Chokepoint: The Financial Effects of Rare Earth Supply Disruptions*

Joshua Ostry†

October 22, 2026

Click here for the latest version

Abstract

This paper constructs a set of high-frequency, news-based rare earth supply shocks to examine how disruptions in these critical inputs affect firm valuations. Using a sample of more than 5,600 publicly-traded firms from 2021 to 2026, I show that rare earth supply disruptions originating from Chinese export policy cause substitution-constrained firms' equity prices to decline by 0.8 percentage points relative to unconstrained firms. These effects are strongest for American and Japanese firms in the defense, battery, semiconductor, and motor vehicle industries. Firms that spend more, both directly and indirectly, on rare earths also underperform, a channel distinct from substitutability. Moreover, firms that do not use rare earths as inputs are still susceptible if they are exposed to China, in line with Chinese rare earth restrictions raising uncertainty over a broader decoupling of U.S.–China supply chains. Finally, non-Chinese rare earth producers, which stand to gain when Chinese supply tightens, outperform unconstrained firms by 5 percentage points after the same shocks. These findings highlight the channels through which the weaponization of critical-material supply chains transmits across global markets.

JEL Codes: G14, F14, F51, Q02.

Key Words: Rare earth elements; critical minerals; supply chains; supply shocks; large language models; geoeconomics; financial markets.

*I thank Cédric Tille, Ugo Panizza, Nathan Sussman, and Rui Esteves for helpful comments and suggestions, as well as my discussant, Ahmet Faruk Aysan, and participants at the conference on the International and Financial Dimensions of Critical Minerals (Lima, 2026). All errors are my own.

†Geneva Graduate Institute. Email: joshua.ostry@graduateinstitute.ch

1 Introduction

Rare earth elements have become central to the global race for technological and energy leadership. As critical and often difficult-to-substitute inputs in advanced manufacturing, clean energy technologies, and defense applications, rare earth elements enter the production of magnets, batteries, electric vehicle motors, wind turbines and semiconductors. At the same time, rare earth production is highly concentrated in China, as it controls 60% of global mining and 85% of global processing. The combination of strong demand in strategic sectors, limited substitutability, and geographic concentration makes rare earths a natural chokepoint for geoeconomic policies such as export controls, sanctions, and tariffs.

Despite efforts by the United States, Europe, Japan, and Australia to diversify supply chains and expand rare earth recycling capacity, China's periodic export restrictions and quota adjustments have significantly disrupted global supply. Such disruptions raise expected input costs and increase uncertainty for firms that rely on rare earths and, more fundamentally, raise the risk that firms will be unable to obtain these critical inputs. They may also raise uncertainty over broader fragmentation, which can affect firms that do not rely on rare earths. Because equity prices reflect the discounted value of expected future dividends, they can provide a forward-looking measure of how markets assess firms' exposure to supply-chain risk. For policymakers concerned with resilience and strategic autonomy, understanding how these risks are priced by markets is therefore essential, yet systematic evidence on how financial markets price rare earth supply disruptions remains limited. This paper addresses this gap by quantifying the channels through which rare earth supply shocks, identified from contemporaneous news reports, affect the share prices of firms worldwide.

To do so, I develop a news-based measure of rare earth supply shocks spanning 2021–2026. Starting from 1,419 Reuters articles containing the term "rare earth," I use a three-stage large-language-model classification to identify exogenous supply events. These supply events are then classified according to their origin (which country is causing the event) and target (the country or countries whose access to or cost of rare earths is affected). Additionally, these events are also separated according to whether the news article presents a surprise event, or contains clarifying information about previously reported events, and whether the news relates to production changes or trade

restrictions/easings. Finally, each shock is coded according to whether it is expected to expand or contract global supply. My strategy builds on narrative shock-identification approaches developed by Känzig 2021 for oil, Alessandri and Gazzani 2025 for natural gas, and Kirk, Passari, and Rey 2026 for electrification materials.

An event that constrains the supply of rare earths can affect the share prices of firms through several channels. First, firms that use rare earths as critical inputs in their production process may find it difficult to substitute away from them, even when supply is constrained. Therefore, I construct an indicator variable for whether a firm operates in an industry for which rare earths are critical inputs based on official policy and geological sources, and refer to such firms as 'substitution-constrained'. Second, I build a continuous measure of industry-level rare earth expenditure (as a share of gross output) using a Leontief inverse approach. This measure, which estimates the sum of direct expenditure on rare earths and indirect expenditure embedded in intermediate inputs via the supply chain, is distinct from whether a firm operates in a difficult-to-substitute industry since firms that spend a lot on rare earths may be able to switch to less rare-earth intensive inputs. This motivates substitutability and expenditure as two distinct channels of transmission. Third, it may be the case that firms that do not use rare earths are still exposed to China, for example via their supply chains. If China imposes trade restrictions on rare earths, it may signal a broader decoupling of US-China supply chains, which would harm the profitability of firms that (indirectly) buy from or sell to China. In order to test the importance of this channel, I construct a firm-level measure of a firm's exposure to China from the text of its 10-K filings, where a firm that mentions China-related keywords more often in the "Risk Factors" section of its report is cataloged as having a greater China exposure.

I investigate the effect of rare earth supply shocks on a sample of more than 5,600 firms across the United States, Japan, Europe, Canada, and Australia, isolating for the aforementioned three transmission channels: substitutability, expenditure, and China-exposure. The main findings are as follows. First, substitution-constrained firms' equity prices underperform unconstrained firms' by 0.35 percentage points on the day of a surprise Chinese export restriction, with the differential effect rising to 0.8 percentage points after a week.[1] Importantly, this result holds when controlling for event,

[1]Over 2021–2026, the constrained-minus-unconstrained return differential has a daily standard deviation of about 0.60 percentage points (equal-weighted, pooled across the five regions).

country and sector-level characteristics, showcasing that these shocks indeed restrict access to rare earths as inputs to production and ultimately weigh on the expected profitability of these firms. Second, jointly controlling for the substitutability and expenditure channels shows that, on impact, a one standard deviation increase in rare earth expenditure results in a further 0.06 p.p. fall in share prices. Third, within the sample of U.S. firms, a one standard deviation increase in a firm's China exposure is associated with an additional decline in its share price of 0.15 p.p. on impact, independently of whether a firm is substitution-constrained. Overall, these results showcase that China's weaponization of rare-earth supply chains transmits to global equity markets via each of the substitutability, expenditure, and China-exposure channels.

While these results show the average response of firms across regions and industries, there also exists significant heterogeneity across these dimensions. I find that the United States and Japan are most affected by rare earth supply shocks, consistent with the fact that China heavily targets these countries when implementing rare earth trade restrictions. Additionally, defense industries (in particular, guided missile and space vehicle manufacturing), as well as the semiconductor, motor and generator, and battery manufacturing industries, are the most vulnerable to Chinese rare earth export restrictions.

Finally, I validate my shock series and test the robustness of my baseline results. Applying the same event study to non-Chinese rare earth producers, I find that they outperform unconstrained firms by 5 percentage points after 10 trading days. This is consistent with the fact that when China constrains rare earth supply, it benefits competing rare earth producers as they may sell at higher prices, gain greater market share or have a higher likelihood of receiving government subsidies, procurement contracts or industrial policy support. This opposite directional response of producers and users is exactly what a contraction in rare earth supply implies, and therefore validates the series as capturing genuine supply shocks. To test robustness, I re-estimate the baseline leaving out one event at a time and excluding events that occur close together in time, and find that my baseline results are not driven by any singularly powerful Chinese rare earth policy shocks, simultaneous tariff events, or overlapping event windows which may confound the share price response differential.

Related Literature. This paper relates to three strands of the literature: geoeconomics, the propagation of supply shocks in concentrated input markets, and narrative identification of supply shocks.

The geoeconomics literature studies how states use economic policies to exert influence. Clayton, Coppola, et al. 2025 document the sharp increase in the use of tariffs, sanctions, and export controls since the late 2000s and their growing focus on economic "chokepoints," namely industries and inputs that are particularly costly to restrict. In related work, Clayton, Maggiori, and Schreger 2024 develop a model in which countries target such chokepoints to increase the cost of non-compliance. Mohr and Trebesch 2025 adopt a broader definition of geoeconomic tools that includes foreign aid, financial infrastructure, and trade agreements. Farrell and Newman 2019 emphasize how central positions in global financial, data, military, and technological networks enable states to exercise such leverage. Earlier work by Hirschman 1980 shows that economic dependence arises when trade is concentrated among a small number of partners, making countries vulnerable to supply shocks. I contribute to this literature by providing the first systematic high-frequency equity-market evidence on how rare earth trade restrictions, a prominent example of chokepoint leverage, affect firms abroad.

A large literature studies how network structure shapes the transmission of supply shocks. Acemoglu et al. 2012, Carvalho 2014, and Baqaee and Farhi 2019 show that idiosyncratic sectoral shocks can generate sizable aggregate fluctuations when upstream sectors are highly concentrated. In concentrated networks, supply disruptions can therefore have amplified macroeconomic and firm-level effects. This mechanism is particularly relevant for rare earths, which are characterized by limited substitutability and highly concentrated production and processing. In response to the U.S. "Entity List" restrictions, Crosignani et al. 2024 document decoupling between affected U.S. firms and both targeted and non-targeted Chinese customers, with little evidence of reshoring or friend-shoring. U.S. firms experienced declines in returns, revenues, profitability, and employment, while Chinese firms re-established domestic supply relationships.

In the specific context of rare earths, Kalantzakos 2017 and Mancheri, Sundaresan, and Chandrashekar 2019 document how export quotas and state-led consolidation enabled China to dominate rare earth production and refining. Following China's 2010

export restrictions, Alfaro et al. 2025 show that U.S. firms highly dependent on rare earths increased patenting activity and formed new links with alternative input suppliers. Related work also studies the macroeconomic consequences of supply shocks in concentrated commodity markets. Kirk, Passari, and Rey 2026 show that adverse supply news in electrification materials raises U.S. CPI and PPI, while Alessandri and Gazzani 2025 document similar amplification effects in European natural gas markets following supply disruptions. I contribute to this literature by identifying three distinct channels through which rare earth supply shocks transmit to firm valuations: firms' ability to substitute away from rare earths, their expenditure on rare earths, and their exposure to China.

These literatures jointly emphasize that supply shocks in concentrated input markets can have large economic effects and that such shocks can be identified using narrative methods.

Finally, this paper builds on the literature using narrative and text-based approaches to identify exogenous supply shocks. Ramey 2011 uses historical narratives of major U.S. events to study government spending multipliers, while Romer and Romer 2004 construct monetary policy shocks based on detailed readings of FOMC records. In commodity markets, Hamilton 1983 and Kilian 2009 show that oil supply disruptions are typically inflationary and recessionary, and Känzig 2021 refines this approach using high-frequency oil price movements around OPEC announcements. More recently, Kirk, Passari, and Rey 2026 use LLM-based text analysis to identify supply and demand shocks in electrification commodities. Building on this approach, I construct the first high-frequency rare earth supply shock series, using a large-language-model classification of rare earth–related news, and estimate how equity markets price these disruptions.

The remainder of the paper proceeds as follows. Section 2 describes the data sources and the shock-classification pipeline. Section 3 sets out the empirical framework and presents the baseline results. Section 4 explores heterogeneity and transmission channels. Section 5 validates the shock series and examines the robustness of the baseline results. The final section concludes.

2 Data

I combine three datasets: (i) a high-frequency, news-based series of rare earth supply shocks; (ii) industry-level measures of rare earth substitutability and expenditure, together with a firm-level measure of exposure to China; and (iii) daily share prices for a global panel of publicly-listed firms.

2.1 Rare Earth Supply Shocks

I begin by collecting every article tagged "rare earth" from the Reuters News Archive. After de-duplication and cleaning I retain 1,419 articles spanning March 2021 through May 2026. From each article I keep the title, publication timestamp, and body text. Having obtained each of these articles, I create a three-stage LLM classification to identify exogenous rare-earth supply events. Specifically, I create three distinct prompts which are meant to (i) classify whether each article discusses a rare earth supply event and, if it does, determine whether the event relates to production or trade restrictions, (ii) further classify the subset of articles discussing supply events according to whether they are a surprise on the publication day of the article or instead provide clarifying information regarding previous events, and (iii) classify each supply event according to its origin (which country is causing the event) and its target (the country or countries whose access to or cost of rare earths is affected). This methodology is transparent and applied uniformly to every article, so that the entire shock series can be regenerated from the raw corpus and the published prompts.[2] The full text of all three prompts is reproduced in Appendix A.

The first-stage prompt reads each article and assigns one of five labels: trade restriction (a newly reported export restriction, quota, ban, licence requirement, or tariff), trade easing (the removal or relaxation of such a restriction), production disruption (a newly reported mining or processing disruption), production expansion (a newly opened mine, refinery, or supply deal), or not a shock. The model also returns a one-line event description and a confidence rating. Rather than search for fixed keywords,

[2]Stages 1 and 2 use Claude Opus 4.7 and Stage 3 uses Claude Sonnet 4.6. The prompts were run between 21 May and 1 June 2026. Because LLM outputs are not fully deterministic, re-running the prompts with a different model version, or at a different date, may change a small number of classifications.

the prompt asks the model to judge whether the article is the first report of a contemporaneous event affecting rare earth supply, so that retrospective, demand-side, or commentary articles are coded not a shock even when the words "export control" or "rare earth" appear. Each event is signed by its expected price effect: trade restrictions and production disruptions take sign $+1$ (supply-constraining, expected to raise rare earth prices), while trade easings and production expansions take sign -1 (supply-expanding, expected to lower prices).

A limitation of Stage 1 is that it reads each article in isolation: an article may present an event as breaking news even though an article on an earlier date already introduced the same event. The purpose of Stage 2 is to resolve this by evaluating each candidate shock not in isolation but within the full context of the articles that preceded it. The articles are processed in chronological order, from oldest to newest, and for each high-confidence Stage-1 shock the second prompt is given the article together with the earlier articles already passed through. It then judges whether the article conveys the first reported instance of an event on its publication date or merely confirms, repeats, or provides clarifying details on something a previous article already reported. The rationale is that articles that provide details about previous events bias the estimated response toward zero, since the true reaction occurred at an earlier, unobserved date.

The third prompt codes two orthogonal dimensions for each event—the event's target and origin country—taking as given that the article reports a genuine supply event. The target is the consumer/beneficiary economy whose access to or cost of rare earths changes; it can take on one of the five sample regions, a global world shock, or a non-sample other economy (such as Korea or India). The origin is where the supply action physically comes from (China, Myanmar, which feeds Chinese processing, or other). For example, a Chinese export control on the U.S. has origin China, target US.

Table 1 summarises the 59 high-confidence events[3] across these dimensions, and the composition is informative for identification. Two features stand out. First, the corpus is dominated by surprise events (46 of 59). Second, the *origin* and *type* dimensions are tightly linked: China-origin shocks are almost exclusively trade-policy actions (22 of 23 are trade shocks), whereas production shocks are almost entirely non-Chinese, reflecting new mines, refineries, and supply deals located outside China. On the tar-

[3]The full list of events (with dates, event descriptions, and the trade/production and surprise/clarifying classifications) is given in Appendix B.

get side, the majority of events either target the United States specifically or are global shocks, with several aimed at Japan and Europe and none at Australia or Canada. The intersection that defines the baseline analysis (surprises and China-origin) contains 14 events: in practice, a set of surprise Chinese export-policy changes. One of the 14 targets India, which lies outside the sample regions, so 13 enter the estimation.

Table 1: Composition of the rare earth supply-shock series

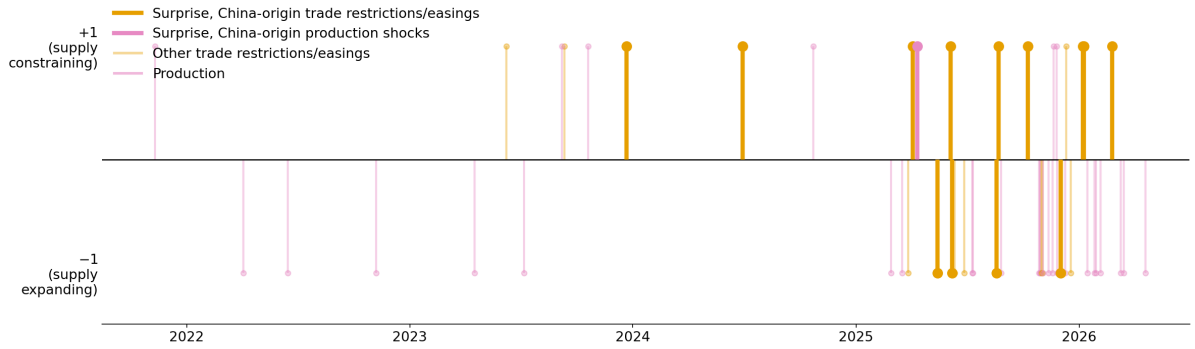
	All	**Surprises**	**Clarifications**	**China-origin**	**Surprise × China**
Total events	59	46	13	23	14
Origin					
China	23	14	9	23	14
Myanmar	3	3	0	0	0
Other	33	29	4	0	0
Target					
United States	21	13	8	7	2
Japan	6	5	1	3	3
Europe	4	4	0	1	1
Australia	0	0	0	0	0
Canada	0	0	0	0	0
Global (world)	25	21	4	11	7
Other	3	3	0	1	1
Shock type					
Trade	26	17	9	22	13
Production	33	29	4	1	1
Direction					
Supply-contracting ($+1$)	21	19	2	12	10
Supply-expanding (-1)	38	27	11	11	4

Notes: Counts of distinct events in the 59-event high-confidence series, by classification dimension. Columns are *not* mutually exclusive: each reports the subset of events satisfying its heading, so the "Surprise × China" column counts surprise, China-origin events. Targets are mutually exclusive (each event has exactly one). "Trade" covers both export restrictions and easings; the *Direction* panel instead splits all events into supply-contracting ($+1$, expected to raise prices) and supply-expanding (-1).

Figure 1 plots the full 59-event series over time. The events are far from evenly spread: as U.S.–China trade tensions escalated, they concentrate heavily between April 2025 and February 2026. Closely spaced events raise the possibility that the response window of one event overlaps that of another. I discuss the choice of horizon in Section 3.1 and show in Section 5.2 that the results are robust to removing overlapping

events.

Figure 1: Rare earth supply shock series, 2021–2026



Notes: Each vertical line marks one of the 59 supply-shock events identified after the first stage of the LLM pipeline on its corresponding date; the line extends to $+1$ for supply-constraining shocks and to -1 for supply-expanding shocks. Color denotes the shock type: yellow for trade policy changes, pink for production shocks. Surprise (identified from stage 2), China-origin events (identified from stage 3), which form the baseline shock set, are drawn opaque; all other events are faded.

Importantly, since a market can only react to a shock once it is next open, the article's timestamp matters when the panel spans five time zones. An event published after a given market's close on day t cannot be reflected in that market's prices until the following trading day, whereas a market that has not yet closed incorporates the same news on day t itself. Dating every event by a single calendar day would therefore misalign the event window across regions, treating the news as a day-0 event in one market but effectively a day-1 event in another. To keep the timing consistent, I assign each event a region-specific event date: for region R, horizon $h = 0$ is the first R market close (in UTC) at or after the article's publication timestamp, and $h = -1$ is the prior R close. Regional trading calendars (and holidays) are taken from the price panel itself, and daylight-saving transitions are handled explicitly. Thus a shock published after the Tokyo close but before the New York close is attributed to the next session in Japan and the same session in the U.S.

2.2 Rare Earth Substitutability and Expenditure

I measure a firm's reliance on rare earths in two complementary ways: a binary, industry-level indicator of whether the firm operates in an industry that uses rare earths as critical, difficult-to-substitute inputs, and a continuous measure of the to-

tal rare earth expenditure embodied in that industry's output. The indicator captures whether an industry critically depends on rare earths; the continuous measure captures its expenditure share.

Industry substitutability indicator. The primary measure is a binary indicator equal to one if a firm operates in at least one six-digit NAICS industry that relies on rare earths as a critical and difficult-to-substitute input to production, an industry whose production process genuinely depends on rare earths rather than using them in a minor or readily replaceable role. I select the set of substitution-constrained industries ex ante from scientific, technical, and policy sources that document the industrial applications of rare earths: the U.S. Geological Survey's *Rare Earth Elements—End Use and Recyclability* (Goonan 2011), which tabulates worldwide rare earth end uses by sector; the U.S. Department of Energy's *Critical Minerals and Materials Strategy* (U.S. Department of Energy 2021); the European Union's *Critical Raw Materials Act* (European Union 2024); and OECD and IEA analyses of critical materials in clean-energy technologies (Kowalski and Legendre 2023; International Energy Agency 2021). These sources map rare earth uses into four broad application categories: (i) electronics and consumer goods (permanent magnets, batteries, displays, lighting); (ii) clean energy and transport (electric and hybrid vehicles, wind turbines, catalytic converters); (iii) medical and scientific applications (medical imaging, optics, oil refining); and (iv) defense and aerospace (guidance and radar systems, heat-resistant alloys).

I then map each documented application to the six-digit NAICS industries whose production directly incorporates the material, linking, for instance, neodymium and dysprosium in permanent magnets to motor and generator manufacturing (NAICS 335312) and motor-vehicle electrical equipment (336320), and cerium in catalytic converters to motor vehicle parts (336390). I deliberately exclude significantly downstream activities (such as the retail or wholesale trade of rare-earth-containing goods) and sectors where rare earths play only a minor or readily substitutable role, so that the classification isolates firms for which rare earth supply conditions plausibly affect production costs. The resulting set of substitution-constrained industries is reported in Figure 2. A firm is coded as substitution-constrained if it belongs to any of these industries and unconstrained otherwise. Because firms may report several NAICS industries, a constrained firm may also operate in unrelated sectors, but the overwhelm-

ing majority of flagged firms are manufacturers for which rare earths are core inputs. I exclude rare earth producers themselves, firms in metal-ore mining, mining support and secondary nonferrous metal refining (NAICS 212290, 213114 and 331492), since a foreign supply restriction may raise their valuations; I study their response separately in Section 5.1.

Figure 2: List of NAICS Industries Corresponding to Rare Earth Uses

NAICS Code	Industry Description
221111	Hydroelectric Power Generation
221115	Wind Electric Power Generation
324110	Petroleum Refineries
325180	Other Basic Inorganic Chemical Manufacturing
327212	Other Pressed and Blown Glass and Glassware Manufacturing
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing
333242	Semiconductor Machinery Manufacturing
334111	Electronic Computer Manufacturing
334412	Bare Printed Circuit Board Manufacturing
334413	Semiconductor and Related Device Manufacturing
334416	Capacitor, Resistor, Coil, Transformer, and Other Inductor Manufacturing
334419	Other Electronic Component Manufacturing
334511	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing
334610	Manufacturing and Reproducing Magnetic and Optical Media
335132	Commercial, Industrial, and Institutional Electric Lighting Fixture Manufacturing
335139	Electric Lamp Bulb and Other Lighting Equipment Manufacturing
335312	Motor and Generator Manufacturing
335910	Battery Manufacturing
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing
336390	Other Motor Vehicle Parts Manufacturing
336414	Guided Missile and Space Vehicle Manufacturing
336415	Guided Missile and Space Vehicle Propulsion Unit and Propulsion Unit Parts Manufacturing
336419	Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment Manufacturing
621512	Diagnostic Imaging Centers
811210	Electronic and Precision Equipment Repair and Maintenance

Continuous expenditure intensity. The dummy treats every substitution-constrained industry alike, yet rare earth dependence varies widely in degree. To capture intensity I construct a continuous measure of rare earth expenditure, equal to the value of rare earth inputs, both used directly and embodied in intermediate inputs, per dollar of an industry's output, built on the 2017 BEA input–output structure. Construction proceeds in two steps. First, for each industry k I compute a direct rare earth cost share

$$f_k = \frac{V_k^{\text{REE}}}{Q_k},$$

where V_k^{REE} is the value of rare earths used directly by industry k (obtained from rare earth tonnages by first-use product from Nkiawete and Vander Wal 2025, valued at USGS annual oxide prices and scaled to U.S. apparent consumption), and Q_k is the industry's gross output. Second, I propagate these direct shares through the production

network using the Leontief inverse,

$$E_j = \sum_k L_{jk}\, f_k, \qquad \mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1},$$

where $\mathbf{A}$ is the BEA 402×402 direct-requirements matrix and L_{jk} is the output of industry k required, directly and indirectly, per dollar of industry j's final demand. E_j therefore measures the total rare earth content embodied in a dollar of an industry's output, and the construction follows Alfaro et al. 2025. Because rare earth expenditure is assigned at the first-use (processing) stage, the Leontief inverse propagates it to downstream users without double-counting. I assign each firm the rare earth expenditure of its highest-expenditure industry, setting expenditure equal to 0 for firms in industries that do not directly or indirectly purchase rare earths.

The expenditure distribution is heavily right-skewed. The highest-intensity industries are motorcycles and bicycles (0.00432), audio and video equipment (0.00313), and miscellaneous electrical equipment (0.00252), followed by expert-flagged industries such as storage battery manufacturing (0.00221) and motor and generator manufacturing (0.00188). This composition already shows that expenditure and the substitution-constrained dummy capture distinct dimensions of rare earth reliance. Several high-expenditure industries are not substitution-constrained (motorcycles and audio equipment outrank batteries), while some difficult-to-substitute industries have very low expenditure: semiconductor manufacturing is near zero (0.00003) because rare earths enter only in trace amounts (cerium oxide as a polishing abrasive, and lanthanum and yttrium oxides in high relative-permittivity dielectrics), even though they are difficult to substitute. The dummy captures substitution constraints and strategic criticality that the cost-share-based expenditure misses, whereas expenditure captures input-cost intensity that the binary indicator ignores. The two are positively but imperfectly correlated (Spearman $\rho \approx 0.42$), so each carries information the other does not, and I report results for both.

2.3 China Exposure

Because rare earth supply shocks are overwhelmingly Chinese export-policy actions, they may reprice not only firms that use rare earths as inputs but also firms broadly ex-

posed to China (through their supply chains, sourcing, or end markets), by signalling escalating U.S.–China decoupling and trade-war risk. To test for this third channel, which is conceptually distinct from direct rare earth input use, I construct a firm-level measure of China exposure.

A direct, firm-level measure of China exposure (such as the share of inputs sourced from, or sales made to, China) is not consistently available, so I build a text-based proxy from firms' annual reports. Every U.S.-listed firm is required to file a 10-K with the SEC each year: a comprehensive annual report that describes the company's business and audited financials and, in a dedicated risk factors section, discloses the material risks to its operations. It is in this risk-factors section that a firm's dependence on China (through suppliers, manufacturing, or sales) is most often laid out. I download every 10-K filed by U.S.-listed firms on the SEC's EDGAR system over filing years 2020–2025, extract the plain text of each filing, locate its risk factors section, and count mentions of China-related keywords per thousand words of that section:

$$\text{China}_{i,y} = \frac{\text{China-keyword mentions in risk factors}_{i,y}}{\text{words in risk factors}_{i,y}} \times 1{,}000.$$

The keywords are "People's Republic of China," "Chinese," "China," and "PRC." Filings whose risk factors section cannot be located (fewer than 500 words) are treated as missing. The procedure matches roughly 2,700 U.S.-listed firms. Because the measure is built from SEC filings, it is available only for U.S. firms, and the China-exposure analysis is correspondingly restricted to the U.S. sample.

To avoid look-ahead bias, I lag the measure by one year: a shock in year y is matched to the firm's 10-K filed in year $y-1$, so the proxy reflects only information that was public before the shock. The resulting $\text{China}_{i,y-1}$ is heavily right-skewed across firms, and the industries with the highest average China exposure are predominantly electronics, machinery, and consumer-goods manufacturers (Figure 3). China exposure is positively but imperfectly correlated with substitutability: firms with high China exposure are not always the same manufacturers that use rare earths (Spearman $\rho \approx 0.39$ with rare earth expenditure). It therefore carries variation distinct from direct input use, which is what allows the two channels to be separated.

Figure 3: Average China exposure by industry

Notes: The 25 six-digit NAICS industries with the highest mean China$_{i,y}$ (China-keyword mentions per 1,000 words of the risk factors section of firms' 10-K filings). Each firm's China$_{i,y}$ is first averaged across its filings, then averaged within each industry to which the firm is assigned; industries with fewer than five firms are excluded, and the number of firms is shown beside each bar.

2.4 Firm Share Prices

Daily share prices are from LSEG Workspace for firms in five indices: the Russell 3000 (U.S.), TOPIX (Japan), STOXX Europe 600, S&P/ASX (Australia), and S&P/TSX (Canada). After de-duplicating, the price data cover 5,720 firms; after removing rare earth producers, the panel contains 5,647 firms and covers the period from January 2021 to May 2026. The outcome variable is firm i's cumulative log return from the close before event e to h trading days afterward, measured on the firm's own regional trading calendar:

$$Ret_{i,e,h} = \ln P_{i,\,\tau_R(e)+h} - \ln P_{i,\,\tau_R(e)-1},$$

where $P_{i,s}$ is firm i's closing price on trading session s, and $\tau_R(e)$ is the session assigned to event e for firm i's region R, the $h = 0$ session defined in Section 2.1. Sessions are counted in trading days along region R's own calendar, so $\tau_R(e) - 1$ is the previous regional close and $\tau_R(e) + h$ the h-th regional close after the event.

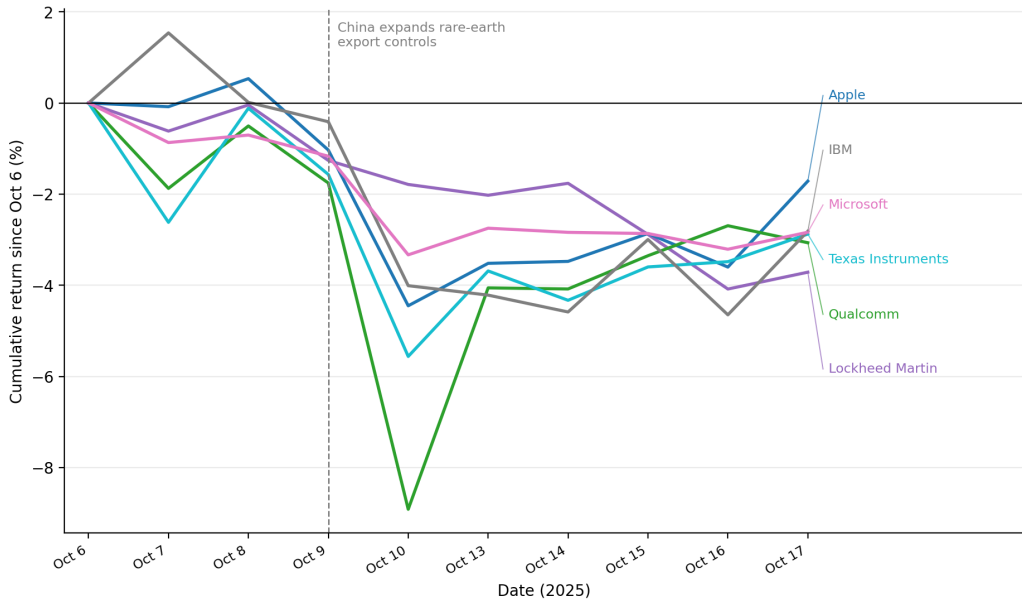
3 Rare Earth Supply Shocks and Firm Valuations

In April 2025, China imposed a series of rare earth export controls, restricting the sale of seven heavy rare earths and eventually prompting a negotiated trade truce with the United States. Then, in the middle of that truce and days before a planned meeting between Presidents Donald Trump and Xi Jinping, China abruptly escalated. On 9 October, China added five more rare earth elements to its control list, extended licensing requirements to any foreign-made product containing only trace amounts of Chinese rare earths, and restricted the export of related technology and expertise. Just when markets had expected Chinese trade policy to be stable, these announcements were a surprise escalation.

Figure 4 plots the cumulative share-price return of a small set of substitution-constrained firms in the days around the announcement. The selected firms span two groups heavily reliant on rare earths: defense (Lockheed Martin) and technology and semiconductors (Apple, IBM, Microsoft, Texas Instruments, and Qualcomm). All of them fall sharply after 9 October. By the middle of the month these firms had lost roughly two to four percent relative to their pre-announcement values. The common,

near-simultaneous decline of firms whose products depend on rare earths suggests that investors quickly repriced the risk of a tightening in Chinese supply.

Figure 4: Share-price response of selected substitution-constrained firms to the 9 October 2025 export controls



Notes: Cumulative share-price return (percent) since 6 October 2025 for a selected set of firms. The dashed vertical line marks 9 October 2025, when China announced an expansion of its rare earth export controls.

This episode is suggestive of how markets reprice firms when rare earth supply adjusts. Yet, it is a single event, and the selected firms may not be representative of the entire set of affected firms, either through their substitution constraints, expenditure on rare earths, or their exposure to China. In the remainder of this section, as well as Section 4, I investigate this relationship systematically.

3.1 Empirical Framework

I employ an event-study approach to examine how firms' equity prices respond to rare earth supply shocks. The design rests on the efficient market hypothesis assumption that a supply-shock announcement alters investors' expectations about the expected future profits and risks associated with access to rare earths, and that these revisions are immediately reflected in share prices. Building on the news-based shock series, I estimate the cumulative share-price response of substitution-constrained firms, relative to unconstrained firms, over a short window of trading days around these supply-

shock events, anchored to each firm's regional trading calendar. Tracing the response horizon by horizon recovers the full dynamic path of the reaction, both on the day of the shock and in the trading days that follow.

As my baseline regression, I estimate the dynamic path of share-price return differentials between substitution-constrained and unconstrained firms around rare earth supply shocks:

$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \beta_h\big(\text{Shock}_e \times \mathbb{1}^{\text{SC}}_{j(i)}\big) + u_{i,e,h}, \tag{1}$$

where $Ret_{i,e,h}$ is firm i's cumulative return through horizon h around event e; Shock_e equals $+1$ for a supply-contracting event and -1 for a supply-expanding event; γ_i is a firm fixed effect; $\mathbb{1}^{\text{SC}}_{j(i)}$ equals one if firm i's industry $j(i)$ is substitution-constrained; and $\alpha_{c(i),e}$ is a fixed effect for each country–event pair, with $c(i)$ the firm's exchange country. The country–event fixed effects absorb the entire average reaction of each national market to each event, whatever moves that market as a whole on the event date. The coefficient of interest, β_h, therefore compares substitution-constrained and unconstrained firms within the same country and event: it measures whether substitution-constrained firms move by more than unconstrained firms when a supply shock hits. This is exactly what the baseline is built to capture: a national market may rise or fall as a whole on a given day, but the substitution-constrained group should move by more. Standard errors are two-way clustered by firm and by event. The baseline uses country–event fixed effects, but the differential is robust to the fixed-effects structure: country–event, sector–event, and country–sector–event fixed effects all deliver a similar response (Appendix D, Table D.1).

I estimate Equation (1) on a single stacked panel of firm–event observations. For each firm I include only the shocks relevant to its market: those that target the firm's own region, together with global shocks that affect all markets. A shock aimed at a different region (for example, a shock targeting Japan paired with a U.S. firm) is dropped from that firm's observations rather than estimated and averaged in. Within this design, I report results for four nested event sets: all high-confidence shocks; China-origin shocks only; surprise shocks only; and their intersection, surprise China-origin shocks.

I estimate responses over $h = -5$ to $h = +10$ trading days, excluding $h = -1$ (the

normalization point). I deliberately do not extend to long horizons: beyond roughly ten trading days the windows of distinct shocks begin to overlap, so long-horizon cumulative returns conflate multiple events. Within this window, closely spaced events raise two issues. First, three pairs of baseline events lie fewer than ten trading days apart (4 and 11 April 2025, 5 and 7 June 2025, and 7 and 9 January 2026), so their response windows overlap. Second, some rare earth events coincide with other trade policy news: on 4 April 2025, China announced its rare earth export controls together with a 34 percent tariff on U.S. imports, in the midst of the broader tariff escalation of early April 2025. Section 5.2 shows that removing the overlapping events, or the 4 April event, leaves the response essentially unchanged. The negative horizons ($h = -5, \ldots, -2$) are retained as a pre-trend / placebo check.

3.2 Baseline Results

Table 2 reports the differential coefficient β_h from Equation (1) for each of the four shock sets. The coefficient of interest, β_h, estimates the difference in cumulative share-price returns between substitution-constrained and unconstrained firms in the same market h trading days after a supply-constraining shock (an event expected to raise rare earth prices), so a negative value means that substitution-constrained firms fall relative to their unconstrained counterparts.

The estimates differ sharply across the four shock sets. Pooling all high-confidence shocks, the differential is statistically indistinguishable from zero at every horizon. Restricting to China-origin shocks recovers a significant decline on impact, with substitution-constrained firms underperforming unconstrained firms by 0.23 percentage points at $h = 0$, though the effect fades within two days; restricting instead to surprise shocks of any origin leaves the impact response null. Only the intersection of the two, surprise China-origin shocks, produces a response that is both large and persistent (Figure 5). On impact, substitution-constrained firms underperform unconstrained firms by 0.35 percentage points, and the differential widens to 0.56 percentage points at $h = 2$ and 0.78 percentage points at $h = 5$, all significant at the one-percent level, before the cumulative gap closes by $h = 10$. The negative (pre-event) horizons, plotted in Figure 5 and Appendix Figure C.1, are small and, apart from a marginally significant coefficient at $h = -5$ for the surprise, China-origin set, insignificant for all four event

sets, consistent with no differential pre-trend between substitution-constrained and unconstrained firms ahead of the shocks. This pattern is evidence of an input-cost channel: a supply-constraining shock raises the expected cost of rare earth inputs for substitution-constrained firms, compressing their margins and lowering their equity valuations relative to unconstrained firms.

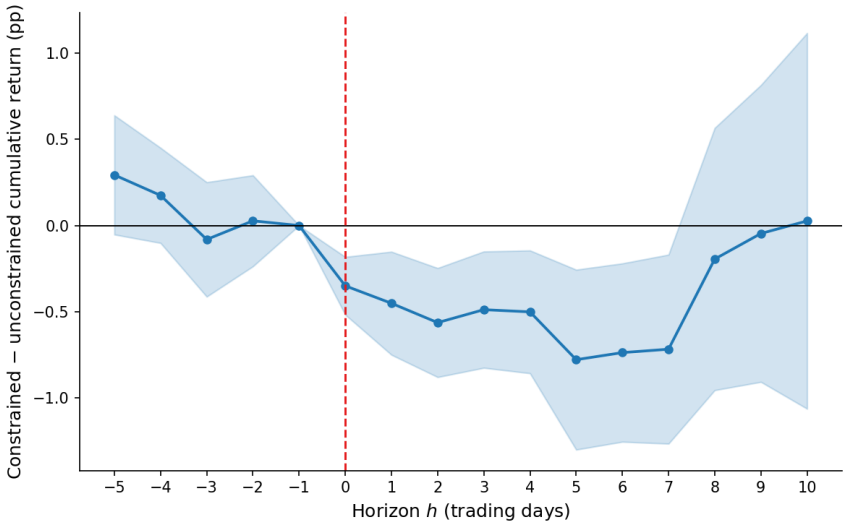
Table 2: Differential response of constrained vs. unconstrained firms, by shock set

Shock set	$h = 0$	$h = 1$	$h = 2$	$h = 3$	$h = 5$
All shocks ($n_{ev} = 56$)	-0.11	-0.11	-0.00	-0.04	+0.08
	(0.08)	(0.14)	(0.16)	(0.18)	(0.23)
China-origin ($n_{ev} = 22$)	-0.23***	-0.34**	-0.30	-0.23	-0.32
	(0.08)	(0.17)	(0.18)	(0.22)	(0.26)
Surprise ($n_{ev} = 43$)	-0.06	+0.04	+0.19	+0.12	+0.32
	(0.11)	(0.16)	(0.20)	(0.22)	(0.29)
Surprise, China-origin ($n_{ev} = 13$)	-0.35***	-0.45***	-0.56***	-0.49***	-0.78***
	(0.09)	(0.15)	(0.16)	(0.17)	(0.27)

Notes: Each row estimates Equation (1) on the indicated event set, including for each firm only own-region and global shocks. All specifications include firm and country–event fixed effects; standard errors (in parentheses) are two-way clustered by firm and event. n_{ev} is the number of distinct events. Coefficients and standard errors are in percentage points. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Taken together, these results indicate that the equity-price response is driven specifically by surprising information, rather than already-reported repetition or clarifying details, about Chinese supply policy. Because China-origin events are almost exclusively trade-policy actions, the effect is, concretely, a reaction to surprise changes in Chinese rare earth export policy. For the remainder of the paper I therefore take the surprise, China-origin set as the baseline shock series. These same shocks also move the share prices of non-Chinese rare earth producers, in the opposite direction to those of substitution-constrained users, which validates them as genuine rare earth supply shocks (Section 5.1).

Figure 5: Differential impulse response to surprise, China-origin shocks



Notes: Differential coefficient β_h from Equation (1) estimated on the surprise, China-origin shock set, in percentage points, with 95% confidence intervals (two-way clustered by firm and event). The response is normalized to zero at $h = -1$, and the dashed line marks the event date ($h = 0$).

4 Dissecting the Equity Response: Transmission Channels and Heterogeneity

4.1 Regional heterogeneity

Does the equity response vary across regions? China does not deploy its rare-earth leverage evenly: it has tightened and loosened access most pointedly toward the United States, as part of the trade war, and toward Japan, with which it has a long history of rare-earth disputes, while Europe has been a less direct object of these actions. Therefore, I take this as motivation to investigate whether certain countries (or regions) are more responsive to rare earth supply shocks.

I estimate the baseline differential separately by firm region:

$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \beta_h^{(r)}\left(\text{Shock}_e \times \mathbb{1}^{\text{SC}}_{j(i)}\right) + u_{i,e,h}, \qquad i \in r, \tag{2}$$

where r indexes the United States, Japan, and Europe, and each regression is run on the firms in region r and the shocks relevant to them: those targeting r together with global shocks, with a world shock and a country-specific shock entered identically.

The surprise, China-origin set contains seven global shocks common to all regions, two events specific to the United States, three specific to Japan, and one specific to Europe. I omit regressions for Australia and Canada because they contain only 17 and 23 substitution-constrained firms, respectively (against 304 in the United States, 310 in Japan, and 84 in Europe). Table 3 reports the per-region differential and Figure 6 plots the corresponding impulse responses.

Table 3: Constrained vs. unconstrained differential by firm region

Firm region	n_{ev}	n_{firms}	$h = 0$	$h = 1$	$h = 2$	$h = 3$	$h = 5$
United States	9	2,839	-0.55***	-0.59***	-0.71***	-0.62**	-0.94**
Japan	10	1,655	-0.20	-0.34	-0.50***	-0.45**	-0.75***
Europe	8	535	-0.00	-0.26	-0.08	-0.03	-0.14

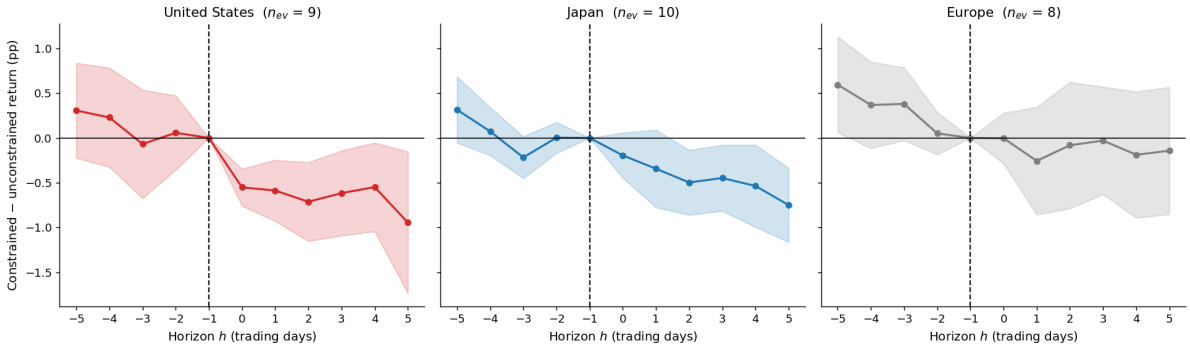
Notes: Equation (2) estimated on each firm region's sub-sample (firm and country–event fixed effects), using surprise, China-origin shocks, with two-way clustered standard errors. Coefficients are in percentage points. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The U.S. differential is the largest: negative, significant at every horizon, and persistent, from -0.55 percentage points on impact to -0.94 at $h = 5$. The Japanese differential is smaller and becomes significant from $h = 2$, growing from -0.20 percentage points on impact to -0.75 at $h = 5$. The European differential is the smallest and is insignificant at every horizon.

This pattern lines up with where China has directed its rare-earth actions. The United States, in the course of the trade war, and Japan, through their longstanding rare-earth disputes, are the two economies China has most directly targeted, and they accordingly face the most country-specific shocks in the sample. The differential concentrates in exactly these two economies and is absent in Europe.

The United States shows the strongest response, and it is also where firm-level disclosures allow a firm's exposure to China to be measured directly. The next section uses this sample to investigate whether a firm's exposure to China, a channel distinct from rare earth dependence, affects their share price response to rare earth supply shocks.

Figure 6: Constrained vs. unconstrained differential by firm region (surprise, China-origin shocks)



Notes: Constrained-minus-unconstrained cumulative-return differential β_h (Equation (1), firm and country–event fixed effects) estimated separately for U.S., Japanese, and European firms on the surprise, China-origin set, in percentage points. Each region's firms enter only with the shocks relevant to them (own-target plus global shocks). Shaded bands are 95% confidence intervals from two-way clustered standard errors (firm and event). Responses are normalized to zero at $h = -1$; the dashed line marks the event date ($h = 0$).

4.2 The China exposure channel

Given that the supply events in the baseline series are Chinese export-policy actions, they may carry information beyond the rare earth market itself, signalling a broader deterioration in U.S.–China relations. If they do, the firms they reprice are not only those that use rare earths as inputs, but also firms whose business is tied to China more generally (those that source from Chinese suppliers, manufacture in China, or sell into the Chinese market), since escalating tension threatens their supply chains and their access to Chinese customers whether or not they use rare earths. This section asks whether such exposure to China is priced separately from rare earth input use. Because the response is concentrated in the United States and the China-exposure proxy is available only for U.S. firms, I work within the U.S. sample.

I measure firm-level China exposure with the text-based proxy of Section 2.3, which counts references to China in the risk factors section of a firm's 10-K filings (mentions per 1,000 words and denoted by $\text{China}_{i,y-1}$), entered per standard deviation across firms (computed by averaging each firm's China exposure across its filings and then taking the standard deviation across those firm-level averages). I estimate two specifications. The first enters China exposure on its own,

$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \delta_h \left(\text{Shock}_e \times \text{China}_{i,y-1}\right) + u_{i,e,h}, \tag{3}$$

and the second enters it jointly with the substitutability indicator,

$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \beta_h \left(\text{Shock}_e \times \mathbb{1}^{\text{SC}}_{j(i)}\right) + \delta_h \left(\text{Shock}_e \times \text{China}_{i,y-1}\right) + u_{i,e,h}, \quad (4)$$

In the first specification, δ_h is the differential return per one-standard-deviation increase in China exposure. In the second, β_h and δ_h each measure a differential holding the other channel fixed: β_h is the substitutability channel holding China exposure constant, and δ_h the China channel holding substitutability constant. Both specifications keep the firm and country–event fixed effects of the baseline. Table 4 reports both specifications on the surprise, China-origin set.

Table 4: China exposure channel (surprise, China-origin shocks, U.S. firms)

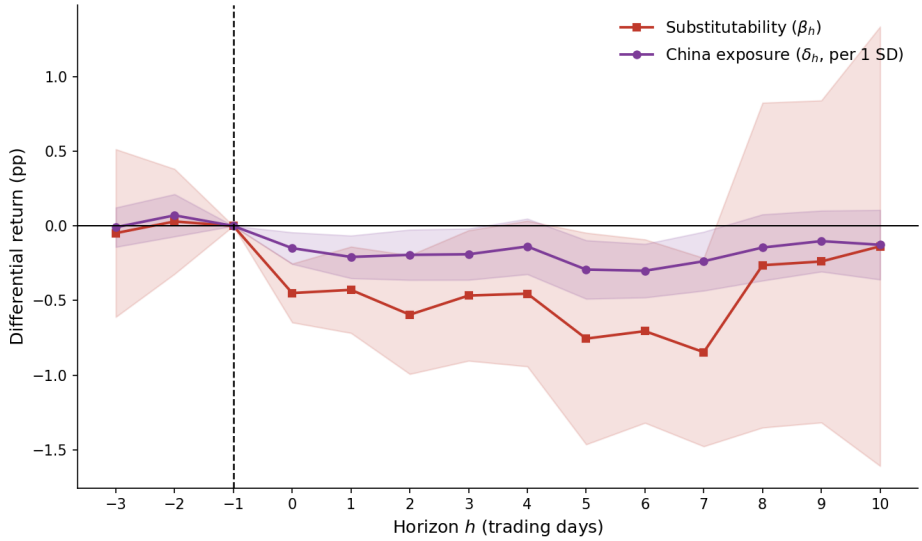
	$h = 0$	$h = 1$	$h = 2$	$h = 3$	$h = 5$
Panel A: China exposure alone, Equation (3)					
China exposure (δ_h)	-0.18***	-0.24***	-0.24***	-0.22**	-0.35***
	(0.05)	(0.08)	(0.09)	(0.09)	(0.11)
Panel B: substitutability and China exposure jointly, Equation (4)					
Substitutability (β_h)	-0.45***	-0.43***	-0.59***	-0.47**	-0.76**
	(0.10)	(0.15)	(0.20)	(0.22)	(0.36)
China exposure (δ_h)	-0.15***	-0.21***	-0.19**	-0.19**	-0.29***
	(0.05)	(0.07)	(0.09)	(0.09)	(0.10)

Notes: Panel A estimates Equation (3) and Panel B estimates Equation (4), both on the surprise, China-origin set ($n_{ev} = 9$, U.S. firms; firm and country–event fixed effects). China exposure is entered per standard deviation across firms; the substitutability indicator is binary. Coefficients and standard errors are in percentage points, with the standard errors in parentheses (two-way clustered by firm and event). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

On its own, China exposure carries a negative differential that is significant on impact through $h = 5$ (Panel A). When entered jointly with the substitution-constrained dummy (Panel B), both coefficients remain negative and significant through $h = 5$; the China-exposure differential is somewhat attenuated relative to entering alone but is not absorbed by the dummy. China exposure thus prices into firm valuations over and above direct rare earth input use, entering as a channel distinct from rare earth use itself.

A one-standard-deviation increase in China exposure is about 0.63 additional China mentions per 1,000 words of the risk factors section. In the joint specification, it lowers the differential by about 0.15 percentage points on impact, 0.19 at $h = 2$, and 0.29 at

Figure 7: China exposure channel (surprise, China-origin shocks, U.S. firms)



Notes: Cumulative-return differentials from the joint specification (Equation (4)) on the surprise, China-origin set ($n_{ev} = 9$, U.S. firms), in percentage points: the substitutability coefficient β_h (red) and the China-exposure coefficient δ_h (purple), the latter expressed per one standard deviation of China exposure across firms so that the two are on a common scale. Shaded bands are 95% confidence intervals from two-way clustered standard errors (firm and event). Responses are normalized to zero at $h = -1$; the dashed vertical line marks the event date ($h = 0$).

$h = 5$. Figure 7 plots the two differentials from the joint specification.

These results are consistent with the interpretation that Chinese rare earth actions are signals about U.S.–China relations more broadly. A firm need not consume rare earths to lose value when Beijing escalates: exposure to China through suppliers, production, or customers is itself repriced when an export-policy shock raises the perceived risk of decoupling. Rare earth input dependence and China exposure are two distinct routes through which the same shocks reach firm valuations.

4.3 Equity response: elasticity or expenditure?

Rare earth substitutability, as captured by the dummy, is binary: it treats every difficult-to-substitute industry alike, recording whether rare earths are critical inputs to an industry but not how much firms spend on them. Does the equity response reflect how essential rare earths are to a firm's production, or how much it spends on them? The substitutability indicator and rare earth expenditure measure two different things. The indicator flags the industries in which rare earths are a difficult-to-substitute input,

regardless of how much is spent on them, whereas expenditure measures the value of rare earth inputs per dollar of output. The two need not coincide: a production process may use only a minute quantity of rare earths and still be very hard to run without them. I therefore ask how the equity response varies with a firm's rare earth expenditure, and whether intensity matters once the critical-input distinction is held fixed.

Across firms, expenditure is small and highly right-skewed: it averages about 0.017 cents per dollar of gross output, with a standard deviation of 0.053 cents.[4] In Table 5, I show that the industries with the highest expenditure are not the same as those the dummy flags: the largest rare earth expenditures belong to motorcycle and bicycle, audio and video equipment, and miscellaneous electrical-equipment manufacturing, none of which the dummy treats as critically dependent. Among the substitution-constrained industries, expenditure ranges widely: battery and motor-and-generator manufacturing sit near the top, whereas semiconductors, guided missiles, and most electronic-component industries sit near the bottom, using only trace quantities of rare earths even though they cannot readily do without them.

Table 5: Selected industries by rare earth expenditure and substitutability status

Industry	Expenditure	Constrained
Motorcycle and bicycle manufacturing	0.00432	No
Audio and video equipment	0.00313	No
Miscellaneous electrical equipment	0.00252	No
Storage battery manufacturing	0.00221	Yes
Motor and generator manufacturing	0.00188	Yes
Search and detection instruments	0.00085	Yes
Semiconductor manufacturing	0.00003	Yes

Notes: Rare earth expenditure (value of rare earth inputs per dollar of output) for selected industries, and whether each is flagged by the substitutability indicator.

I estimate two specifications. The first replaces the dummy in the baseline with the continuous expenditure score,

$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \delta_h \left(\text{Shock}_e \times E_{j(i)}\right) + u_{i,e,h}, \tag{5}$$

[4]The distribution of expenditure across firms is shown in Appendix E.

and the second enters the dummy and expenditure jointly,

$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \beta_h \left(\text{Shock}_e \times \mathbb{1}^{\text{SC}}_{j(i)}\right) + \delta_h \left(\text{Shock}_e \times E_{j(i)}\right) + u_{i,e,h}, \tag{6}$$

where $E_{j(i)}$ is the total rare earth expenditure (on first-use and downstream products) of firm i's industry, entered per standard deviation across firms (one value per firm). Both keep the firm and country–event fixed effects of the baseline. In the joint specification, β_h is the response to critical dependence holding intensity fixed, and δ_h the response to intensity holding the critical-input distinction fixed.

Table 6: Rare earth expenditure, alone and jointly with substitutability (surprise, China-origin shocks)

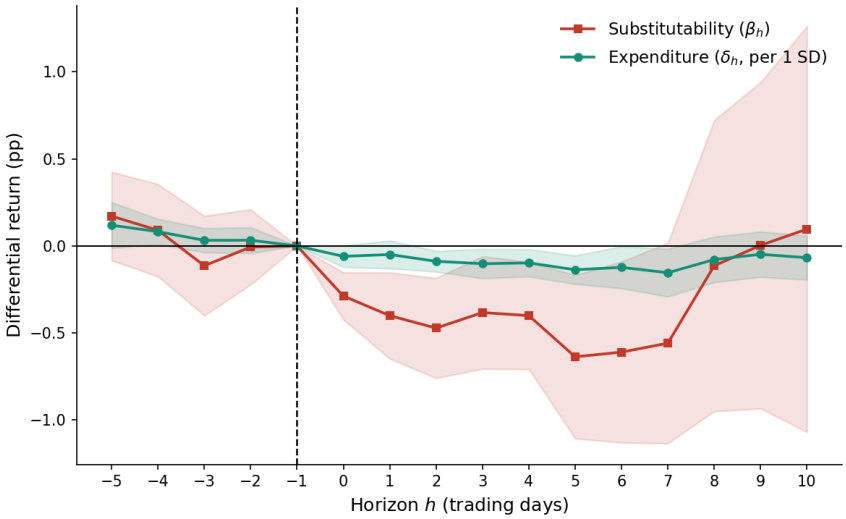
	$h=0$	$h=1$	$h=2$	$h=3$	$h=5$
Panel A: expenditure alone, Equation (5)					
Expenditure (δ_h)	-0.09***	-0.10*	-0.14***	-0.15***	-0.21***
	(0.04)	(0.05)	(0.04)	(0.05)	(0.06)
Panel B: substitutability and expenditure jointly, Equation (6)					
Substitutability (β_h)	-0.29***	-0.40***	-0.47***	-0.38**	-0.64***
	(0.07)	(0.13)	(0.15)	(0.16)	(0.24)
Expenditure (δ_h)	-0.06*	-0.05	-0.09***	-0.10**	-0.14***
	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)

Notes: Panel A estimates Equation (5) and Panel B estimates Equation (6), both on the surprise, China-origin set ($n_{ev} = 13$; firm and country–event fixed effects). Expenditure is entered per standard deviation across firms; the substitutability indicator is binary. Coefficients and standard errors are in percentage points, with standard errors in parentheses (two-way clustered by firm and event). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

On its own, expenditure carries a strong negative differential, significant through $h = 5$: more rare-earth-intensive firms underperform after a constraining shock. Entered jointly with the dummy, both survive. The dummy retains its magnitude and significance at every horizon through $h = 5$, and the expenditure coefficient, though attenuated (for example, from -0.09 to -0.06 on impact), stays negative and significant at most horizons. Critical dependence and expenditure intensity therefore load independently: each carries information the other does not.

Reporting expenditure per standard deviation (5.3×10^{-4} of output value) puts its coefficient on the same footing as the dummy. Figure 8 plots the two differentials from the joint specification (Equation (6)) on a common scale.

Figure 8: Expenditure and substitutability in the horserace (surprise, China-origin shocks)



Notes: Cumulative-return differentials from the joint specification (Equation (6)) on the surprise, China-origin set ($n_{ev} = 13$), in percentage points: the substitutability coefficient β_h (red) and the expenditure coefficient δ_h (teal). The latter is expressed per one standard deviation of expenditure across firms. Shaded bands are 95% confidence intervals from two-way clustered standard errors (firm and event).

Both channels are present, but they are not equal. A one-standard-deviation increase in expenditure moves the differential by about 0.06 percentage points on impact and 0.14 by $h = 5$, while the dummy moves it by 0.29 and 0.64 percentage points, respectively, which is four to five times as much. Rare earth expenditure matters, but the larger losses fall on firms that use rare earths as critical, difficult-to-substitute inputs rather than on the heaviest spenders. Semiconductors are the clearest case: their rare earth expenditure is near the bottom of the substitution-constrained set, because rare earths enter only in trace amounts (cerium oxide as a polishing abrasive in wafer manufacturing, and lanthanum and yttrium oxides in high relative-permittivity dielectrics), where they are hard to substitute, yet semiconductor firms suffer among the largest losses in the cross-section (Section 4.4) when supply is constrained. Nonetheless, these results show that firms who spend significant amounts on rare earths and have difficulty substituting away from them are most vulnerable to supply-constraining events.

4.4 Heterogeneity across industries

Having found that rare earth substitutability and expenditure, as well as exposure to China, all matter for firm performance, a closer look at which particular industries are most affected is warranted. In the baseline event study, the differential response to supply shocks averages across all substitution-constrained firms, although it need not be evenly spread. The response should concentrate in the industries that genuinely depend on rare earths rather than spread uniformly across the substitution-constrained set.

To investigate this, I estimate the same differential as the baseline, except now do so industry by industry, with the treatment redefined as membership in a single industry. For each substitution-constrained NAICS industry j with at least ten sample firms, I estimate the following regression:

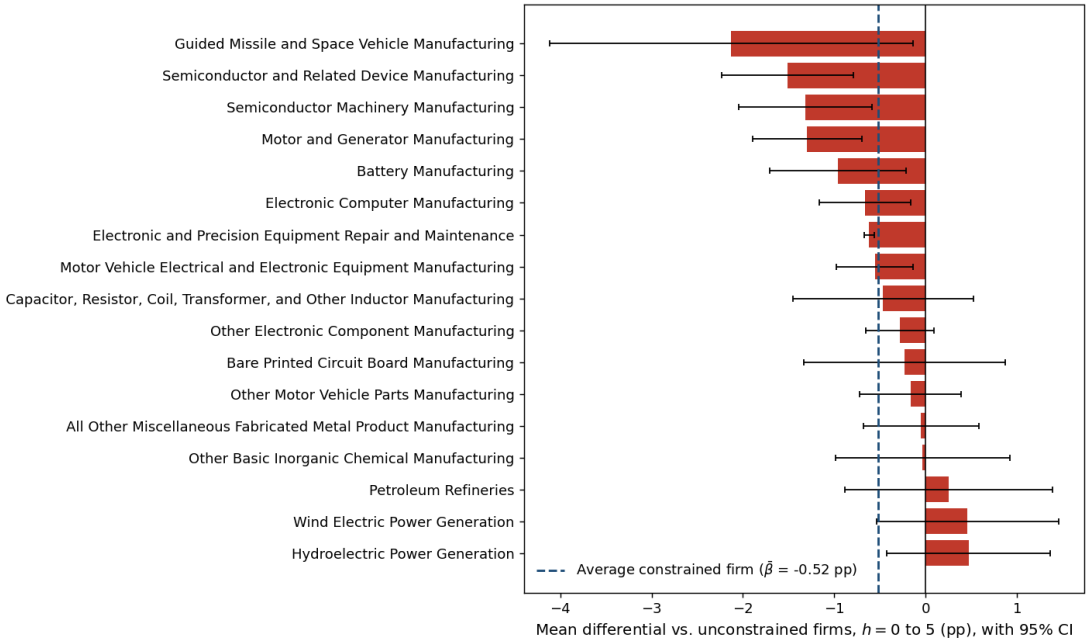
$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \beta_{j,h} \left(\text{Shock}_e \times \mathbb{1}\{j(i) = j\} \right) + u_{i,e,h}, \tag{7}$$

where $\beta_{j,h}$ is now the difference in share price returns between firms in industry j and all unconstrained firms h days after a supply-constraining event, keeping the firm and country–event fixed effects of the baseline. We can interpret $\beta_{j,h}$ as industry j's own differential relative to unconstrained firms: if $\beta_{j,h}$ is more negative than β_h, then firms in industry j are particularly vulnerable to supply constraining events relative to the average constrained firm.

I summarize each industry by its average over the first six trading days ($h = 0$ to 5), $\bar{\beta}_j = \frac{1}{6} \sum_{h=0}^{5} \beta_{j,h}$, on the surprise, China-origin set.[5] Figure 9 reports $\bar{\beta}_j$ for the substitution-constrained industries, and the negative differential concentrates in the most rare-earth-intensive manufacturing. The dashed vertical line marks the pooled differential for the average constrained firm ($\bar{\beta} = -0.52$ percentage points, averaged over $h = 0$ to 5), so industries whose bars fall to its left are more vulnerable than the typical constrained firm and those to its right less so. The largest declines are in guided-missile and space-vehicle manufacturing (about -2.1 percentage points), semiconductors and semiconductor machinery (about -1.5 and -1.3), motor and gen-

[5] A single horizon's estimate for an individual industry, which is identified off relatively few firms and events, is noisy; the average over the first six trading days smooths this idiosyncratic variation and is therefore preferred. The cross-industry ranking is stable across horizons regardless.

Figure 9: Per-industry differential, substitution-constrained industries (surprise, China-origin shocks)



Notes: Per-industry response relative to unconstrained firms (Equation (7), firm and country–event fixed effects) on the surprise, China-origin set, averaged over horizons $h = 0$ to 5 and shown in percentage points, for the substitution-constrained industries with at least ten sample firms. Whiskers are 95% confidence intervals from two-way clustered standard errors (firm and event). The solid vertical line at zero is the unconstrained benchmark; the dashed vertical line marks the pooled baseline differential β_h averaged over $h = 0$ to 5 (Equation (1)), i.e. the average constrained firm.

erator manufacturing (-1.3), and battery and electronic-computer manufacturing (roughly -1.0 and -0.7): the industries in which permanent magnets, battery materials, and rare-earth-dependent electronics are core inputs. The only substitution-constrained industries on the positive side are wind and hydroelectric power generation and petroleum refining, although the returns of firms in these industries are not statistically different from the returns of unconstrained firms.

The constrained-versus-unconstrained differential compares substitution-constrained firms to a control group that is unconstrained. A complementary question is how each industry moved relative to the entire market on supply-shock days. I therefore re-estimate the per-industry response with the rest of the market as the comparison group: for each six-digit NAICS industry j with at least ten sample firms,

$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \delta_{j,h}\left(\text{Shock}_e \times \mathbb{1}\{j(i) = j\}\right) + u_{i,e,h}, \tag{8}$$

estimated on the full panel of firms. The specification is identical in form to Equation (7), with the same firm and country–event fixed effects; the only difference is the estimation sample. There the regression includes industry j and the unconstrained firms alone, so the comparison group is the unconstrained pool; here it includes every firm, so the comparison group is all other industries, substitution-constrained and unconstrained alike. Because every firm now enters the regression, $\delta_{j,h}$ measures industry j's differential return relative to all other firms in the sample (every industry except j) on event days. Because the benchmark is the whole market rather than a control group defined by rare-earth reliance, the resulting ranking does not presuppose which industries are most affected, whether through substitutability, expenditure, or China exposure. I summarize each industry by $\bar{\delta}_j = \frac{1}{6}\sum_{h=0}^{5} \delta_{j,h}$ on the surprise, China-origin set.

Figure 10 ranks all 113 industries by $\bar{\delta}_j$, with each bar's width proportional to the industry's total market capitalization, so that the visual weight reflects the market value at stake rather than the number of firms. The three panels are identical except for how the bars are colored: by substitutability status (panel a), by expenditure (panel b), and by average China exposure (panel c).

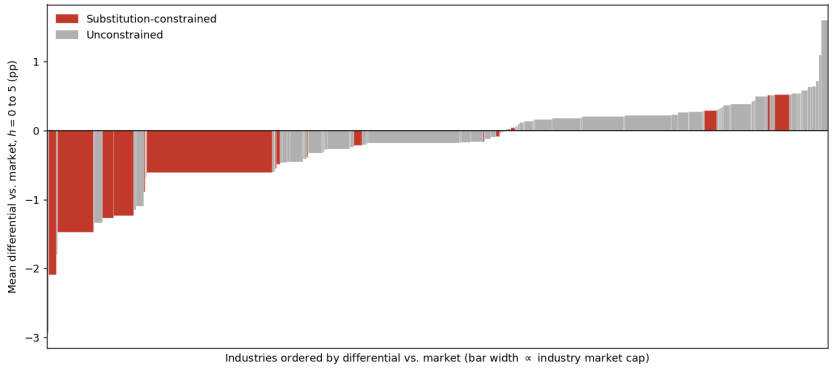
Across the three panels the same picture emerges. Industries in which it is difficult to substitute away from rare earths again fall on the negative side of the distribution (panel a); greater rare earth expenditure deepens the decline, with the heaviest spenders dropping more than those that spend little (panel b); and industries more exposed to China are hit harder than those with little exposure (panel c). What the market-capitalization weighting adds is that the pattern is not confined to small firms: a large share of the market value that moves on supply-shock days sits in big, substitution-constrained industries, so the channels identified in the preceding regressions reach the market's largest names as well.

5 Validation and Robustness

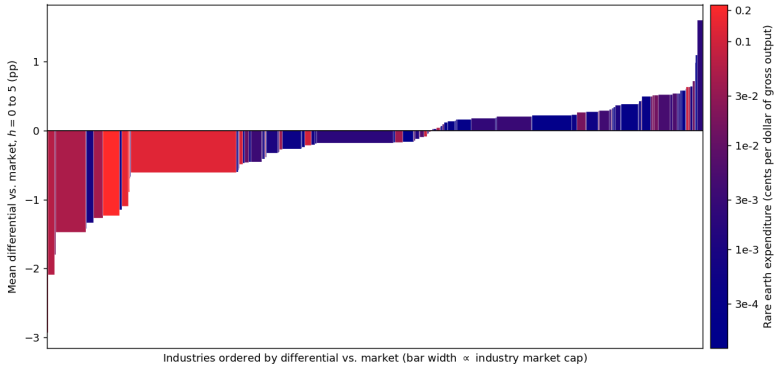
In the previous sections, I consider primarily how rare earth users, and in particular, firms that find it difficult to substitute away from rare earth inputs, respond to a set of 13 surprise, China-origin rare earth supply events. This raises two points. First,

Figure 10: Per-industry differential versus the market, by substitutability, expenditure, and China exposure (surprise, China-origin shocks)

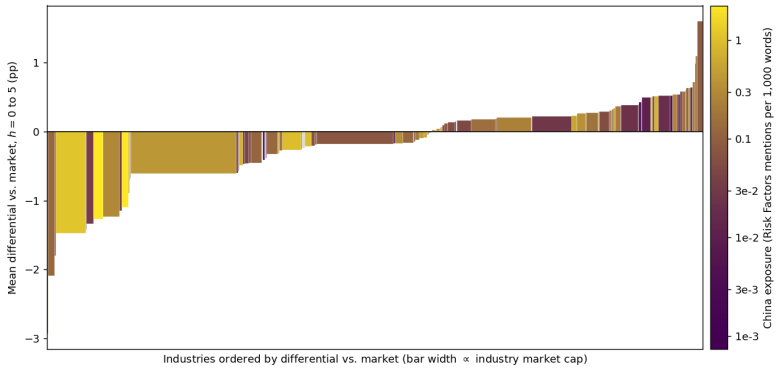
(a) By substitutability status



(b) Shaded by expenditure



(c) Shaded by average China exposure



Notes: $\bar{\delta}_j$ for all 113 industries with at least ten sample firms (Equation (8)), ranked from most negative (left) to most positive (right) on the surprise, China-origin set, in percentage points. Each bar's width is proportional to the industry's total market capitalization, converted to USD. Panels differ only in coloring: (a) substitution-constrained industries in red, others grey; (b) shaded by the industry's average expenditure (cents per dollar of gross output); (c) shaded by average China exposure (risk factors mentions per 1,000 words).

if the rare earth supply events that I identify indeed affect the global supply of rare earths, non-Chinese producers should also be affected, albeit in the opposite way as users. Second, the share price response of difficult-to-substitute firms to the shock series could be driven by particular events: with only 13 events, a single, powerful Chinese trade restriction or easing could carry substantial weight, and events that occur close together in time could have overlapping response windows. I investigate these points below.

5.1 Validation with rare earth producers

The shock series is constructed from news articles, and the baseline tests its effect on firms that use rare earths. A natural check on the series itself is whether the same events move share prices of non-Chinese rare earth miners and processors, and in particular, in the opposite direction of rare earth users. A Chinese export restriction should raise the price that non-Chinese rare earth producers can obtain, increase their sales volume by having a greater market share, or increase the probability that they receive subsidies, procurement contracts or industrial policy support. These channels should improve their profitability, and hence their share prices should rise, whereas an easing should have the opposite effect. If the events selected by the classification pipeline carried no information about rare earth supply, producers would not respond.

To identify non-Chinese rare earth producers, I use the rare earth industry map of Asian Metal (2026), a provider of metals market data and prices that also operates an online marketplace for metals. The map lists firms that have bought or sold rare earth products through the marketplace, roughly 2,000 firms in over 100 countries, spanning the supply chain from mining and separation to the manufacture of magnets and other end products. I match the firms on the map to their listed securities and keep those whose main business is the production of rare earths: miners and developers of rare earth deposits, separation and processing firms, recyclers of rare earth magnets, and producers of rare earth metals, alloys and magnets. Table F.1 in the Appendix lists each producer together with a description of its rare earth business from its annual report or regulatory filings. I keep producers listed in the five sample regions; none of them is part of the estimation sample.

This yields 25 publicly listed rare earth producers outside China: eleven in Aus-

tralia (including Lynas Rare Earths, Iluka Resources, and Arafura Rare Earths), nine in Canada (including Neo Performance Materials, Ucore Rare Metals, and Mkango Resources), and five in the United States (including MP Materials, Energy Fuels, and USA Rare Earth). Prices are in U.S. dollars from the same source as the main sample.[6]

I then estimate Equation (1), replacing the substitution-constrained indicator with a producer indicator and restricting the sample to producers and unconstrained firms:

$$Ret_{i,e,h} = \alpha_{c(i),e} + \gamma_i + \beta_h^P \left(\text{Shock}_e \times \mathbb{1}_i^{\text{P}}\right) + u_{i,e,h}, \tag{9}$$

where $\mathbb{1}_i^{\text{P}}$ equals one if firm i is a rare earth producer and all other terms are as in Equation (1). The coefficient β_h^P measures the cumulative return of producers relative to unconstrained firms in the same country following a supply-contracting shock, so the series is validated if β_h^P is positive.

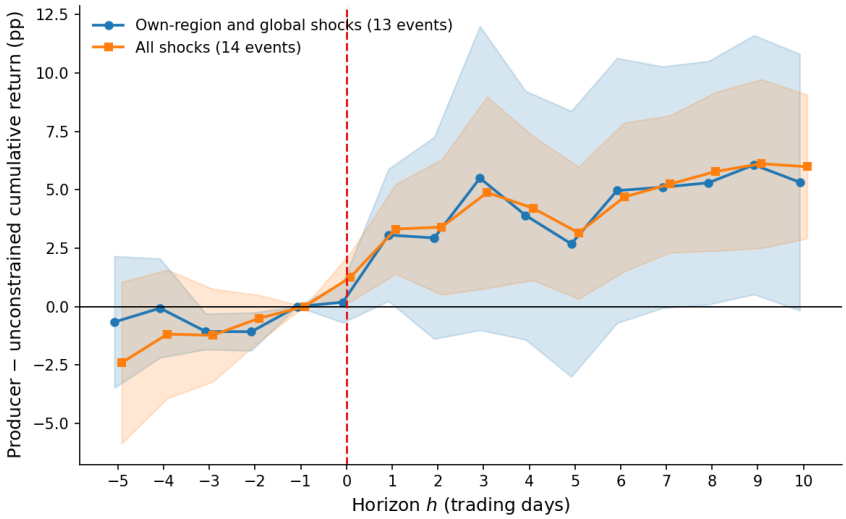
I estimate Equation (9) under two rules for which shocks a firm responds to. The first follows the baseline: each firm enters only for shocks that target its own region or the world. The second lets every firm, producers and unconstrained firms alike, enter for every shock. A Chinese restriction aimed at one country tightens the global market for the rare earths it covers, so a non-Chinese producer may benefit even when the restriction targets another region; an export restriction on the United States, for example, can raise demand for Australian supply. The asymmetry with the baseline reflects how the two groups are affected: a restriction aimed at one country limits access only for users in that country, but redirects their demand to non-Chinese suppliers wherever these are listed. Under the second rule, the one baseline event that targets India also enters, so the number of events rises from 13 to 14. In both cases, returns are anchored to each region's trading calendar, and standard errors are two-way clustered by firm and event.

Figure 11 shows that producers rise relative to unconstrained firms after surprise, China-origin shocks. Under the baseline rule, producers outperform by 3.06 percentage points at $h = 1$ (significant at the five-percent level) and by 5.50 percentage points

[6]The 25 producers are, in Australia: ABx Group, Arafura Rare Earths, Australian Strategic Materials, Critica, Energy Transition Minerals, Hastings Technology Metals, Iluka Resources, Ionic Rare Earths, Lynas Rare Earths, Northern Minerals, and VHM; in Canada: Aclara Resources, Appia Rare Earths & Uranium, Avalon Advanced Materials, Geomega Resources, Leading Edge Materials, Mkango Resources, Neo Performance Materials, Search Minerals, and Ucore Rare Metals; and in the United States: Critical Metals, Energy Fuels, MP Materials, Rare Element Resources, and USA Rare Earth.

at $h = 3$, and the gain persists, reaching 5.32 percentage points at $h = 10$ (Table 7). Letting every firm respond to every shock leaves the point estimates almost unchanged but tightens the confidence intervals, because the 20 Australian and Canadian producers now also enter the events that target the United States, Japan and Europe: producers outperform by 1.25 percentage points on impact and by 5.99 percentage points at $h = 10$, significant at every horizon from impact onward. The response is several times larger than the decline of substitution-constrained users, which is consistent with producers being mostly small, undiversified firms whose value depends directly on their share of global rare earth supply. This contrasts with users, where although many of them use rare earths as difficult-to-substitute inputs, the share of their operations that is affected by global rare earth supply is likely small relative to non-Chinese producers. It is important to note, however, that the estimates are noisier than for users, reflecting the small number of producers and their volatile returns. Overall, the events in the shock series move rare earth producers in the direction implied by a change in rare earth supply, which supports their interpretation as rare earth supply shocks.

Figure 11: Response of rare earth producers to surprise, China-origin shocks



Notes: Coefficient β_h^P from Equation (9), estimated on 25 non-Chinese rare earth producers and the unconstrained firms of the main sample, for the surprise, China-origin shock set, in percentage points, with 95% confidence intervals (two-way clustered by firm and event). Blue: each firm enters only for own-region and global shocks (13 events). Orange: every firm enters for every shock (14 events). The responses are normalized to zero at $h = -1$, and the dashed line marks the event date ($h = 0$).

Table 7: Response of rare earth producers to surprise, China-origin shocks

	$h=0$	$h=1$	$h=3$	$h=5$	$h=7$	$h=10$
Own-region and global shocks ($n_{ev}=13$)	+0.19	+3.06**	+5.50*	+2.68	+5.11*	+5.32*
	(0.44)	(1.44)	(3.32)	(2.90)	(2.64)	(2.80)
All shocks ($n_{ev}=14$)	+1.25**	+3.32***	+4.88**	+3.16**	+5.24***	+5.99***
	(0.53)	(0.98)	(2.09)	(1.44)	(1.50)	(1.57)

Notes: Estimates of Equation (9) on 25 rare earth producers and the unconstrained firms, for the surprise, China-origin shock set. Row 1 includes for each firm only own-region and global shocks; row 2 includes every shock for every firm. The specification includes firm and country–event fixed effects; standard errors (in parentheses) are two-way clustered by firm and event. n_{ev} is the number of distinct events. Coefficients and standard errors are in percentage points. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

5.2 Sensitivity to individual and overlapping events

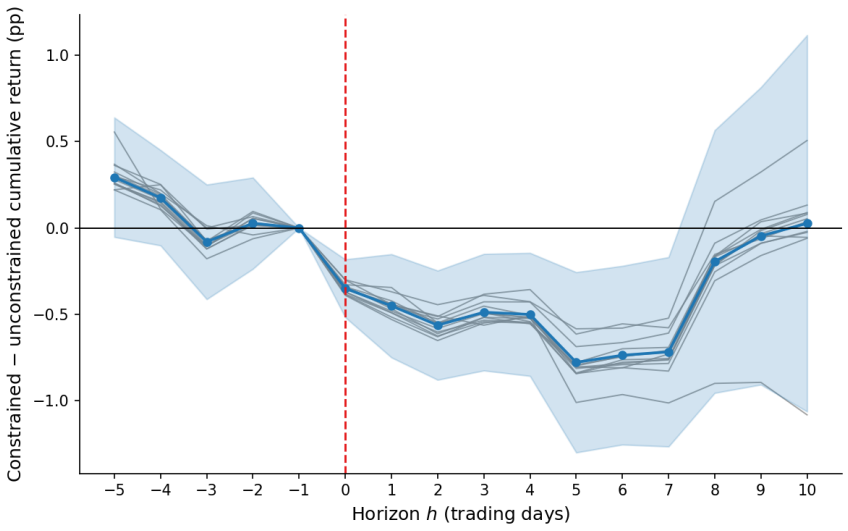
To check whether a single event drives the baseline result, I drop each of the 13 baseline events, one at a time, and re-estimate Equation (1) at every horizon on the remaining 12 events. Let $\beta_h^{(-k)}$ denote the differential coefficient at horizon h when event k is excluded. If the baseline reflects a common response across events, the 13 estimates $\beta_h^{(-k)}$ should lie close to the full-sample estimate β_h. If instead it is driven by one event, dropping that event should move the estimate sharply toward zero.

Figure 12 plots the 13 leave-one-event-out impulse responses, as well as the baseline from Equation (1). Each of the estimates sits tightly around the baseline at every horizon up to $h=7$, and they all remain negative and statistically significant at the ten-percent level over that window. On impact, the differential ranges from -0.30 to -0.39 percentage points, against a baseline of -0.35; at $h=2$ it ranges from -0.45 to -0.65, and at $h=5$ from -0.58 to -1.01 (Table 8).

One important event to note is 4 April 2025, in which China imposed export controls on rare earths. Paired with these export controls, China simultaneously imposed a 34 percent tariff on US imports, which could potentially confound the effect of the rare earth shock with a tariff shock if difficult-to-substitute firms are more affected by the tariff shock than the remainder of the market. However, dropping this potentially confounded event leaves the results mostly unchanged. On impact, the differential becomes -0.30; at $h=2$ it becomes -0.51, and at $h=5$, it becomes -0.80. The differentials, after dropping 4 April, maintain their statistical significance over the same horizon windows relative to the baseline, providing evidence that simultaneous tariff events do not seem to be driving the differential share price response.

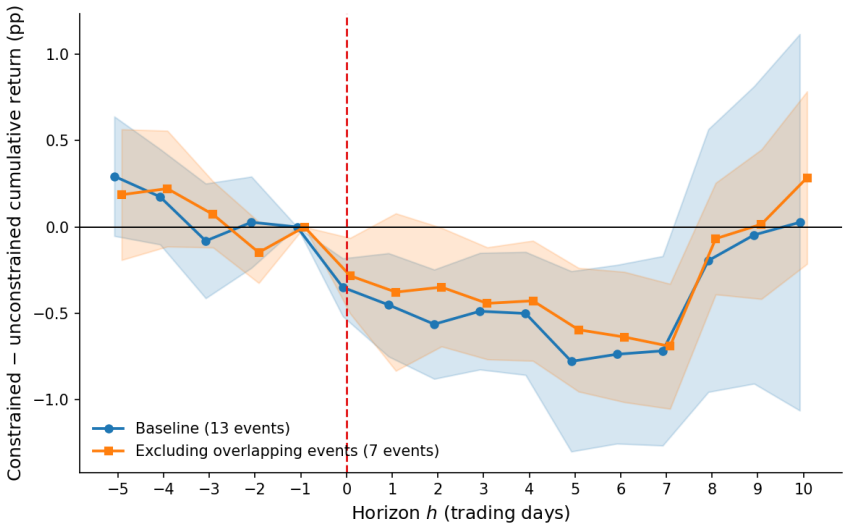
A related concern is that some baseline events occur close together in time, so that their response windows overlap and the estimated response to one event partly reflects the response to another. Three pairs of baseline events lie fewer than ten trading days apart: 4 and 11 April 2025, 5 and 7 June 2025, and 7 and 9 January 2026. To check whether this overlap drives the results, I re-estimate Equation (1) after removing all six of these events, which leaves seven baseline events. The differential remains negative and statistically significant from impact to $h = 5$, with the exception of $h = 1$: it is -0.28 percentage points on impact, -0.35 at $h = 2$, and -0.60 at $h = 5$ (Table 8 and Figure 13), and the pre-event coefficients are small and statistically insignificant. The on-impact response, which is least exposed to overlapping windows, is nearly identical to the baseline (-0.28 against -0.35), while the response at later horizons is somewhat smaller without the overlapping events. I nonetheless retain all 13 events in the baseline: the overlapping events are themselves distinct and economically important announcements, and excluding them leaves the conclusions unchanged.

Figure 12: Leave-one-event-out impulse responses



Notes: The blue line is the baseline differential coefficient β_h from Equation (1) estimated on the surprise, China-origin shock set, in percentage points, with 95% confidence intervals (two-way clustered by firm and event). Each grey line re-estimates Equation (1) dropping one of the 13 baseline events. The response is normalized to zero at $h = -1$, and the dashed line marks the event date ($h = 0$).

Figure 13: Baseline response with and without overlapping events



Notes: Differential coefficient β_h from Equation (1) estimated on the surprise, China-origin shock set, in percentage points, with 95% confidence intervals (two-way clustered by firm and event). Blue: all 13 baseline events. Orange: excluding the six events that lie fewer than ten trading days from another baseline event (4 and 11 April 2025, 5 and 7 June 2025, and 7 and 9 January 2026). The responses are normalized to zero at $h = -1$, and the dashed line marks the event date ($h = 0$).

Table 8: Robustness of the baseline response

	$h=0$	$h=1$	$h=2$	$h=3$	$h=5$
Baseline ($n_{ev}=13$)	-0.35***	-0.45***	-0.56***	-0.49***	-0.78***
	(0.09)	(0.15)	(0.16)	(0.17)	(0.27)
Leave one event out: range	[-0.39, -0.30]	[-0.53, -0.34]	[-0.65, -0.45]	[-0.56, -0.38]	[-1.01, -0.58]
Excluding overlapping events ($n_{ev}=7$)	-0.28**	-0.38	-0.35**	-0.44***	-0.60***
	(0.11)	(0.23)	(0.18)	(0.17)	(0.18)

Notes: Row 1 estimates Equation (1) on the surprise, China-origin shock set, including for each firm only own-region and global shocks. Row 2 reports the smallest and largest coefficient across the 13 regressions that drop one baseline event at a time. Row 3 re-estimates Equation (1) excluding the six baseline events that lie fewer than ten trading days from another baseline event (4 and 11 April 2025, 5 and 7 June 2025, and 7 and 9 January 2026). All specifications include firm and country–event fixed effects; standard errors (in parentheses) are two-way clustered by firm and event. n_{ev} is the number of distinct events. Coefficients and standard errors are in percentage points. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

6 Conclusion

This paper studies how investors price rare earth supply disruptions. I construct a news-based measure of supply shocks using an LLM pipeline that classifies rare-earth news, filters for surprise events, and codes each event's origin and target. Next, I build an indicator variable to capture technical substitutability between rare earths and other inputs (namely, substitution-constrained or unconstrained industries), as well as a measure of rare earth expenditure (relative to gross output) from input–output tables. Additionally, I develop a firm-level measure of exposure to China from 10-K disclosures. I then estimate the dynamic response of share prices to rare earth supply shocks across a panel of publicly listed firms, investigating substitutability, expenditure, and exposure to China as three distinct transmission channels.

First, the central finding is that the equity-price response is driven specifically by surprise, China-origin shocks (in reality, surprise tightenings or easings of Chinese export policy). Second, following a surprise Chinese tightening, substitution-constrained firms underperform unconstrained firms by 0.35 percentage points on impact, widening to 0.8 points during the first trading week. Third, the effect is concentrated in the economies China directly targeted, namely the United States and Japan, and in the most rare-earth-intensive industries, including defense (guided-missile and space-vehicle), semiconductor, motor and generator, battery, and electronic-component manufacturing. Fourth, the response also scales with rare earth expenditure: firms and industries that spend more on rare earths are repriced more sharply, so how much a firm spends on rare earths and how hard they are to substitute operate as two distinct channels. Fifth, firms with greater China exposure experience additional losses, consistent with markets repricing broad China risk alongside rare-earth access per se. Finally, the same shocks move non-Chinese rare earth producers in the opposite direction: these firms, which stand to gain when Chinese supply tightens, outperform unconstrained firms by about 5 percentage points.

My findings have important policy salience. Firms with certain structural characteristics will face acute risks from any further escalation in rare earth export restrictions as markets reprice exposures very rapidly. Moreover, sensitive industries (semiconductors, defense, electric motors, and batteries) are key drivers of overall macroeconomic performance, as well as being strategically central to growth strategies and

national security. These sectors' reliance on input supplies from China will remain a first-order concern for industrial and security policy. The financial channels documented here offer a way to quantify, in real time, the magnitude of critical transmission channels.

References

Acemoglu, Daron et al. (2012). "The network origins of aggregate fluctuations". In: *Econometrica* 80.5, pp. 1977–2016.

Alessandri, Piergiorgio and Andrea Gazzani (2025). "Natural gas and the macroeconomy: not all energy shocks are alike". In: *Journal of Monetary Economics* 151, p. 103749.

Alfaro, Laura et al. (2025). *Trade and Industrial Policy in Supply Chains: Directed Technological Change in Rare Earths*. Tech. rep. National Bureau of Economic Research.

Asian Metal (2026). *Rare Earth Industry Map*. URL: https://www.asianmetal.com (visited on 10/2026).

Baqaee, David Rezza and Emmanuel Farhi (2019). "The macroeconomic impact of microeconomic shocks: Beyond Hulten's theorem". In: *Econometrica* 87.4, pp. 1155–1203.

Carvalho, Vasco M (2014). "From micro to macro via production networks". In: *Journal of Economic Perspectives* 28.4, pp. 23–48.

Clayton, Christopher, Antonio Coppola, et al. (2025). "Geoeconomic Pressure". In: *Columbia Business School Research Paper Forthcoming, Stanford University Graduate School of Business Research Paper Forthcoming*.

Clayton, Christopher, Matteo Maggiori, and Jesse Schreger (2024). "A theory of economic coercion and fragmentation". In: *Available at SSRN 4767131*.

Crosignani, Matteo et al. (2024). "Securing technological leadership? the cost of export controls on firms". In: *FRB of New York Staff Report* 1096.

European Union (2024). *Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020*.

Farrell, Henry and Abraham Newman (2019). "Weaponized Interdependence". In: *International Security* 44.1, pp. 42–79.

Goonan, Thomas G (2011). *Rare earth elements: End use and recyclability*. US Department of the Interior, US Geological Survey Reston, VA, USA.

Hamilton, James D (1983). "Oil and the macroeconomy since World War II". In: *Journal of political economy* 91.2, pp. 228–248.

Hirschman, Albert O (1980). *National power and the structure of foreign trade*. Vol. 105. Univ of California Press.

International Energy Agency (2021). *The Role of Critical Minerals in Clean Energy Transitions*. Tech. rep. Paris: International Energy Agency. URL: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

Kalantzakos, Sophia (2017). *China and the geopolitics of rare earths*. Oxford University Press.

Känzig, Diego (2021). "The Macroeconomic Effects of Oil Supply News". In: *American Economic Review* 111.4, pp. 1092–1125.

Kilian, Lutz (2009). "Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market". In: *American economic review* 99.3, pp. 1053–1069.

Kirk, Josh, Evgenia Passari, and Hélène Rey (2026). *Exorbitant Privilege of the Periodic Table? Geoeconomics, Endogenous Centrality and Strategic Minerals for the Green Transition*. NBER Working Paper 35497. National Bureau of Economic Research. DOI: 10.3386/w35497.

Kowalski, Przemyslaw and Clarisse Legendre (2023). *Raw Materials Critical for the Green Transition: Production, International Trade and Export Restrictions*. OECD Trade Policy Papers 269. OECD. DOI: 10.1787/c6bb598b-en.

Mancheri, Nabeel A., Lalitha Sundaresan, and Anand Chandrashekar (2019). "Dominance of China in Rare Earth Elements: Policy Implications for the West". In: *Resources Policy* 63, p. 101428.

Mohr, Cathrin and Christoph Trebesch (2025). "Geoeconomics". In: *Annual Review of Economics* 17.

Nkiawete, Mpila Makiesse and Randy Lee Vander Wal (2025). "Rare earth elements: Sector allocations and supply chain considerations". In: *Journal of Rare Earths* 43.1, pp. 1–8. DOI: 10.1016/j.jre.2024.01.020.

Ramey, Valerie A (2011). "Identifying government spending shocks: It's all in the timing". In: *The quarterly journal of economics* 126.1, pp. 1–50.

Romer, Christina D and David H Romer (2004). "A new measure of monetary shocks: Derivation and implications". In: *American economic review* 94.4, pp. 1055–1084.

U.S. Department of Energy (2021). *Critical Minerals and Materials: U.S. Department of Energy's Strategy to Support Domestic Critical Mineral and Material Supply Chains (FY 2021–FY 2031)*. Tech. rep. U.S. Department of Energy.

A LLM Classification Prompts

This appendix reproduces, in full, the three prompts used in the classification pipeline of Section 2.1: Stage 1 (event classification), Stage 2 (surprise filter), and Stage 3 (origin and target). Each prompt is passed verbatim to the model, so that the entire shock series can be regenerated from the raw corpus together with these prompts.

Stage 1 (event classification).

```
You are classifying Reuters news articles for an academic research project on rare earth
supply shocks.

Your task: identify articles that report a BREAKING NEWS event directly affecting the global
supply
of rare earth elements (REEs) - e.g. lanthanum, cerium, neodymium, dysprosium, terbium,
yttrium,
and related elements.

## Labels

Assign exactly one label per article:

TRADE_RESTRICT - A government (most often China) announces, implements, or expands a new
export
restriction, quota, ban, licence requirement, or tariff on rare earth exports. The action
must be
newly reported on or near the article's publication date - not a retrospective account.

TRADE_EASE - A government removes, reduces, or relaxes an existing rare earth trade
restriction.
Includes new bilateral or multilateral trade agreements that explicitly expand access to REE
supplies.
Must be a concrete, newly reported action.

PROD_DISRUPT - A newly reported disruption to rare earth mining or processing output: mine
closure,
production cut, environmental shutdown, accident, or natural disaster affecting a REE
operation.

PROD_EXPAND - A newly announced or newly opened rare earth mine, processing facility, or
refinery.
Also a newly signed supply agreement that concretely expands access to REE production (e.g. a
 country
securing a new REE offtake deal). Must be a concrete new development - not a proposal still
under
feasibility study or discussion.

NOT_A_SHOCK - Use this for everything that does not qualify as a supply shock, including:
```

```
  - Analysis, commentary, or editorialising about existing or past restrictions
  - Retrospective coverage: the article describes events that already occurred and were
already reported
  - Diplomatic discussions, negotiations, or proposals with no confirmed policy action yet
  - Demand-side news: EV adoption, magnet demand forecasts, downstream industry trends
  - General market outlook, price movements, or industry-trend pieces
  - Follow-up or background coverage of a shock already in the public record
  - Articles about lithium, cobalt, or other critical minerals that do not specifically
concern REEs

## Breaking-news criterion (critical)

Only assign TRADE_RESTRICT, TRADE_EASE, PROD_DISRUPT, or PROD_EXPAND if the article is the
FIRST REPORT of a newly occurring event. Ask yourself:

  "On this article's publication date, was this event newly announced or newly revealed?"

If the answer is no - if the article is recapping, contextualising, or following up on
something
that entered the public record earlier - assign NOT_A_SHOCK regardless of how important the
underlying event was.

## Output format

Return a JSON array with one object per article, in exactly this format:
[
  {
    "id": <integer article id>,
    "label": "<one of the five labels>",
    "event": "<one sentence describing the supply event, or empty string if NOT_A_SHOCK>",
    "confidence": "<HIGH, MEDIUM, or LOW>"
  },
  ...
]

Return only the JSON array - no markdown fences, no preamble, no trailing text.
```

Stage 2 (surprise filter).

```
You are a financial economist assessing whether a Reuters news article reports a
surprise development in rare earth element (REE) supply, or whether it confirms,
repeats, or provides clarifying details on information that was already in the
public record at the time of publication.

This assessment is for an academic event study. The key question is whether equity
markets could have learned something new from this article on its publication date,
or whether the information had already been reported earlier.

The articles are fed to you in chronological order, from oldest to newest. Along with
```

```
the current article, you are given the earlier articles that have already been
processed. Judge the article against these earlier articles specifically: an event is
CLARIFYING if the information it conveys was already introduced in one of the
previously processed articles, and SURPRISE only if that information is not already
present in them. Do not rely on your own background knowledge of what was likely
reported - use only the articles provided.

## Definitions

SURPRISE - The article is the first reported instance of this specific development on
its publication date. Assign this if:
  - The article is an exclusive or first report of a new government action, ban, or
    licence issuance not previously reported
  - The event described was not telegraphed by prior reporting in the days before
  - The article reveals specific, actionable details (named companies, quantities,
    effective dates) that were not previously public
  - The action represents a surprise escalation or de-escalation

CLARIFYING - The article confirms, repeats, or provides clarifying details on something
a previous article already reported. Assign this if:
  - One of the earlier, already-processed articles already reported this same
    development, announcement, or licence issuance
  - The article confirms, officially announces, repeats, or provides follow-up detail
    on something already reported earlier (even by 1-2 days)
  - The event was widely anticipated based on prior signals described in the article
    itself (e.g. 'the move, which had been hinted at...')
  - The article is primarily analysis, context, or market reaction to a prior event
  - The action is a routine extension of an existing policy (not a new policy)
  - The article reports on an outcome that logically and predictably followed from
    a prior event within the last 1-2 weeks

## Output format

Return a JSON object in exactly this format:
{
  "classification": "SURPRISE" or "CLARIFYING",
  "confidence": "HIGH", "MEDIUM", or "LOW",
  "reason": "<one sentence explaining the key evidence from the article text>"
}

Return only the JSON object - no markdown fences, no preamble, no trailing text.
```

Stage 3 (origin and target).

```
You are classifying Reuters news articles about rare earth element (REE) supply shocks
for an academic event study. Each article you receive has ALREADY been determined to
report a genuine REE supply event (a government trade action, a mining/processing
disruption, or a new supply/production development). Do NOT re-judge whether it is a
shock. Classify it along two independent dimensions: TARGET and ORIGIN.
```

```
## Dimension 1 - TARGET: whose rare-earth supply position changes?

Identify the country/region whose ACCESS TO or COST OF rare earths is changed - i.e. the
CONSUMER / BENEFICIARY side, NEVER the producer or the country where a mine or plant
happens to be located.

Allowed values:
- US, Japan, Europe, Australia, Canada   (the five sample regions)
- world   - the event affects the global REE market roughly uniformly (all importers)
- other   - a specific country that is NOT a sample region and NOT global (e.g. South
            Korea, India, or China itself as a feedstock recipient)

Rules:
1. Tag the BENEFICIARY / AFFECTED CONSUMER, never the producer.
   - "Australian miner signs supply deal with a US firm" -> US (US gains supply), not
Australia.
   - "Japan's JOGMEC invests in a French REE project" -> Japan (Japan secures supply), not
Europe.
2. A restriction aimed at a specific country targets that country.
   - "China imposes export controls on Japanese firms" -> Japan.
   - "China retaliates against US tariffs with REE curbs" -> US.
3. A general restriction or easing that hits all importers -> world.
   - "China expands rare-earth export restrictions" (no single target) -> world.
   - "China issues streamlined export licenses" (broad) -> world.
4. ANY mine closure, production cut, accident, or disruption -> world (it tightens global
   supply regardless of where it happens).
5. New supply / production capacity:
   - with a named customer in a sample region -> that region (e.g. "supplies US magnet makers
" -> US);
   - with no named customer, or framed as meeting general/rising demand or domestic supply ->
 world;
   - with a customer OUTSIDE the five sample regions (e.g. Korean automakers) -> other.
6. If CHINA itself is the beneficiary (a foreign source resumes shipping feedstock TO China),
   classify as world - Chinese processing serves the global market, so easing China's input
   loosens global supply.
7. Use a single target where possible. Use "world" alone (do not also list specific regions).
   List multiple specific regions only if the article explicitly and equally names several.

## Dimension 2 - ORIGIN: where does the supply-relevant action come from?

China dominates REE mining and especially processing, so origin governs a shock's magnitude.
Assign EXACTLY ONE:
- China   - a Chinese government policy (export control, quota, licence, ban, easing) or a
            disruption to Chinese production/processing.
- Myanmar - a disruption to or change in Myanmar's REE output. Myanmar is a major heavy-REE
            feedstock source for Chinese processors, so a Myanmar disruption effectively cuts
            Chinese (hence global) output.
- other   - any other origin: a non-Chinese government's trade action (Namibia, Malaysia,
            Vietnam, ...) or a mine/processing/supply development located outside China and
```

```
            Myanmar (US, Australia, Europe, Canada, ...).

Origin = WHERE THE ACTION PHYSICALLY ORIGINATES (the policy-maker for trade actions; the
producer/territory for production events), NOT who benefits.
- "China lifts curbs on exports to India" -> origin China, target other (India).
- "Myanmar rebels allow REE exports to resume to China" -> origin Myanmar, target world.
- "MP Materials signs US supply deal" -> origin other (US producer), target US.

## Output

Return ONE JSON object, no markdown fences, no extra text:
{
  "targets": [one or more of "US","Japan","Europe","Australia","Canada","world","other"],
  "target_other_detail": "<non-sample country name if 'other' is used, else null>",
  "origin": "China" | "Myanmar" | "other",
  "origin_detail": "<the specific country/source of the action>",
  "reason": "<one sentence citing the key evidence from the article>"
}
```

B List of Rare Earth Supply Shock Events

Table B.1 lists the 59 high-confidence supply-shock events identified by the classification pipeline of Section 2.1, in chronological order. For each event I report the date, a one-line description of the underlying event (rather than the article headline), whether it is a trade or a production shock, and whether it is classified as a surprise or a clarification.

Table B.1: Rare earth supply shock events, 2021–2026

Date	Event	Type	Novelty
11/10/21	Greenland's parliament passed legislation banning uranium mining, halting development of the Kuannersuit rare earth project.	Production	Surprise
4/4/22	Iluka Resources commits to building Australia's first rare earths refinery at Eneabba with A$1 billion in government-backed debt, targeting production from 2025.	Production	Surprise
6/15/22	Lynas signed a $120 million follow-on contract with the U.S. Department of Defense to build a commercial heavy rare earths separation facility in Texas.	Production	Surprise
11/7/22	Arafura Rare Earths signs a binding supply deal with Hyundai and Kia to provide up to 1,500 tonnes/year of NdPr oxide from its Nolans project in Australia.	Production	Surprise

continued on next page

Table B.1 (continued)

Date	Event	Type	Novelty
4/17/23	Tanzania signed $667 million agreements with three Australian companies including Peak Rare Earths to develop rare earth and graphite projects.	Production	Surprise
6/8/23	Namibia banned the export of unprocessed rare earth minerals and other critical minerals including lithium, cobalt, and manganese.	Trade	Surprise
7/7/23	Neo Performance Materials begins construction of a rare earth permanent magnet manufacturing facility in Narva, Estonia.	Production	Surprise
9/7/23	Rare earth mines in Myanmar's Pangwa region were suspended starting Sept. 4 for inspections, disrupting feedstock supply to Chinese refineries.	Production	Surprise
9/11/23	Malaysia's Prime Minister announced plans to ban exports of rare earth raw materials to boost domestic processing.	Trade	Surprise
10/20/23	Lynas Rare Earths announced a temporary shutdown of most of its Malaysian operations in the December quarter for upgrades, reducing rare earth processing output.	Production	Surprise
12/21/23	China banned the export of technology to extract and separate rare earths.	Trade	Clarification
12/22/23	China banned the export of technology to manufacture rare earth magnets, adding it to existing bans on rare earth extraction and separation technology.	Trade	Surprise
6/29/24	China's State Council issued new rare earth regulations declaring REE resources state property and establishing a traceability system for mining, smelting and exports, effective Oct 1, 2024.	Trade	Surprise
10/23/24	Kachin Independence Army seized control of Panwa, a major Myanmar rare earth mining hub supplying China, likely disrupting REO shipments.	Production	Surprise
2/27/25	Russia's Rusal announced the launch of a scandium production facility this year at its Bogoslovsky Aluminium Plant, starting at 1.5 tonnes/year with capacity to scale to 19 tonnes/year.	Production	Surprise
3/17/25	Japan's JOGMEC and Iwatani to invest up to $120 million in France's Caremag rare earth refining project with offtake for half its dysprosium and terbium output.	Production	Clarification
3/27/25	Myanmar's KIA rebel group, which controls major rare earth mining areas in Kachin state, announces it will allow exports of stockpiled rare earths to China starting Thursday with a 35,000 yuan/ton tax.	Trade	Surprise
4/4/25	China announces export curbs on some rare earths as part of retaliation against US tariffs.	Trade	Surprise
4/10/25	China added seven rare earths (including dysprosium, terbium, samarium, yttrium) and rare earth magnets to its export control list amid escalating US trade war.	Trade	Clarification
4/11/25	Chinese rare earth exports of the seven controlled elements halted as of 4 April pending licenses, with sellers declaring force majeure.	Trade	Clarification
5/13/25	China agreed to lift export countermeasures issued after 2 April, including restrictions on rare earth minerals and magnets, as part of US-China tariff truce.	Trade	Clarification

continued on next page

Table B.1 (continued)

Date	Event	Type	Novelty
5/14/25	China issued the first rare earth magnet export permits since April restrictions, including to Volkswagen suppliers.	Trade	Surprise
6/5/25	China implemented a new national tracking system for rare earth magnets, requiring producers to submit trading volumes and client names, adding scrutiny on top of April export curbs.	Trade	Surprise
6/7/25	Trump says Xi agreed to let rare earth minerals and magnets flow to the US, and China granted temporary export licenses to rare-earth suppliers of the top three US automakers.	Trade	Surprise
6/11/25	U.S. and China announce a framework deal under which China will remove export restrictions and supply rare earths and magnets to the U.S.	Trade	Clarification
6/27/25	US and China reach agreement to expedite rare earth and magnet shipments to the US, resolving the dispute stalling the May deal.	Trade	Clarification
7/10/25	MP Materials announces a multibillion-dollar deal with the US DoD to build a new rare earth magnet factory boosting output to 10,000 metric tons per year, with DoD becoming its largest shareholder and guaranteeing a $110/kg price floor.	Production	Surprise
7/11/25	US Department of Defense signed a multibillion-dollar deal with MP Materials to become its largest shareholder and guarantee a $110/kg floor price to boost domestic rare earth magnet production.	Production	Clarification
8/18/25	Vulcan Elements signed a five-year supply deal with ReElement Technologies for thousands of metric tons annually of non-China rare earth oxides beginning 2026.	Production	Surprise
8/19/25	China lifted curbs on export of rare earth magnets to India, according to Indian media reports.	Trade	Surprise
8/22/25	China issued new measures bringing imported rare earth raw materials into its mining, smelting and separation quota system, further tightening supply controls.	Trade	Surprise
8/26/25	Critical Metals signed a 10-year agreement to supply up to 10,000 tonnes/year of heavy rare earth concentrate from Greenland's Tanbreez Project to Ucore's US government-funded Louisiana processing facility.	Production	Surprise
10/9/25	China adds holmium, erbium, thulium, europium, ytterbium and rare earth processing equipment to its export control list, requiring licences.	Trade	Surprise
10/27/25	Ramaco Resources announced a new US rare earth and critical mineral stockpiling and processing hub in Wyoming at its Brook Mine site.	Production	Surprise
10/29/25	Lynas announces new A$180 million heavy rare earth separation facility in Malaysia with 5,000 tpa capacity.	Production	Surprise
10/30/25	Japan's Sojitz begins first imports of heavy rare earths (dysprosium, terbium) from Lynas's Australian ore processed in Malaysia, concretely expanding non-China REE supply for Japan.	Production	Surprise
10/31/25	China agrees to pause for one year the latest rare earth and battery export controls announced since October as part of a US-China trade truce.	Trade	Clarification

continued on next page

Table B.1 (continued)

Date	Event	Type	Novelty
11/2/25	China agreed to a one-year pause on its newly announced rare earth export controls as part of the Trump-Xi trade deal reached in Busan.	Trade	Clarification
11/3/25	Vulcan Elements announced a partnership with the US government and ReElement Technologies, backed by $620M Pentagon loan and other financing, to build a 10,000-tonne rare earth magnet facility in North Carolina.	Production	Surprise
11/12/25	Solvay signed two supply agreements with US magnet makers Noveon and Permag for rare earth oxides from its French processing plant.	Production	Surprise
11/19/25	Vulcan Elements announced a $1 billion rare earth magnet manufacturing facility in Benson, North Carolina, partly funded by the Pentagon.	Production	Surprise
11/20/25	Malaysia suspended operations at MCRE Resources' rare earth mining site in Perak after river contamination and excessive radiation readings were detected.	Production	Surprise
11/25/25	Lynas Rare Earths warned of a one-month production shortfall this quarter due to power supply disruptions at its Kalgoorlie processing facility in Western Australia, affecting downstream output in Malaysia.	Production	Surprise
11/26/25	India approved an $816 million programme to establish domestic rare earth permanent magnet manufacturing capacity of 6,000 tons per annum.	Production	Surprise
12/2/25	China issued the first batch of new streamlined 'general licences' for rare earth exports, accelerating shipments to specific customers following the Trump-Xi summit.	Trade	Surprise
12/4/25	China announces it is issuing streamlined rare earth export licenses, easing earlier export controls following the Trump-Xi meeting.	Trade	Clarification
12/9/25	Critical Metals announced a joint venture with Romania's FPCU to build a rare earth processing facility in Romania using concentrates from its Tanbreez mine.	Production	Surprise
12/11/25	Vietnam's parliament approved a revised law restricting exports of refined rare earths and reaffirming its ban on rare earth ore exports.	Trade	Surprise
12/18/25	China's Commerce Ministry announced it has granted new general licenses for rare earth exports to streamline shipments.	Trade	Clarification
1/7/26	China bans exports of dual-use items, including certain rare earth elements, to Japanese military users effective immediately.	Trade	Surprise
1/9/26	China began restricting exports of heavy rare earths and magnets to Japanese companies following its dual-use export ban on Japan.	Trade	Surprise
1/15/26	Mkango's subsidiary HyProMag opened Britain's first commercial rare earth magnet recycling plant in Birmingham, with capacity of 100-300 tons per year.	Production	Surprise
1/26/26	US government to take 10% stake in USA Rare Earth as part of $1.6 billion package to develop Texas mine and Oklahoma magnet facility.	Production	Clarification

continued on next page

Table B.1 (continued)

Date	Event	Type	Novelty
1/29/26	Cyclic Materials announced an $82 million investment to build a rare-earth recycling campus in South Carolina, with initial capacity of 600 tonnes of MREO per year.	Production	Surprise
2/5/26	U.S. government agreed a $565 million financing package with Brazilian rare earths miner Serra Verde to refinance debt and expand production, with an option for a minority equity stake.	Production	Clarification
2/24/26	China prohibits export of dual-use items including rare earths to 20 Japanese entities tied to Japan's military.	Trade	Surprise
3/10/26	Lynas revamped its supply agreement with Japan Australia Rare Earths, locking in 5,000 tonnes/year of NdPr and 50% of its heavy rare earth output for Japan.	Production	Surprise
3/15/26	Lynas signs binding letter of intent with the US government for a four-year rare earth oxide supply deal worth ~$96 million with a floor price for NdPr oxide.	Production	Surprise
4/20/26	USA Rare Earth announced a $2.8 billion acquisition of Brazil's Serra Verde, gaining control of the heavy-rare-earth-rich Pela Ema mine.	Production	Surprise

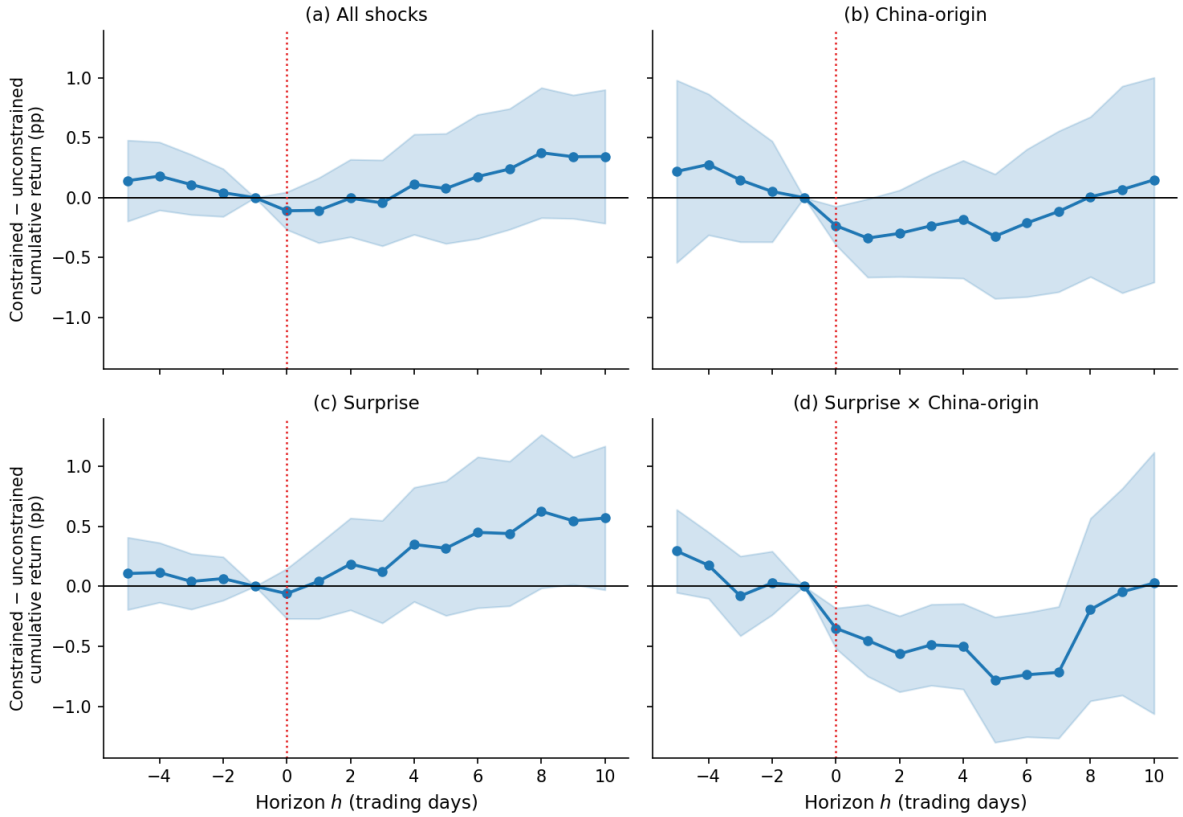
C Impulse Responses by Shock Set

Figure C.1 plots the differential impulse responses from Equation (1) for all four shock sets on a common scale: all high-confidence shocks, China-origin shocks only, surprise shocks only, and their intersection. Only the surprise, China-origin set (panel d) produces a response that is both large and persistent; the other three are statistically indistinguishable from zero across the window.

D Robustness: Fixed-Effects Structures

Table D.1 reports the differential coefficient β_h from Equation (1) on the surprise, China-origin set under three fixed-effects structures: country–event (the baseline), sector–event, and country–sector–event fixed effects. The estimate is stable across all three, confirming that the differential is not an artifact of the fixed-effects choice or of sector composition.

Figure C.1: Differential impulse responses by shock set



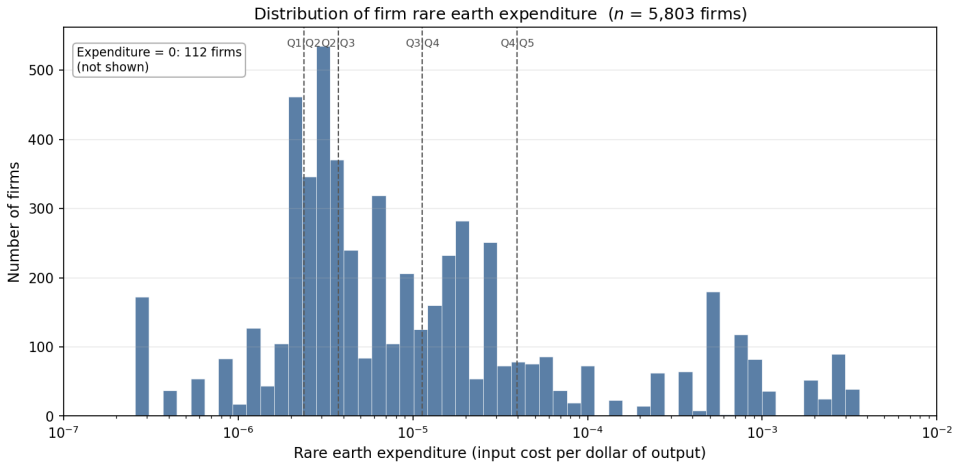
Notes: Each panel plots the differential coefficient β_h from Equation (1) estimated on the indicated shock set, in percentage points, with 95% confidence intervals (two-way clustered by firm and event) and a common vertical scale. Responses are normalized to zero at $h = -1$; the dashed line marks the event date ($h = 0$).

Table D.1: Differential response under alternative fixed-effects structures

Fixed effects	$h = 0$	$h = 1$	$h = 2$	$h = 3$	$h = 5$
Country–event (baseline)	-0.35***	-0.45***	-0.56***	-0.49***	-0.78***
	(0.09)	(0.15)	(0.16)	(0.17)	(0.27)
Sector–event	-0.39***	-0.52***	-0.51***	-0.43***	-0.84***
	(0.07)	(0.13)	(0.15)	(0.15)	(0.17)
Country–sector–event	-0.34***	-0.47***	-0.53***	-0.44***	-0.92***
	(0.08)	(0.15)	(0.14)	(0.16)	(0.20)

Notes: Differential coefficient β_h from Equation (1) on the surprise, China-origin set ($n_{ev} = 13$), under three fixed-effects structures, each in addition to firm fixed effects. Coefficients and standard errors are in percentage points, with standard errors in parentheses (two-way clustered by firm and event). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure E.1: Distribution of the rare earth expenditure across firms



Notes: Cross-firm distribution of rare earth expenditure (the value of rare earth inputs per dollar of output). The distribution is heavily right-skewed: most firms cluster near zero (median 6×10^{-6}), with a long upper tail reaching about 4×10^{-3}.

E Distribution of Rare Earth Expenditure

F Rare Earth Producers

Table F.1: Rare earth producers used in the validation

Firm	Producer type	Excerpt from annual filing
United States		
MP Materials	Miner; separation and processing; metals, alloys and magnets	"The Materials segment operates Mountain Pass, which produces refined rare earth oxides and related products as well as rare earth concentrate products. [...] The Magnetics segment operates the Independence Facility, where the Company began production of magnetic precursor products in December 2024" [Form 10-K, FY2024]
Energy Fuels	Separation and processing	"The Company is currently acquiring monazite from a third-party miner in Florida and Georgia, which it processes into RE Carbonate and separated REEs." [Form 10-K, FY2024]

Continued on next page

Table F.1, continued

Firm	Producer type	Excerpt from annual filing
Rare Element Resources	Developer	"We are currently focused on demonstrating the technical and economic feasibility of our proprietary processing and separation technology through the operation of a Demonstration Plant and advancing the Bear Lodge REE Project through permitting and licensing." [Form 10-K, FY2025]
USA Rare Earth	Developer; metals, alloys and magnets	"we plan to mine raw material from our deposit at Round Top in Sierra Blanca, Texas [...] In November 2025, we acquired Less Common Metals Ltd. ('Less Common Metals'), a proven ex-China producer of both light and heavy rare earth metals and alloys at scale." [Form 10-K, FY2025]
Critical Metals	Developer	"The Tanbreez Project, located in Southern Greenland, is a permitted, globally significant critical minerals asset positioned to unlock a sustainable, reliable and long-term rare earths supply for North America and Europe." [Form 20-F, FY2026]
Australia		
ABx Group	Developer	"Rare earths are a strategic focus for ABX Group, with the Company capitalising on its major discoveries in Tasmania as well as a series of commodity tailwinds." [Annual Report, FY2024]
Arafura Rare Earths	Developer	"The Nolans Project is on track to become Australia's first ore-to-oxide rare earths processing facility that will produce responsibly mined and processed NdPr." [Annual Report, FY2025]
Australian Strategic Materials	Metals, alloys and magnets; developer	"Our Korean Metals Plant (KMP), opened in 2022, is producing a range of light and heavy rare earth metals and alloys, addressing the increasing demand from manufacturers seeking alternatives to traditional supply sources." [Annual Report, FY2025]
Critica	Developer	"The Jupiter Project (Jupiter) is a high-grade, clay-hosted rare earths deposit located within the broader Brothers landholding." [Annual Report, FY2025]

Continued on next page

Table F.1, continued

Firm	Producer type	Excerpt from annual filing
Energy Transition Minerals	Developer	"Kvanefjeld is one of the world's largest undeveloped rare earth deposits, with a JORC-compliant Mineral Resource exceeding one billion tonnes." [Annual Report, FY2025]
Hastings Technology Metals	Developer	"Yangibana is now the most advanced rare earth project under construction and is ready to progress to plant construction." [Annual Report, FY2025]
Iluka Resources	Developer; separation and processing	"Via the company's development of Australia's first fully-integrated rare earths refinery at Eneabba in Western Australia, Iluka is set to become a globally material supplier of separated rare earth oxides." [Annual Report, FY2023]
Ionic Rare Earths	Recycler; developer	"The principal activity during the year of the Group was the completion of a feasibility study for the construction of a commercial magnet recycling plant at the 100% owned Ionic Technologies subsidiary in Belfast, UK" [Annual Report, FY2025]
Lynas Rare Earths	Miner; separation and processing	"The principal activities of the Group are: Integrated mining of Rare Earth minerals in Australia and minerals processing in Australia and Malaysia; and Development of Rare Earth deposits." [Annual Report, FY2024]
Northern Minerals	Developer	"During the year the principal continuing activities of Northern Minerals consisted of progressing the completion of a Definitive Feasibility Study (DFS) for a commercial-scale mining and processing operation at its Brown Range Heavy Rare Earth Project" [Annual Financial Statements, FY2025]
VHM	Developer	"VHM holds 100% of the flagship Goschen Rare Earth and Mineral Sands Project [...] The Project would involve the mining and processing of heavy mineral sands and rare earth minerals." [Annual Report, FY2025]
Canada		

Continued on next page

Table F.1, continued

Firm	Producer type	Excerpt from annual filing
Aclara Resources	Developer	"Aclara's flagship project is the Carina Project, a 9,863 ha HREE ionic clay project located in Nova Roma, Goiás, Brazil. The Company is also advancing the Penco Module, a 600 ha HREE ionic clay project located in Biobío, Chile." [Annual Information Form, FY2025]
Appia Rare Earths & Uranium	Developer	"Appia is a publicly traded Canadian company in the rare earth element and uranium sectors. The Company is currently focusing on delineating high-grade critical rare earth elements and gallium on the Alces Lake property" [MD&A, FY2025]
Avalon Advanced Materials	Developer	"The Company is advancing the Nechalacho Rare Earth Elements and Zirconium Project in the Northwest Territories, which contains all light and heavy rare earth elements" [Annual Information Form, FY2025]
Geomega Resources	Recycler	"The plant is designed to process NdFeB magnet feedstock and produce recycled rare earth oxides at a planned throughput of approximately 1.5 tonnes of feed material per day." [MD&A, FY2026]
Leading Edge Materials	Developer	"The portfolio of projects includes the 100% owned Woxna Graphite mine (Sweden), the 100% owned Norra Kärr Heavy Rare Earth Elements ('HREE') project (Sweden), and the 51% owned Bihor Sud Nickel Cobalt exploration project (Romania)." [MD&A, FY2025]
Mkango Resources	Recycler; metals, alloys and magnets; developer	"Mkango is focused on becoming a market leader in rare earth magnet recycling and manufacturing through its 79.4% owned subsidiary, Maginito. [...] Mkango owns the advanced-stage Songwe Hill Project in Malawi" [MD&A, FY2025]
Neo Performance Materials	Separation and processing; metals, alloys and magnets	"Neo is a vertically integrated rare earth magnetics company with separations, metal making and magnet making capabilities serving global customers." [Annual Information Form, FY2025]

Continued on next page

Table F.1, continued

Firm	Producer type	Excerpt from annual filing
Search Minerals	Developer	"Search is developing Critical Rare Earth Element ('CREE') mineral assets in south-east and central Labrador, Canada." [MD&A, FY2025]
Ucore Rare Metals	Separation and processing; developer	"The Company has commenced development of its first planned SMC in Louisiana, which is intended to serve as a commercial-scale rare earth separation and processing facility utilizing the Company's RapidSX™ technology." [MD&A, FY2025]

Notes: Producers of rare earths listed outside China in the five sample regions, identified from Asian Metal's rare earth industry map. Producer types: miners operate a producing rare earth mine; developers hold a rare earth deposit or project that is not yet in commercial production; separation and processing firms refine rare earth concentrate into oxides; recyclers recover rare earths from magnets or scrap; producers of metals, alloys and magnets make rare earth metals, alloys or magnets. Excerpts are verbatim from each firm's most recent annual filing (annual report, Form 10-K or 20-F, Annual Information Form, or Management's Discussion and Analysis); the fiscal year is in brackets and "[...]" marks omitted text.