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EXORBITANT PRIVILEGE OF THE PERIODIC TABLE? GEOECONOMICS, ENDOGENOUS CENTRALITY AND STRATEGIC MINERALS FOR THE GREEN TRANSITION

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ABSTRACT. Trade networks underpinning the energy transition are *endogenous* economic objects, and their structure is a source of market power. Using bilateral trade data for thirteen electrification metals over 1995–2023, we show that trade in these materials has reorganised into a hub-and-spoke system centred on China, in sharp contrast to the more diffuse, multilateral structure of fossil fuels. This centrality did not follow from resource endowments: China holds few of the underlying reserves. It was built through processing investment, industrial policy, and commodity-targeted development finance, an equilibrium outcome rather than a geographical accident. We formalise this logic in a stylised model in which a country chooses how central to become, and show that centrality can map into pricing power: the world price of critical minerals response to a strategic supply cut is stronger when the network is more concentrated, the downstream demand and the competitive fringe supply are more inelastic. Constructing text-based, commodity-specific supply shocks and estimating local projections, we find that supply contractions in critical metals raise consumer inflation in the European Union and the United States by roughly twice as much as comparable fossil-fuel shocks, and more persistently. Centrality is therefore not merely a descriptive feature of the new resource map: it can create leverage over global prices. The green transition reduces strategic dependence on hydrocarbon exporters but reconstitutes it around the architecture of mineral supply chains.

JEL classification codes: F14, F51, Q32, L13, O13.

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1. INTRODUCTION

Economic interdependence is increasingly treated by governments as an instrument of statecraft rather than a purely allocative outcome. Export controls, sanctions, and the deliberate cultivation of supply-chain chokepoints have become important tools of policy, and the theoretical case for why they work is by now well understood: control of a critical input in a global network confers influence out of proportion to a country's economic size (Hirschman 1945; Farrell and Newman 2019; Clayton, Maggiori, and Schreger 2026). The same logic underpins the "exorbitant privilege" of the issuer of the

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dominant currency, whose position at the centre of the financial network yields structural advantages beyond its domestic weight (Gourinchas and Rey 2007a; Gourinchas and Rey 2022). In each case, power is embedded in the *structure* of exchange.

A structure, however, is not a primitive. Networks are built. The parallel with the international monetary system is exact: the dollar's central position was not bequeathed by fundamentals but constructed—through postwar institutions, market depth, and self-reinforcing network externalities—and it yields an 'exorbitant privilege' Gourinchas and Rey 2007a out of proportion to US economic size. What we document is the commodity-market counterpart: a centrality in critical-mineral processing that was likewise built, and that likewise confers structural power. In both cases the centre position is endogenous." This paper studies the trade networks that the green transition is creating, and advances a single organising claim: these networks are *endogenous*, and their endogeneity is economically consequential because network position can be a source of *market power*. Concretely, we show that trade in the metals required for electrification has reorganised into a hub-and-spoke system centred on China; that China's central position was manufactured through investment and policy rather than inherited from resource endowments; and that this position confers measurable leverage over global prices - the ability to move world prices by altering supply. Centrality in a network does not necessarily come with pricing power (it depends on substitutability, for example), but in this case we estimate the pricing power to be large and persistent.

The distinction from the classical view of trade matters. In a frictionless, competitive benchmark, the geography of trade reflects exogenously given comparative advantages. For fossile fuels, endowments mostly determined trade patterns. The electrification transition departs from this benchmark. The materials at stake—lithium, cobalt, nickel, and the processed intermediates built from them—are produced and, more importantly, *processed* in a handful of locations, with long investment lead times and limited substitutability in end use. In such an environment a country that concentrates processing capacity faces a downward-sloping residual demand curve for its output and can, by withholding supply, raise the global price. This is market power; what is distinctive is that it is acquired by occupying the centre of a trade network, and that the network position is itself a choice variable.

We make this argument in three steps. First, we provide a stylised model in which a dominant country chooses how central to become. A competitive fringe supply of other countries and a downstream demand curve determine the residual demand the dominant country faces; ex ante, the country invests in processing capacity—optionally subsidised by industrial policy—and this investment determines its equilibrium centrality. The model delivers three results that discipline the empirical work. (i) *Centrality is linked to pricing power*: the intermediary country's Lerner index is increasing in its share of the network and decreasing in the elasticities of downstream demand and of the competitive fringe supply of critical minerals. (ii) *Pricing power is what supply shocks reveal*: the elasticity of the world price with respect to a strategic supply cut equals the Lerner index, so a network-central node produces larger and more persistent price responses precisely where substitution is slow and fringe entry is slow and small. (iii) *Centrality is endogenous*: optimal capacity investment is increasing in the value of the leverage it creates and in downstream inelasticity, and industrial-policy subsidies raise it. Networks, in other words, are equilibrium objects shaped by policy.

Second, we characterise the networks empirically. Using CEPII-BACI bilateral trade data at the HS six-digit level over 1995–2023, we build annual directed, weighted trade networks for thirteen electrification metals and for fossil fuels, and compute graph-theoretic measures of centrality, market dominance, and local clustering. Three facts emerge. China's Katz centrality in electrification materials rises sharply from around 2005 and overtakes the United States, whereas in fossil fuels the two remain balanced. This is the signature of a system reorganising around a single hub rather than diffusing. Clustering coefficients for electrification materials collapse towards zero as peripheral suppliers route their exports through Chinese processing rather than trading with one another, the graph-theoretic footprint of hub-and-spoke formation; fossil-fuel networks have a more distributed, multilateral structure. The average export value per trading relationship, a market-dominance metric, reflects how individual materials confer leverage: the Democratic Republic of Congo in cobalt and Indonesia in nickel achieve influence far exceeding their aggregate trade volumes.

The Indonesian nickel episode is our clearest evidence that centrality is *built*. Indonesia's 2020 ban on raw nickel-ore exports, combined with Chinese processing investment under the Belt and Road Initiative, transformed the country from a raw-ore exporter into a dominant supplier of processed nickel in the space of a few years, and pulled China's nickel centrality up with it. We show that China's commodity-targeted development finance—using AidData's transition-minerals dataset (Walsh et al. 2025)—is directed disproportionately at the materials and countries where this network-building improves its centrality. These are policy instruments acting on the network, exactly the endogenous margin the stylised model isolates.

Third, we estimate the pricing power that centrality may confer. Building on the automated-narrative approach of Lumbanraja et al. (2025), we construct commodity-specific supply shocks from a corpus of over eight million news articles using a weakly supervised, teacher–student text-classification pipeline—together with demand shocks that enter the regressions purely as controls—and estimate local projections (Jordà 2023) of the response of producer and consumer prices to supply innovations. A one-standard-deviation supply contraction in electrification metals raises CPI inflation in the United States and the European Union by roughly one percentage point—about twice the response to a comparable fossil-fuel shock—and the effect is more persistent. The asymmetry is even stronger for producer inflation. The fossil-fuel response lines up with existing oil-shock benchmarks (Känzig 2021). This asymmetry is precisely the model's prediction: where a central node faces an inelastic supply fringe and inelastic downstream demand, supply disturbances pass through to prices strongly and durably. The local-projection coefficients are, in this reading, an estimate of the leverage that the endogenous network confers.

Taken together, the results draw attention to the "new resource map" of the energy transition. The transition from fossile fuels does not abolish strategic dependence; it relocates it from hydrocarbon reserves, which are geographically dispersed and buffered by reserves and deep markets, to mineral processing chains, which are concentrated, thin, and slow to replicate. Because the central position is endogenous, it is contestable: diversification of supply, strategic reserves for metals, and processing investment by other economies all raise the fringe elasticity and erode the hub's pricing power. The policy problem is therefore not only security of access but the design of the network structure itself.
Related literature. The paper connects four literatures, which we treat through an economics lens.

Geoeconomics and market power in networks. Our starting point is the classical analysis of how asymmetric trade dependence generates political and economic leverage (Hirschman 1945), formalised recently as "weaponised interdependence" (Farrell and Newman 2019; Farrell and Newman 2023) and as models of geoeconomic coercion and dependence (Clayton, Maggiori, and Schreger 2026; Clayton, Maggiori, and Schreger 2025; Mohr and Trebesch 2025; Broner et al. 2025). Relative to this work, which largely takes network positions as given and studies their exploitation, our contribution is to emphasize the *endogeneity* of the network -position is chosen through investment and industrial policy- and to tie it explicitly to price-setting power that we then estimate.

Dominance and structural power in international macro-finance. A parallel literature studies how occupying the centre of the international monetary and financial network confers structural advantage: hegemonic stability and exorbitant privilege (Kindleberger 1973; Gourinchas and Rey 2007a; Gourinchas and Rey 2007b; Gourinchas and Rey 2022), dominant-currency pricing (Gopinath 2015), and the global financial cycle through which a central node transmits shocks worldwide (Rey 2013; Miranda-Agrippino and Nenova 2022; Degasperi, Hong, and Ricco 2024; Rey, Stavrakeva, and Tang 2023).Just as US monetary policy shocks affect financial prices globally, we identify commodity trade networks as an additional domain in which centrality is accumulated and through which shocks propagate internationally (Miranda-Agrippino and Rey 2020 and Miranda-Agrippino, Nenova, and Rey 2022). But China, this time, occupies the central position.

Industrial policy and the endogenous formation of comparative advantage. That centrality is built rather than endowed connects to the revival of the economics of industrial policy (Juhasz, Lane, and Rodrik 2024), which provides evidence that targeted interventions can durably reshape the structure of production. Indonesia's export-restriction-cum-processing strategy is an example, and China's outbound development finance (Custer et al. 2023; Walsh et al. 2025) is the financing counterpart.

Commodity networks, supply shocks, and inflation. Finally, we build on work showing that commodity markets are a powerful conduit for the international transmission of inflation (Degasperi, Hong, and Ricco 2024; Malliaropulos, Passari, and Petroulakis 2025) and that non-oil supply disruptions move inflation and activity at least as much as oil (Lumbanraja et al. 2025), as well as on evidence that China is pivotal in industrial-metals markets (Miranda-Agrippino, Nenova, and Rey 2022). Alfaro et al. (2025) studies strategic dependence in global rare-earth supply chains and the exposure it creates for downstream producers. Our contribution is to link the network structure of a market directly to the size and persistence of the price response its supply shocks generate.

Contributions. Relative to this literature the paper makes four contributions. First, it characterises global trade networks for critical electrification minerals over nearly three decades, spanning the arc from before China's WTO accession to the mature electric-vehicle era. Second, it develops a tractable model in which network centrality is chosen and maps into pricing power, unifying the geoeconomics and industrial-organisation readings of the same facts. Third, it constructs commodity-specific supply and demand shocks from text, extending Lumbanraja et al. (2025) with a method that handles the sparse news coverage of individual metals. Fourth, it estimates the pricing leverage that the endogenous network confers, connecting network position to macroeconomic outcomes.

The remainder of the paper is organised as follows. Section 2 presents the model. Section 3 describes the data and network measures. Section 4 documents the endogenous rise of China's centrality and the hub-and-spoke architecture. Section 5 studies material-specific leverage and the Indonesian nickel case. Section 6 estimates the price effects of supply shocks. Section 7 discusses implications and Section 8 concludes.

2. A Model of Endogenous Centrality and Pricing Power

This section presents a stylised model that formalises the paper's organising claim: a country can *choose* to become the central node of a trade network, and centrality translates into the ability to move the world price by altering supply. The model is deliberately minimal. Its purpose is to make precise what "centrality is pricing power" means, to show that this power is endogenous to investment and policy, and to map its comparative statics onto the empirical objects we measure—graph-theoretic centrality, a market-dominance metric, and the impulse responses of prices to supply shocks. We interpret the model as a device for organising the empirics rather than as a structural model to be estimated.

2.1. **Environment.** Consider the market for a single processed electrification metal (the argument applies material by material). The rest of the world demands the processed good according to a downward-sloping demand curve $Q = D(p)$, with $D'(p) < 0$, arising from downstream producers of batteries, motors, grids, and renewables for whom the metal is a poorly substitutable input. Let

$$\varepsilon_D \equiv -\frac{D'(p)\, p}{D(p)} > 0 \tag{1}$$

denote the (opposite of) the price elasticity of demand. Low substitutability in end use—engineers can economise on nickel or cobalt but cannot eliminate it without performance losses—makes ε_D small.

Supply is provided by two segments. A *competitive fringe*, comprising many small producers and processors elsewhere in the world, supplies $S_f(p)$ with $S_f'(p) \geq 0$ and elasticity

$$\varepsilon_S \;\equiv\; \frac{S_f'(p)\, p}{S_f(p)} \;\geq\; 0. \tag{2}$$

The fringe elasticity is governed by how quickly alternative processing capacity can respond to price. For metals with long mine and refinery lead times, few substitutes, and no strategic reserves, ε_S is small, especially at short and medium horizons; for fossil fuels, deep spot markets, spare capacity, and strategic petroleum reserves make the analogous fringe far more elastic.

A single *intermediary country*—China in the application—supplies the residual. It operates processing capacity with constant marginal cost c and produces quantity q. Market clearing requires

$$D(p) \;=\; S_f(p) \;+\; q. \tag{3}$$

We summarise the country's position by its equilibrium market share,

$$\alpha \;\equiv\; \frac{q}{D(p)} \;=\; \frac{D(p) - S_f(p)}{D(p)} \;\in\; [0,1], \tag{4}$$

which we will refer to as its *centrality*. When $\alpha \to 0$ the intermediary country is a price-taking fringe member; when $\alpha \to 1$ it is the sole processor and the market is a monopoly. In the empirical sections, α is the primitive that graph-theoretic centrality (Katz) and the market-dominance metric are designed to capture.

2.2. **Pricing power.** Facing the residual demand $D_r(p) \equiv D(p) - S_f(p)$, the intermediary country is dominant.[1] Its perceived residual-demand elasticity is

$$\varepsilon_r \;=\; -\frac{D_r'(p)\, p}{D_r(p)} \;=\; \frac{\varepsilon_D\, D(p) + \varepsilon_S\, S_f(p)}{D(p) - S_f(p)} \;=\; \frac{\varepsilon_D + (1-\alpha)\, \varepsilon_S}{\alpha}. \tag{5}$$

Profit maximisation, $\max_q\, [p(q) - c]\, q$, yields the standard Lerner condition $(p-c)/p = 1/\varepsilon_r$ (Lerner 1934), and substituting (5)—itself the classic dominant-firm residual-elasticity formula of Landes and Posner (1981)—gives our first result.

Proposition 1 (Centrality is pricing power)**.** *The intermediary country's Lerner index is*

$$\mathcal{L} \;\equiv\; \frac{p-c}{p} \;=\; \frac{\alpha}{\varepsilon_D + (1-\alpha)\, \varepsilon_S}. \tag{6}$$

[1]The dominant-firm-with-competitive-fringe structure originates with Forchheimer (1908) and is a standard building block of industrial organisation; see Tirole (1988) and Carlton and Perloff (2005).

It is strictly increasing in centrality α and strictly decreasing in the demand elasticity ε_D and the fringe elasticity of supply ε_S. As $\alpha \to 1$, $\mathcal{L} \to 1/\varepsilon_D$ (monopoly); as $\alpha \to 0$, $\mathcal{L} \to 0$ (price-taking).

2

Proposition 1 states that markup power is not a fixed attribute of a country but a function of its position in the network: the closer a node comes to intermediating the entire market, and the more inelastic downstream demand and the competitive fringe, the greater its power over price. This is the sense in which "being at the centre" is an economic, and not merely a descriptive, statement.
Centrality versus market power. It is worth being precise about what a network-centrality measure does and does not capture, because the two are easily conflated. Centrality is a proxy for the *share and essentiality* of a node—the α channel—but not for market power itself, which by (6) additionally requires an inelastic fringe and inelastic demand. The two can diverge sharply. A pure transshipment hub through which goods merely route can be highly central by any degree- or betweenness-based measure yet hold no pricing power, because the fringe re-routes freely ($\varepsilon_S \to \infty$) and $\mathcal{L} \to 0$. What distinguishes the central node in electrification metals is that its processing stage is a genuine capacity bottleneck served by an inelastic short-run fringe, so that high α coincides with low ε_S. Because this coincidence is an empirical claim and not a definitional one, we do not assume it: we measure centrality (Katz, Section 3) and the pricing-power object (the supply-shock pass-through, Section 6) *separately*, and read their alignment—both large for electrification metals, neither for fossil fuels—as a *test* of the identification rather than as an assumption built into it.

2.3. **Altering prices by altering supply.** Pricing power in the sense of Proposition 1 is exercised through the choice of quantity. Consider a marginal reduction in the intermediary country's supply—a strategic or coercive cut $dq < 0$, or equivalently an export restriction—holding fringe behaviour and demand fixed. Differentiating (3),

$$\frac{dp}{dq} = \frac{1}{D'(p) - S_f'(p)} < 0, \qquad \text{so that} \qquad \underbrace{\frac{d\ln p}{d\ln q}}_{\text{price impact of a supply cut}} = \frac{\alpha}{\varepsilon_D + (1-\alpha)\,\varepsilon_S} = \mathcal{L}. \tag{7}$$

Proposition 2 (Supply shocks reveal pricing power)**.** *The elasticity of the world price with respect to a supply cut by the central node equals its Lerner index, $d\ln p/d\ln q = \mathcal{L}$. Hence the price impact of a supply disturbance is larger the greater the node's centrality α and the smaller the elasticities ε_D and ε_S. When the fringe adjusts slowly (ε_S low at short and medium horizons), the price response is not only larger but more persistent.*

[2]This characterisation presumes the usual interior dominant-firm condition that residual demand is elastic at the optimum, $\varepsilon_r > 1$, equivalently $\varepsilon_D + (1-\alpha)\varepsilon_S > \alpha$; we maintain this regularity condition throughout, as it holds for the demand and fringe elasticities relevant to our application

Proposition 2 is the bridge from macroeconomics to geopolitics. The same object—$\mathcal{L} = \alpha/[\varepsilon_D + (1-\alpha)\varepsilon_S]$—is simultaneously the intermediary country's markup and the pass-through of its supply decisions into the global price. A network-central node in a market with an inelastic fringe and inelastic demand can therefore move world prices by moving its own supply, and the magnitude of that leverage is what an econometrician recovers by regressing prices on supply innovations. This is why the local-projection coefficients of Section 6 are informative about network power, as reduced-form-evidence on $\mathcal{L}$. The contrast we find between electrification metals (high α, low ε_D, low ε_S) and fossil fuels (lower α, higher ε_S owing to reserves and spare capacity) is the contrast between a large, persistent response and a small one.

2.4. **Endogenous centrality.** The final and most important step endogenises α. Before the market opens, the intermediary country invests I in processing capacity and in securing upstream inputs. It matters *how* this investment raises centrality. It does so not by expanding the intermediary country's own output—that would lower the price and shrink its markup—but by acting on the competitive fringe: by monopolising ore, deterring rival processing capacity, and tying up supply through long-term arrangements, investment shifts the fringe supply schedule inward and makes it less elastic, $S_f(p; I)$ with $\partial S_f/\partial I < 0$ and $\partial \varepsilon_S/\partial I \leq 0$. A smaller, steeper fringe mechanically raises both the residual share α *and* the residual-demand inelasticity, so that α and the Lerner index $\mathcal{L}$ in (6) rise together rather than trading off. We accordingly write $\alpha = \alpha(I)$ with $\alpha'(I) > 0$ and $\alpha''(I) < 0$ as a reduced form for this fringe-foreclosure channel; the endowment of the intermediary country enters nowhere. Investment carries convex cost $\kappa(I)$, which industrial policy—domestic subsidies, or outbound development finance that secures upstream ore—reduces at the margin by $\sigma \geq 0$, so the effective marginal cost of capacity is $\kappa'(I) - \sigma$.[3] The intermediary country chooses I to maximise

$$\Pi(I) \;=\; \underbrace{\big[p(\alpha(I)) - c\big]\, q(\alpha(I))}_{\text{market rents } = R(\alpha)} \;+\; \underbrace{V(\alpha(I))}_{\text{strategic value of leverage}} \;-\; \kappa(I) \;+\; \sigma I, \tag{8}$$

where market rents $R(\alpha)$ are increasing in α (higher markup and volume), and $V(\alpha)$ is the value the state attaches to the geoeconomic leverage that centrality confers, with $V'(\alpha) \geq 0$ (we microfound V below). The first-order condition is

$$\big[R'(\alpha) + V'(\alpha)\big]\, \alpha'(I) \;=\; \kappa'(I) - \sigma. \tag{9}$$

Proposition 3 (Centrality is endogenous)**.** *The equilibrium centrality $\alpha^* = \alpha(I^*)$ characterised by (9) is increasing in the strategic value of leverage (higher V'), in the policy subsidy σ, and in downstream inelasticity (lower ε_D, which raises R' through the markup channel of Proposition 1). It does not depend on the intermediary*

[3] The subsidy σ stands in for the targeted industrial-policy interventions whose effectiveness in durably reshaping the structure of production is documented by Juhasz, Lane, and Rodrik (2024).

country's own resource endowment. Networks are therefore equilibrium objects: their structure is chosen, and policy shifts it.

Proposition 3 is the statement that "China put itself in the middle." The central position is the solution to an investment problem in which both ordinary rents and strategic value reward centrality, and in which subsidies and development finance lower its cost. Crucially, endowment plays no role: a country with negligible domestic reserves—China holds little of the world's nickel, cobalt, or lithium—can nonetheless become the network's hub by investing in processing, exactly what the data show. The same logic operates one tier upstream through partners: Indonesia's ore-export ban is an instrument that reallocates processing rents and, by tying ore access to in-country refining, raises the effective α of the China–Indonesia processing complex (Section 5). This endogeneity mirrors the international monetary system, where the reserve issuer's central position is sustained by network externalities and hysteresis rather than fundamentals—the 'exorbitant privilege' is itself built and, in principle, contestable.

Microfoundations for the strategic value $V(\alpha)$. We have written $V(\alpha)$ as a reduced form, but it is not a free parameter: it admits at least two complementary microfoundations, each of which is increasing in centrality and so delivers the monotonicity $V'(\alpha) \geq 0$ that Proposition 3 requires. They are not mutually exclusive, and $V(\alpha)$ is best read as their sum.

(i) Coercion value. Centrality is an instrument of coercion: by credibly threatening to withhold supply, the hub can extract policy or commercial concessions from dependent partners. In the geoeconomic-bargaining framework of Clayton, Maggiori, and Schreger (2025) and Clayton, Maggiori, and Schreger (2026), the value a government derives from an economic linkage is precisely the concession it can extract by threatening to sever it, and that value rises with the target's dependence—here increasing in α. This formalises Hirschman (1945) and weaponised interdependence (Farrell and Newman 2019; Farrell and Newman 2023): $V(\alpha)$ is the expected payoff of the coercion option, the probability it is exercised times the concessions a more dependent target will yield. Concretely, one can write $V(\alpha) = \pi\, C(\alpha)$, where $C(\alpha)$ is the concession extracted from a partner whose cost of substituting away from the hub is increasing in α, and π the probability the state finds it worthwhile to exercise the threat.

(ii) Security / option value. Finally, centrality confers priority of access when global supply is disrupted: a central processor can service its domestic downstream industry first and ration exports, an option whose value rises with the frequency and severity of supply shocks and with α. This supply-security value is the mirror image of the importer vulnerability that Section 6 quantifies—the same inelasticities that make a supply cut painful for importers make guaranteed access valuable for the hub.

Each reading yields $V'(\alpha) \geq 0$, and each ties the strategic premium on centrality to a distinct, recognised economic mechanism—coercion rents, or the option value of security—rather than to an unexplained taste for power.

2.5. **Relation to the literature.** Our framework is closely related to the geoeconomic-pressure work of Clayton, Maggiori, and Schreger 2025; Clayton, Maggiori, and Schreger 2026), and the comparison is clarifying. From a multi-sector CES production network they derive, for a hegemon m threatening target n by withholding an input in industry J, the power measure

$$\text{Power}_{mnJ} \;=\; -\frac{\beta}{1-\beta}\,\frac{1}{\sigma_J-1}\,\Omega_{nJ}\,\log\bigl(1-\omega_{nJRm}\bigr), \tag{10}$$

where ω_{nJRm} is the hegemon's share of n's foreign input spending, Ω_{nJ} the expenditure weight of the input, and σ_J its substitution elasticity. This is governed by the same the forces as in our Lerner index $\mathcal{L} = \alpha/[\varepsilon_D + (1-\alpha)\varepsilon_S]$ (Proposition 1): power rises with the controlling country's share ($\omega \to 1$ mirrors $\alpha \to 1$) and with inelastic substitution (low σ_J mirrors low $\varepsilon_D, \varepsilon_S$). The two measures price different things—(10) the target's *welfare* loss, our Proposition 2 the *price* a central supplier commands, $d \ln p / d \ln q = -\mathcal{L}$—but they are linked through the expenditure weight: to first order the target's consumer-price loss is $\Omega_{nJ} \times \mathcal{L}$, so their power kernel $-\log(1-\omega)/(\sigma_J - 1)$ plays the role of our $\mathcal{L}$, and our estimated inflation pass-through is a reduced-form empirical counterpart of their structurally computed Power_{mnJ}.

Against this benchmark our contribution is twofold. First, and most importantly, *we endogenise what they take as given*: Clayton, Maggiori, and Schreger 2025; Clayton, Maggiori, and Schreger 2026 measure power at fixed input–output shares (ω, Ω), whereas our central result (Proposition 3) is that the control share α (their ω) is *chosen*—built through processing investment, industrial policy, and development finance. Their cross-sectional question "which sectors are chokepoints" becomes the dynamic question "how chokepoints are built." Second, we provide the exporter/supply side and its macroeconomic footprint—the pass-through of supply restrictions into global prices and into US and EU inflation—complementing their importer/welfare side. The two papers are thus supply- and demand-side accounts of a single mechanism: the conversion of a built-up network position into power over prices and over the welfare of dependent economies.

2.6. **Mapping the model to the measurement.** The model gives three empirical counterparts that structure the rest of the paper.

Centrality α. We do not observe α directly but measure its network footprint. Katz centrality (Section 3) captures a node's share of direct and indirect trade intermediation and is our proxy for α; the collapse of local clustering towards zero is the graph-theoretic signature of a rising α in a hub-and-spoke configuration. Section 4 shows a sharp rise of centrality for China in electrification metals after 2005 but not in fossil fuels.

Residual market power $\mathcal{L}$, cross-section. Our market-dominance metric—average export value per trading relationship—identifies materials and countries for which a single supplier faces a steep residual demand, the cross-sectional analogue of a high $\mathcal{L}$. Section 5 uses it to isolate cobalt (DRC) and nickel (Indonesia).

Pricing power $\mathcal{L}$, time series. By Proposition 2, the pass-through of supply shocks into prices *is* $\mathcal{L}$. Our empirical shocks, however, use one-standard-deviation innovations to commodity-wide (not China-specific) supply indices, and the CPI regressions further layer in downstream cost pass-through, monetary policy, and inventory adjustment. Section 6 estimates these responses via local projections and finds them large and persistent for electrification metals relative to fossil fuels, consistent with $\alpha_{\text{metals}} > \alpha_{\text{fossils}}$ and $\varepsilon_S^{\text{metals}} < \varepsilon_S^{\text{fossils}}$. We read these coefficients as evidence on relative price and inflation leverage across the two markets rather than as numerical estimates of $\mathcal{L}$ itself, which would require additional scaling assumptions.

Two further comparative statics are worth flagging because they discipline the discussion of Section 7. First, since $\mathcal{L}$ is decreasing in ε_S, any policy that thickens the competitive fringe—diversified processing investment abroad, recycling, or strategic metal reserves that supply the market when the hub withholds—directly erodes the hub's pricing power. Second, since α is endogenous through (9), the leverage is contestable ex ante: it can be competed away by rival investment before it is exercised, not only mitigated ex post.

3. Data and Network Measurement

We measure trade networks in two steps. First, we identify the trade flows relevant to the energy transition and classify them by material and by stage of processing. Second, we build annual directed, weighted networks and compute the graph-theoretic statistics that proxy for the model's objects.

3.1. **Materials and trade data.**

We focus on the metals and minerals identified as critical for electrification in Table 1.SF.1 of the IMF's *World Economic Outlook* (International Monetary Fund 2021): aluminium, chromium, cobalt, copper, graphite, lead, lithium, manganese, molybdenum, nickel, silicon, silver, vanadium, and zinc. Mapping these materials to trade codes requires care because many have industrial uses well beyond the energy transition. We therefore build a transparent, replicable classification of Harmonised System (HS) six-digit codes: for each candidate code we identify the principal industries that use it, retain the code only if those industries are material to electrification, and classify the retained code as a raw or a processed good. Appendix A details the procedure; Appendix Table B.1 lists the resulting codes, their processing status, and 2022 trade values. The distinction between raw and processed forms is central to the paper: it is at the processing stage that centrality is built, and the model's intermediary country is a processor rather than a miner. For example, artificial graphite (HS 380110) and lithium carbonate (HS 283691) are processed intermediates essential to battery production, whereas the corresponding ores are raw inputs.

Bilateral trade flows come from CEPII's BACI dataset, itself constructed from UN COMTRADE with reconciliation of mirror flows (Gaulier and Zignago 2010; CEPII 2010). We use the HS92 vintage spanning 1995–2023. For comparison throughout, we construct a parallel fossil-fuel aggregate (oil, natural gas, coal), which in 2023 is dominated by oil (65.6% of fossil-fuel trade by value), followed by natural gas (23.6%) and coal (10.9%).

3.2. **Networks and measures.** For each year t we form a directed, weighted graph $G_t = (V_t, E_t)$ whose nodes V_t are countries and whose edges carry bilateral trade in current USD, with w_{ij} the value of exports from i to j. We compute four statistics, each chosen for its correspondence to the model.

Weighted degree (trade strength). A node's total trade,

$$s_i \;=\; \sum_{j \in V} \big(w_{ij} + w_{ji}\big), \tag{11}$$

measures gross involvement in the market. It is a scale measure and is not, by itself, informative about market power.

Market dominance. To capture residual market power in the cross-section we use the average export value per active relationship,

$$d_i \;=\; \frac{\sum_{j \in V} w_{ij}}{\big|\{\, j \in V : w_{ij} > 0 \,\}\big|}. \tag{12}$$

A high d_i identifies a country that ships large values through few relationships concentrated in particular goods. It deliberately isolates asymmetric influence from sheer volume: a country can dominate a critical material without large aggregate trade.

Katz centrality. To capture a node's share of *direct and indirect* intermediation—the model's centrality α—we use Katz centrality,

$$k_i \;=\; \beta + \alpha_K \sum_{j \in V} A_{ij}\, k_j, \tag{13}$$

where $A_{ij} = w_{ij}$. Katz centrality is well suited to trade networks because it remains well defined on the weakly connected graphs where eigenvector centrality fails to converge; the attenuation factor α_K discounts distant connections and β sets a baseline. We set $\alpha_K = 0.9/\lambda_{\max}$, where $\lambda_{\max}$ is the largest eigenvalue of A computed each year, to guarantee convergence, and $\beta = 10^{-6}$ so that negligibly connected nodes remain near zero given edge weights spanning 10^3 to 10^{12} USD.[4]

Local clustering. We compute each node's local clustering coefficient using NetworkX (Hagberg, Schult, and Swart 2008). High clustering indicates tight, closed regional trading triangles; low clustering indicates open triplets in which peripheral nodes trade through a common hub rather than with

[4]We denote the Katz attenuation factor α_K to avoid conflict with the model's centrality parameter α.

one another. In the model, a rising α realised through a hub-and-spoke topology drives clustering towards zero, so the clustering series is a direct test of hub formation.

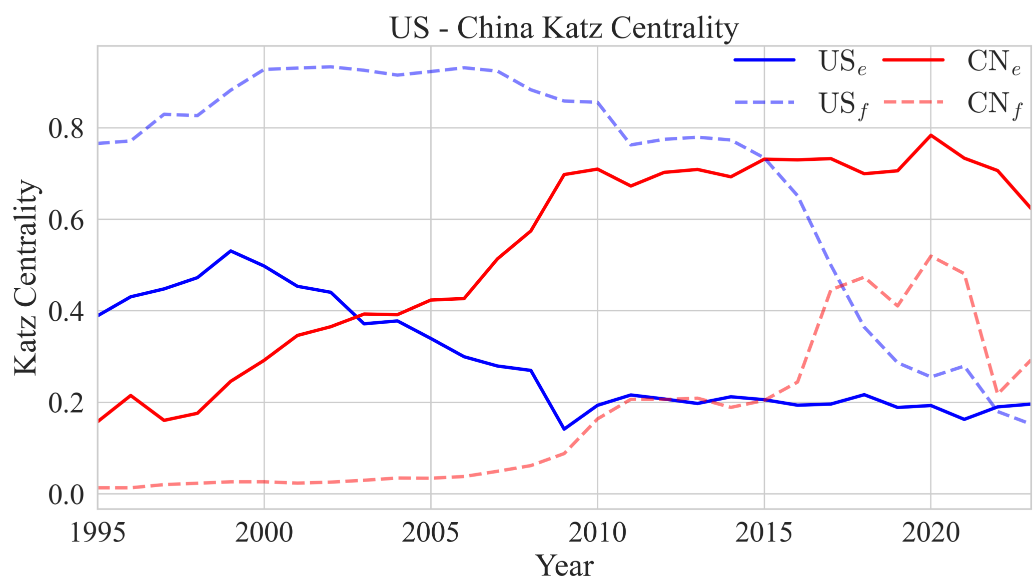
4. The Endogenous Rise of a Central Node

This section establishes two facts that together identify a rising, endogenously built centrality α for China in electrification metals: its Katz centrality overtakes that of the United States after 2005, and the network's local clustering collapses towards zero in the hub-and-spoke pattern the model illustrates. Neither fact appears in fossil fuels, where centrality remains balanced and clustering distributed. Because China holds few of the underlying reserves, these facts point to centrality acquired through processing investment rather than endowment—the empirical content of Proposition 3.

4.1. **Chinese centrality increases in electrification metals.**

Figure 1 plots Katz centrality for the United States and China, separately for electrification materials and fossil fuels. In electrification metals (solid lines) China's centrality rises steeply from around 2005 and moves above that of the United States, whose centrality declines over the same period. In fossil fuels (dashed lines) China's centrality also rises—consistent with its post-2001 WTO integration and growing energy imports—but it tracks rather than overtakes the United States, and the two remain broadly balanced throughout.

FIGURE 1. Katz centrality of the United States and China in electrification materials (e, solid) and fossil fuels (f, dashed), 1995–2023.



The divergence is exactly what the model implies when the two markets differ in the endogenous margin. Fossil-fuel networks are anchored by geographically dispersed reserves, sunk extraction and refining infrastructure, and mature contracting institutions—features that keep the effective fringe elastic and cap any single node's attainable α. China's rising involvement there operates through diversification of import sources (Central Asia, Africa, Latin America, alongside the Middle East) and enhances its energy security without reorganising the market around itself. Electrification metals have no comparable anchor: the binding constraint is processing capacity, which is replicable through investment. China's early and sustained investment in refining, rare-earth processing, and integrated supply arrangements let it capture a rising share of intermediation—raising α—while the United States' share fell. This is the market power of Proposition 1 being accumulated, not a change in comparative advantage in the ground.

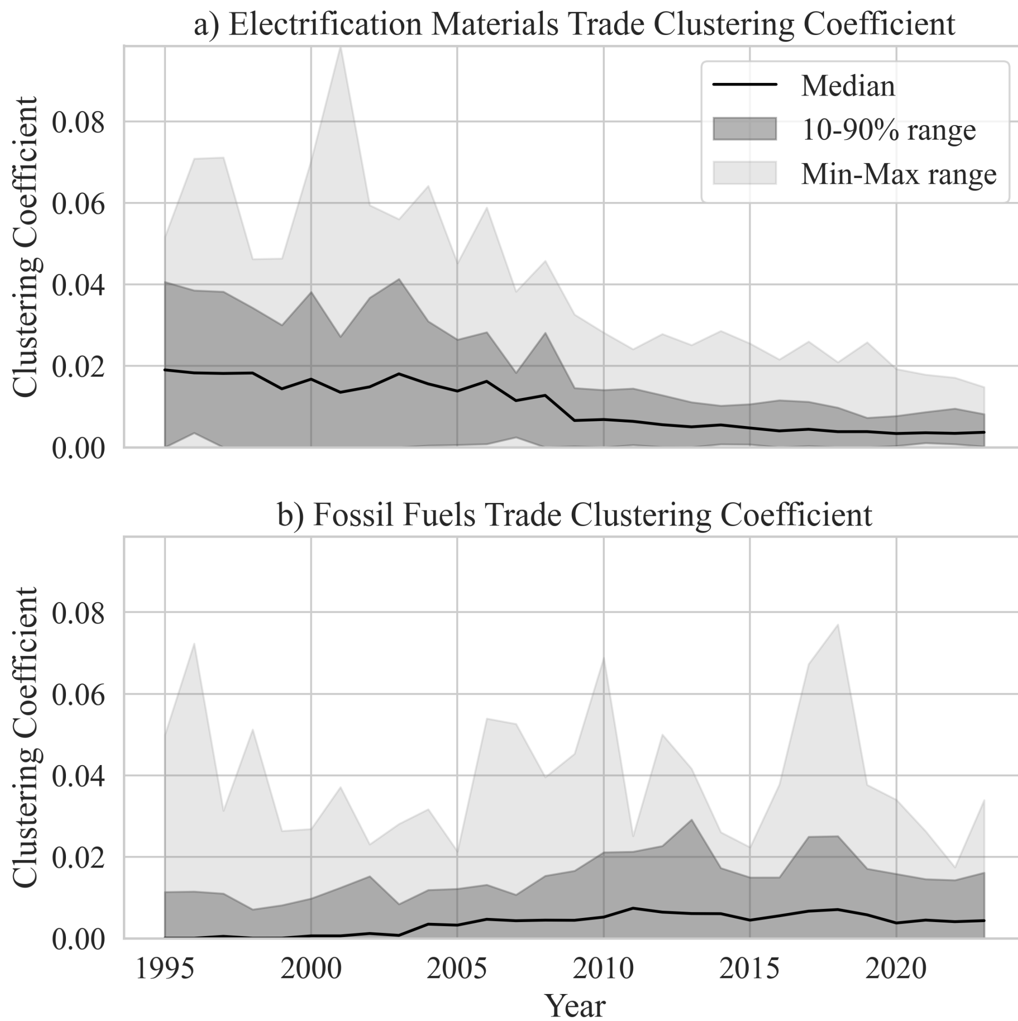
4.2. **Hub-and-spoke formation: the collapse of clustering.** Figure 2 tracks the distribution of local clustering coefficients over 1995–2022 for the two commodity groups. Electrification metals (Panel A) show clustering falling towards zero: the maximum declines from roughly 0.08 in the mid-1990s to near zero by 2020, and the 10–90% range compresses. Fossil fuels (Panel B) retain a positive, distributed clustering structure, with the median around 0.005–0.010 and episodic spikes (1996, 2010, 2018) that mark temporary regional blocs before the network returns to its multilateral baseline.

Falling clustering alongside rising centrality is not a contradiction: it is the graph-theoretic fingerprint of hub-and-spoke formation. In a hub-and-spoke system peripheral suppliers trade with the hub but not with each other, so potential trading triangles remain open and clustering falls even as trade volumes and partner counts grow. As China consolidated its position as the dominant processor, raw-material suppliers increasingly routed exports through Chinese facilities instead of developing direct relationships among themselves. Cobalt from the DRC, lithium from Chile, and nickel from Indonesia flow predominantly to China and only marginally to one another or other countries. The declining clustering is thus the dissolution of regional blocs into a single hub-organised component—precisely the topology through which a rising α is realised, and the reason declustering coincides with *more* concentrated, not more balanced, influence.

Figure 3 makes the contrast visible in the 2023 flow maps. Panel A shows electrification metals radiating from a dominant Chinese hub, with thick raw-material flows arriving from South America (Chilean lithium) and Africa (Congolese cobalt) and value-added products redistributed outward. Panel B shows fossil fuels retaining a dispersed, multi-centre structure. The electrification network is simultaneously more globally integrated (lower clustering) and more exposed to a single point of failure (higher concentration of the intermediation function)—the efficiency-versus-vulnerability trade-off that a hub-and-spoke architecture entails.

The upshot is that the energy transition is not substituting one commodity for another within a fixed market structure. It is generating a different structure—one in which a single node has, through investment, made itself central. The next two sections show where this leverage is concentrated (Section 5) and estimate how large it is (Section 6).

FIGURE 2. Trade-network clustering over time. Median (black), 10–90% range (dark grey), and min–max range (light grey) of the local clustering coefficient, 1995–2022. (A) Electrification materials; (B) fossil fuels.

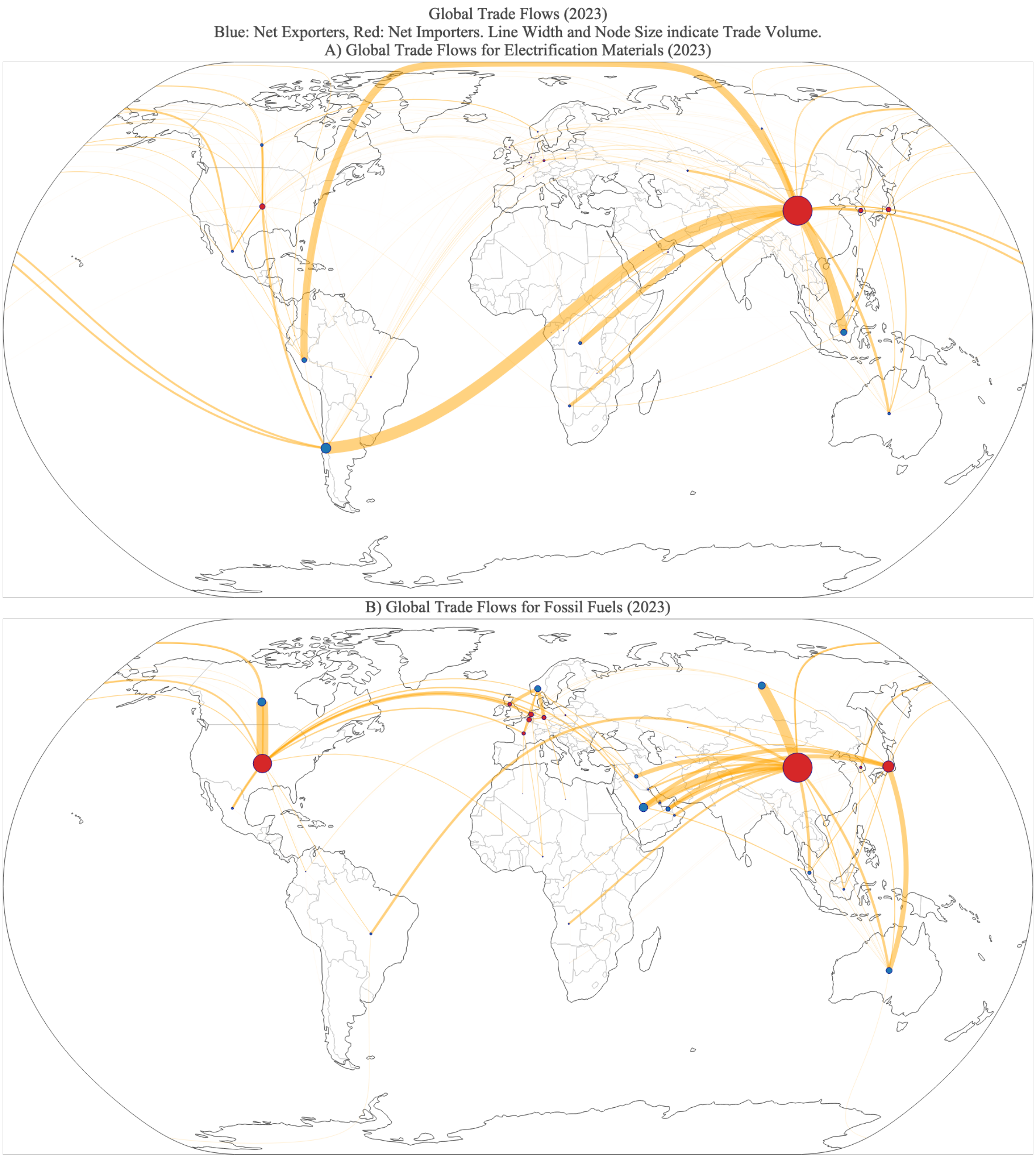


5. Material-Specific Leverage and the Building of Centrality

Centrality in the aggregate network is built material by material, and the leverage it confers is concentrated in materials with thin fringes and few substitutes—low ε_S and ε_D in the model. This section uses the market-dominance metric to locate that leverage, focusing on cobalt (DRC) and nickel (Indonesia) as illustrative examples, and then uses the Indonesian nickel episode and China's commodity-targeted finance as direct evidence that the position is *built* through policy, as in Proposition 3.

5.1. **Where residual market power concentrates.** Copper accounts for roughly half of electrification-material trade by value (Figure 4), and its scale would mask the materials where supply is most concentrated. We therefore compute market dominance excluding copper. Figure 5 shows that, on this metric, the DRC and Indonesia repeatedly emerge as the most dominant exporters globally despite

FIGURE 3. Global trade flows in 2023: (A) electrification materials, showing China's central hub; (B) fossil fuels, showing a distributed network.



modest aggregate volumes—the cross-sectional signature of a high Lerner index concentrated in a single material.

The DRC's dominance stems from cobalt, where it controls roughly 70% of global production and for which lithium-ion batteries have few viable substitutes—a market with low ε_D and a thin fringe,

FIGURE 4. Electrification-material trade volume by material, 1995–2023.

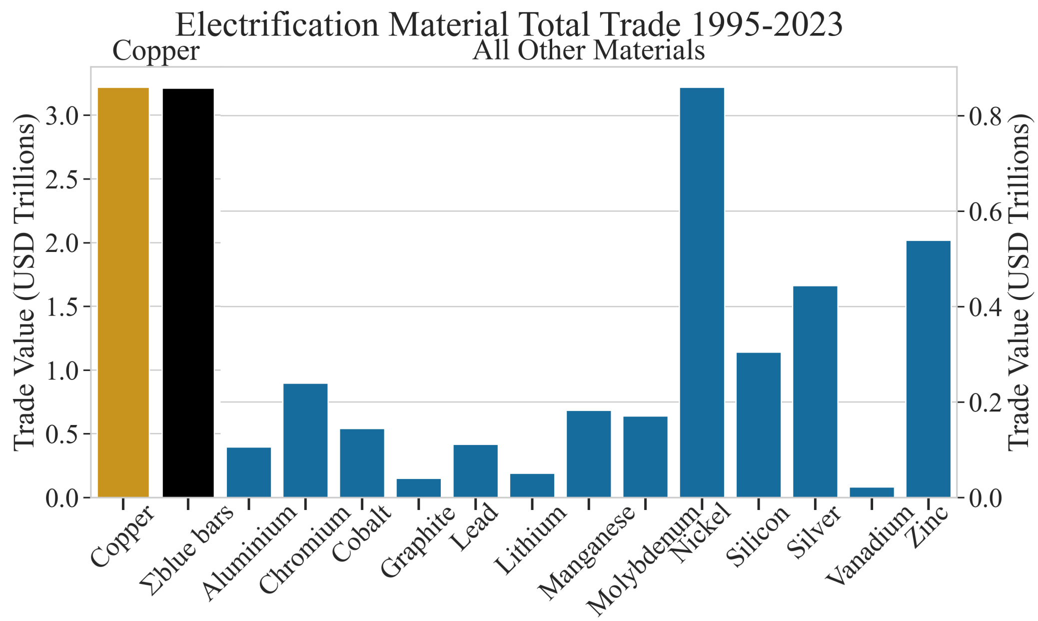
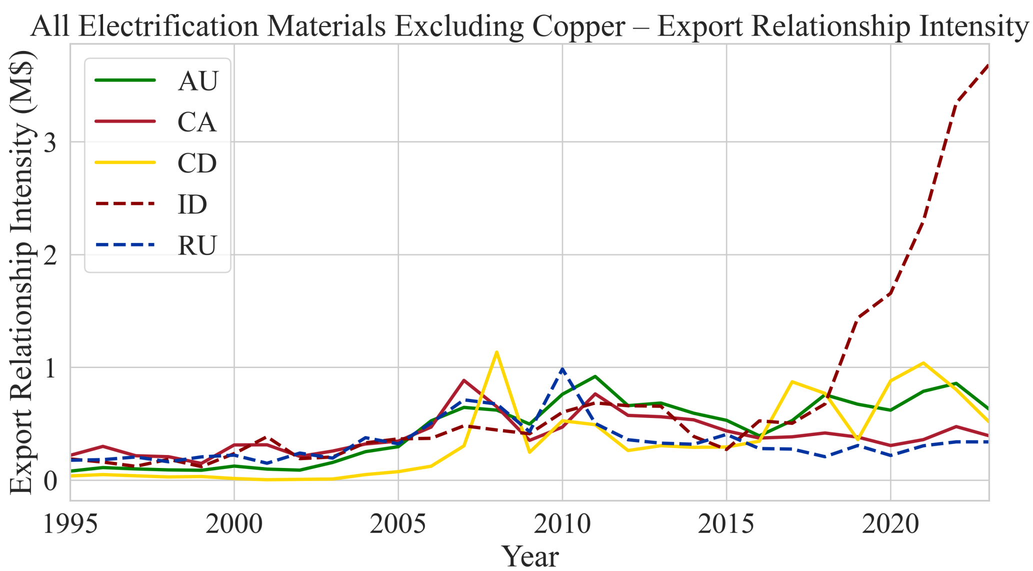


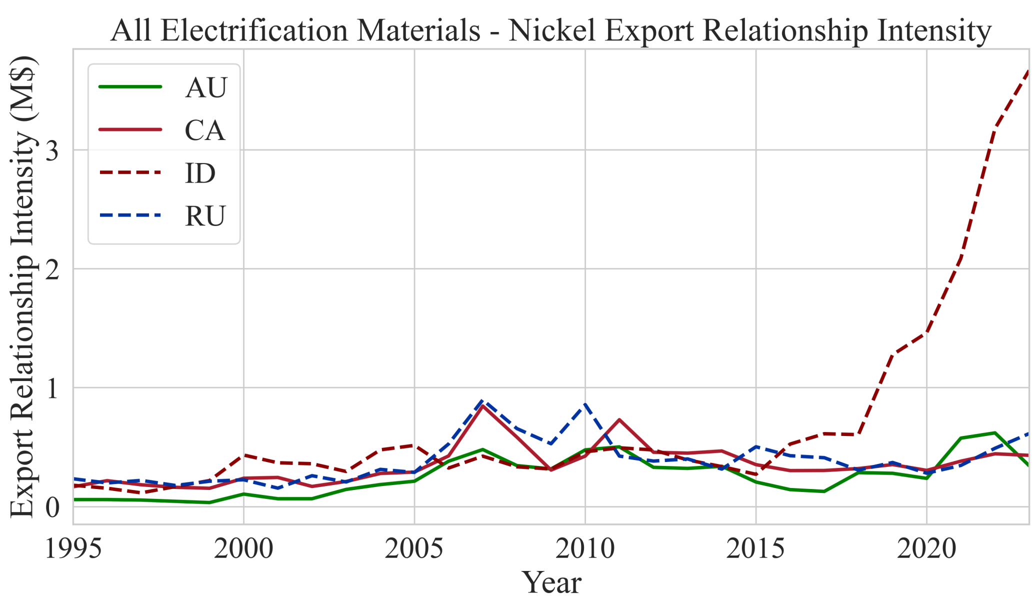
FIGURE 5. Top-5 countries by market dominance in electrification-material trade, excluding copper.



so that even a small supplier faces steep residual demand and holds real leverage. Indonesia's rising dominance reflects nickel, where policy converted a raw-ore position into control of processed output. The general point is a direct implication of the model: because electrification technologies impose specific, poorly substitutable material requirements, individual countries controlling a single mineral can wield influence far exceeding their aggregate trade—leverage that has no analogue in oil or gas, where multiple producers substitute for one another and ε_S is high.

5.2. **Indonesia's nickel transformation: centrality by policy.** The Indonesian nickel episode illustrates cleanly that α is a choice variable. Figure 6 shows Indonesia's market dominance in nickel rising steeply after 2013 and accelerating in the early 2020s. Two policy instruments drove the trajectory, one on each side of the China–Indonesia processing complex. On the Indonesian side, a resource-based industrialisation strategy—a 2009 mining law implemented from 2014, culminating in a full ban on raw nickel-ore exports in January 2020—forced value addition onshore (UNCTAD 2017; Tritto 2023). On the Chinese side, outbound investment under the Belt and Road Initiative financed the smelting and refining capacity that the ban made necessary, beginning with the Morowali industrial park agreed during President Xi's 2013 visit to Jakarta and reflecting Beijing's drive to secure nickel it lacks domestically (Tritto 2023; Guberman, Schreiber, and Perry 2024). The ore-export ban and the investment response are, in the language of the model, an increase in σ and a reallocation of processing rents that jointly raise the effective centrality of the complex. By 2023 Indonesia produced over half of global nickel (SMM 2023) and its export revenues had risen by an order of magnitude relative to the mid-2010s (Zhang 2024).

FIGURE 6. Top-5 countries by market dominance in nickel trade.



The weighted-degree series for nickel (Figure 7) confirms the mechanism. China's nickel trade strength surges after 2018; the timing coincides with Indonesia's ore-export restrictions, indicating that Chinese firms responded to the ban by establishing downstream operations that turned Indonesia into a node of China's value chain. Indonesia's own trade strength rises more than tenfold between the early 2000s and 2023, tracking the policy timeline. Traditional nickel powers do not follow: Canada remains constrained, Russia is volatile and declining (reflecting sanctions and geopolitical frictions), and the Netherlands holds a stable but modest position. The lesson is the model's: resource endowment is neither necessary nor sufficient for market power. Reserves without processing—the traditional exporters—did not translate into influence, whereas processing capacity built by policy did.

FIGURE 7. Nickel weighted-degree centrality, top-5 countries, 1995–2023.

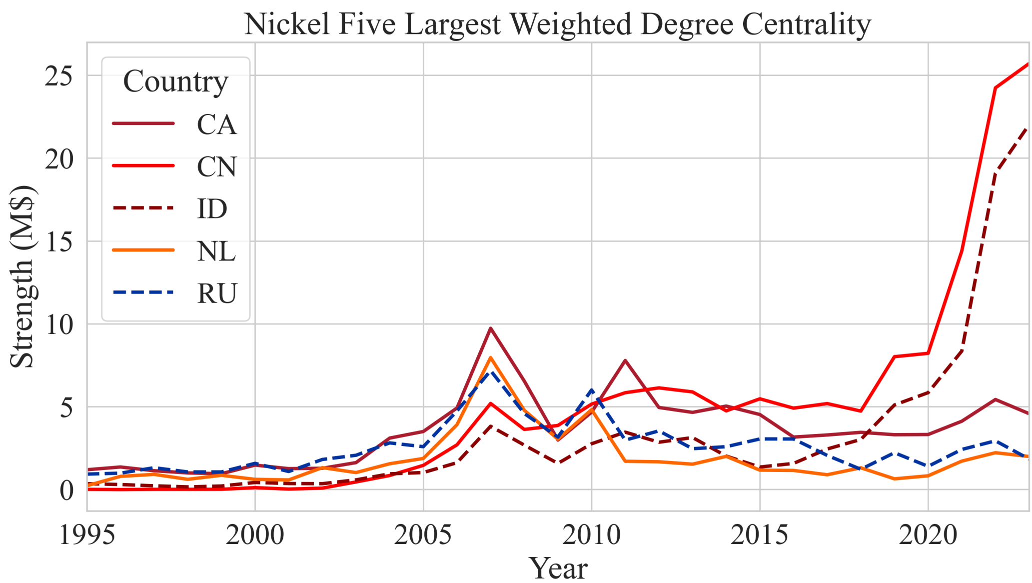
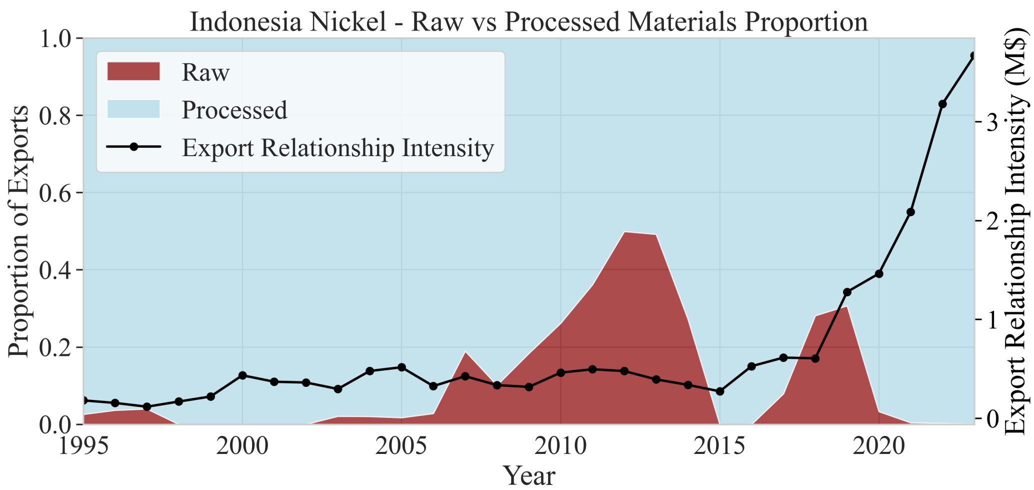


Figure 8 decomposes Indonesia's dominance into raw and processed nickel. The raw share rises until the ban and then falls to near zero, while total dominance keeps climbing—the export restriction shifting the country up the value chain exactly as intended. (The temporary relaxation permitting low-purity ore exports from January 2017 to December 2019 explains the interim uptick in raw shipments (International Energy Agency 2024).) The episode is a template other producers may imitate, with two implications the model makes precise: successful imitation would thicken the global processing fringe and erode the hub's pricing power, whereas failure to imitate leaves importers exposed to a network whose centrality was deliberately constructed.

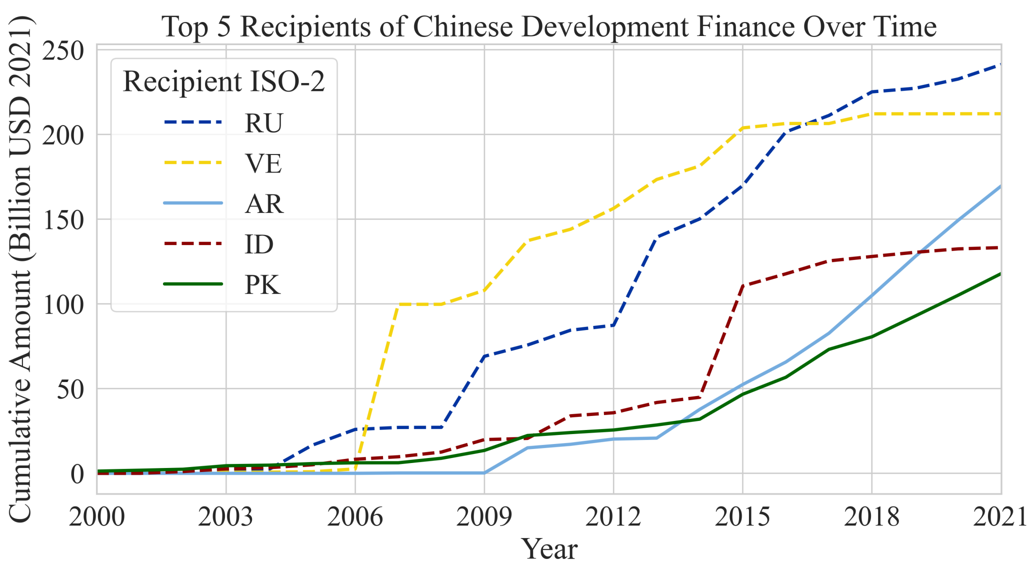
5.3. **Financing centrality: commodity-targeted development finance.** If centrality is built by investment, its financing should be visible and targeted. We examine China's outbound development finance using AidData's Global Chinese Development Finance dataset (GCDF 3.0) (Custer et al. 2023) and its transition-minerals refinement (CFTM 1.0), which labels commitments by the commodity they support (Walsh et al. 2025). Aggregate finance (Figure 9) is concentrated among large recipients—Russia, Venezuela, Argentina, Indonesia, Pakistan—that only partly overlap with the countries pivotal for electrification metals; Indonesia is the sole overlap. But the commodity-labelled data (Figure 10) reveal a tighter pattern: transition-mineral finance lines up with a country's role as a critical-material exporter and with its exports to China. This is the financing counterpart of Proposition 3: development finance functions as the subsidy σ that lowers the cost of building processing centrality, directed

FIGURE 8. Indonesian nickel market dominance: raw versus processed shares, 1995–2023.



at exactly the materials where the leverage pays off. We note the standard caveat that these data may miss private or state-adjacent flows and so likely understate the targeting.

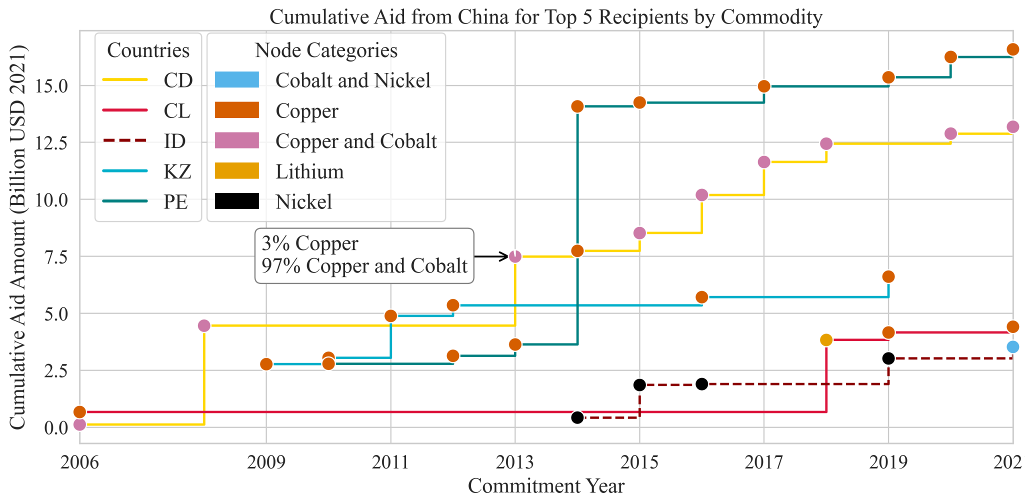
FIGURE 9. Cumulative Chinese development finance, five largest recipients (Custer et al. 2023).



6. FROM CENTRALITY TO PRICING POWER: SUPPLY SHOCKS AND INFLATION

By Proposition 2, the pass-through of a supply disturbance into the world price equals the central node's Lerner index $\mathcal{L} = \alpha/[\varepsilon_D + (1-\alpha)\varepsilon_S]$. The concentration and thin fringes documented above imply that this pass-through should be large and persistent for electrification metals and smaller for fossil fuels, where reserves and spare capacity keep the fringe elastic. This section tests that prediction. Our object of interest is the supply shock: we construct commodity-specific supply innovations from news text—alongside demand innovations that serve throughout as controls—and estimate, by local

FIGURE 10. Chinese commodity-targeted finance, five largest recipients (Walsh et al. 2025).



projections, the effect of supply shocks on producer and on consumer inflation in the United States and the European Union. The estimated responses are our empirical counterpart to $\mathcal{L}$: they constitute a proxy measure of the pricing leverage the endogenous network confers. [5]. Section 6 estimates these reduced-form responses via local projections and finds them large and persistent for electrification metals relative to fossil fuels, consistent with $\alpha_{\text{metals}} > \alpha_{\text{fossils}}$ and $\varepsilon_S^{\text{metals}} < \varepsilon_S^{\text{fossils}}$. We read these coefficients as evidence on relative price and inflation leverage across the two markets rather than as numerical estimates of $\mathcal{L}$ itself, which would require additional scaling assumptions. Throughout this section we report impulse responses to a one-standard-deviation contraction, i.e. a negative supply innovation, signed so that a positive coefficient denotes the price or inflation increase associated with tighter supply.

6.1. **Constructing the supply shocks from text.** Measuring supply and demand disturbances separately is essential: only supply-side innovations map to the intermediary country's quantity choice in the model, and the demand disturbances enter our specifications solely as controls. We follow the automated-narrative logic of Lumbanraja et al. (2025), but because news coverage of some individual metals is sparse relative to oil, a supervised dictionary is less optimal. We instead use a weakly supervised, teacher–student pipeline (Zhou 2017; Lee 2013), summarised in five stages.

(i) Data. We collect articles from Dow Jones Factiva covering 20 commodities over 2000–2024, yielding over eight million articles. *(ii) Teacher labelling.* A large language model (DeepSeek R1) with structured prompts annotates 5,750 articles per commodity into four categories: supply increase, supply decrease, demand increase, and demand decrease. *(iii) Validation.* A subset of annotations is checked manually before training. *(iv) Student training.* A ModernBERT-Large classifier is fine-tuned on the

[5]This measure is imperfect as it captures generic supply disturbances as opposed to strategic supply cuts executed by the central node. Our empirical shocks are one-standard-deviation innovations to commodity-wide (not China-specific) supply indices, and the CPI regressions further layer in downstream cost pass-through, monetary policy, and inventory adjustment.

teacher labels with Bayesian hyperparameter optimisation. *(v) Corpus labelling.* The student model labels the full corpus. We then embed articles (all-MiniLM-L6-v2) and cluster (DBSCAN) to identify distinct market events. The student attains large speed gains while replicating the teacher annotations closely, enabling scalable, commodity-level sentiment extraction.

We aggregate the resulting article-level signals into two production-weighted baskets, using dynamic global production weights from the S&P GSCI. The *electrification-metals* basket comprises aluminium, copper, lead, nickel, silver, and zinc; we restrict to these six because each is (a) identified as a critical electrification input (World Economic Forum 2025), (b) highly tradable with deep, liquid global markets so that supply disruptions transmit broadly rather than remaining local, and (c) a constituent of both the S&P GSCI and the Bloomberg Commodity Index, anchoring our weights in market-recognised conventions and permitting comparison against price benchmarks. The *fossil-fuel* basket comprises crude oil and natural gas.

For each basket we define the supply innovation $S_{k,t}$ ($k \in \{\text{metals}, \text{fossils}\}$) as the residual from an AR(1) regression of the net supply index on its own lag, purging predictable persistence; the demand innovation $D_{k,t}$ is defined analogously and enters the local projections below only as a control. This isolates the unanticipated component of supply conditions—the empirical analogue of the model's exogenous supply cut.

6.2. **Local projections.** We estimate impulse responses by local projections (Jordà 2023). Following (Jordà 2023), we specify the dependent variable as a long difference rather than a level: writing $x(t) \equiv ln(CPI(t))$, the long difference $\Delta(h)x(t+h) \equiv x(t+h) - x(t-1)$ measures the cumulative percentage change in the CPI level from just before the shock to horizon h. For the United States,

$$\Delta(h)x(t+h) = \alpha^h + \beta^h S_{k,t} + \Sigma(j=1..p)\gamma(j)^h \Delta x(t-j) + \delta^h D_{k,t-1} + \theta^h S_{-k,t-1} + \lambda^h D_{-k,t-1} + \varepsilon^h_{t+h}, \tag{14}$$

where $\Delta x(t-j) \equiv x(t-j) - x(t-j-1)$ are p = 4 lags of (log-differenced) CPI inflation included as controls, rather than lags of the level, following (Jordà 2023) recommendation, $S_{k,t}$ is the own-basket supply innovation, $-k$ denotes the alternative basket, and $p = 4$ lags of the dependent variable are included; lagged own-demand and cross-basket innovations control for intra- and cross-market spillovers. The coefficient $100\times\beta^h$ traces the cumulative percentage impulse response and is our estimate of the inflation leverage of a supply shock—the empirical counterpart to $\mathcal{L}$, subject to the scaling caveats discussed in Section 2.5. We adopt the long-differences specification following Jordà (2023), who notes that estimating in levels is not generally recommended: although the levels and long-difference specifications coincide numerically when the lagged level is included among the controls, omitting it—as sometimes happens in practice—leads to invalid estimates and inference when the dependent variable is (near) unit-root, precisely the case for the price level over horizons of up to 24 months. Specifying the dependent variable directly as a long difference delivers the cumulative percentage change of interest and avoids this risk. Standard errors are Newey-West. For the EU we estimate a panel over member economies with country fixed effects and Driscoll–Kraay (Driscoll and Kraay 1998) standard errors to accommodate cross-sectional dependence from shared global shocks:

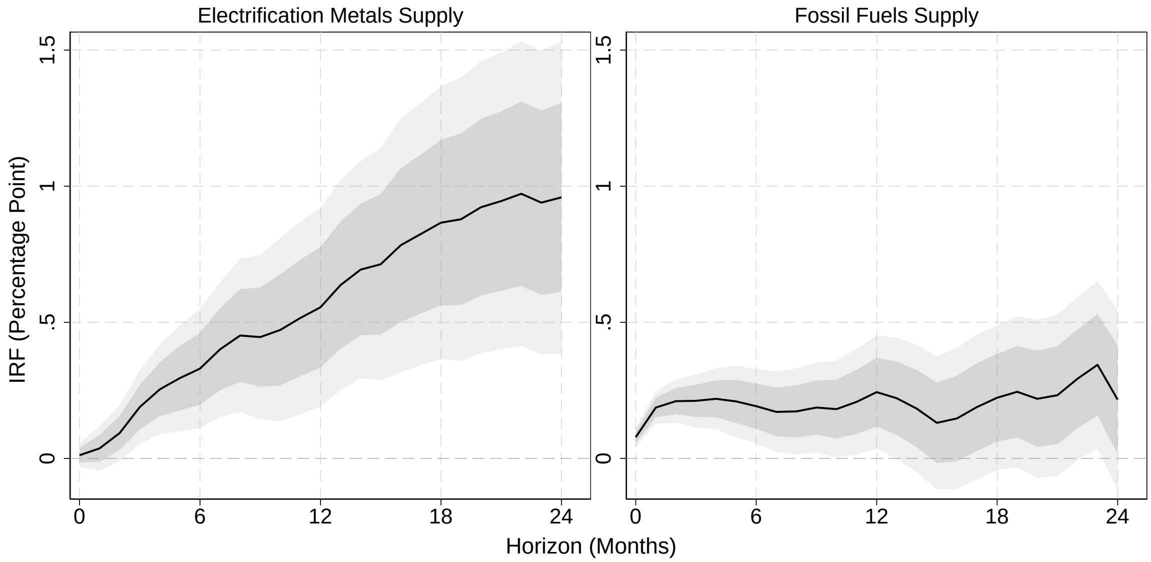
$$\begin{aligned}\Delta_h x_{i,t+h} = \alpha_i^h + \beta^h S_{k,t} + \sum_{j=1}^{p} \gamma_j^h \, \Delta x_{i,t-j} \\ + \delta^h D_{k,t-1} + \theta^h S_{-k,t-1} + \lambda^h D_{-k,t-1} + \varepsilon_{i,t+h}^h,\end{aligned} \tag{15}$$

with $\Delta(h)x(i, t+h)$ and $\Delta x(i, t-j)$ defined analogously to the US case for each EU member economy i. CPIs are from the IMF's International Financial Statistics and Eurostat.

Exogenous innovations as a proxy for strategic restrictions. A caveat on interpretation is in order. By construction the supply innovations $S_{k,t}$ are the *unanticipated* component of supply conditions—AR(1) residuals of the text-based supply indices—and are therefore not the exact empirical equivalent of the deliberate, strategic supply restriction dq that a central country contemplates in Proposition 2. A coercive export cut is a *choice*, and a perfectly anticipated one would already be embedded in prices, inventories, and expectations, leaving no residual to identify. The two objects coincide, however, precisely to the extent that a strategic restriction is *unexpected by the rest of the world*. An export ban, licensing regime, or quota that markets have not priced in arrives as an innovation to global supply and transmits to prices through exactly the residual-demand channel of Section 2, so its price impact is captured by our estimated β^h. This is the empirically relevant case, because the leverage of a restriction derives largely from its being hard to anticipate and pre-empt: once a cut is foreseen, stockpiling, substitution, and fringe entry erode its bite. Our local-projection coefficients should accordingly be read as the pass-through of *surprise* supply contractions—the component of any strategic restriction that the rest of the world has not anticipated, and hence the component through which coercive leverage actually operates. To that extent they are a natural, if imperfect, empirical proxy for the price effect of a strategic supply cut by the centre country.

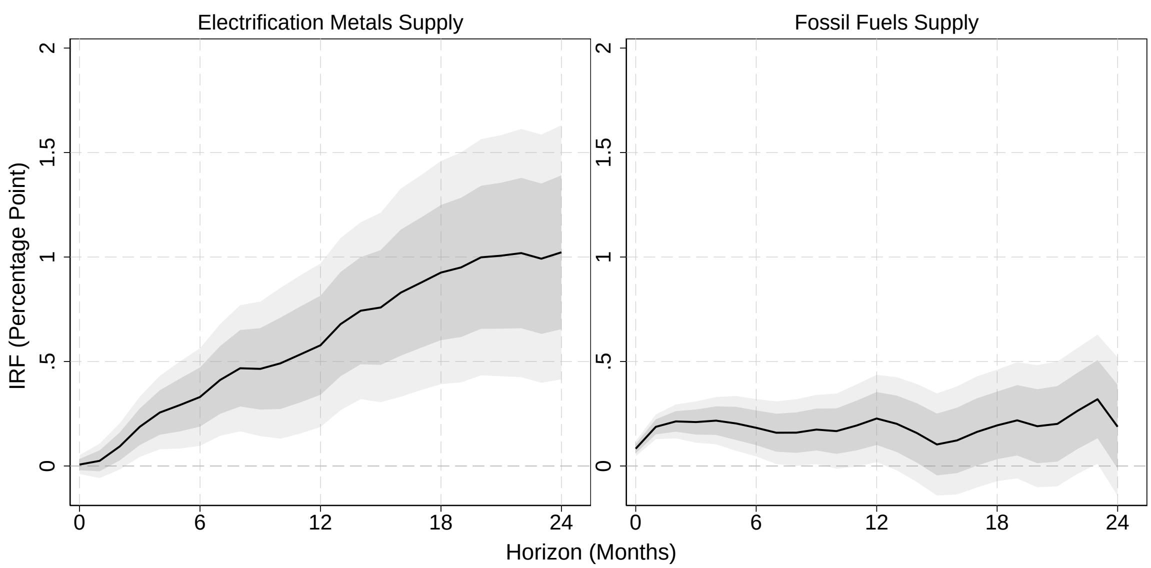
6.3. **Results.** *Inflation.* The inflation responses are the paper's central quantitative result and confirm the model's asymmetry. A one-standard-deviation supply contraction in electrification metals raises CPI by roughly one percentage point in both the United States (Figure 11) and the EU (Figure 12); the comparable fossil-fuel shock raises CPI by slightly less than half a percentage point. The fossil response aligns with Känzig (2021), who finds similar CPI sensitivity to identified oil shocks (response to an oil-supply shock equivalent to a 10% oil-price increase) over a longer sample, providing an external benchmark for our fossil basket. For completeness, we report the fossil and electrification metals CPI local projections in (log) levels as in Känzig (2021) for the US case in Figure C.2, Appendix C.

FIGURE 11. US CPI response to supply disturbances



Note: Impulse responses of US CPI to a one-standard-deviation supply contraction. Left: electrification-metals supply index. Right: fossil production-weighted supply index. Supply indices are AR(1) residuals. Newey–West standard errors.

FIGURE 12. EU CPI response to supply disturbances

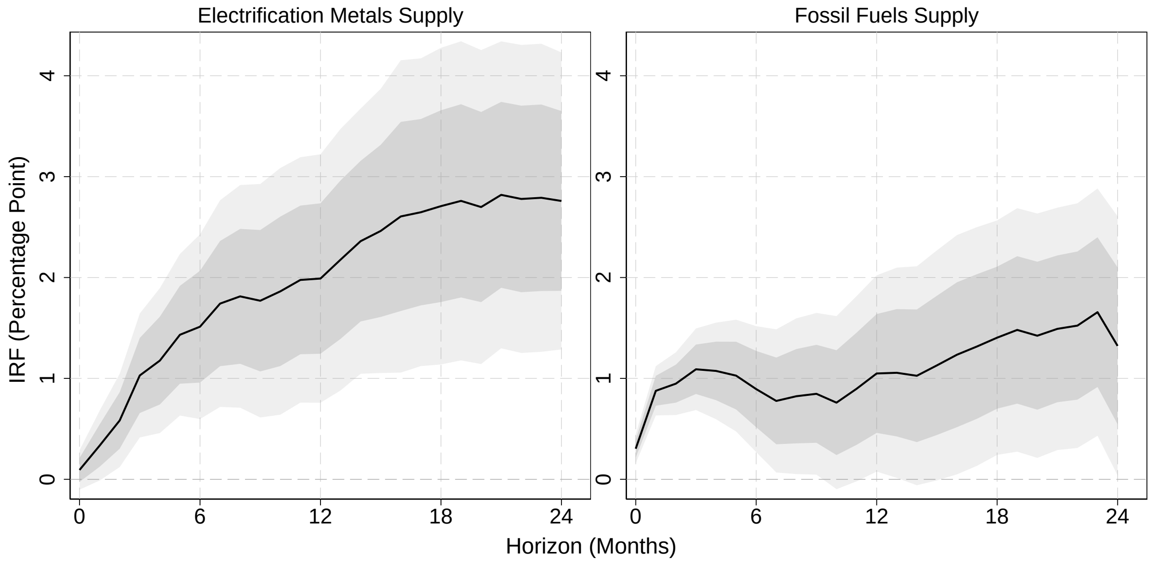


Note: Impulse responses of EU CPI to a one-standard-deviation supply contraction. Left: electrification-metals supply index. Right: fossil production-weighted supply index. Supply indices are AR(1) residuals. All panels include country fixed effects; Driscoll–Kraay standard errors.

The metals response is not only larger but more persistent over the projection horizon. Both features are predicted by Proposition 2. Because $\mathcal{L} = \alpha/[\varepsilon_D + (1-\alpha)\varepsilon_S]$ is decreasing in ε_S and ε_D, the metals basket—high centrality, an inelastic fringe (10–20-year mine and refinery lead times, no strategic reserves), and low downstream substitutability—should exhibit a larger pass-through, while the fossil basket—buffered by strategic reserves, spare capacity, and deep spot markets that make the fringe elastic—should exhibit a smaller one. Persistence follows from the same logic: the metals fringe is inelastic not only on impact but at medium horizons, so the price level adjusts slowly. Three concrete mechanisms underlie the low elasticities: the absence of shock-absorbing buffers for metals comparable to petroleum reserves; constrained substitution, since designs can economise on but not eliminate copper or nickel; and demand made price-inelastic by policy-driven green mandates, so that manufacturers absorb higher input costs to maintain output.

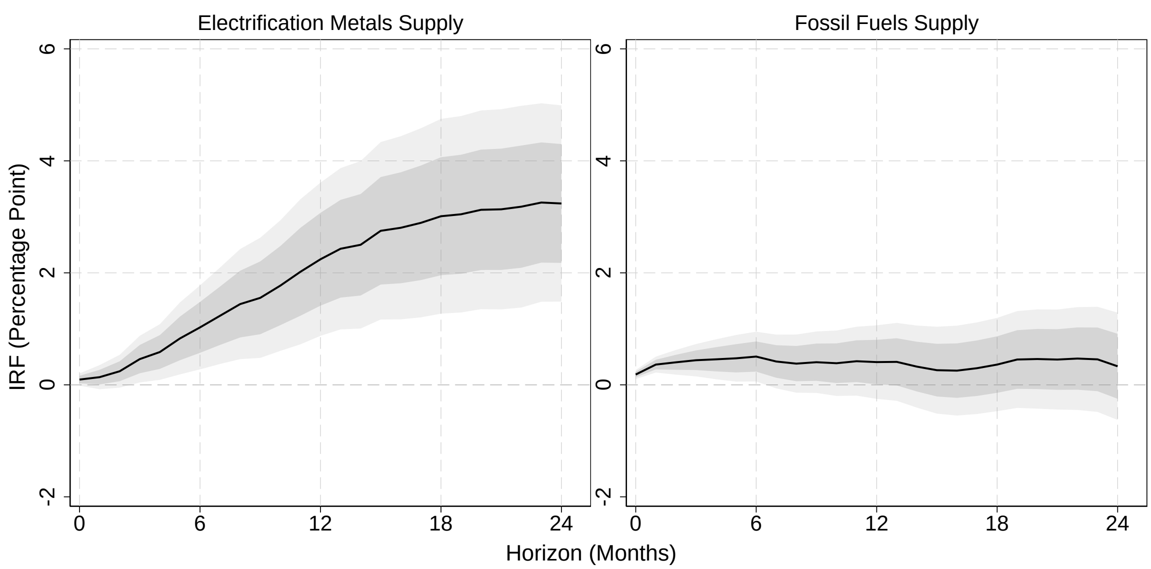
Additionally, we re-estimate the long-differences local projections of Section 6.2 using the producer price index (PPI) in place of the CPI, for both the US and the EU panel. The resulting impulse responses are strikingly similar in shape to their CPI counterparts: in both economies the electrification-metals basket generates a larger, more persistent response than the fossil-fuel basket, and both profiles rise over the first several months before decaying slowly, closely mirroring the dynamics of Figures 11–12. However, the magnitudes of Figures 13–14 are substantially larger: the PPI responses run roughly 2.5–3 times the size of the corresponding CPI responses in both baskets and both regions, putting the metals-basket PPI response at roughly 2.5–3 percentage points and the fossil-basket response at roughly 1.25–1.5 percentage points, against the one and one-half percentage point CPI responses reported above. This is precisely what the wholesale-to-retail attenuation mechanism discussed above would predict: producer prices sit closer to the commodity shock in the pricing chain, ahead of the retail mark-ups, taxes, and administratively smoothed pricing that damp the transmission of wholesale costs into headline CPI. That the ordering and persistence of the response survive intact from PPI to CPI, while the level attenuates by a broadly similar factor across both baskets and both currency areas, indicates that our CPI estimates are a conservative lower bound on the pricing leverage the network confers at the producer level, and that the attenuation itself is not basket-specific.

FIGURE 13. US PPI response to supply disturbances



Note: Impulse responses of US PPI to a one-standard-deviation supply contraction. Left: electrification-metals supply index. Right: fossil production-weighted supply index. Supply indices are AR(1) residuals. Newey–West standard errors.

FIGURE 14. EU PPI response to supply disturbances



Note: Impulse responses of EU PPI to a one-standard-deviation supply contraction. Left: electrification-metals supply index. Right: fossil production-weighted supply index. Supply indices are AR(1) residuals. All panels include country fixed effects; Driscoll–Kraay standard errors.

Read through the model, the local-projection coefficients are an estimate of the pricing power that the endogenously built network confers. They also carry a forward-looking implication: as economies electrify, macroeconomic sensitivity to fossil-fuel disruptions will fade while sensitivity to metal bottlenecks grows, so that supply-concentration risk in electrification metals warrants the analytical attention historically reserved for oil. The leverage we estimate is a property of the current network; because α is endogenous (Proposition 3), it can be eroded by policies that thicken the fringe, a point we develop next.

7. Discussion

Our results recast a set of facts usually read through international relations in the language of market power and endogenous industry structure, and this reframing changes the policy problem.

Leverage without endowment. The central empirical lesson is that market power in electrification metals derives from processing position, not from reserves. China holds little of the world's nickel, cobalt, or lithium yet intermediates their processed forms; traditional reserve-rich exporters (Canada, Russia in nickel) hold reserves yet lack influence. Proposition 1 rationalises this: the Lerner index depends on the share of intermediation α and on fringe and demand elasticities, none of which is pinned down by who owns the ore. The security question is therefore mis-specified when framed as access to deposits; it is a question about who controls processing, and processing is contestable.

Why the green transition does not dissolve strategic dependence. It is tempting to read decarbonisation as a reduction in geoeconomic vulnerability, since it lessens reliance on a small set of hydrocarbon exporters. Our findings qualify this sharply. Fossil-fuel markets are buffered—dispersed reserves, strategic petroleum reserves, spare capacity, deep and liquid spot markets—which in the model corresponds to a high fringe elasticity ε_S and hence limited pass-through and limited attainable centrality. Electrification metals invert each of these features: concentrated processing, negligible reserves, long lead times, and thin markets, i.e. low ε_S and low ε_D. The transition thus relocates strategic dependence from a buffered, multilateral system to an unbuffered, hub-organised one. That the estimated inflation pass-through is roughly twice as large for metals is the macroeconomic expression of this shift.

Industrial policy and the endogenous margin. Indonesia's nickel strategy is the clearest evidence that centrality is chosen. Export restrictions combined with investment incentives moved the country from raw-ore exporter to processed-nickel supplier, and pulled the China–Indonesia complex's centrality up with it. This is consistent with the revived economics of industrial policy (Juhasz, Lane, and Rodrik 2024): targeted intervention durably reshaped the structure of production and the distribution of rents. It also cuts against a simple resource-curse reading, since the intervention captured value rather than dissipating it. The same instruments, however, are double-edged: what lets one producer build position also fragments global supply and can raise aggregate volatility.

Effective levers follow from the comparative statics. Because $\mathcal{L}$ falls in ε_S and because α is set by (9), the effective levers are those that thicken the competitive fringe or contest the hub's position ex ante. "Friend-shoring" arrangements and instruments such as the EU Critical Raw Materials Act aim in this direction, but the model clarifies both their promise and their limits: they raise ε_S only to the extent they add genuinely responsive processing capacity, and the required investment is large and slow. Strategic reserves for metals—the analogue of the strategic petroleum reserve—would raise the short-horizon fringe elasticity directly and are, in the model, the most immediate way to compress pass-through and blunt coercive supply cuts. Recycling and material substitution raise ε_S and ε_D respectively over longer horizons. The design problem is thus not only securing access but deliberately shaping network structure toward a more elastic, "strategically balanced" configuration.

Limitations. Trade-flow data do not fully capture supply chains in which processing spans multiple jurisdictions, and the dual-use nature of many HS codes introduces classification judgment (Appendix A); we have sought to make these choices transparent and replicable. Data on capital flows into extraction and processing remain weaker than the trade data, limiting a fully parallel financial-network analysis. The model is stylised and interpretive rather than structural: we read the local-projection coefficients as informative about $\mathcal{L}$ but do not identify α, ε_D, and ε_S separately, which structural estimation could pursue. Finally, the set of "critical" materials will evolve with technology, potentially shifting the specific dependencies we document even as the mechanism persists.

8. Conclusion

The green transition is reorganising the geography of commodity trade, and this paper argues that the reorganisation is best understood as the endogenous formation of a market structure that confers pricing power. Trade in electrification metals has consolidated into a hub-and-spoke network centred on China, whose central position was built through processing investment, industrial policy, and commodity-targeted finance rather than inherited from resource endowments. A stylised model shows that such centrality is chosen and that it maps one-for-one into the ability to move world prices by altering supply: the pass-through of a strategic supply cut equals the central node's markup. Taking this prediction to the data, we find that supply contractions in electrification metals raise consumer and producer inflation in the United States and the European Union by roughly twice as much, and more persistently, than comparable fossil-fuel shocks—an estimate of the leverage the network confers. There is an exorbitant privilege of the periodic table. The green transition is producing a commodity analogue of the dollar's exorbitant privilege: a constructed, self-reinforcing centrality that confers power over prices. Unlike the dollar's, it is young and still contestable—which is precisely why the design of these networks is now an object of policy.

Three implications stand out. Market power in these materials rests on control of processing, not reserves, so security policy framed around access to deposits is mis-targeted. The transition does not abolish strategic dependence but relocates it from a buffered, multilateral hydrocarbon system to an unbuffered, hub-organised mineral one. And because network position is endogenous, the leverage is contestable: policies that thicken the competitive fringe—diversified processing, recycling, substitution, and strategic metal reserves—erode it, most directly at short horizons through reserves. The central task for the economics of the energy transition is therefore not only to secure supply but to design the structure of the networks through which supply flows. We see structural estimation of the pricing-power channel, better data on capital flows into processing, and analysis of the strategic interaction among consuming blocs building rival capacity as the natural next steps of this research agenda.

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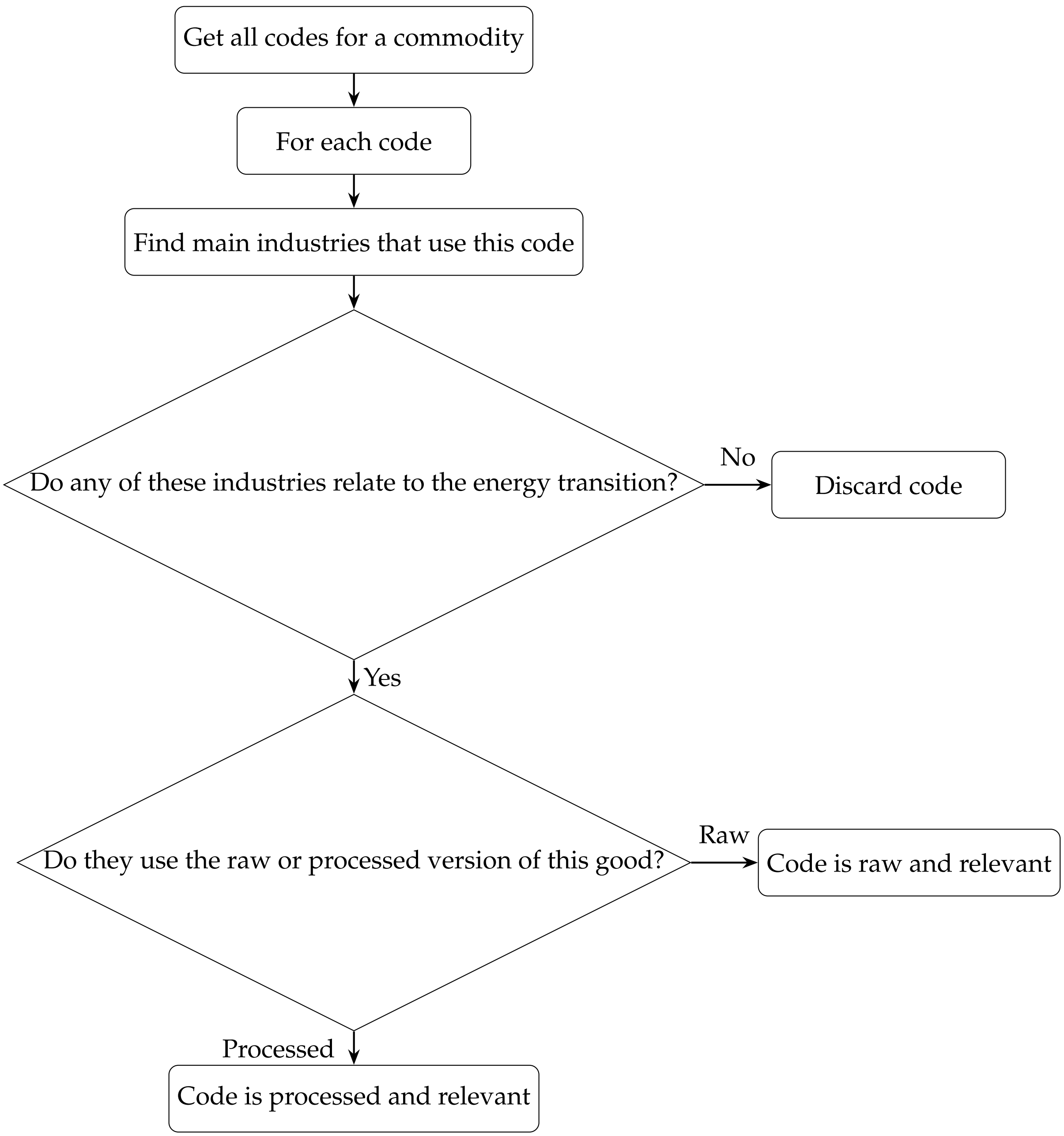
APPENDIX A. MATERIAL CODE SELECTION

Flowchart A.1 outlines the process used to select material codes relevant to the energy transition. The process begins by identifying all codes associated with a commodity, then determining whether the main industries using each code relate to the energy transition; retained codes are classified as raw or processed.

FIGURE A.1. Flowchart for the material code selection process.



Appendix B. Identified Material Codes

Table B.1 lists the HS codes identified as relevant to the energy transition, with their names, processing status, and total 2022 trade value. Codes were selected for their relevance to energy-transition industries—renewable technologies, electric vehicles, and energy storage.

Table B.1: HS codes and relationship to the energy transition

HS code	Name	Relevant?	Processed?	2022 Trade ($B)
250410	Graphite: natural, in powder or in flakes	Yes	No	0.76
260200	Manganese ores, concentrates, iron ores $>$ 20% Manganese	Yes	No	7.46
260300	Copper ores and concentrates	Yes	No	90.10
260400	Nickel ores and concentrates	Yes	No	4.70
260500	Cobalt ores and concentrates	Yes	No	0.21
260600	Aluminium ores and concentrates	Yes	No	7.24
260700	Lead ores and concentrates	Yes	No	6.81
260800	Zinc ores and concentrates	Yes	No	14.10
261000	Chromium ores and concentrates	Yes	No	3.50
261310	Molybdenum concentrates, roasted	Yes	No	3.42
261390	Molybdenum ores and concentrates except roasted	Yes	No	2.62
261590	Niobium, tantalum and vanadium ores and concentrates	Yes	No	0.66
261610	Silver ores and concentrates	Yes	No	3.75
280461	Silicon, $>$ 99.99% pure	Yes	Yes	5.95
280469	Silicon, $<$ 99.99% pure	Yes	Yes	6.09
281122	Silicon dioxide	No	Yes	3.88
2818	Aluminium Oxide	No	No	19.60
282010	Manganese dioxide	Yes	Yes	0.26
282090	Manganese oxides other than manganese dioxide	Yes	No	0.24
282200	Cobalt oxides and hydroxides: commercial cobalt oxides	Yes	No	2.10
282520	Lithium oxide and hydroxide	Yes	Yes	5.40

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Table B.1 – *continued from previous page*

HS code	Name	Relevant?	Processed?	Total Trade 2022 ($B)
282530	Vanadium oxides and hydroxides	Yes	Yes	0.61
282540	Nickel oxides and hydroxides	Yes	No	0.66
282550	Copper oxides and hydroxides	Yes	Yes	0.65
282734	Chlorides: of cobalt	No	No	0.00
282735	Nickel chloride	Yes	No	0.07
283691	Lithium carbonates	Yes	Yes	9.68
284321	Silver nitrate	No	No	0.25
284920	Silicon carbide	Yes	Yes	1.38
291523	Cobalt acetates	No	No	0.00
380110	Artificial graphite	Yes	Yes	2.56
391000	Silicones, primary forms	No	Yes	8.08
710610	Silver powder	Yes	Yes	1.94
710691	Silver in unwrought forms	Yes	Yes	22.70
710692	Silver semi-manufactured including gold/platinum plat	No	Yes	5.72
720211	Ferro-manganese, $>$ 2% carbon	Yes	No	2.21
720219	Ferro-manganese, $<$ 2% carbon	Yes	No	1.87
720221	Ferro-silicon, $>$ 55% silicon	Yes	Yes	3.77
720229	Ferro-silicon, $<$ 55% silicon	Yes	Yes	0.72
720230	Ferro-silico-manganese	No	Yes	3.48
720241	Ferro-chromium, $>$ 4% carbon	Yes	Yes	9.75
720249	Ferro-chromium, $<$ 4%	Yes	Yes	0.93
720250	Ferro-silico-chromium	No	Yes	0.14
720260	Ferro-Nickel	Yes	Yes	18.80
720270	Ferro-molybdenum	Yes	Yes	3.81
720292	Ferro-vanadium	No	Yes	0.81
740110	Copper mattes	Yes	Yes	1.64
740200	Unrefined copper, copper anodes, electrolytic refining	Yes	No	17.40
740311	Copper cathodes and sections of cathodes unwrought	Yes	Yes	87.20

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Table B.1 – *continued from previous page*

HS code	Name	Relevant?	Processed?	Total Trade 2022 ($B)
740811	Wire of refined copper $>$ 6 mm wide	Yes	Yes	19.50
740819	Wire of refined copper $<$ 6 mm wide	Yes	Yes	4.53
740821	Wire, copper-zinc base alloy	Yes	Yes	0.81
740822	Wire, copper-nickel or copper-nickel-zinc base alloy	Yes	Yes	0.18
740829	Wire, copper alloy, except nickel/zinc alloys	Yes	Yes	0.72
750110	Nickel mattes	Yes	Yes	9.90
750120	Nickel oxide sinters, intermediate nickel products ne	Yes	Yes	6.14
750210	Nickel unwrought, not alloyed	Yes	Yes	17.80
750220	Nickel unwrought, alloyed	Yes	No	1.15
750300	Nickel waste or scrap	Yes	No	1.29
750400	Nickel powders and flakes	Yes	Yes	2.40
790111	Zinc, not alloyed, unwrought, $>$ 99% pure	Yes	Yes	11.40
790112	Zinc, not alloyed, unwrought, $<$ 99% pure	Yes	Yes	4.10
790120	Zinc alloys unwrought	Yes	Yes	2.85
810510	Cobalt: mattes and other intermediate products of cobalt metallurgy, unwrought cobalt, waste and scrap, powders	Yes	Yes	9.25
810590	Cobalt: articles n.e.s. in heading no. 8105	Yes	Yes	0.85
811221	Chromium and articles thereof: unwrought chromium, powders	Yes	Yes	0.69
811240	Vanadium, articles thereof, waste or scrap/powders	No	No	0.00
850613	Silver oxide primary cells, batteries volume $<$ 300 cc	No	Yes	0.25
850640	Silver Oxide Batteries	No	Yes	0.25
850650	Lithium Batteries	Yes	Yes	3.43
850660	Air-Zinc Batteries	Yes	Yes	0.37

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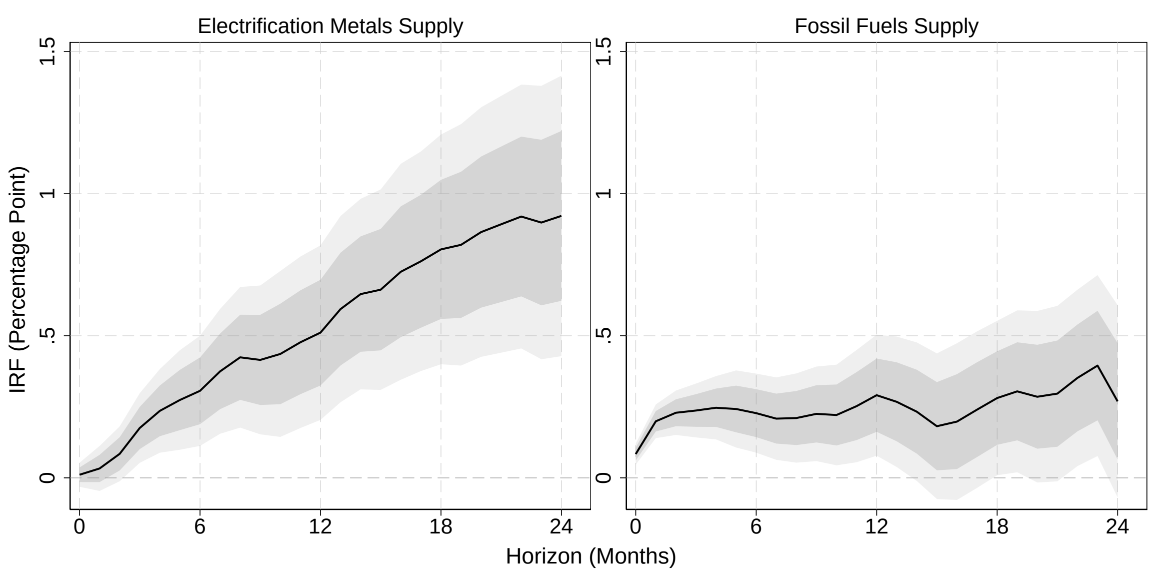
Table B.1 – *continued from previous page*

HS code	Name	Relevant?	Processed?	Total Trade 2022 ($B)
850760	Electric accumulators: lithium-ion, including separators, whether or not rectangular (including square)	Yes	Yes	94.70
854140	Photosensitive/photovoltaic/LED semiconductor	Yes	Yes	87.70
854411	Insulated winding wire of copper	Yes	Yes	6.90
854519	Carbon and graphite electrodes, except for furnaces	No	Yes	2.19

Appendix C. Fossil and electrification metals CPI local projections in log levels, US case

Figure C.2. US CPI response to supply disturbances



Note: Impulse responses of US CPI to a one-standard-deviation supply contraction. Local projections in log levels. Left: electrification-metals supply index. Right: fossil production-weighted supply index. Supply indices are AR(1) residuals. Newey–West standard errors.