The economics of the critical minerals value chain and climate policy

Executive Summary

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Abstract

Minerals-rich economies must balance climate goals with industrial development. We present a model in which policy timing and credibility shape outcomes along the mining–refining–clean-tech chain. Early, credible action expands downstream capacity, accelerates learning and raises welfare; delay narrows feasible choices and weakens results. Calibrated to Chile, most gains come from processing and battery output rather than mining. Emissions fall modestly under national accounting, while fiscal efficiency is higher under delay. By 2040, however, early action delivers significantly more pack output and consumer benefits, showing that credibility brings investment forward and reduces uncertainty.

Keywords: Critical Minerals, Transition Plans, Industrial Policy, Environmental Regulation, Climate Change

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Executive summary

Purpose and research question

The world's shift to clean energy is lifting demand for a handful of critical minerals at unprecedented speed. Lithium, copper, nickel and cobalt are essential for batteries, electric vehicles and grid storage. Supply is concentrated in a few countries, including Chile, which means the choices these economies make will shape global markets (International Energy Agency, 2021). For Chile and its peers the transition is both an opportunity and a test: to support global decarbonisation and, at the same time, turn mineral wealth into broad-based, long-term prosperity.

This brief sets out a practical way for a minerals-rich country to plan and sequence its transition so that three goals are met together. First, cut emissions in line with national targets. Second, move more value-adding activity onshore by building refining and manufacturing at home, not just exporting raw ore. Third, manage fiscal exposure and protect the plan's credibility, so that investors believe the policy path and bring capital in earlier. We use Chile as the central case. The analysis treats climate planning as an industrial and fiscal strategy, not a stand-alone environmental document, and it is written for decision makers balancing growth, sustainability and resilience. In plain terms, it helps answer three questions: what to do, when to do it, and how to pay for it while keeping the plan credible.

Framework

We look at three possible pathways for Chile's climate-industry strategy, mapped to timeframes that mirror real policy cycles: the near term to 2025, the medium term to 2035, and the long term to 2050. This framing reflects how governments typically update national plans and targets over roughly ten-year horizons (United Nations Framework Convention on Climate Change, 2022).

- **Business as usual (BAU)** – current policies continue, with no major new push.
- **Early plan** – the full package of policies is announced and implemented now, in the run-up to 2025.
- **Delay plan** – a similar package is introduced only in the next policy window, in the 2030s, with implementation around 2035.

The analysis is built on a tractable open-economy model designed to capture the realities of a resource-rich country. It combines three blocks of activity — mining, refining, and clean-technology manufacturing — with familiar tools from trade and industrial organisation: Cournot competition among firms, an Armington aggregator for inputs, and learning-by-doing effects that reduce costs as production scales (Fajgelbaum, Goldberg, Kennedy, & Khandelwal, 2020). Importantly, the model also incorporates credibility constraints: later governments are

often unable to deliver the full ambition of earlier announcements, because international evidence shows that promises tend to be revised down between successive rounds of climate commitments (United Nations Framework Convention on Climate Change, 2022). We capture this with a proxy that limits the feasible “revision space” at each policy update.

The policy package we test is the same toolkit ministers already use. It includes:

- targeted support to midstream and downstream capacity,
- minimum abatement standards in mining and refining,
- selective export duties on raw materials, and
- where appropriate, time-bound incentives for clean-technology production and R&D.

We also evaluate trade-policy levers explicitly, showing how tariffs on imported refined inputs may raise domestic costs and shrink the scale of downstream industries, rather than support them (Fajgelbaum et al., 2020).

Finally, the calibration of the model draws on Chile’s own strategy. This emphasises public-private partnerships in strategic salt flats, protection of sensitive ecosystems, the adoption of direct lithium extraction (DLE) technologies, and a stronger role for domestic processing (Government of Chile, 2023).

Key findings

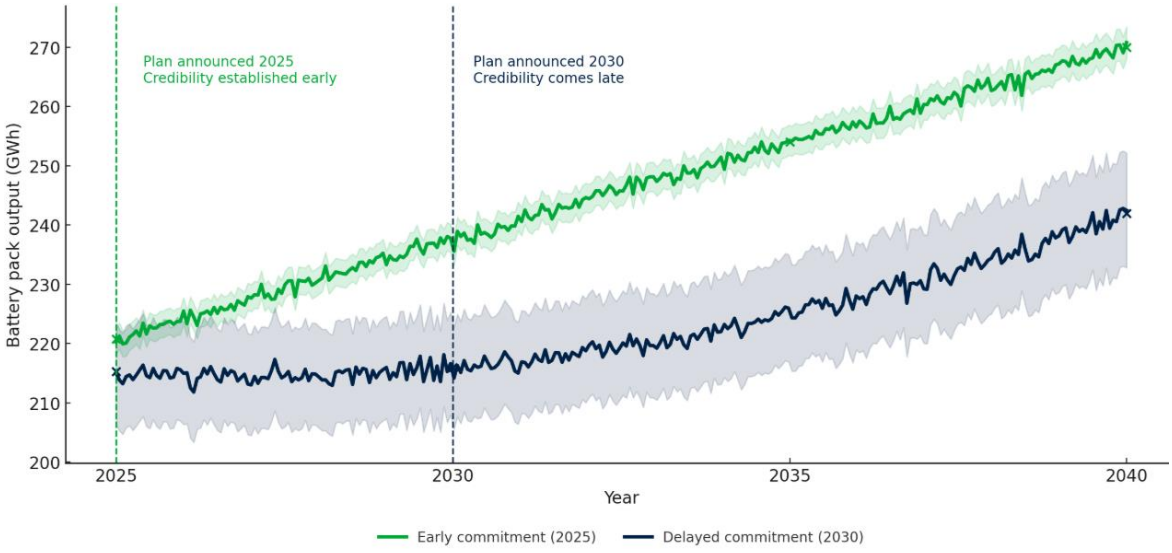
First, timing is economically material. On the surface, the total welfare gain looks almost the same in both cases — about USD 49 billion under the Early plan and USD 48 billion under the Delay plan. The USD 1 billion gap is not large in itself. What matters is where the gains come from. Early action allows domestic refining and battery production to scale up sooner, which drives faster learning and bigger consumer benefits. By 2035, mining output is only about 1½ percent higher under Early, but downstream pack production and consumer surplus are noticeably larger, showing that the main payoff is in the industries that add value, not in extracting more ore.

Second, the key issue is value for money. Whichever path is chosen, the programme costs government more upfront than it raises in revenue, so both Early and Delay add to the budget deficit. Early action delivers slightly higher overall welfare, but it is less efficient in fiscal terms: every unit of deficit produces about 2.7 units of welfare, compared with about 5.2 under Delay. This makes the choice of timing as much a fiscal policy decision as an environmental one. If budgets are tight, the figures point towards Delay. But if concessional climate finance or international support helps meet the cost, then moving early becomes more attractive, because it brings forward scale, learning and emissions cuts.

Third, earlier action cuts more emissions by 2035. At the medium-term decision point in 2035, both Early and Delay reduce national emissions compared with business as usual. The Early plan achieves a modestly larger cut — about 30 percent higher than Delay. The overall numbers look small because the policy mainly affects refining and clean-tech manufacturing over a limited time, while most national emissions come from other sectors. The key message is that moving early brings forward deployment and learning, so the country locks in extra abatement sooner, even if the headline figures appear modest.

Fourth, credibility is an economic asset. When governments commit to narrow, pre-announced revision windows, investors trust that the plan will not swing widely later. That credibility brings private capital in sooner and makes the difference between Early and Delay more visible. In our calibration, stronger credibility means that by 2040 the Early plan delivers around 30 more gigawatt-hours of battery-pack output and about USD 27 billion more in consumer benefits than Delay (see Figure 1). This fits with wider evidence: countries with clearer, more robust net-zero targets tend to see earlier investment moves (Green, Hale, & Arceo, 2025), and international reviews show that climate pledges are typically tightened only moderately between successive NDC rounds, not abandoned (United Nations Framework Convention on Climate Change, 2022).

Figure 1. Early action builds scale with greater certainty



Fifth, avoid blunt protection on refined inputs. Intermediates — things like refined lithium or cathode materials that are used to make batteries — are essential building blocks for downstream industries. Putting tariffs on these inputs simply raises domestic costs and squeezes margins for local producers. If the policy goal is to grow scale and learning in battery

packs and related clean technologies, targeted and time-bound support works better than protection that makes those inputs more expensive (Fajgelbaum et al., 2020).

Implications for Chile

First, if there is fiscal space, front-load. Early action delivers slightly higher total welfare and earlier emissions cuts, because domestic refining and battery production scale up sooner and learning effects kick in earlier. So you get more activity and abatement by the 2035 decision point, even though the aggregate welfare gap with Delay is small in level terms.

However, if budgets bind, sequence deliberately. Both paths require public money upfront, but per unit of deficit the Delay plan delivers more welfare. Therefore, a phased roll-out can achieve almost the same overall outcome with better value for money. Treat timing itself as a policy lever: bring measures in when they shift the most private activity for each unit of public spend.

Second, de-risk private capital to bring investment forward. Investors move earlier when the plan is predictable and clean inputs are available. That is why transparent PPPs in strategic salt flats, strong safeguards for sensitive salt flats, faster clean-power build-out and DLE adoption, plus a small, pre-announced revision window, all matter. In the results, greater credibility and earlier clean inputs show up as more downstream output and higher consumer benefits by 2035 under Early, even though mining volumes are much the same. Therefore, these measures are the practical route to crowd investment in sooner and realise the Early plan's advantages.

Third, be surgical on trade policy to grow scale. Tariffs on refined inputs raise domestic costs and thin margins for local manufacturers. In the model's comparative statics, this reduces downstream capacity, which is the opposite of what you need for scale and learning. Therefore, where input tariffs would lift costs, prefer targeted, time-bound investment support and R&D partnerships that lower costs and help firms expand, rather than protection that makes their inputs dearer.

Future work

First, test how results shift with credibility. The model shows that outcomes depend on whether a plan is believed. A fuller sensitivity analysis would spell out how the benefits of acting early rise or fall as credibility strengthens or weakens, giving policymakers a clearer map of the risks.

Second, make credibility instrument-specific. At present credibility is treated as a single, economy-wide constraint. In reality, each instrument carries its own level of trust: standards, subsidies, tariffs and R&D support are not believed in equally. Capturing these differences would give a more realistic guide to how policy packages are received.

Third, bring social licence into the frame. Mining projects stand or fall on local acceptance. Water use, environmental safeguards and community benefits were not modelled explicitly, yet they often determine whether investment happens at all. Factoring social licence into the analysis would help avoid costly blockages.

Fourth, validate with other country cases. To test the robustness of the results, the model should be applied to different settings such as Indonesia and Australia. This would separate what is country-specific from what is general, strengthen the evidence base and provide benchmarks that make regional co-operation easier.

References

Fajgelbaum, P. D., Goldberg, P. K., Kennedy, P. J., & Khandelwal, A. K. (2020). The return to protectionism. Quarterly Journal of Economics, 135(1), 1–55. https://doi.org/10.1093/qje/qjz036

Government of Chile. (2023). National Lithium Strategy. Santiago: Government of Chile.

Green, J. F., Hale, T. N., & Arceo, A. (2025). The net zero wave: Identifying patterns in the uptake and robustness of national and corporate net zero targets 2015–2023. Climate Policy, 25(4), 642–655. https://doi.org/10.1080/14693062.2024.2405221

International Energy Agency. (2021). The role of critical minerals in clean energy transitions. Paris: IEA.

United Nations Framework Convention on Climate Change. (2022). Nationally determined contributions under the Paris Agreement: Synthesis report. Bonn: UNFCCC.

van der Ploeg, F. (2011). Natural resources: Curse or blessing? Journal of Economic Literature, 49(2), 366–420. https://doi.org/10.1257/jel.49.2.366