Critical Minerals, Geopolitics, and the Green Transition

Tomás Domínguez-Iino
UChicago

Jonathan Elliott
Johns Hopkins

Allan Hsiao
Stanford

October 3, 2025

Critical minerals will fuel the green transition

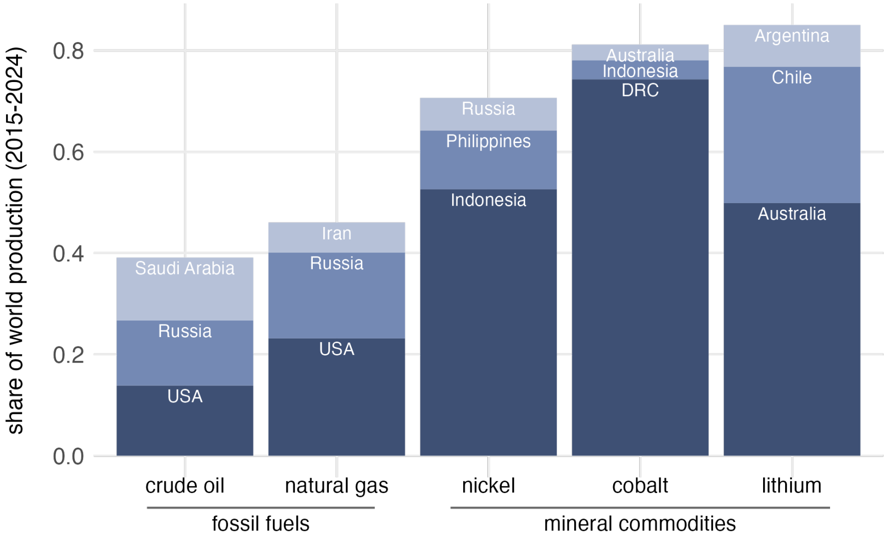
- Lithium, nickel, cobalt, and other minerals
  - Critical for producing advanced batteries
  - Geographic concentration, active policy intervention, and global trade

- What are the global impacts of industrial policy for minerals?
  - Highlighting policy spillover effects
  - With implications for **geopolitics** and **green adoption**

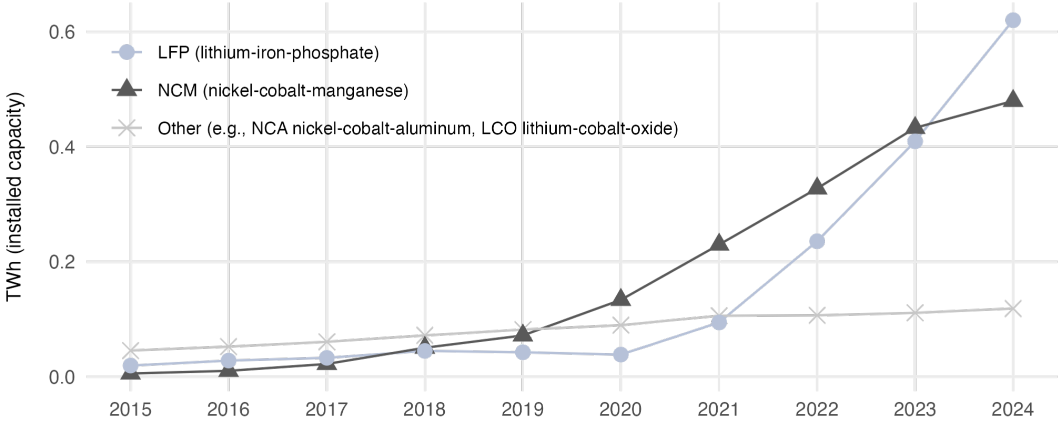
Data

- Annual, mine-level mineral production (GlobalData, Benchmark Minerals)
  - Capacity, ore grade, ownership structure, mine type, mining method
- Annual, global (or continent-level) battery consumption (Benchmark Minerals)
  - By battery chemistry: lithium-heavy (LFP) vs. nickel-heavy (NCM)
- Annual prices + battery-mineral “recipes”
  - Battery prices (ICCSINO)
  - Mineral prices (Trading Economics)

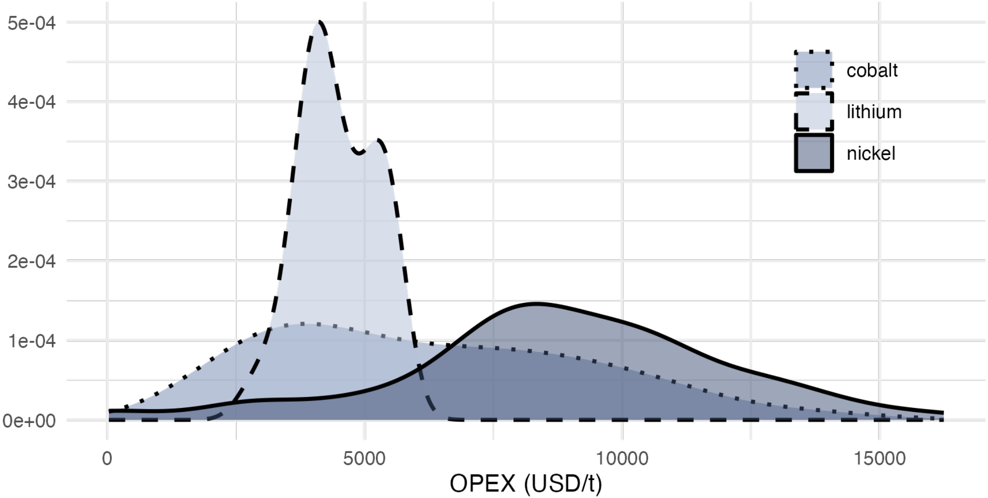
Critical minerals are geographically concentrated



Critical minerals power advanced batteries



Mines have heterogeneous costs



Theory

- Two **minerals** m
  - ℓ: lithium produced by country ℓ
  - n: nickel produced by country n

- Three **technologies** j
  - L: lithium-heavy
  - N: nickel-heavy
  - T: traditional without ℓ or n

- **Prices** p^m and **policy** τ^m
  - Mineral supply $s^m(p^m + \tau^m)$, mineral demand $d^m(d_L, d_N)$
  - Technology demand $d_j(p_L, p_N, p_T)$ for $p_j(p^\ell, p^n)$

Complementarity and substitution

- Own-price demand elasticity
  - Higher $p^\ell \rightarrow$ lower d^ℓ
  - Partly offset by substitution to technology N, which still uses ℓ
- Cross-price demand elasticity
  - Higher $p^n \rightarrow$ lower d^ℓ or higher d^ℓ
  - **Complements**: lower d^ℓ from joint use in technologies L and N
  - **Substitutes**: higher d^ℓ from shift to technology L, which uses more ℓ
- On net, lithium and nickel can be gross complements or substitutes

Geopolitics and green adoption

- Countries set mineral policy τ^m, which has spillover effects
  - Consider τ^ℓ that restricts s^ℓ

- Geopolitics
  - Own-policy effect: lower s^ℓ, higher p^ℓ
  - Cross-policy effect if **complements**: higher p_N, lower d_N, lower p^n
  - Cross-policy effect if **substitutes**: higher p_L, higher d_N, higher p^n

- Green adoption
  - **Complements**: higher or lower $d_L + d_N$ (higher p^ℓ but lower p^n)
  - **Substitutes**: unambiguously lower $d_L + d_N$ (higher p^ℓ and higher p^n)

Empirical model

- **Demand** d_j for technologies
  - Almost ideal demand system
  - Derived demand d^m for minerals

- **Supply** s^m of minerals
  - Mine-level data and estimation

Demand by technology j, year t

- Expenditure shares w at prices p

$$w_{jt} = \alpha_{jt} + \beta_j \log \frac{x_t}{P_t} + \sum_{\hat{j}} \gamma_{j\hat{j}} \ln p_{\hat{j}t}$$

- Translog price index

$$P_t = \sum_j \alpha_{jt} \ln p_{jt} + \frac{1}{2} \sum_{j,\hat{j}} \gamma_{j\hat{j}} \ln p_{jt} \ln p_{\hat{j}t}$$

- **Estimation:** iterative linear least-squares
    - Instrumenting for prices with supply shocks

Supply by mineral $m(i)$, mine i, year t

- Ore extraction s for ore grade γ, crude extraction S

$$s^{it} = \gamma^{it} S^{it}$$

- Linear ore revenues (as price takers), quadratic crude costs

$$r^{it} = p^{mt}\gamma^{it}, \quad c^{it} = a^{i} + \frac{b^{m}}{k^{i}} S^{it} + \varepsilon^{it}$$

- **Estimation:** linear FOC with fixed effects (μ^{i}, μ^{mt}), mine-level variation γ^{it}

$$\frac{S^{it}}{k^{i}} = \frac{p^{mt}\gamma^{it}}{b^{m}} - \frac{a^{i}}{b^{m}} - \frac{\varepsilon^{it}}{b^{m}}$$

Equilibrium prices

- Technologies derive from minerals according to **recipes** R_j^m
- Mineral prices clear mineral markets

$$d^{mt} = \sum_j R_j^m d_{jt} + o^{mt}, \quad s^{mt} = \sum_{i \in I^{mt}} s^{it}$$

- Technology prices follow from mineral prices

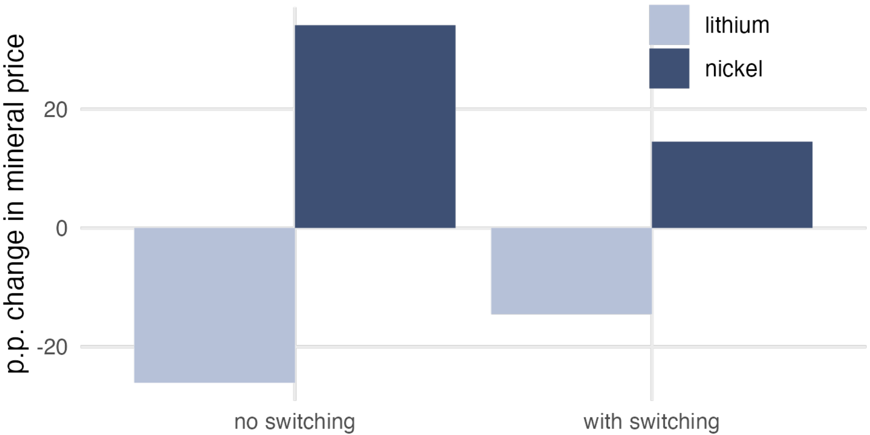
$$p_{jt} = \sum_m R_j^m p^{mt}$$

Counterfactuals

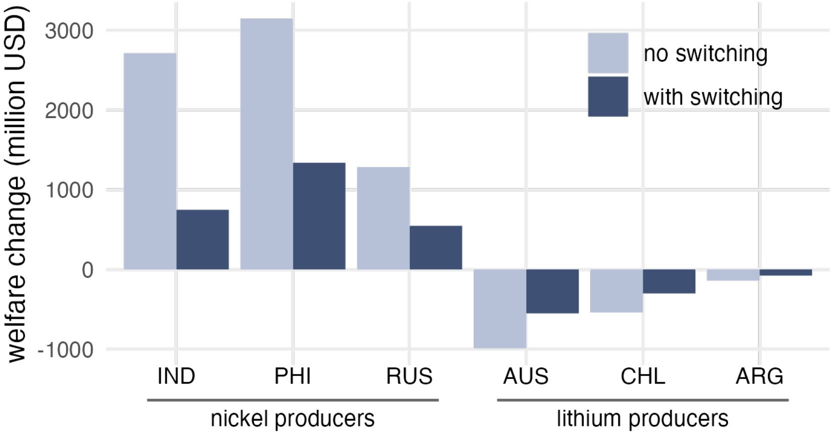
- **Indonesian nickel policy** and Australian lithium policy
  - Impose optimal tax policy τ^m, solve for equilibrium (p^m, s^m)
  - Evaluate geopolitics and green adoption

- Decompose policy spillovers
  - With tech switching: complementarity + substitution
  - No tech switching: only complementarity
  - Difference: only substitution

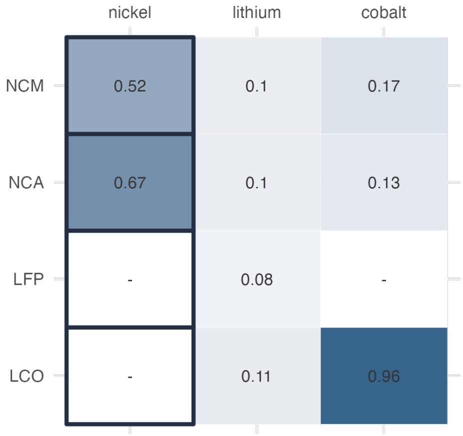
Price effects of Indonesian nickel policy

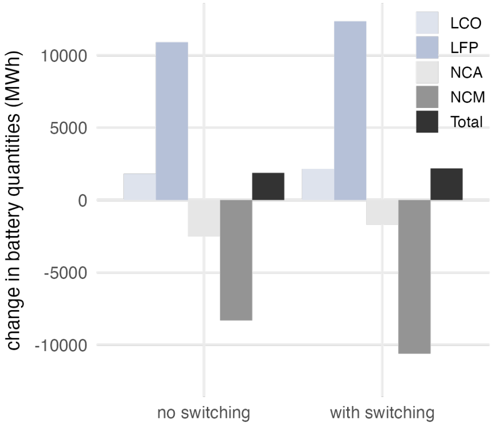


Geopolitics under Indonesian nickel policy

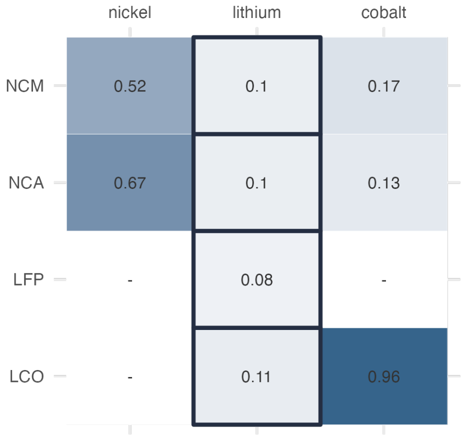


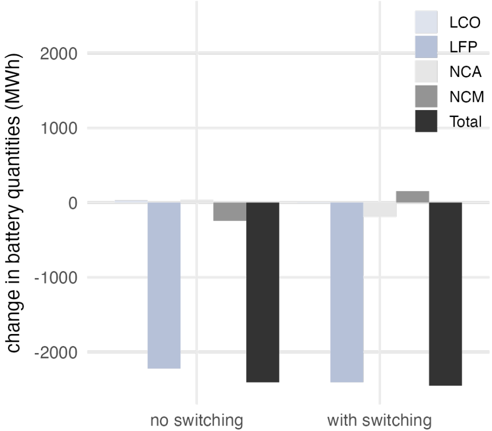
Green adoption under Indonesian nickel policy





Green adoption under Australian lithium policy





Summary

- Critical minerals will fuel the green transition
- Industrial policy has **policy spillovers**
  - With implications for geopolitics and green adoption