Review*, **107** (6), 1564–1610.

Borensztein, E., De Gregorio, J. and Lee, J.-W. (1998). How does foreign direct investment affect economic growth? *Journal of International Economics*, **45** (1), 115–135.

Cameron, A. C., Gelbach, J. B. and Miller, D. L. (2008). Bootstrap-based improvements for inference with clustered errors. *The Review of Economics and Statistics*, **90** (3), 414–427.

Caramento, A. (2020). Cultivating backward linkages to Zambia's copper mines: Debating the design of, and obstacles to, local content. *The Extractive Industries and Society*, **7** (2), 310–320.

Carvalho, V. M., Nirei, M., Saito, Y. U. and Tahbaz-Salehi, A. (2021). Supply chain disruptions: Evidence from the great east Japan earthquake. *The Quarterly Journal of Economics*, **136** (2), 1255–1321.

Chacha, P. W., Kirui, B. K. and Wiedemann, V. (2024). Supply chains in times of crisis: Evidence from Kenya's production network. *World Development*, **173**, 106363.

Cust, J. and Poelhekke, S. (2015). The local economic impacts of natural resource extraction. *Annual Review of Resource Economics*, **7** (1), 251–268.

De Haas, R. and Poelhekke, S. (2019). Mining matters: Natural resource extraction and firm-level constraints. *Journal of International Economics*, **117**, 109–124.

Demir, B., Javorcik, B., Michalski, T. K. and Ors, E. (2024). Financial constraints and propagation of shocks in production networks. *Review of Economics and Statistics*, **106** (2), 437–454.

Dhyne, E., Kikkawa, A. K., Mogstad, M. and Tintelnot, F. (2021). Trade and domestic production networks. *The Review of Economic Studies*, **88** (2), 643–668.

—, —, — and — (2023). Measuring the share of imports in final consumption. In *AEA Papers and Proceedings*, vol. 113, pp. 81–86.

Eggert, R. G. (2001). Mining and economic sustainability: National economies and local communities. *A Study Prepared for the Mining, Minerals, and Sustainable Development Project, Colorado School of Mines*.

Ericsson, M., Löf, O., Paltseva, E., Toews, G. and Troya-Martinez, M. (2026). Not the New Oil Yet: Critical mineral rents, unpublished manuscript.

Fessehaie, J. (2012). What determines the breadth and depth of Zambia's backward linkages to copper mining? The role of public policy and value chain dynamics. *Resources Policy*, **37** (4), 443–451.

— and Morris, M. (2013). Value chain dynamics of Chinese copper mining in Zambia: enclave or linkage development? *The European Journal of Development Research*, **25**, 537–556.

— and Rustomjee, Z. (2018). Resource-based industrialisation in Southern Africa: Domestic policies, corporate strategies and regional dynamics. *Development Southern Africa*, **35** (3), 404–418.

Gabaix, X. (2011). The granular origins of aggregate fluctuations. *Econometrica*, **79** (3), 733–772.

Gilbert, C. L. (2024). Is there a copper super-cycle? *Mineral Economics*, **37** (2), 359–380.

Guzmán, J. I. and Silva, E. (2018). Copper price determination: fundamentals versus non-fundamentals. *Mineral Economics*, **31** (3), 283–300.

Hirschman, A. O. (1958). *The strategy of economic development*. New Haven, CT: Yale University Press.

Ho, P., Knittel, C. and Concordel, A. (2026). The differential impacts of critical mineral prices and oil prices on the economy. *Oxford Review of Economic Policy*, **42** (1), 91–110.

International Energy Agency (2025). *Global Critical Minerals Outlook 2025*. Tech. rep., International Energy Agency, Paris.

International Monetary Fund (2025). *Zambia: 2025 Article IV Consultation, Fifth Review Under the Extended Credit Facility Arrangement, and Financing Assurances Review*. Tech. Rep. 25/225, International Monetary Fund, Washington, DC.

Javorcik, B. S. (2004). Does foreign direct investment increase the productivity of domestic firms? In search of spillovers through backward linkages. *American Economic Review*, **94** (3), 605–627.

Kanyinji, P. and Tembo, G. (2019). The impact of geographical location on inclusion of small and medium enterprises in the mining global value chain in Zambia: A case of selected small and medium enterprises (smes) in the mining area. *African Journal of Business Management*, **13** (16), 519–528.

Kolala, C. and Bwalya Umar, B. (2019). National benefits, local costs? Local residents' views on environmental and social effects of large-scale mining in Chingola, Zambia. In *Natural Resources Forum*, Wiley Online Library, vol. 43, pp. 205–217.

Koren, M. and Tenreyro, S. (2007). Volatility and development. *The Quarterly Journal of Economics*, **122** (1), 243–287.

Kotsadam, A. and Tolonen, A. (2016). African mining, gender, and local employment. *World Development*, **83**, 325–339.

Li, H., Kopiński, D. and Taylor, I. (2022). China and the troubled prospects for Africa's economic take-off: Linkage formation and spillover effects in Zambia. *Journal of Southern African Studies*, **48** (5), 861–882.

Mamo, N., Bhattacharyya, S. and Moradi, A. (2019). Intensive and extensive margins of mining and development: Evidence from Sub-Saharan Africa. *Journal of Development Economics*, **139**, 28–49.

Markusen, J. R. and Venables, A. J. (1999). Foreign direct investment as a catalyst for industrial development. *European Economic Review*, **43** (2), 335–356.

Montiel Olea, J. L. and Pflueger, C. (2013). A robust test for weak instruments. *Journal of Business & Economic Statistics*, **31** (3), 358–369.

Moretti, E. (2010). Local multipliers. *American Economic Review*, **100** (2), 373–377.

Mutesa, F. and Meyns, P. (2024). Key features of Zambia's political economy. In H. Chitonge, C. Fundanga, M. Kabinga and V. Songwe (eds.), *The Oxford Handbook of the Zambian Economy*, Oxford: Oxford University Press, pp. 78–98.

Narantungalag, O. (2025). Large-scale mining and local impacts: Evidence from Mongolia. *Australian Journal of Agricultural and Resource Economics*, **69** (2), 265–280.

Nguyen-Tien, V. (2026). *Input uncertainty and firm performance: Evidence from critical minerals*. CEP Discussion Paper, Centre for Economic Performance, London School of Economics.

Ostry, J. E. (2026). *Chokepoint: The financial effects of rare earth supply disruptions*. IHEID Working Paper HEIDWP10-2026, Graduate Institute of International and Development Studies, Geneva.

Panon, L., Lebastard, L., Mancini, M., Borin, A., Tofani, P. C., Cariola, G., Essers, D., Gentili, E., Linarello, A., Padellini, T. *et al.* (2026). Inputs in distress: Geoeconomic fragmentation and firms' sourcing. *European Economic Review*, **187**, 105355.

Robbins, G. (2013). Mining FDI and urban economies in Sub-Saharan Africa: exploring the possible linkages. *Local Economy*, **28** (2), 158–169.

Rodríguez-Puello, G. and Kekezi, O. (2025). *Local economic shocks and entrepreneurship dynamics*. SOFI Working Paper 13/2025, Swedish Institute for Social Research (SOFI), Stockholm University.

Romani, I. G., Comincioli, N. and Vergalli, S. (2025). Climate policy and cartelization risk for critical minerals: An application to the copper market. *Energy Economics*, **149**, 108775.

Sachs, J. D. and Warner, A. M. (2001). The curse of natural resources. *European Economic Review*, **45** (4-6), 827–838.

Setzler, B. and Tintelnot, F. (2021). The effects of foreign multinationals on workers and firms in the united states. *The Quarterly Journal of Economics*, **136** (3), 1943–1991.

Shah, M. (2012). *The informal sector in Zambia: can it disappear? Should it disappear?* International Growth Centre.

Shi, W. and Seim, B. (2021). A reputation deficit? The myths and reality of Chinese investment in Zambia. *Journal of East Asian Studies*, **21** (2), 259–282.

Siachinji, B., Kabeya-Saini, Y., Mwiya, B., Zulu-Chisanga, S. *et al.* (2026). Is market development an effective strategy for enhancing performance? a study of SME suppliers in the Zambian mining sector. *SBS Journal of Applied Business Research*, **14** (1), 113–135.

Sikamo, J., Mwanza, A. and Mweemba, C. (2016). Copper mining in Zambia – history and future. *Journal of the Southern African Institute of Mining and Metallurgy*, **116** (6), 491–496.

Teka, Z. (2011). Backward linkages in the manufacturing sector in the oil and gas value chain in Angola. *MMCP Discussion Papers*, **11**, 1–60.

United Nations (2024). *World Economic Situation and Prospects as of mid-2024*. Tech. Rep. E/2024/56, United Nations, Department of Economic and Social Affairs, New York.

van der Ploeg, F. (2011). Natural resources: curse or blessing? *Journal of Economic Literature*, **49** (2), 366–420.

Van der Ploeg, F. and Poelhekke, S. (2009). Volatility and the natural resource curse. *Oxford economic papers*, **61** (4), 727–760.

Von der Goltz, J. and Barnwal, P. (2019). Mines: The local wealth and health effects of mineral mining in developing countries. *Journal of Development Economics*, **139**, 1–16.

Walters, A. (1944). The international copper cartel. *Southern Economic Journal*, **11** (2), 133–156.

Wegenast, T., Krauser, M., Strüver, G. and Giesen, J. (2019). At Africa's expense? Disaggregating the employment effects of Chinese mining operations in Sub-Saharan Africa. *World Development*, **118**, 39–51.

Wilson, N. (2012). Economic booms and risky sexual behavior: evidence from Zambian copper mining cities. *Journal of Health Economics*, **31** (6), 797–812.

Zabré, H. R., Farnham, A., Diagbouga, S. P., Fink, G., Divall, M. J., Winkler, M. S. and Knoblauch, A. M. (2021). Changes in household wealth in communities living in proximity to a large-scale copper mine in Zambia. *Resources Policy*, **74**, 102395.

Zambia Statistics Agency (2024). *2023 Labour Force Survey Report*. Tech. rep., Zambia Statistics Agency, Lusaka, Zambia.

Appendix

A Tables

A.1 Data Summary Statistics

A.2 Copper Mines

A.3 Copper Mine Suppliers

A.4 Heterogeneity

Table 1: Summary Statistics

	Mean	SD	Min.	Max.	N
Panel A. Copper Production					
Period (Year-Month)			2013m1	2023m12	
# Unique copper mines	11				
Chinese-owned mine (share of mine-months)	0.36	0.48	0	1	1,452
Cu production (mt)	6,594	6,457	7	26,833	1,279
Cu production (mt), Chinese-owned mines	2,317	1,806	7	7,997	501
Panel B. Copper Price					
Copper price (USD/mt)	6,908	1,465	4,472	10,231	131
Panel C. Domestic VAT Data					
Period (Year-Month)			2013m9	2022m11	
# Unique purchasers					13,999
# Unique suppliers					34,916
# Unique copper mine purchasers					10
# Unique copper mine purchasers, Chinese-owned					4
# Unique copper mine suppliers (as purchasers)					2,438
Procurement value, all firms (ZMW mil.)	0.19	32.30	-92,917	6,535	10,858,703
Procurement value, copper mines (ZMW mil.)	2.52	22.97	-715	3,112	260,360
Procurement value, copper mine suppliers (ZMW mil.)	0.20	5.23	-2,332	1,912	3,575,408
Panel D. Import Data					
Period (Year-Month)			2013m11	2023m12	
# Unique importers					14,751
# Unique countries of origin					233
# Unique copper mine importers					10
# Unique copper mine importers, Chinese-owned					4
# Unique copper mine suppliers (as importers)					2,270
Import value, all firms (ZMW mil.)	0.16	5.01	0	12,251	10,737,440
Import value, copper mines (ZMW mil.)	0.48	4.99	0	2,215	465,944
Import value, copper mine suppliers (ZMW mil.)	0.09	4.82	0	12,251	6,746,451

Notes: Values are per transaction, in millions of ZMW, deflated with the monthly Zambian CPI to prices of the last month of each dataset (domestic: November 2022; imports: December 2023). Copper production is in metric tons per mine-month; mine-months without reported production are excluded (N = 1,279 of 1,452). The domestic VAT data exclude six transactions with nominal values above ZMW 5 billion and 810 records with unreadable amounts; in this table they still include transactions between copper mines and among one mine and its subsidiaries (see Table 2 for the regression samples). Negative values are credit notes. The import data are restricted to firms that also appear in the domestic VAT records, as purchasers or suppliers. Copper mine suppliers are counted over all their transactions, including months before their first sale to a copper mine.

Table 2: Copper Mines × Copper Mine Suppliers

	Mean	SD	Min.	Max.	N
Panel A. Copper Mines					
# Unique copper mines, domestic procurement					10
Procurement value per transaction (ZMW mil.)	1.90	13.98	-226	1,210	252,006
Procurement transactions per mine-month	228.68	216.59	1	1,255	1,102
Procurement value per mine-month (ZMW mil.)	433.72	420.26	-0.30	4,448	1,102
# Unique copper mines, imports					10
Import value per transaction (ZMW mil.)	0.48	4.99	0	2,215	465,944
Import transactions per mine-month	391.55	588.05	1	3,592	1,190
Import value per mine-month (ZMW mil.)	188.52	288.33	0.01	2,505	1,190
Panel B. Copper Mine Suppliers					
# Unique copper mine suppliers, domestic procurement					2,409
Procurement value per transaction (ZMW mil.)	0.21	5.60	-2,332	1,912	3,077,975
Procurement transactions per firm-month	27.83	63.52	1	2,559	110,618
Procurement value per firm-month (ZMW mil.)	5.80	49.79	-2,332	3,446	110,618
# Unique copper mine suppliers, imports					2,248
Import value per transaction (ZMW mil.)	0.10	1.01	0	580	5,709,552
Import transactions per firm-month	91.82	1,008.01	1	45,560	62,182
Import value per firm-month (ZMW mil.)	8.76	45.92	0	4,794	62,182

Notes: Values are in millions of ZMW, deflated with the monthly Zambian CPI. Per-transaction rows are computed over individual transactions; count and per-month rows over mine-months (Panel A) or supplier-months (Panel B). Panel B covers each supplier's transactions from the month of its first sale to a copper mine onward. The domestic procurement sample excludes six transactions with nominal values above ZMW 5 billion, 810 records with unreadable amounts, all transactions between copper mines, and all transactions among one particular mine and its subsidiaries. The import data are restricted to firms that also appear in the domestic VAT records, as purchasers or suppliers.

Table 3: Main Results: Copper Mines, Domestic Procurement

Dependent variable:	Log(procurement value), per transaction			Log(# of procurement transactions)			Log(procurement value), total		
Specification:	OLS	OLS, lagged	2SLS	OLS	OLS, lagged	2SLS	OLS	OLS, lagged	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log(Cu production)	0.225***		-3.237**	0.213***		2.175***	0.516***		0.700*
	(0.059)		(1.323)	(0.049)		(0.550)	(0.066)		(0.361)
	[0.062]		[2.243]						
Log(Cu prod., t-1Q)		0.366***			0.333***			0.754***	
		(0.065)			(0.061)			(0.082)	
		[0.073]							
Year FE	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Month FE	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Firm FE	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Wild bootstrap p				< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.068
Stock–Yogo 10% crit.			16.38			16.38			16.38
MOP 10% crit.			23.11			23.11			23.11
1st stage effective F-stat			6.69			17.33			17.16
Mean of outcome	11.530	11.531	11.530	5.035	5.046	5.035	19.374	19.394	19.374
Observations	244,591	243,897	244,591	1,035	1,024	1,035	1,033	1,022	1,033
R^2	0.074	0.074		0.522	0.532		0.630	0.641	

Notes: The sample excludes six transactions with nominal procurement values above ZMW 5 billion, 810 records with unreadable amounts, all transactions between copper mines, and all transactions among one particular mine and its subsidiaries. The dependent variable is inflation-adjusted procurement value; zero and negative values drop out of the logs. Columns 1–3 are estimated on individual transactions (each transaction weighted equally); Columns 4–9 on mine-month totals. Log(Cu prod., t-1Q) is the log of the mine's total production over the three preceding months (missing unless all three are reported). Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these. For Columns 1–3, alternative standard errors clustered at the Year-Month × Firm level are shown in brackets. For Columns 4–9, wild cluster bootstrap p-values (Year-Month clusters, 9,999 replications) are reported. 2SLS specifications instrument log copper production with the log international copper price and do not include fixed effects. The effective first-stage F-statistic follows Montiel Olea and Pflueger (2013); in this just-identified setting it equals the Kleibergen–Paap rk Wald F-statistic. The 10% Stock–Yogo and 10% Montiel Olea–Pflueger critical values are shown for comparison; Column 3 falls below both, and Columns 6 and 9 exceed the Stock–Yogo value but fall below the Montiel Olea–Pflueger value.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 4: Sensitivity Results: Copper Mines, Domestic Procurement

Dependent variable:	Log(procurement value), total					
Specification:	Year and Month FE	Firm FE + time trend	Robust SE	Excluding 2020	Including Subsidiary	Including Cu–Cu and Subsidiary
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Cu production)	0.815***	0.536***	0.516***	0.487***	0.497***	0.480***
	(0.026)	(0.066)	(0.067)	(0.067)	(0.065)	(0.063)
Year FE	Yes	No	Yes	Yes	Yes	Yes
Month FE	Yes	No	Yes	Yes	Yes	Yes
Firm FE	No	Yes	Yes	Yes	Yes	Yes
Linear time trend	No	Yes	No	No	No	No
Year-Month clustering	Yes	Yes	No	Yes	Yes	Yes
Robust SE	No	No	Yes	No	No	No
Wild bootstrap p	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001
Sample excludes:						
Outliers	Yes	Yes	Yes	Yes	Yes	Yes
Transactions between copper mines	Yes	Yes	Yes	Yes	Yes	No
Transactions among one mine subsidiaries	Yes	Yes	Yes	Yes	No	No
Transactions in 2020 (COVID-19)	No	No	No	Yes	No	No
Mean of outcome	19.374	19.374	19.374	19.331	19.448	19.584
Observations	1,033	1,033	1,033	922	1,033	1,034
R^2	0.549	0.620	0.630	0.675	0.661	0.644

Notes: Mine-month regressions. The dependent variable is the log of total inflation-adjusted procurement value. Outliers are the six transactions with nominal values above ZMW 5 billion and 810 records with unreadable amounts. Columns 1–4 use the baseline sample of Table 3, which also excludes all transactions between copper mines and all transactions among one mine and its subsidiaries; Column 4 further drops January–December 2020, the year most affected by COVID-19. Column 5 adds back transactions among a mine and its subsidiaries, and Column 6 also adds back transactions between copper mines. Column 2 replaces year and month fixed effects with a linear Year-Month trend. Standard errors are clustered at the Year-Month level, except in Column 3 (heteroskedasticity-robust); significance stars are based on the standard errors shown in parentheses. Wild cluster bootstrap p-values use Year-Month clusters. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 5: Shift-Share 2SLS: Copper Mines, Domestic Procurement

Dependent variable:	Log(procurement value), per transaction	Log(# of procurement transactions)	Log(procurement value), total
Specification:	2SLS	2SLS	2SLS
	(1)	(2)	(3)
Log(Cu production)	0.646*	-0.370*	1.340***
	(0.356)	(0.204)	(0.318)
Year-Month FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
First stage: share × log Cu price	-3.031	-3.464	-3.464
	(0.366)	(0.388)	(0.388)
1st stage effective F-stat	68.59	79.60	80.06
Mean of outcome	11.651	4.941	19.281
Number of mines	9	9	9
Observations	198,320	948	946

Notes: Same sample as Table 3, restricted to the nine copper mines with production in March–August 2013. Log copper production is instrumented with the mine's share of total copper production in March–August 2013 interacted with the log international copper price. Year-Month fixed effects absorb the common copper price; firm fixed effects absorb the time-invariant share. The first-stage row reports the coefficient on the instrument in the first-stage regression, with its standard error in parentheses. The effective first-stage F-statistic follows Montiel Olea and Pflueger (2013); in this just-identified setting it equals the Kleibergen–Paap rk Wald F-statistic. Column 1 is estimated on individual transactions; Columns 2–3 on mine-month totals. Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 6: Main Results: Copper Mines, Imports

Dependent variable:	Log(import value), per transaction			Log(# of import transactions)			Log(import value), total		
Specification:	OLS	OLS, lagged	2SLS	OLS	OLS, lagged	2SLS	OLS	OLS, lagged	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log(Cu production)	-0.298***		-3.174***	0.295***		2.058***	0.188***		2.233***
	(0.052)		(0.691)	(0.058)		(0.350)	(0.070)		(0.393)
Log(Cu prod., t-1Q)		-0.448***			0.470***			0.285***	
		(0.061)			(0.067)			(0.085)	
Year FE	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Month FE	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Firm FE	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Stock–Yogo 10% crit.			16.38			16.38			16.38
MOP 10% crit.			23.11			23.11			23.11
1st stage effective F-stat			26.34			33.32			33.32
Mean of outcome	10.272	10.272	10.272	4.649	4.654	4.649	17.593	17.606	17.593
Observations	454,740	452,226	454,740	1,149	1,137	1,149	1,149	1,137	1,149
R^2	0.185	0.187		0.829	0.834		0.751	0.755	

Notes: The dependent variable is inflation-adjusted import value of the copper mines; zero values drop out of the logs. Columns 1–3 are estimated on individual import transactions (each transaction weighted equally); Columns 4–9 on mine-month totals. Log(Cu prod., t-1Q) is the log of the mine's total production over the three preceding months. Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these. 2SLS specifications instrument log copper production with the log international copper price and do not include fixed effects. The effective first-stage F-statistic follows Montiel Olea and Pflueger (2013); in this just-identified setting it equals the Kleibergen–Paap rk Wald F-statistic. The 10% Stock–Yogo and 10% Montiel Olea–Pflueger critical values are shown for comparison.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 7: Sensitivity Results: Copper Mines, Imports

Dependent variable:	Log(import value), total			
Specification:	Year and Month FE	Firm FE + time trend	Robust SE	Excluding 2020
	(1)	(2)	(3)	(4)
Log(Cu production)	1.345***	0.186**	0.188***	0.210***
	(0.049)	(0.077)	(0.072)	(0.068)
Year FE	Yes	No	Yes	Yes
Month FE	Yes	No	Yes	Yes
Firm FE	No	Yes	Yes	Yes
Linear time trend	No	Yes	No	No
Year-Month clustering	Yes	Yes	No	Yes
Robust SE	No	No	Yes	No
Mean of outcome	17.593	17.593	17.593	17.601
Observations	1,149	1,149	1,149	1,038
R^2	0.534	0.728	0.751	0.756

Notes: Mine-month regressions. The dependent variable is the log of total inflation-adjusted import value of the copper mines. Column 2 replaces year and month fixed effects with a linear Year-Month trend. Column 4 drops January–December 2020, the year most affected by COVID-19. Standard errors are clustered at the Year-Month level, except in Column 3 (heteroskedasticity-robust); significance stars are based on the standard errors shown in parentheses.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 8: Main Results: Copper Mine Suppliers, Domestic Procurement

Dependent variable:	Log(procurement value), per transaction		Log(# of procurement transactions)		Log(procurement value), total	
Specification:	OLS	OLS, lagged	OLS	OLS, lagged	OLS	OLS, lagged
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Cu production)	0.047***		0.068***		0.069***	
	(0.011)		(0.005)		(0.011)	
Log(Cu prod., t-1Q)		0.062***		0.055***		0.052***
		(0.009)		(0.006)		(0.013)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean of outcome	8.637	8.682	2.516	2.696	12.577	12.852
Observations	3,035,852	2,726,417	109,717	88,141	109,254	87,961
R^2	0.272	0.272	0.714	0.735	0.757	0.784

Notes: Copper mine suppliers are registered firms outside the ZEITI mining registry that sold to one of the copper mines at least once. The dependent variable is the supplier's own inflation-adjusted domestic procurement; zero and negative values drop out of the logs. The data exclude six transactions with nominal values above ZMW 5 billion and 810 records with unreadable amounts. Log(Cu production) is the log of the total monthly copper production of all mines the supplier has sold to at least once up to and including that month. Log(Cu prod., t-1Q) is the log of that total over the three preceding months; it is only defined if the supplier has domestic purchases in each of those months. Columns 1–2 are estimated on individual transactions; Columns 3–6 on supplier-month totals. Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 9: Main Results: Copper Mine Suppliers, Imports

Dependent variable:	Log(import value), per transaction		Log(# of import transactions)		Log(import value), total	
Specification:	OLS	OLS, lagged	OLS	OLS, lagged	OLS	OLS, lagged
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Cu production)	-0.049***		0.076***		0.099***	
	(0.019)		(0.008)		(0.012)	
Log(Cu prod., t-1Q)		-0.080***		0.078***		0.076***
		(0.022)		(0.010)		(0.016)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean of outcome	7.886	7.834	2.095	2.789	13.546	14.526
Observations	5,682,579	5,490,943	61,601	36,980	61,601	36,980
R^2	0.604	0.606	0.738	0.741	0.701	0.714

Notes: Copper mine suppliers as defined in Table 8, observed in the import data. The dependent variable is the supplier's inflation-adjusted import value; zero values drop out of the logs. Log(Cu production) is the log of the total monthly copper production of all mines the supplier has sold to at least once up to and including that month. Log(Cu prod., t-1Q) is the log of that total over the three preceding months; it is only defined if the supplier has imports in each of those months. Columns 1–2 are estimated on individual import transactions; Columns 3–6 on supplier-month totals. Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 10: Number of Copper Mine Customers: Copper Mine Suppliers, Domestic Procurement

Dependent variable:	Log(procurement value), per transaction			Log(# of procurement transactions)			Log(procurement value), total		
Specification:	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
# copper mine customers	0.024***	-0.184***		0.056***	0.336***		0.144***	-0.055	
	(0.008)	(0.054)		(0.005)	(0.051)		(0.009)	(0.079)	
Log(Cu price)		-0.111***	-0.044		0.225***	0.139***		0.076	0.116**
		(0.039)	(0.035)		(0.040)	(0.039)		(0.063)	(0.058)
# customers × Log(Cu price)		0.024***			-0.032***			0.023**	
		(0.006)			(0.006)			(0.009)	
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean of outcome	8.606	8.606	8.606	2.505	2.505	2.505	12.592	12.592	12.592
Observations	3,546,237	3,546,237	3,546,237	128,816	128,816	128,816	128,304	128,304	128,304
R^2	0.270	0.270	0.270	0.700	0.700	0.699	0.746	0.746	0.745

Notes: Sample: all supplier-months of the copper mine suppliers in Table 8, including months before their first sale to a copper mine (when the number of mine customers is zero). The dependent variable is the supplier's own inflation-adjusted domestic procurement value; zero and negative values drop out of the logs. # copper mine customers is the number of copper mines the supplier has sold to at least once up to and including that month. Log(Cu price) is the log international copper price (USD/mt). In Columns 2, 5, and 8, the coefficient on # copper mine customers is evaluated at a log copper price of zero and is not separately interpretable. Columns 1–3 are estimated on individual transactions; Columns 4–9 on supplier-month totals. Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 11: Number of Copper Mine Customers: Copper Mine Suppliers, Imports

Dependent variable:	Log(import value), per transaction			Log(# of import transactions)			Log(import value), total		
Specification:	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
# copper mine customers	0.065***	-0.335***		0.069***	0.087*		0.092***	0.124*	
	(0.015)	(0.072)		(0.006)	(0.050)		(0.010)	(0.073)	
Log(Cu price)		-0.008	0.119		0.209**	0.198*		0.128	0.109
		(0.134)	(0.129)		(0.104)	(0.110)		(0.134)	(0.138)
# customers × Log(Cu price)		0.045***			-0.002			-0.004	
		(0.008)			(0.006)			(0.008)	
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean of outcome	7.907	7.907	7.907	2.064	2.064	2.064	13.503	13.503	13.503
Observations	6,746,188	6,746,188	6,746,188	71,459	71,459	71,459	71,459	71,459	71,459
R^2	0.580	0.580	0.580	0.729	0.729	0.728	0.691	0.691	0.690

Notes: Sample: all supplier-months of the copper mine suppliers in Table 9, including months before their first sale to a copper mine (when the number of mine customers is zero). The dependent variable is the supplier's own inflation-adjusted import value; zero values drop out of the logs. # copper mine customers is the number of copper mines the supplier has sold to at least once up to and including that month. Log(Cu price) is the log international copper price (USD/mt). In Columns 2, 5, and 8, the coefficient on # copper mine customers is evaluated at a log copper price of zero and is not separately interpretable. Columns 1–3 are estimated on individual transactions; Columns 4–9 on supplier-month totals. Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 12: Sensitivity Results: Copper Mine Suppliers, Domestic Procurement

Dependent variable:	Log(procurement value), total					
Specification:	Year and Month FE	Firm FE + time trend	Robust SE	Firm clustering	Supplier threshold: 5+ transactions	Supplier threshold: 5+ in one month
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Cu production)	0.033**	0.077***	0.069***	0.069***	0.083***	0.268***
	(0.016)	(0.012)	(0.007)	(0.021)	(0.013)	(0.031)
Year FE	Yes	No	Yes	Yes	Yes	Yes
Month FE	Yes	No	Yes	Yes	Yes	Yes
Firm FE	No	Yes	Yes	Yes	Yes	Yes
Linear time trend	No	Yes	No	No	No	No
Year-Month clustering	Yes	Yes	No	No	Yes	Yes
Robust SE	No	No	Yes	No	No	No
Firm clustering	No	No	No	Yes	No	No
Mean of outcome	12.575	12.577	12.577	12.577	12.604	12.957
Observations	109,390	109,254	109,254	109,254	80,916	30,424
R^2	0.013	0.755	0.757	0.757	0.761	0.796

Notes: Supplier-month regressions; Columns 1–4 use the sample and treatment of Table 8, Column 5. The dependent variable is the log of the supplier's total inflation-adjusted domestic procurement. Column 2 replaces year and month fixed effects with a linear Year-Month trend. Columns 5 and 6 use stricter definitions of a copper mine supplier: in Column 5, a firm counts as a mine supplier from the month in which its cumulative number of sales to copper mines reaches five; in Column 6, from the first month in which it makes at least five sales to copper mines. Standard errors are clustered at the Year-Month level, except in Column 3 (heteroskedasticity-robust) and Column 4 (clustered by firm); significance stars are based on the standard errors shown in parentheses.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 13: Sensitivity Results: Copper Mine Suppliers, Imports

Dependent variable:	Log(import value), total					
Specification:	Year and Month FE	Firm FE + time trend	Robust SE	Firm clustering	Supplier threshold: 5+ transactions	Supplier threshold: 5+ in one month
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Cu production)	0.221***	0.118***	0.099***	0.099**	0.126***	0.129***
	(0.008)	(0.015)	(0.013)	(0.041)	(0.019)	(0.038)
Year FE	Yes	No	Yes	Yes	Yes	Yes
Month FE	Yes	No	Yes	Yes	Yes	Yes
Firm FE	No	Yes	Yes	Yes	Yes	Yes
Linear time trend	No	Yes	No	No	No	No
Year-Month clustering	Yes	Yes	No	No	Yes	Yes
Robust SE	No	No	Yes	No	No	No
Firm clustering	No	No	No	Yes	No	No
Mean of outcome	13.532	13.546	13.546	13.546	13.599	13.982
Observations	61,919	61,601	61,601	61,601	48,034	23,640
R^2	0.022	0.697	0.701	0.701	0.710	0.748

Notes: Supplier-month regressions; Columns 1–4 use the sample and treatment of Table 9, Column 5. The dependent variable is the log of the supplier's total inflation-adjusted import value. Column 2 replaces year and month fixed effects with a linear Year-Month trend. Columns 5 and 6 use stricter definitions of a copper mine supplier: in Column 5, a firm counts as a mine supplier from the month in which its cumulative number of sales to copper mines reaches five; in Column 6, from the first month in which it makes at least five sales to copper mines. Standard errors are clustered at the Year-Month level, except in Column 3 (heteroskedasticity-robust) and Column 4 (clustered by firm); significance stars are based on the standard errors shown in parentheses.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 14: Chinese Firms: Copper Mines, Domestic Procurement

Dependent variable:	Log(procurement value), per transaction			Log(# of procurement transactions)			Log(procurement value), total		
Specification:	Level	Interaction	Interaction, lagged	Level	Interaction	Interaction, lagged	Level	Interaction	Interaction, lagged
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Chinese mine	-0.243***			-0.568***			-0.336***		
	(0.079)			(0.054)			(0.078)		
Log(Cu production)	0.073**	0.039		0.241***	0.302***		0.733***	0.371***	
	(0.032)	(0.077)		(0.025)	(0.061)		(0.036)	(0.067)	
Chinese mine × Log(Cu production)		0.588***			-0.161			0.264*	
		(0.119)			(0.113)			(0.139)	
Log(Cu prod., $t-1Q$)			0.132			0.490***			0.594***
			(0.085)			(0.085)			(0.107)
Chinese mine × Log(Cu prod., $t-1Q$)			0.743***			-0.298**			0.305**
			(0.152)			(0.148)			(0.144)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Mean of outcome (all mines)	11.530	11.530	11.531	5.035	5.035	5.046	19.374	19.374	19.394
Mean of outcome (Chinese mines)	11.325	11.325	11.336	4.468	4.468	4.482	18.500	18.500	18.540
Observations	244,591	244,591	243,897	1,035	1,035	1,024	1,033	1,033	1,022
R^2	0.025	0.076	0.076	0.300	0.523	0.536	0.558	0.632	0.643

Notes: Same sample as Table 3. Chinese Mine equals one for the four copper mines with a Chinese majority owner. Level columns (1, 4, 7) omit firm fixed effects so that the level difference between Chinese-owned and other mines is identified. Interaction columns include firm fixed effects, which absorb the time-invariant Chinese Mine indicator; they identify only whether the response to production differs by ownership. Log(Cu production) in the interaction columns is the slope for non-Chinese mines; the slope for Chinese mines is the sum of this coefficient and the interaction. Columns 1–3 are estimated on individual transactions; Columns 4–9 on mine-month totals. Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table 15: Chinese Firms: Copper Mines, Imports

Dependent variable:	Log(import value), per transaction			Log(# of import transactions)			Log(import value), total		
Specification:	Level	Interaction	Interaction, lagged	Level	Interaction	Interaction, lagged	Level	Interaction	Interaction, lagged
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Chinese Mine	-0.725***			-1.077***			-1.564***		
	(0.184)			(0.073)			(0.071)		
Log(Cu production)	-0.896***	-0.304***		1.079***	0.300***		0.998***	0.270***	
	(0.105)	(0.055)		(0.054)	(0.055)		(0.050)	(0.067)	
Chinese Mine × Log(Cu production)		0.085			-0.011			-0.164	
		(0.108)			(0.123)			(0.145)	
Log(Cu prod., t-1Q)			-0.452***			0.390***			0.371***
			(0.065)			(0.078)			(0.094)
Chinese Mine × Log(Cu prod., t-1Q)			0.059			0.166			-0.178
			(0.133)			(0.146)			(0.182)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Mean of outcome, Chinese mines	10.866	10.866	10.864	3.063	3.063	3.070	15.769	15.769	15.794
Mean of outcome	10.272	10.272	10.272	4.649	4.649	4.654	17.593	17.593	17.606
Observations	454,740	454,740	452,226	1,149	1,149	1,137	1,149	1,149	1,137
R^2	0.074	0.185	0.187	0.701	0.829	0.834	0.615	0.751	0.755

Notes: Same sample as Table 6. Chinese Mine equals one for the four copper mines with a Chinese majority owner. Level columns (1, 4, 7) omit firm fixed effects so that the level difference between Chinese-owned and other mines is identified. Interaction columns include firm fixed effects, which absorb the time-invariant Chinese Mine indicator; they identify only whether the response to production differs by ownership. Log(Cu production) in the interaction columns is the slope for non-Chinese mines. Columns 1–3 are estimated on individual import transactions; Columns 4–9 on mine-month totals. Standard errors clustered at the Year-Month level are reported in parentheses; significance stars are based on these.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 16: Copper Mine Suppliers by Sector

Sector	Total Firms	Share (%)
Mining	76	2.37
Mining and Quarrying	76	2.37
Trade & Distribution	1,551	48.29
Wholesale and retail trade; repair of motor vehicles and motorcycles	1,551	48.29
Manufacturing	242	7.53
Manufacturing	242	7.53
Business & Professional Services	547	17.03
Professional, scientific and technical activities	321	9.99
Administrative and support service activities	142	4.42
Information and communication	42	1.31
Financial and insurance activities	26	0.81
Real estate activities	13	0.40
Public administration and defense; compulsory social security	2	0.06
Activities of extraterritorial organizations and bodies	1	0.03
Construction	292	9.09
Construction	292	9.09
Social & Other Services	237	7.38
Education	5	0.16
Human health and social work activities	5	0.16
Arts, entertainment and recreation	1	0.03
Accommodation and food service activities	33	1.03
Other service activities	193	6.01
Transport	125	3.89
Transportation and storage	125	3.89
Utilities	25	0.78
Electricity, gas, steam and air conditioning supply	11	0.34
Water supply; sewerage, waste management and remediation	14	0.44
Agriculture	21	0.65
Agriculture, forestry and fishing	21	0.65
Missing sector information	96	2.99
Total	3,212	100.00

Notes: Number of copper mine suppliers by ZRA (ISIC) sector, grouped as in Table 17. Copper mine suppliers are registered firms that sold to one of the copper mines at least once and are not in the ZEITI mining registry; the 76 suppliers in Mining and Quarrying are firms registered in that ISIC sector (for example, mining contractors) that do not appear in the ZEITI registry.

Table 17: Industry Elasticities: Copper Mine Procurement by Supplier Sector

Sector	β	SE	p-value	N	Mines	Mean
Mining	0.723***	0.104	0.000	1,014	10	17.421
Trade & Distribution	0.659***	0.097	0.000	1,030	10	17.969
Manufacturing	0.456***	0.062	0.000	1,020	10	16.685
Business & Professional Services	0.340***	0.103	0.001	1,020	10	16.818
Construction	0.320**	0.148	0.033	936	10	15.224
Social & Other Services	0.230**	0.114	0.046	980	10	15.354
Transport	0.166**	0.083	0.049	933	10	14.903
Utilities	0.065	0.075	0.385	853	10	17.633
Agriculture	-0.247	0.245	0.315	268	7	12.802

Notes: Each row is a separate mine-month regression of the log of the copper mines' total inflation-adjusted procurement from suppliers in that sector on log copper production, with year, month, and firm fixed effects, using the sample of Table 3 (all suppliers, not only the copper mine suppliers of Table 16). Mine-months without purchases from the sector drop out. β is the elasticity; Mean is the mean of the dependent variable. Standard errors are clustered at the Year-Month level; significance stars are based on these. *Mines* denotes the number of copper mines purchasing from firms in the respective sector. Sectors group firms according to their ZRA classifications as follows: (1) Mining: Mining and Quarrying; (2) Trade & Distribution: Wholesale and retail trade; repair of motor vehicles and motorcycles; (3) Manufacturing: Manufacturing; (4) Business & Professional Services: Professional, scientific and technical activities; Administrative and support service activities; Information and communication; Financial and insurance activities; Real estate activities; Public administration and defense; compulsory social security; and Activities of extraterritorial organizations and bodies; (5) Construction: Construction; (6) Social & Other Services: Education; Human health and social work activities; Arts, entertainment and recreation; Accommodation and food service activities; and Other service activities; (7) Transport: Transportation and storage; (8) Utilities: Electricity, gas, steam and air conditioning supply; and Water supply, sewerage, waste management and remediation activities; and (9) Agriculture: Agriculture, forestry and fishing. CEC is reclassified from its ZRA-recorded sector into Utilities, alongside ZESCO.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 18: Copper Production and Mining Employment

Dependent variable:	Log total employment				Log contract employment			
Specification	Mine FE	All FE	Mine FE +Lag	All FE +Lag	Mine FE	All FE	Mine FE + Lag	All FE + Lag
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: 2019–2023								
Log copper production (t)	0.168*	0.150*	0.166	0.154	-0.008	-0.011	-0.017	-0.017
	(0.091)	(0.087)	(0.112)	(0.107)	(0.030)	(0.036)	(0.031)	(0.038)
Log copper production ($t-1$)			0.013	0.000			-0.020	-0.021
			(0.047)	(0.049)			(0.032)	(0.038)
Cumulative elasticity ($\beta_0+\beta_1$)			0.179**	0.154*			-0.037	-0.039
Cumulative SE			(0.081)	(0.078)			(0.042)	(0.052)
Cumulative p-value			0.033	0.054			0.389	0.461
Observations	276	276	265	265	259	259	249	249
R^2	0.937	0.941	0.934	0.937	0.965	0.965	0.964	0.965
Mine FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Month FE	No	Yes	No	Yes	No	Yes	No	Yes
Panel B: 2022–2023								
Log copper production (t)	0.173	0.173	0.184	0.177	0.065**	0.064*	0.062**	0.062*
	(0.134)	(0.132)	(0.149)	(0.141)	(0.028)	(0.033)	(0.030)	(0.032)
Log copper production ($t-1$)			-0.034	-0.043			0.025	0.026
			(0.083)	(0.098)			(0.021)	(0.025)
Cumulative elasticity ($\beta_0+\beta_1$)			0.149	0.134			0.088**	0.088*
Cumulative SE			(0.098)	(0.101)			(0.033)	(0.047)
Cumulative p-value			0.145	0.201			0.016	0.075
Observations	175	175	172	172	165	165	162	162
R^2	0.949	0.953	0.945	0.950	0.989	0.990	0.988	0.988
Mine FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Month FE	No	Yes	No	Yes	No	Yes	No	Yes

Notes: The dependent variable is log monthly total employment in Columns (1)–(4) and log monthly contract employment in Columns (5)–(8). The explanatory variable is log monthly copper production (metric tons). Columns (1)–(2) and (5)–(6) include contemporaneous production only; Columns (3)–(4) and (7)–(8) also include its one-calendar-month lag. The cumulative elasticity is $\beta_0+\beta_1$, with standard error and two-sided p-value from `lincom` testing the null that the sum equals zero. Panel A uses available monthly employment returns from 2019, 2020, 2022, and 2023 and excludes Lumwana (misreporting). Panel B uses 2022–2023 and includes Lumwana. Employment data were supplied by the Mines Safety Department of Zambia's Ministry of Mines and Minerals Development. Monthly employment returns are unavailable for 2021, and 2020 coverage is incomplete. Lagged production is taken from the immediately preceding calendar month, without skipping months lacking employment data. Sample sizes differ across outcomes and according to the availability of lagged production. Mine FE denote mining-company fixed effects; All FE includes mining-company, year, and calendar-month fixed effects. Standard errors are clustered by calendar year-month and reported in parentheses. $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table 19: Monthly Copper Production Volatility and Implied Input-Demand Responses

		Predicted increase for +1 SD (%)	
Production-volatility measure	SD of $\log Q_{it}$	Domestic procurement	Imports
Pooled (across mines and months)	1.226	88.2	25.9
Within mine (mine mean removed)	0.528	31.3	10.4
FE residual (mine, year, month)	0.516	30.5	10.2
Monthly change in $\log Q_{it}$	0.336	18.9	6.5

Notes. Q_{it} denotes monthly copper output of mine i, following Equation (1). The main sample covers September 2013–November 2022 (1,069 positive-production mine-months across ten mines); the aggregate `TOTAL` series and missing production are excluded. The pooled SD of $\log Q_{it}$ combines between-mine and time variation. The within-mine SD removes each mine's mean. The FE-residual SD removes mine (ϕ_i), calendar-year (ϕ_y), and calendar-month (ϕ_m) effects. The monthly-change SD uses 1,053 changes across consecutive observed months. The final two rows use alternative samples. Predicted domestic procurement and import responses use the baseline OLS coefficients $\hat{\beta}_1 = 0.516$ and $\hat{\beta}_1 = 0.188$, respectively (Tables 3 and 6), as described in the text. These are standardized associations, not causal decompositions of expenditure volatility.

Table 20: Mining Customer Diversification and Production Volatility

Number of Mine Customers	Combinations of Mine Customer	Mean SD, $\log Q$	Implied decline (%) in demand
1	10	0.430	19.4
2	45	0.292	13.7
3	120	0.239	11.5
4	210	0.202	9.8
5	252	0.175	8.6
6	210	0.154	7.6
7	120	0.137	6.8
8	45	0.123	6.1
9	10	0.110	5.5
10	1	0.099	5.0

Notes: The table considers all $2^{10}-1 = 1{,}023$ nonempty combinations of ten Zambian copper mines. Each combination is treated as a hypothetical supplier's portfolio of mine customers. For a combination c, monthly portfolio production is the sum of its constituent mines' production, $Q_{ct} = \sum_{m \in c} Q_{mt}$. Volatility is $\sigma_c = SD_t(\log Q_{ct})$, calculated using monthly production without fixed effects, detrending, or smoothing. All combinations use the same 73 months with positive production reported for all ten mines within September 2013–November 2022; these months need not be consecutive. The second column is $10k$ for a portfolio of k mines. The third column averages σ_c over combinations with k mines. The final column averages the simulated percentage decline $100[1-\exp(-0.516\sigma_c)]$ across those combinations, rather than applying the formula to the mean SD. The elasticity 0.516 is estimated for mines' own domestic procurement, not for Tier 1 suppliers. The table illustrates production-volatility diversification under a constant elasticity; it does not measure actual supplier demand responses or use observed supplier portfolios.

B Data dictionary

Zambia Copper Production 2013 to 2023: Zambia Ministry of Mines and Mineral Development.

Zambia Domestic VAT 2013 to 2022: Zambia Revenue Authority.

Zambia Imports 2013 to 2023: Zambia Revenue Authority, received June 6, 2024.

ISIC list: Zambia Revenue Authority.

Tax Online VAT returns: Zambia Revenue Authority.

Zambia Payment Flows 2013 to 2023: Zambia Extractive Industries Transparency Initiative, latest year received June 13, 2024.

Zambia Consumer Price Index 2013 to 2023: Zambia Statistics Agency.

Zambia Copper Price 2013 to 2022: The World Bank.

USD-ZMW Exchange rate 2013 to 2023: U.S. Bureau of Labor Statistics

C Online Appendix

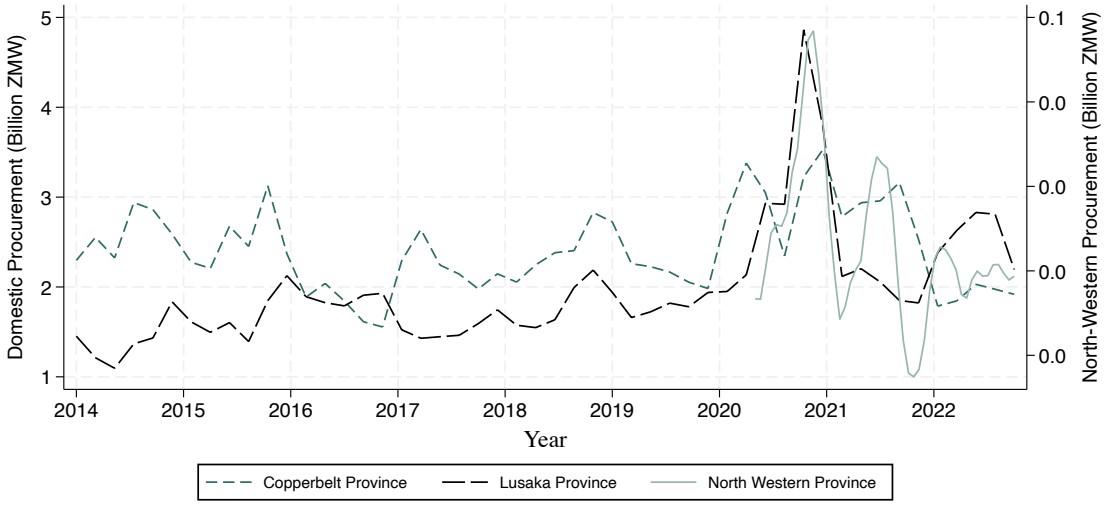


Figure 11: Monthly Total Procurement Value by Copper Mines by Province of Copper Mine Supplier

Notes: Monthly series, January 2014 to October 2022. Total domestic procurement of the copper mines in billion ZMW, inflation-adjusted with the monthly CPI; the sample is that of Table 3 (excluding six transactions above ZMW 5 billion, 810 records with unreadable amounts, transactions between copper mines, and transactions among one particular mine and its subsidiaries), and negative values (credit notes) are excluded before summing, split by supplier region of registration: Copperbelt Province (Y axis 1), Lusaka Province (Y axis 1), Northwestern Province (Y axis 2).