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Global implications of export controls on rare earths: a model-based assessment

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Abstract

In April and in October 2025 China imposed export controls on rare earths amid escalating trade tensions with the United States. Although these measures were too short-lived to generate macroeconomic effects, they signalled China's ability to draw on its dominant position in the rare earth supply chain. This paper provides a structured assessment of the potential macroeconomic consequences associated with rare earth supply disruptions. First, it documents that exposure to rare earth supply disruptions is concentrated in high-tech and security-sensitive sectors including automotive, electronics and defence-related industries. Second, drawing on earlier episodes of Chinese export restrictions on critical minerals (notably in 2010 and 2023), it highlights two key mitigating forces from the targeted countries' perspective: practical and strategic constraints on China's ability to implement strict export bans, and innovation-led substitution by targeted countries. Third, the paper quantifies the global macroeconomic implications of a hypothetical scenario of stringent but partial Chinese export restrictions on rare earths lasting for 18 months. To do so, the analysis combines, for the various segments of the transmission chain, a partial equilibrium setup, a closed-economy DSGE model, and the multi-country multi-sector dynamic model of Aguilar et al. (2026). The main results, across specifications, suggest estimated output losses for the United States ranging between 0.3% and 0.6%, with the largest impacts concentrated in automotive and electronics manufacturing. The results at the same time highlight the sensitivity of model-based estimates to assumptions on the substitutability of rare earths and the severity of restrictions.

Keywords: export restrictions, critical minerals, supply chain, export ban, trade modelling

JEL codes: F13, F17, C63, C68, Q37

Non-technical summary

Rare earth elements (REEs) are essential inputs to many industries, and China's dominance over their supply chain has raised concerns about strategic dependencies, including for the euro area.

Although the global market for REEs is small, these materials are indispensable for producing key components such as the permanent magnets used in electric vehicles, renewable energy technologies, medical equipment and defence systems. China dominates critical stages of the REE supply chain, particularly refining and permanent magnet production, leaving many countries highly dependent on supply from the country. The short-lived export controls introduced in 2025 demonstrated how China's dominance can be leveraged as part of a broader geoeconomic strategy. Beyond raising prices, export restrictions can also serve as visible and immediate instruments of leverage in trade negotiations, signalling resolve and shaping bargaining positions. In April and October 2025 such controls coincided with renewed trade tensions and were widely interpreted as part of a negotiation dynamic between China and the United States.

This paper aims to fill an analytical gap by using a comprehensive set of models to assess the global implications of export restrictions on REEs.

Despite their criticality, the literature analysing the implications of export controls remains scarce and the few existing studies generally focus on narrow analytical approaches (e.g. partial equilibrium and static models) which do not capture the full macroeconomic consequences, including effects on inflation. To address this gap, this paper combines three complementary economic models. First, a partial equilibrium framework is used to estimate the impact on output, based on a stylised production function with limited substitutability for REE inputs. Second, a closed-economy DSGE model is employed to analyse broader effects on inflation and economic activity in the targeted economy. Finally, the state-of-the-art global multi-country multi-sector model of Aguilar et al. (2026) examines how export restrictions propagate internationally through global supply chains. To the best of our knowledge, this paper is the first to use such a combined modelling approach to quantify the macroeconomic impact of export controls on REEs.

The paper first examines how critical REEs are for the economy by analysing the REE supply chain and past episodes of Chinese export restrictions.

Although only a relatively small share of output directly depends on REEs, granular sectoral analysis reveals that several high-tech and defence-related sectors – such as semiconductors, automobiles, aircraft, military and medical equipment – are particularly exposed. Nevertheless, previous episodes of Chinese export restrictions on critical minerals (in 2010 and 2023) had limited macroeconomic impacts. This partly reflects the practical and strategic constraints that China faces in enforcing severe export bans, notably as a complete cut-off could accelerate substitution away from REEs and weaken China's leverage over time. At the same time, the threat of such measures can remain economically and geopolitically relevant even when their realised macroeconomic impact is limited.

Model simulations suggest that export restrictions on REEs would lead to supply-driven output losses and higher inflation in importing economies such as the United States and the euro area. We assess a hypothetical scenario of stringent but partial Chinese export restrictions lasting 18 months – a period long enough to exhaust western inventories but sufficiently limited and temporary to avoid permanent substitution. Under this scenario, US output is estimated to decline by around 0.3-0.6%, with the automotive and electronics sectors particularly affected. Inflationary pressures would arise in REE-importing countries as higher input costs and input shortages propagate through global supply chains. Model simulations also underscore that the outcomes are sensitive to the degree of substitutability and the severity of restrictions. Under more extreme scenarios (near-total export ban and low substitutability), losses are estimated to be around 2% – with such disproportionately larger losses illustrating the non-linear nature of the impact.

The economic impact would differ across countries, reflecting geopolitical alignment with China and exposure to REE-intensive industries. In the scenario considered, Chinese REE exports to geopolitically distant countries decline more strongly – in line with actual developments during the April-May 2025 restrictions. In addition, economies with large automotive and electronics sectors are particularly affected, as these industries rely heavily on REE inputs. A final important factor is the dependence on Chinese supply, which is particularly high in the United States (around 75% of total REE imports). For China, the results of the multi-country multi-sector model suggest that export restrictions generate short-term gains in domestic value added, as creating global scarcity makes it possible to capture part of the bottleneck rent. Nevertheless, at the global level, export restrictions lead to lower output and higher inflation.

Beyond its analytical contribution, this paper offers policy-relevant insights for economic security and supply chain resilience. First, it shows that strong dependence on rare earths creates strategic vulnerabilities concentrated in a small number of high-tech and security-sensitive industries where supply disruptions can lead to sizeable downstream output losses. Second, by comparing past export restrictions with hypothetical scenarios, the analysis shows that while severe and sustained bans are difficult to enforce, stringent but partial and temporary restrictions can still generate meaningful economic effects. Third, the results indicate that such restrictions can generate non-negligible output losses and inflationary pressures in importing economies, with the magnitude of the effects depending critically on substitution possibilities. Finally, the findings underscore the importance of timely policy responses, including inventory management, technological substitution and recycling, and international coordination to strengthen supply chain resilience.

1 Introduction

“The Middle East has oil; China has rare earths” – Deng Xiaoping

Rare earth elements (REEs) are critical inputs in a wide range of high-tech and security-sensitive applications. REEs are a set of minerals with unique properties that make them indispensable to produce advanced components in various industries, such as permanent magnets, catalysts and specialised alloys. These inputs feed into high-tech and security-sensitive sectors, including semiconductors, automotive, aerospace, defence and medical equipment. Although the global market value of REEs is relatively small (around USD 5 billion), their strategic importance is disproportionate because they are difficult to substitute and occupy an upstream position in many global value chains.

China’s dominance over the REE supply chain has increasingly raised concerns about strategic dependencies, including for the euro area. Over recent decades, China has established a leading position in key stages of the value chain, particularly in refining and permanent magnet production, leaving the rest of the world structurally dependent on Chinese supply.¹ In 2025 China imposed short-lived export controls on REEs, first on 4 April targeting seven heavy REEs, and subsequently on 9 October introducing additional licence requirements. While these episodes were too brief to generate significant macroeconomic effects, they illustrated China’s willingness to leverage its dominance in REEs as part of a broader geo-economic strategy.

Despite the criticality of REE inputs and rising geopolitical tensions, model-based assessments of export restrictions remain scarce. Existing analyses predominantly rely on partial equilibrium frameworks or empirical reduced-form approaches that can illustrate relevant transmission mechanisms but do not capture comprehensive macroeconomic effects (e.g. Fung and Korinek, 2013; Mancheri, 2015). While the literature has also turned to network-based static models (e.g. Alfaro et al., 2025), these can illustrate how disruptions reallocate trade flows and production globally but cannot capture the transmission dynamics, notably the impact on the nominal side.

Export controls should also be understood as strategic instruments in dynamic trade negotiations, rather than purely as revenue-raising or protectionist tools. When dominant suppliers possess substantial market power, price increases alone may be insufficient to achieve bargaining or signalling objectives. Administrative export restrictions are more visible, harder to circumvent, and generate immediate supply disruptions, allowing governments to exert leverage in bilateral relations. This was evident in April and October 2025, when China imposed rare earth export controls that effectively pressured the United States to

¹ In the mid-1980s China started implementing policies like export tax reimbursements, followed by a ban on foreign ownership in REE mining, smelting and separation projects. In the 2000s China emerged as the dominant player in REEs due to abundant mining reserves, low labour costs and lax environmental regulations.

return to negotiations, highlighting the role of critical mineral leverage in China's geoeconomic strategy. We treat such controls as exogenous and focus on quantifying their macroeconomic consequences in this strategic context.

This paper aims to fill this analytical gap by assembling a comprehensive modelling toolkit to assess the global implications of export restrictions on REEs. It employs three complementary models. First, a static partial equilibrium framework provides first-round output loss estimates, based on a stylised production function where substitutability between REEs and other inputs is limited. Then, a closed-economy DSGE embeds this production function into a New Keynesian environment, uncovering general equilibrium effects on inflation and activity in the targeted economy. Finally, the state-of-the-art multi-country multi-sector model of Aguilar et al. (2026) analyses the propagation of export controls through global input-output linkages, allowing for supply chain amplification across countries and sectors. To our knowledge, this paper is the first to employ such a complementary toolkit to quantify the macroeconomic impact of export controls on rare earths.

The paper first assesses the criticality of REEs based on analysis of the supply chain and past episodes of Chinese export restrictions on critical minerals. We establish a comprehensive mapping of industries exposed to REEs at a granular level. While only a limited share of output is directly reliant on REEs – between 4 and 7% in the United States – the sectoral analysis highlights that high-tech and defence-related sectors are especially vulnerable, notably semiconductors, automobiles, aircraft, military and medical equipment. We assess the implications of Chinese export restrictions in the light of past episodes (e.g. 2010 and 2023), which generated only modest macroeconomic impacts. These insights reflect, in particular, China's practical and strategic difficulties in enforcing more severe bans, as a complete cut-off of REEs could trigger large-scale substitution and erode the country's leverage over the medium term. At the same time, the possibility of targeted and temporary restrictions can remain economically and geopolitically relevant, by shaping expectations and bargaining positions even when their realised macroeconomic impact is contained.

Model simulations indicate that REE-importing economies such as the United States and the euro area would face a supply-driven contraction in output alongside inflationary pressures. We calibrate a scenario of stringent yet partial Chinese export restrictions lasting 18 months – long enough to exhaust western inventories, but sufficiently limited and temporary to avoid permanent substitution. Results from the three models consistently point to US output losses of between 0.3% and 0.6% under this scenario, with the automotive and electronics sectors among the most affected. Export controls also create inflationary pressures in both the United States and the euro area by raising upstream production costs and creating downstream product shortages. Model-based estimates are, however, sensitive to substitution elasticities and the severity of restrictions. Under a near-total export ban with very low substitution, US output losses could reach 2%, illustrating the non-linear nature of the shock.

Losses are heterogeneous across countries, depending on geopolitical distance to China and exposure to REE-intensive industries. In our scenario,

Chinese exports of REEs to geopolitically distant countries decline more strongly, consistent with developments following the April 2025 restrictions. Sectoral exposure, particularly to the automotive and electronics, is also a key determinant of how strongly an economy is affected. Another source of heterogeneous losses is reliance on Chinese imports, which is around 75% for the United States. On the Chinese side, simulations using the multi-country multi-sector model of Aguilar et al. (2026) point to short-run gains in value added, as China captures part of the scarcity-related rents created by the bottleneck. Nevertheless, at the global level, Chinese export restrictions would result in lower output and higher inflation.

Beyond its analytical contributions, the paper provides policy-relevant insights into economic security and supply chain resilience. First, it identifies that exposure to rare earth supply disruptions is highly concentrated in REE-intensive downstream sectors, notably automotive and electronics, despite the small aggregate cost share of REEs. Second, by contrasting past episodes with model-based scenarios, the analysis clarifies that while severe export bans face practical and strategic constraints, stringent but partial and temporary restrictions can still generate meaningful economic effects. Third, model simulations point to supply-driven output losses and cost-push inflation in importing economies, with estimated US output losses of 0.3–0.6% under the baseline scenario and strong sensitivity to substitution elasticities and the severity of restrictions. Finally, the findings underscore the importance of timely policy responses, including inventory management, technological substitution and recycling, and international coordination to strengthen supply chain resilience.

The rest of the paper is organised as follows: **Section 2** analyses the supply chain of REEs, reviews past episodes of Chinese export controls and discusses broader escalation risks beyond REEs. Based on these elements, it designs a plausible scenario of restrictions on REEs, which **Section 3** assesses within a static partial equilibrium framework. Expanding the modelling framework, **Section 4** provides a quantitative analysis of the macroeconomic transmission of export controls through a closed-economy DSGE. **Section 5** complements the analysis with the state-of-the-art New Keynesian multi-country multi-sector model of Aguilar et al. (2026). **Section 6** concludes.

2 Risks from supply disruptions in REEs

2.1 The REE supply chain

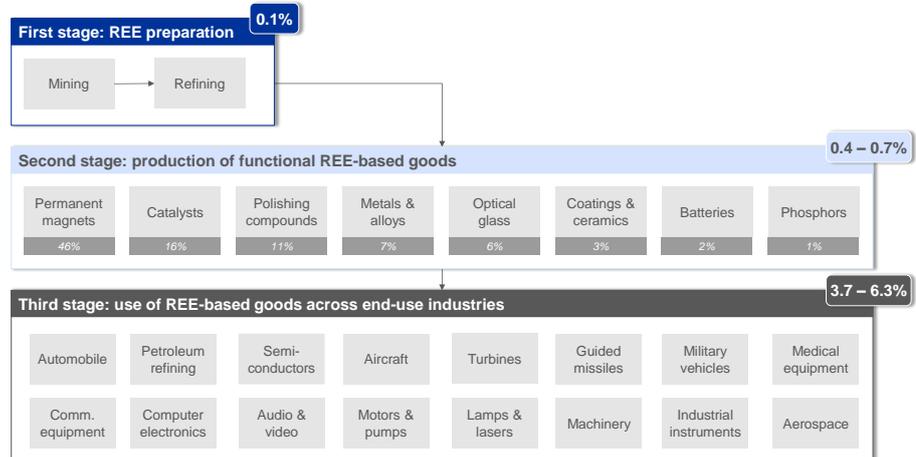
While sectors reliant on REEs account for a limited share of output, their strategic importance is disproportionately high. REEs are a group of 17 elements with unique magnetic, catalytic and luminescent properties.² Upon being mined and refined, they are used for advanced products such as permanent magnets (e.g. for electric vehicle motors, wind turbines and defence systems), catalysts (e.g. for petroleum refining), polishing powders (e.g. for semiconductor wafers), specialised optical glass (e.g. for lasers and night-vision systems) and high-performance alloys (e.g. for aerospace and defence). These REE-based products then feed into strategic sectors in high-tech and security-sensitive industries notably semiconductors, automotive, aerospace, defence and medical equipment. As applications typically involve tiny, but strategically essential, quantities of REEs, the output at risk in downstream industries is far larger than the value of the initial inputs (Chart 1). Overall, a granular sectoral analysis (Table A1 in the Appendix) point to sectors reliant on REEs accounting for 4-7% of US output.

Chart 1

Schematic view of the REE supply chain

(bubbles indicate percentage of total US output)

REEs supply chain and most-exposed industries



Sources: Alfaro et al. (2025), International Energy Agency (2025a; 2025b), U.S. Geological Survey (2025a), U.S. Department of Energy (2023), US Bureau of Economic Analysis, and authors.

Notes: Output shares based on NAICS six-digit industries. Lower bound values account for partial exposure; upper bound consider all sectoral output to be REE-reliant. See Table A1 in the Appendix for sectoral details. Values below "functional REE-based goods" indicate use shares in 2023 based on National Resources Canada (2025).

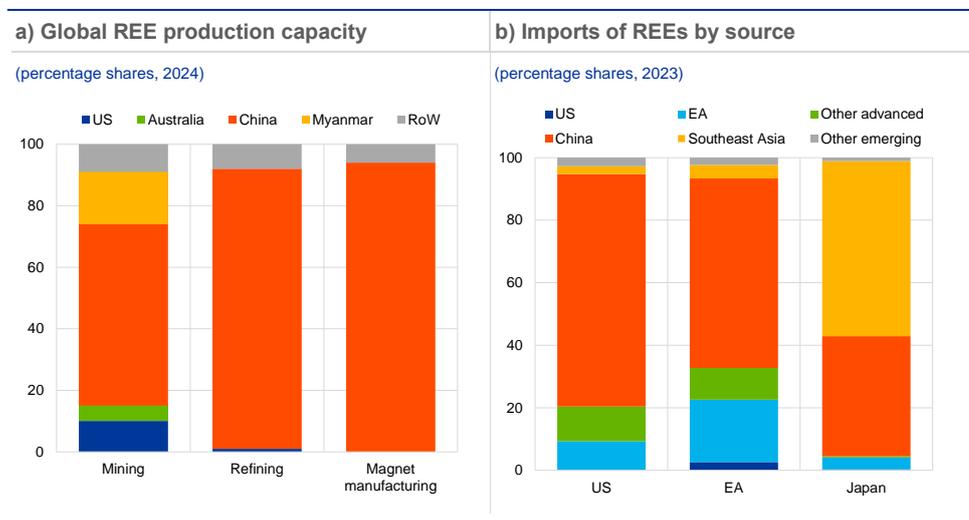
China dominates the REE value chain, making geographical substitution

highly challenging. Although REEs are relatively abundant in the earth's crust, they

² The 17 elements are scandium, yttrium and the lanthanides: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium.

do not occur as pure metals and require multi-stage processing that is technologically complex, costly and environmentally demanding (Balaram, 2019). China overwhelmingly dominates this critical midstream step, controlling 90% of global refining capacity (Chart 2, panel a). China has also built a significantly strong position in high-end products, holding more than 90% of global capacity for permanent magnets. As a result, while REE mining is geographically dispersed, even countries that have developed mining capacities generally remain reliant on China for refining (especially for heavy REEs like dysprosium and terbium).³ This creates indirect reliance on China despite efforts to diversify mining of REEs (Banin et al., 2025). Owing to its dominance over the REE supply chain, most western countries remain heavily reliant on China for imports of REEs (Chart 2, panel b).

Chart 2
China's footprint over the REE supply chain



Sources: International Energy Agency (2025b), BACI database and authors.

Notes: In panel a), "Mining" and "Refining" relate to magnet rare earths (neodymium, praseodymium, dysprosium, terbium) and "Magnet manufacturing" to neodymium-iron-boron permanent magnets. Panel b) is based on REE-related products identified in Georgitzikis (2023) and U.S. Geological Survey (2025b), namely HS six-digit codes 280530, 284610, 284690, 360690, and 850511.

Technological substitution to non-REE-based products, while feasible for some uses, is especially hard for cutting-edge applications (e.g. defence and high-tech). For certain applications such as polishing compounds or phosphors, REE-based materials can be more easily replaced as they require lower purity or can be substituted by alternative technologies (Ku et al., 2015). Likewise, some electric motors and turbine generators can use alternative ferrite or Al-Ni-Co (aluminium-

³ While Gros (2025) argues that the United States has a trade surplus of rare earth compounds with China (HS code 2846), these exports mainly consist of low-purity mixed rare earth carbonates and oxides, which are unsuitable for producing high-end products such as permanent magnets or catalysts that require high-purity, individually separated rare earth oxides for which the United States crucially depends on China (Rare Earth Exchanges, 2025). Refining is a complex process that involves several steps from ores, concentrates or mixed compounds (which the United States exports) to separated high-purity oxides (which China produces at scale). As these individual steps do not relate one-to-one to HS codes, this can make trade data misleading. As a result, while US exports can be used for low-purity applications such as glass polishing, they cannot replace China's output in products that require separated, high-purity individual REEs (e.g. magnets, catalysts). It should also be noted that producing functional magnets involves further steps of metallisation (converting oxides into metals), alloying (mixing metal with other elements), milling and pressing (cooling alloy into flakes or ingots, then crushing and milling into a very fine powder, pressed afterwards into the desired shape), sintering (heating a pressed block to fuse particles together and create dense magnet material), and finishing (where the material is machined to precise dimensions, coated and magnetised).

nickel-cobalt) magnets, although often with efficiency losses and bulkier design. Several carmakers have already reduced the use of REEs in new motors (International Energy Agency, 2021; Gielen and Lyons, 2022).⁴ But stronger magnets like neodymium-iron-boron or samarium-cobalt remain indispensable for high-end applications (e.g. fighter jets, aerospace gyros, MRI machines, specialised lasers), as no alternatives match their high energy density and heat resistance. Importantly, the supply of samarium can be severely constrained, given China's near monopoly.

2.2 Past episodes of export restrictions on critical minerals

Previous Chinese export restrictions on REEs or critical raw materials had modest macroeconomic effects. In September 2010 China reportedly halted exports of REEs to Japan – then the largest importer of them and reliant on the country for 80-90% of its supply. Despite global REE prices surging and localised disruptions, macroeconomic effects were assessed to be negligible, and the episode was dubbed “*the crisis ... that wasn't*” (Gholz, 2014). Similarly, the Chinese restrictions on exports of gallium and germanium to the United States since July 2023 did not materially affect US consumption of the minerals over 2023-2024. In April 2025 export restrictions significantly dented Chinese exports and increased prices of targeted rare earths (Chart 3, panel a), with some carmakers reportedly forced to cut utilisation rates or temporarily shut down factories.⁵ Yet global supply chain pressures remained contained over that period, including for industries more exposed to REEs (Chart 3, panel b), partly because restrictions applied for only two months, after which Chinese REE exports recovered. A similar pattern emerged in early 2026, when Chinese restrictions on dual-use exports to Japan caused localised price spikes and temporary production pauses for major automakers, without triggering broader and persistent supply chain disruptions.

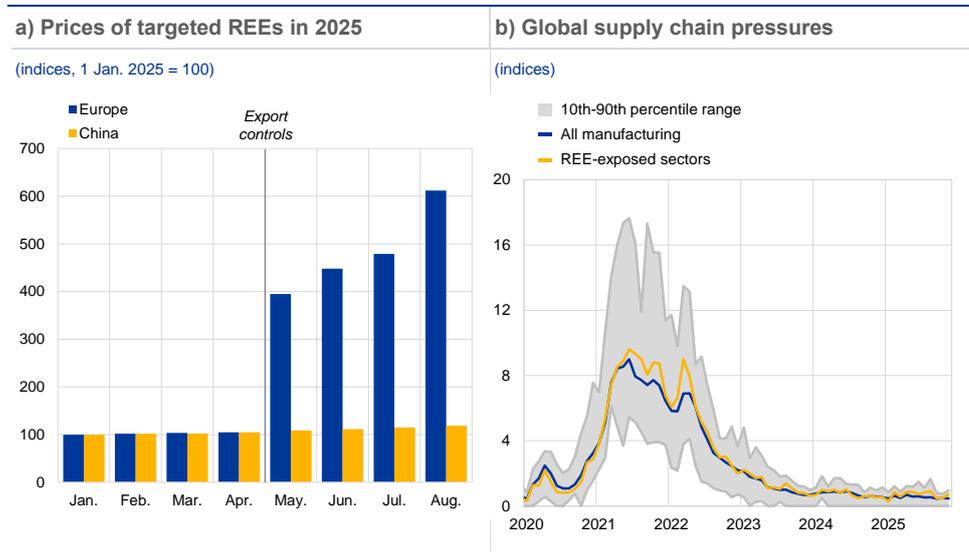
The limited impacts of previous episodes highlight mitigating factors, notably the difficulty for China to implement severe bans, trade re-routing, innovation-led substitution and policy responses. Even under purported export bans, REE flows between China and the targeted countries continued (Evenett and Fritz, 2023). Reasons include endemic smuggling, China's own strategic interest in avoiding large-scale substitution, and the fact that restrictions were not outright bans but rather exports controls (Godek, 2023; Nguemgaing et al., 2025). In addition, during the Chinese ban on gallium and germanium exports to the United States, trade re-routing via third countries was a key factor in preserving US consumption of these

⁴ This includes the world's two largest automakers, Toyota and Volkswagen, moving to scale down or eliminate the use of REE-based magnets in their EVs, with Nissan and BMW doing the same for some new models (Reuters, 2021). Renault and Tesla are also reported to have eliminated REE-based magnets from some models (Gielen and Lyons, 2022). More recently, BMW unveiled a production-ready motor for electric vehicles without rare earths (Bork, 2025). For a recent overview of substitution to REE-free motors, please see Rangarajan et al. (2025). For an overview including wind turbines and lighting, in addition to electric vehicles, see Pavel et al. (2016).

⁵ Ford reported the shutdown of a factory (CBS News, 2025) and Suzuki halted the production of its Swift model (Reuters, 2025a). In India, Maruti-Suzuki reported a cut in production goals (The Times of India, 2025) while Bajaj Auto mentioned a possible “zero month” in August (The Economic Times, 2025).

minerals (Godek, 2025). A third mitigating factor comes from the literature on directed technological change which posits that when a hard-to-substitute input becomes scarce, R&D efforts increase the efficiency of that input, reduce its usage, or substitute it entirely (e.g. Acemoglu, 2002; Aghion et al., 2016). Alfaro et al. (2025) showed how this channel might have been at play for Japan in 2010. While innovation is typically a medium-to-long-term channel, Japanese firms adjusted in the short run by speeding up application of innovations already developed, recycling REEs and stopping use of them in less valuable goods (Gholz and Hughes, 2021). Finally, Japanese authorities mitigated the 2010 shock with an emergency programme to secure alternative sourcing and stockpile REEs, a strategy that has remained relevant in 2026.⁶ These episodes illustrate how export controls can be used as a source of strategic leverage even when aggregate macroeconomic effects remain limited.

Chart 3
REE prices and supply chain constraints



Sources: International Energy Agency (2025a), Bloomberg, Wood Mackenzie, S&P Global and authors.
Notes: Panel a) is based on the average price for dysprosium, terbium and yttrium. In panel b) values above one indicate supply chain pressures tighter than in normal times. "REE-exposed sectors" include chemicals, electrical items, semiconductors, aluminium, steel and stainless steel. The 10th-90th percentile range is based on 20 industries.

2.3 Hypothetical scenario: a partial Chinese export ban on REEs

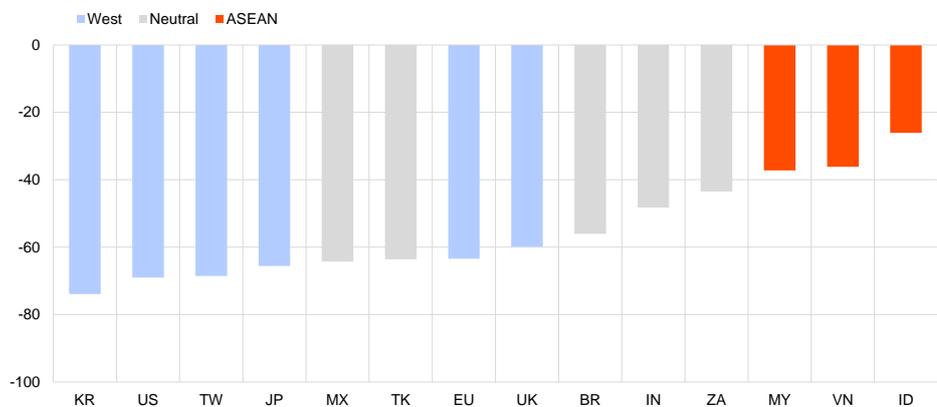
Against this background, we calibrate an adverse scenario of stringent yet partial Chinese export restrictions on REEs. We posit that China targets not only ores, but also oxides and REE-based products like alloys and permanent magnets. We calibrate the magnitude of the supply shock to be the average decline in Chinese exports over April-May 2025 (Chart 4). Such partial restrictions are consistent with

⁶ During the January 2026 escalation of China-Japan trade frictions involving restrictions on selected dual-use rare earths and magnets, Japan's existing inventories and diversified sourcing, including from Central Asia, helped soften immediate supply chain disruptions and prompted firms to accelerate deep-sea mining and broader diversification efforts.

controls that meaningfully restrict supply, but abide by China’s strategic objectives of limiting long-term substitution and shielding close partners like Vietnam or Malaysia.⁷ The risk for China is that an export ban on REEs could resemble a “*one-shot bazooka*” (Clarke, 2025) with too stringent restrictions prompting a permanent supply chain diversification away from China over the medium term. In our scenario calibration, we also constrain non-Chinese supply of REEs to reflect its dominance in refining and the hypothetical application of export controls on foreign-made goods containing Chinese REEs, as enacted in October 2025.

Chart 4
Decline in Chinese REE exports

(percent, April-May 2025 average compared to 2024 average)



Source: Trade Data Monitor.

Notes: Based on Chinese customs data on exports: reported declines for imports in targeted countries are generally much smaller (e.g. -37% in US import data versus -69% in Chinese export data). Based on main products targeted by Chinese export restrictions in April 2025 (HS codes 280530, 284690 and 850511 at six-digit level). Relates to nominal trade. Country allocation (West and Neutral) is based on Attinasi et al. (2024).

We calibrate export controls to last for 18 months: long enough to deplete inventories, but short enough to avoid large-scale substitution. Duration is key: restrictions need to persist long enough to deplete stockpiles, but they also have to remain temporary to discourage structural substitution and retain leverage over the medium term. Blakemore et al. (2025) assess US private inventories of REEs to be able to cover only a few months – consistent with press reports of REE inventories across western economies being sufficient for two to three months (Reuters, 2025b) and up to three to six months (Financial Times, 2025). On substitution, Blakemore et al. (2025) estimate that after two to five years, mining, refining and recycling capacity would expand globally, making the supply chain less dependent on China.⁸ Around two years also appears to be the minimum time needed to develop REE-free substitutes: for example, Hitachi unveiled an REE-free motor and Aichi a

⁷ More pragmatically, the presence of Chinese-owned firms in ASEAN countries is likely to limit the extent of restrictions on export to these destinations.

⁸ Expanding capacity might take longer; the International Energy Agency (2025b) reports a lead time of eight years for new mining projects. In the same vein, Struyven et al. (2025) estimate that new refining projects take around five years to ramp up production. Moreover, fully substituting away from China would be challenging because known reserves of heavy REEs are scarce outside Myanmar and China and refining demands advanced technology and expertise currently concentrated in China.

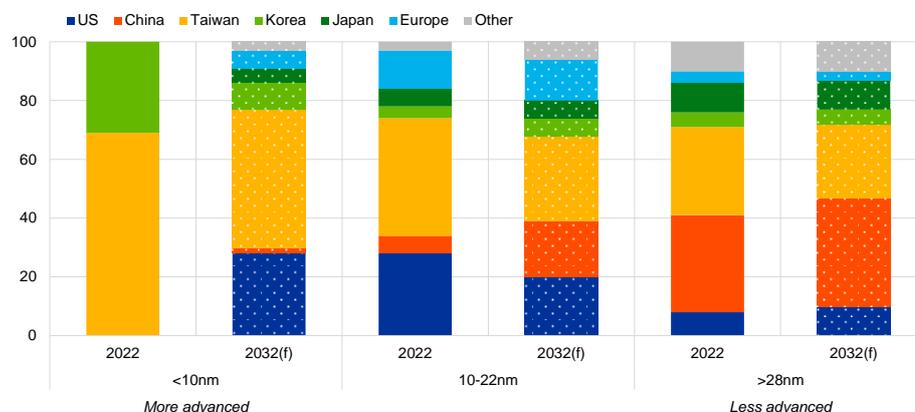
dysprosium-free magnet in 2012 – roughly two years after the Chinese restrictions on exports to Japan. We assume restrictions will last 18 months.

2.4 Escalation risks beyond REEs

Export controls on REEs are likely to unfold within a broader escalation of trade tensions between China and the United States. In such a context, REEs could become a strategic instrument in an intensifying tit-for-tat dynamic shaped by structural factors, including the increasingly tariff-centric and transactional nature of US trade policy, persistent industrial overcapacity in China and the ongoing technological race. A further escalation of the geopolitical stand-off between the United States and China could deepen global supply chain fragmentation and amplify the associated economic fallout (Jouvanceau et al., 2025). Beyond the United States, Chinese restrictions on exports of REEs to the rest of the world could also risk triggering retaliatory measures from other major economies, raising the prospect of a wider trade fragmentation scenario extending beyond minerals (Attinasi et al., 2024).

Chart 5
Global semiconductor capacity

(percentage shares)



Sources: Boston Consulting Group, Semiconductor Industry Association, and authors.

Notes: Data for logic chips only (memory chips, also subject to US export restrictions, are omitted). Nanometre (nm) refers to the process node and indicates the size of the smallest features in a chip; smaller nodes typically enable higher performance, energy efficiency and transistor density.

In particular, the United States could retaliate by tightening export controls on semiconductors, although the macroeconomic impact of such measures would likely remain limited. While China dominates upstream REE inputs in the high-tech value chain, the United States retains leverage downstream through restrictions on advanced chips and key manufacturing equipment. These effects would be magnified if joined by other countries, such as Japan and the Netherlands,

which currently apply narrower controls.⁹ Stricter measures could further delay Chinese semiconductor production, raise costs and restrict access to cutting-edge technologies. China's reliance on foreign tools remains significant, as it currently produces no advanced chips (<10nm) and is projected to reach a modest 2% global share by 2032 (Chart 5). Even so, existing estimates suggest that the broader macroeconomic impact of tighter semiconductor export controls would remain small – below 0.1% in a partial equilibrium model, in line with Loo and Samp (2023).¹⁰ In addition, tighter US restrictions are likely to accelerate Chinese investment in domestic technological capabilities.

⁹ Several factors could limit this possibility, including foreign firms' reliance on the Chinese market, China's strength in mature chip production (>28nm) and supply chain vulnerabilities in the West – as illustrated by the Nexperia episode, which triggered chip shortages in the EU. This saw the Dutch government intervene in the Chinese-owned chipmaker in September 2025 – an action followed by Chinese export restrictions on Nexperia semiconductors produced in China. The measures disrupted supplies of mature node components critical to Europe's automotive sector and were paused in November 2025 amid concerns about escalating potential production shutdowns.

¹⁰ The model is a partial equilibrium model as in [Section 3](#). The elasticity of substitution between semiconductors and other inputs is 0.75, based on Petterson (2025). The expenditure share of semiconductors is calibrated using Chinese import reliance for semiconductors from Goujon et al. (2024), the share of semiconductors in Chinese imports of electronics (based on granular trade BACI data), and the share of electronics in expenditures (based on OECD input-output tables).

3 Criticality of REE inputs in a partial equilibrium framework

3.1 Model description and calibration

The first model is a static partial equilibrium framework based on a single non-linear production function. The model is a constant elasticity of substitution (CES) production function as in the equation below, where output Y is produced with two factors: REEs (R) and all other inputs (X). This stylised framework depends on two key parameters: the elasticity of substitution between REEs and other inputs (σ), and the expenditure share of REEs (α). The latter is calibrated using the net import reliance of the United States for REEs (U.S. Geological Survey, 2025c), the share of REEs in total imports (based on granular BACI trade data), and the share of imports in expenditures (based on OECD input-output tables). The value obtained (0.0003) is consistent with the estimates of Alfaro et al. (2025). The elasticity of substitution is based on short-term elasticities of Shojaeddini et al. (2025), who provide estimates for individual elements.¹¹

$$Y = \left[\alpha^{\frac{1}{\sigma}} R^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}} X^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

While highly stylised, this framework is common in the literature to assess the impact of supply disruptions on production. The CES specification captures input substitutability between production factors in a parsimonious way, allowing for closed form and easily computable output loss estimates. The ability of this setup to provide credible first-order approximations of the impact of disruptions was the main argument supporting its use in Bachmann et al. (2024) on the impact of Russian gas disruptions in 2022. Likewise, Borin et al. (2023) applied the same framework to assess the impact of western sanctions on Russia. Very close to our focus, Panon et al. (2024) employ a similar partial equilibrium model based on a single production function to evaluate output losses that could arise following disruptions to the supply of critical inputs from China.

¹¹ While the elasticities of substitution required for our calibration are conceptually distinct from the demand elasticities in Shojaeddini et al. (2025), we rely on their results for two reasons. First, in the constant elasticity frameworks commonly used in trade modelling, the price elasticity of demand provides a direct and empirically grounded approximation for the elasticity of substitution across varieties. Second, Shojaeddini et al. (2025) deliver sector-level elasticities estimated on granular, high-frequency data capturing firms' responses to price changes – precisely the type of behavioural margin relevant for substitution across suppliers or technologies. Their empirical estimates therefore offer a suitable and internally consistent benchmark for our model, in the absence of equally granular micro-evidence specifically estimating substitution elasticities.

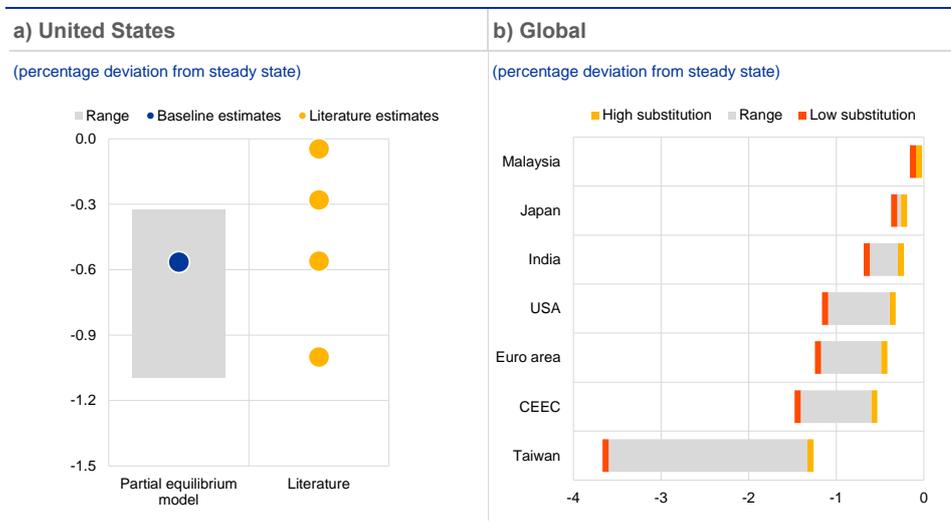
3.2 Static output losses

The static partial equilibrium model points to US output losses of around 0.6%, with some sensitivity depending on the elasticity of substitution. Calibrating the model using elasticities of substitution from Shojaeddini et al. (2025) yields a baseline estimate around 0.6% – broadly in line with the literature (Chart 6, panel a). Qualitatively, the impact is also in line with the findings of Attinasi et al. (2025a), where supply disruptions to tiny but strategically essential inputs create output losses that are disproportionately larger than the initial value of inputs. Nevertheless, the range around this estimate highlights the high sensitivity of outcomes to the elasticity of substitution, reflecting the dependence of the economic impact on how easily firms can adjust their production lines when REEs become scarce.

Across countries, heterogenous impacts arise from differences in geopolitical alignment with China, sectoral exposure and import reliance on China. First, Chinese REE exports to geopolitically distant countries are assumed to decline more than those to close countries like Malaysia – in line with the April-May 2025 episode. A second factor is the share of exposed industries, notably automotive and electronics, which explains why Taiwan would face higher output losses. Finally, the impact reflects import reliance on China, with the United States more vulnerable than Japan, which has reduced its dependence since the 2010 episode (Chart 6, panel b).

Chart 6

Output losses based on static partial equilibrium model (partial export ban)



Source: authors.

Notes: The range is obtained by varying substitution elasticities around the weighted average of Shojaeddini et al. (2025) at 0.10, which is used for "Baseline estimates" in panel a). In panel a), "Literature" relates to Struyven et al. (2025), short-term estimates of Alfaro et al. (2025), Loo (2025), and U.S. Geological Survey (2025a). In panel b), "CEEC" refers to central and eastern European countries (Bulgaria, Czech Republic, Hungary, Poland, Romania).

4 Macroeconomic transmission in a closed-economy DSGE

4.1 Model description and calibration

Our second model is a closed-economy New Keynesian (NK) DSGE framework that uncovers the general equilibrium effects of REE supply disruptions. We embed a two-sector production structure in an NK model – akin to Basu et al. (2012) – including an REE-intensive sector that depends critically on REE inputs (see **Box 1**). Aggregate outcomes are shaped by a household sector that smooths consumption and supplies labour, two production sectors, and a central bank committed to stabilising inflation through a Taylor rule. Firms face Rotemberg price adjustment costs, creating sticky prices that transmit marginal cost increases into gradual inflation. The rest-of-economy sector, which uses only labour, is not directly affected by disruptions to REEs, but reacts indirectly via general equilibrium dynamics.

This model assesses the macroeconomic transmission of Chinese export restrictions to the US economy. We calibrate the model using the empirical foundations from Section 2 – setting the share of REE-exposed output at 7% and the REE share in the composite input at 1% (Chart 1). The substitution elasticity is set at 0.10, consistent with the low short-run substitutability documented by Shojaeddini et al. (2025), making this sector highly sensitive to REE supply restrictions. We assume households consume a fixed real share of goods from the REE-intensive sector, meaning they cannot substitute across sectors in response to relative price fluctuations. This assumption captures the criticality of REE-intensive goods in the short run – consistent with limited alternatives for producing final goods that require REE – and implies that the sectoral supply shock cannot be fully absorbed by a shift in consumer demand. Instead, adjustment falls on production, prices and economy-wide demand conditions through monetary policy transmission.

Box 1

Quantifying the macroeconomic impact of REE supply restrictions

Prepared by Valentin Jouvanceau

This box quantifies the macroeconomic impact on the United States of Chinese restrictions on supply of REEs using a stylised two-sector New Keynesian (NK) DSGE model. From a macroeconomic perspective, the key question is not whether REEs matter for strategic industries – this is well established – but whether plausible disruptions to REE access can generate meaningful movements in aggregate inflation and output.

Recent assessments by US policy institutions underline the potential macroeconomic relevance of REE disruptions. U.S. Geological Survey (2025a), which evaluates more than 1,200 trade-disruption scenarios, reports probability-weighted changes in US GDP and finds that several

rare earth elements rank among the largest sources of potential losses. In particular, samarium is associated with an estimated GDP loss of nearly USD 4.5 billion in Chinese disruption scenarios.¹²

The existing literature provides limited guidance on the general equilibrium implications of export restrictions in the presence of nominal rigidities and monetary policy. Policy-oriented and trade-focused studies analyse export controls as industrial policy instruments and their effects on raw material markets and global supply (Fung and Korinek, 2013; Mancheri, 2015), while recent work on REE supply chains highlights directed technological change and reallocation responses (Alfaro et al., 2025). The engineering and energy transition literatures document potential pathways for reducing reliance on REEs, but emphasise that high-performance applications often face limited short-run substitutes (Gielen and Lyons, 2022; Widmer et al., 2024), a finding supported by evidence of increasing price inelasticity in critical mineral demand (Shojaeddini et al., 2024). Models of production networks show that strong complementarities and low substitution elasticities can amplify sectoral bottlenecks into sizeable aggregate effects (Jones, 2011; Baqaee and Farhi, 2019). However, for REEs, it remains relatively less quantified how these cost pressures interact with nominal rigidities and monetary policy to shape inflation and output dynamics.

Three empirical facts guide the design and calibration of the stylised DSGE model. First, rare earth use is concentrated in a narrow set of strategically important intermediate goods, including permanent magnets, catalysts, specialised alloys and optical components used in semiconductors, automotive manufacturing, and aerospace and defence. Second, while physical quantities and cost shares are small, downstream activity is large relative to the initial raw material input, with around 4-7% of US output relying on REE-intensive production (Table A1; Chart 1). Third, the scope for short-run technological substitution is limited, with recent evidence pointing to a substitution elasticity of around 0.10.¹³ These features discipline both the size and rigidity of the REE-intensive sector. The full calibration is reported in Table A2 in the Appendix.

The REE export restriction scenarios are calibrated based on import dependence, recent trade developments and historical precedent. The United States remains highly reliant on Chinese REE imports (Chart 2), and the sharp but partial export contractions observed in April-May 2025 illustrate both the feasibility and limits of such measures. Persistent bottlenecks in refining and separation further constrain short-run supply reorientation. Taken together, these factors motivate a calibration corresponding to a 50% effective decline in US REE availability, reflecting the combined impact of export controls and midstream bottlenecks.¹⁴

¹² Several other middle and heavy rare earth elements also rank among the largest probability-weighted GDP losses, including lutetium (USD 2.1 billion), terbium (USD 1.8 billion), dysprosium (USD 1.6 billion), gadolinium (USD 758 million) and yttrium (USD 295 million), reflecting the near-complete lack of production outside China (U.S. Geological Survey, 2025a).

¹³ Short-run substitution away from rare earths is limited in high-performance applications. While some uses can adjust designs or reduce material intensity, key applications – especially permanent magnets – have few near-term alternatives without significant performance losses (Gielen and Lyons, 2022; Widmer et al., 2024). Consistent with this, recent evidence points to very low substitution elasticities, with a weighted-average estimate of around 0.10 for REEs (Shojaeddini et al., 2025).

¹⁴ Bilateral exposure is quantified using product-level BACI trade data (Gaulier and Zignago, 2010). In April-May 2025, Chinese REE exports to the United States contracted sharply but did not cease, consistent with partial export controls rather than a full embargo. Similar patterns were observed in earlier episodes (Gholz, 2014). Partial restrictions can impose substantial costs, while limiting incentives for rapid substitution and reshoring that would erode leverage (Nguemgaing et al., 2025). An additional constraint arises at the refining stage: even when mining is geographically diversified, separation and purification capacity remains highly concentrated, creating a midstream bottleneck that limits short-run supply reorientation (International Energy Agency, 2025a, 2025b).

The macroeconomic effects of REE supply disruptions are assessed using a two-sector New Keynesian DSGE model. The economy produces a final good in a labour-only sector O and an REE-intensive sector S , whose output share is calibrated to 7% to match empirical exposure. Aggregate variables are Cobb-Douglas composites of sectoral counterparts, and sectoral consumption shares are assumed fixed to focus on supply-side propagation, consistent with limited alternatives for producing final goods that require REE. Households have standard CRRA preferences, firms are monopolistic competitors with Rotemberg price adjustment costs, and monetary policy follows a Taylor rule responding to aggregate inflation with a muted coefficient, reflecting appropriate restraint given the supply-driven nature of the shock (Hofmann et al. 2024).

The REE channel enters entirely through the CES production structure of sector S , which combines labour with a composite intermediate input M_t defined as:

$$M_t = \left[\alpha^{\frac{1}{\sigma_R}} R_t^{\frac{\sigma_R-1}{\sigma_R}} + (1-\alpha)^{\frac{1}{\sigma_R}} X_t^{\frac{\sigma_R-1}{\sigma_R}} \right]^{\frac{\sigma_R}{\sigma_R-1}}$$

where R_t denotes REE inputs, X_t non-REE inputs, α the REE share, and σ_R the elasticity of substitution. The associated unit cost is:

$$p_t^M = \left[\alpha p_t^R^{1-\sigma_R} + (1-\alpha) p_t^X^{1-\sigma_R} \right]^{\frac{1}{1-\sigma_R}}$$

Export controls are modelled as an exogenous increase in p_t^R , calibrated to induce a 50% reduction in REE use given low substitutability. This reduced-form wedge transmits supply constraints directly to marginal costs, inflation and monetary policy.

The model is calibrated to reflect low substitutability, persistent shocks and observed trade dependencies. The REE share α is set to 1%, consistent with evidence that rare earths account for a small fraction of material inputs despite their critical role, while substitution elasticity $\sigma_R = 0.10$ reflects the limited short-run substitutability documented in the literature (Shojaeddini et al. 2025). The shock follows an AR(1) process to capture persistence, reflecting the fact that export controls can remain binding over multiple quarters. Overall, the calibration aligns the model with observed trade dependencies and recent policy signals, while the propagation mechanism is consistent with the macroeconomic literature on sectoral shocks and limited substitution, ensuring that the simulated disruption and its transmission are empirically grounded.

A large REE supply shock generates strong sectoral inflation but limited aggregate effects.

In the baseline calibration ($s_Y = 7\%$, $\alpha = 1\%$, $\sigma_R = 0.10$), the shadow price wedge required to reduce R_t by 50% is large, close to 500%, reflecting near-Leontief complementarity at low substitution elasticity σ_R (Chart A, black solid lines). This wedge raises the composite input cost p_t^M by 5% on impact. As the composite enters sector S 's marginal cost with a non-trivial weight, sectoral marginal costs increase by approximately 2.5%, generating a 2 percentage point rise in year-on-year inflation in sector S on impact, which continues to build over the first year owing to price rigidities. Aggregation dampens the CPI response. With the REE-intensive sector accounting for only 7% of the consumption basket, aggregate year-on-year inflation rises by about 0.2 percentage points after one year. This triggers a persistent monetary tightening of roughly 0.2 percentage points (annualised) and aggregate output growth declines by around 0.2 percentage points on impact, reflecting both the direct contraction in sector S and indirect spillovers through tighter monetary policy.

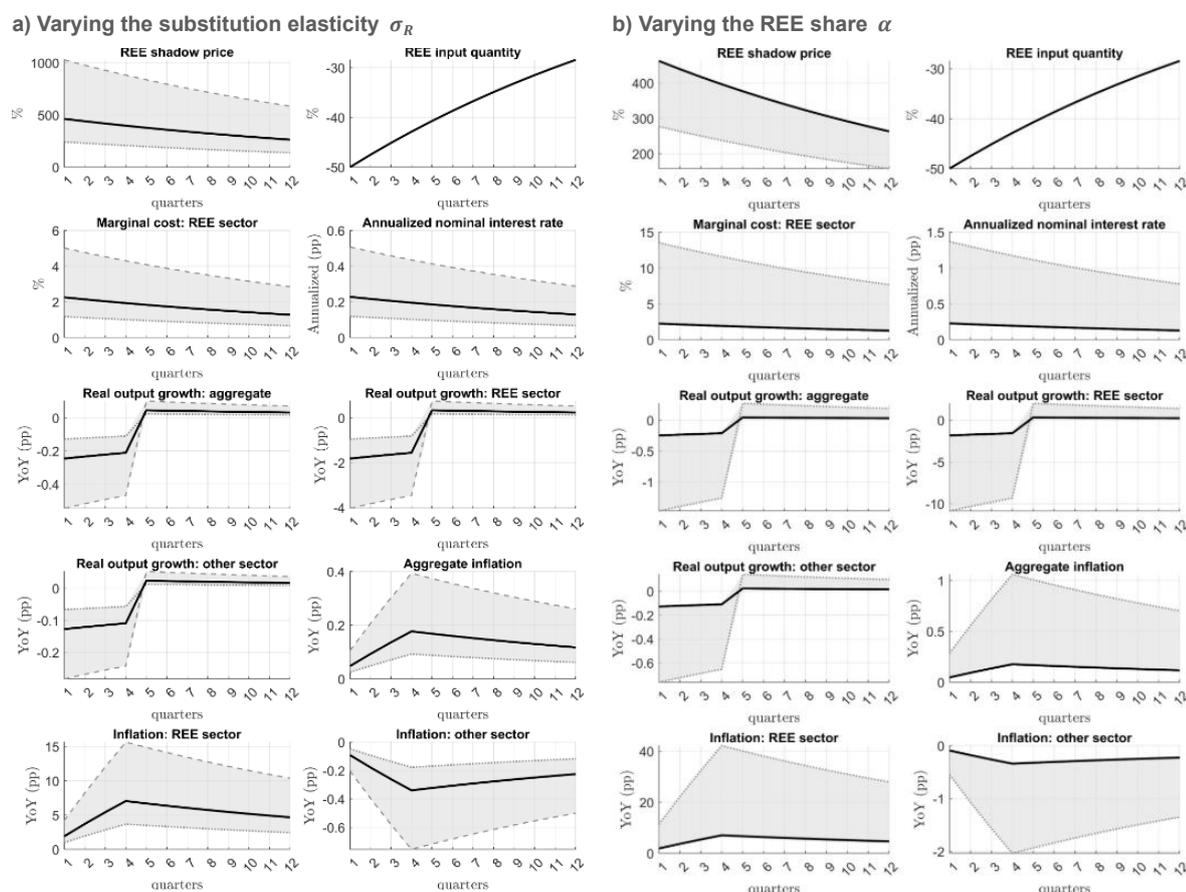
Greater input substitutability dampens, while low substitutability amplifies, the inflation and output effects of REE disruptions.

First, the substitution elasticity σ_R is varied around the baseline value of 0.10, with the REE price wedge p_t^R recalibrated in each case to ensure a 50% decline in REE use R_t (Chart A, panel a). When σ_R is higher, substitution toward alternative inputs X_t is easier, so a smaller price wedge is sufficient to generate the same decline, resulting in more muted increases in composite input costs, sectoral marginal costs, inflation and output losses. When σ_R is closer to zero, the production structure approaches a bottleneck technology amplifying scarcity: achieving a 50% reduction then requires a much larger wedge, leading to stronger inflationary pressures and larger output contractions.

Higher REE-intensity amplifies macroeconomic effects. Second, the REE share α is raised above the baseline 1%, holding all other parameters constant, to capture the fact that some strategic segments are far more REE-intensive than the average (Chart A, panel b). A higher α increases the sensitivity of composite input costs to the REE price wedge, so a given scarcity shock translates into larger increases in marginal costs and stronger sectoral inflation. Through aggregation, this leads to a larger CPI response, tighter monetary policy and a deeper output contraction. The results show that even when aggregate exposure is limited, macroeconomic effects can become sizeable in highly REE-dependent segments.

Chart A

Sensitivity of impulse responses to REE structural parameters



Notes: Impulse responses to an REE price wedge shock, with the shock size rescaled in each specification so that the impact response of REE input quantity equals -50% of its steady-state level. Panel (a) varies σ_R holding $\alpha = 0.01$ fixed; panel (b) varies α holding $\sigma_R = 0.10$ fixed. In panel (a), the solid black line denotes the benchmark $\sigma_R = 0.10$; the light grey shaded area shows the envelope for $\sigma_R \in [0.04, 0.20]$; and the grey dashed and dotted lines correspond to

$\sigma_R = 0.04$ and $\sigma_R = 0.20$, respectively. In panel (b), the solid black line denotes the baseline $\alpha = 0.01$; the grey dotted line is the upper bound $\alpha = 0.10$; and the light grey shaded area the envelope $\alpha \in [0.01, 0.10]$. Units: REE shadow price, REE input quantity and REE marginal cost are reported as percentage deviations from steady state; year-on-year output growth and inflation are reported as percentage point deviations; the annualised nominal interest rate is reported as a percentage point deviation.

Taken together, the exercise highlights that REE restrictions have important aggregate effects through a supply-side cost channel in a sticky price monetary economy. The aggregate impact is governed primarily by two empirically grounded parameters – the *substitution elasticity* and the *REE share* – alongside sectoral exposure and the interaction between nominal rigidities and monetary policy. The framework clarifies when a plausibly-sized disruption - here, a 50% effective decline in US availability - generates meaningful macroeconomic effects, and when it remains largely confined to the affected sector.

4.2 Output and inflation impacts from export controls

The DSGE model isolates a key inflationary transmission mechanism operating through the supply side. Export restrictions are modelled as an

exogenous increase in the shadow price of REE inputs, representing the scarcity penalty faced by firms under constrained supply. The magnitude of this wedge is calibrated so that firms optimally reduce REE use by 50%, matching a scenario of a 50% effective decline in US availability grounded in import dependence and refining bottlenecks. The higher shadow price raises the composite input cost, lifting marginal costs in the REE-intensive sector and generating sectoral inflation. Through price-setting frictions, this sectoral inflation propagates to aggregate inflation gradually, triggering a monetary tightening under the Taylor rule. Aggregate output declines through the direct contraction of REE-intensive sector activity and the indirect demand channel operating through tighter monetary policy and spillovers into the rest-of-economy sector. **Box 1** illustrates how the magnitude of these effects depends critically on two empirically grounded parameters – substitution elasticity and REE share – and their interaction with monetary policy responses.

While obtained through a stylised model, the inflationary impact of export restrictions broadly aligns with the literature. Javorcik and Schweiger (2024) warn that access to critical raw materials could become a major source of inflationary shocks amid geopolitical tensions. When a major supplier restricts exports of a critical input, importing countries typically face reduced supply and sharply higher import prices (OECD 2010). For example, following a territorial dispute with Japan in 2010, China increased export restrictions on REEs, causing global prices to spike by factors of 10 to 45 and remain high for about five years (Alfaro et al. 2025). The more dominant the supplier, the more pronounced the inflationary and contractionary impact on importing economies (U.S. International Trade Commission 2009). The framework clarifies when a plausibly-sized disruption translates into meaningful inflation and output dynamics through nominal rigidities and policy transmission, and when it remains primarily a sectoral event with limited aggregate consequences – a distinction governed by substitution elasticities, cost shares, sectoral exposure weights and the monetary policy response.

5 Propagation via global value chains in a multi-country multi-sector model

5.1 Model description and calibration

We use the multi-country multi-sector (MCMS-ONKIO) model of Aguilar et al.¹⁵ (2026) to examine how export restrictions propagate via global value chains.¹⁶

The model is a multi-country multi-sector DSGE covering four regions (the euro area, United States, China and rest of the world) and 44 sectors. Compared with the closed-economy DGSE in [Section 4](#), this setup captures amplification across countries and sectors – a key feature for upstream and hard-to-substitute inputs like REEs. In the model, households consume composites of domestic and imported varieties, while firms combine domestic and foreign intermediates in production. This setup makes it possible to feature sectoral production linkages and international trade in both intermediate and final goods, thereby accounting for *amplification effects* via global production chains and *substitution effects* via international trade. The model thus captures the propagation of shocks both downstream to consumers and upstream to suppliers, reflecting direct and indirect linkages (see [Box 2](#)).

Box 2

Inflation dynamics in a multi-country multi-sector New Keynesian model with production networks

Prepared by Pablo Aguilar

The multi-country multi-sector New Keynesian (MCMS-ONKIO) model embeds sectoral heterogeneity and international production networks into inflation dynamics, allowing cost shocks to propagate across sectors and borders through input-output linkages. This box summarises the key transmission mechanisms in the model and clarifies why both dimensions are essential for understanding inflation in an open economy. The focus is deliberately on the model's structural features, rather than the specific experiment analysed in the main text. A useful reference point is the standard one-sector New Keynesian Phillips curve,

$$\pi_t = \beta E_t \pi_{t+1} + \tilde{\kappa} y_t$$

where inflation depends on expected future inflation and the aggregate output gap. In this benchmark, sectoral heterogeneity and production networks are abstracted from, and – under standard conditions – stabilising the output gap is sufficient to stabilise inflation (the “divine coincidence”). External shocks affect domestic inflation only insofar as they move aggregate slack.

¹⁵ The model builds on the Open New Keynesian Input-Output (ONKIO) framework of Aguilar et al. (2026a) and adopts its multi-country multi-sector (MCMS) calibration to the euro area, the United States, China and the rest of the world in Aguilar et al. (2026b)

¹⁶ We select the Aguilar et al. (2026b) model over the Baqaee and Farhi (2024) framework – which was used in previous analysis of trade barriers, for example in Attinasi et al. (2025b) – because the former makes it possible to uncover dynamic effects. In addition, as shown in Attinasi et al. (2025c), the elasticity of substitution across inputs tends to have little influence over model outcomes. As this elasticity is a key parameter for hard-to-substitute inputs such as REEs, this is a clear limitation.

The multi-country multi-sector framework departs from this benchmark along two structural dimensions. First, production is disaggregated across sectors that differ in their exposure to intermediate inputs and in their position within the production network. With nominal rigidities, sectoral prices adjust sluggishly, allowing relative prices to deviate persistently from their efficient (flexible price) counterparts. Second, sectors source intermediate inputs not only domestically but also from abroad. International input-output (IO) linkages therefore enter marginal costs directly, enabling foreign cost and price disturbances to propagate into domestic inflation even in the absence of large movements in domestic demand conditions.

Formally, the paper derives a system of sectoral (vector) Phillips curves and shows how expressing marginal costs in terms of wages, domestic input prices and imported input prices alters inflation dynamics once general equilibrium interactions are taken into account. For the purpose of this box, the analytical results can be summarised schematically as

$$\pi_t \approx \beta E_t \pi_{t+1} + \kappa^{MCMS} \tilde{y}_t + \Gamma \tilde{s}_t, \quad \kappa^{MCMS} > \kappa$$

where \tilde{s}_t denotes a summary measure of inefficient sectoral relative price or terms of trade (ToT) gaps. This expression is not a primitive equilibrium condition of the model, but a reduced-form representation that highlights how inflation dynamics differ from the one-sector benchmark. In the full model, these effects arise from the interaction of sectoral inflation equations through domestic and international production networks.

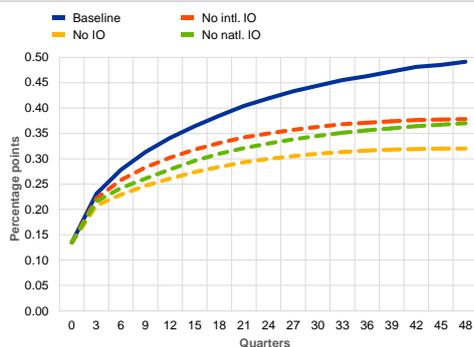
International IO linkages tighten the inflation-activity trade-off by amplifying the marginal cost response to aggregate output movements. When domestic production expands, firms demand more intermediate inputs, some of which are imported. As output rises more than domestic absorption, a stronger increase in labour supply is required to sustain production. Through the labour-supply condition, this translates into a larger increase in real wages and marginal costs than in a closed-economy or a one-sector setting. Analytically, the paper shows that the coefficient linking inflation to the output gap is strictly larger once international production networks are taken into account, implying a steeper Phillips curve.

Sectoral heterogeneity introduces an additional inflationary channel through inefficient relative price and ToT adjustments. Sector-specific shocks and foreign price movements generate heterogeneous cost pressures across sectors. With nominal rigidities, sectoral prices adjust at different speeds, leading to persistent relative price distortions. These distortions propagate through domestic and international IO linkages, affecting marginal costs and wages across sectors. As a result, aggregate inflation can respond to sectoral relative price and ToT gaps even when the aggregate output gap is closed, breaking the divine coincidence that holds in the one-sector benchmark.

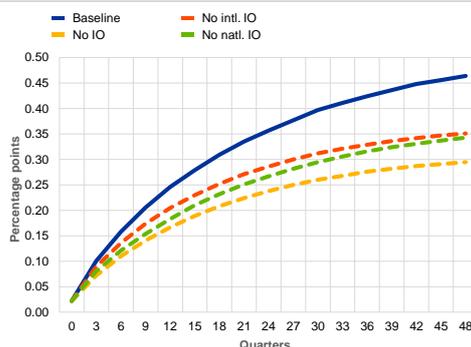
Chart B

Inflation dynamics following a cost-push shock: the role of production networks

a) Headline inflation



b) Core inflation



Sources: Aguilar et al. (2026a and 2026b).

Notes: Cumulative impulse response functions of headline (Panel A1) and core (Panel A2) inflation under the baseline scenario, and when the full, international, or national input-output (IO) structure is switched off, following an energy shock. In all cases where the IO structure is switched off, energy is still included as an intermediate input.

Production networks – especially international input-output (IO) linkages – significantly amplify and prolong inflation dynamics relative to a closed one-sector economy (Chart B).

Following an upstream energy cost shock, headline and core inflation respond more strongly and persistently in the baseline MCMS model than in counterfactual economies with weakened or absent IO links. This reflects the amplification of marginal costs through domestic and imported intermediate inputs, which steepens the effective inflation-activity trade-off. At the same time, the persistent response of core inflation highlights the role of sectoral heterogeneity and sluggish relative price adjustment, as heterogeneous cost pressures propagate through domestic and international production networks and affect aggregate inflation beyond what is implied by aggregate slack alone.

Taken together, these mechanisms explain why the multi-country multi-sector framework is particularly well suited for analysing shocks that originate in specific upstream inputs and propagate through global value chains. International production networks amplify the inflationary response to output fluctuations, while sectoral heterogeneity and network propagation make inflation depend on the sectoral origin of shocks, not only on aggregate slack. These features provide the conceptual underpinning for the quantitative analysis and motivate the use of a multi-country multi-sector model in this context.

Note: Based on Aguilar et al. (2026)

The shock is modelled mainly as a targeted increase in bilateral Chinese REE export costs. We mimic quantitative restrictions on exports through an increase in iceberg trade costs applied to China’s REE-related exports – as in Alfaro et al. (2025). The magnitude of the increase in iceberg trade costs is calibrated using

granular trade data, allowing for sector- and destination-specific shocks.¹⁷ Because REEs sit upstream in the input-output network, restricting their availability acts as a supply chain disruption: non-Chinese producers lose access to a critical imported input, while China retains domestic access – an asymmetry consistent with the logic of export restrictions. The shock then propagates across countries and sectors through global value chains, as firms adjust their sourcing and households reallocate consumption. The supply shock via iceberg trade costs is supplemented by a demand shock which aims at mimicking the effects of the rationing of demand for downstream goods – in line with Baqaee and Farhi (2022) and consistent with the literature showing that quantity constraints upstream can manifest as demand shocks for downstream goods (e.g. Guerrieri et al., 2022; Kharroubi and Smets, 2024). Overall, this setup makes it possible to depress the volume of REE shipments and replicate the effects of export controls without explicitly modelling quantity caps.

We mimic rigidities associated with REEs by constraining elasticities of substitution across inputs and suppliers. The Aguilar et al. (2026) model features nested CES production functions, allowing substitution at different layers. In a first calibration, we constrain elasticities of substitution across inputs in the intermediate inputs bundle used by producers. This effectively limits substitution away from REEs and towards other inputs, reflecting the limited technological substitution discussed in **Section 2**. In a second calibration, we also assume that substitution across sources is constrained – meaning producers cannot shift easily their sourcing of REE inputs away from China towards other (domestic or foreign) suppliers. This captures China’s dominance over the REE supply chain, constraining geographical substitution in the model. Such low elasticities of substitution magnify the impact on production costs, competitiveness and trade flows along global value chains.

5.2 Global macroeconomic implications of export controls

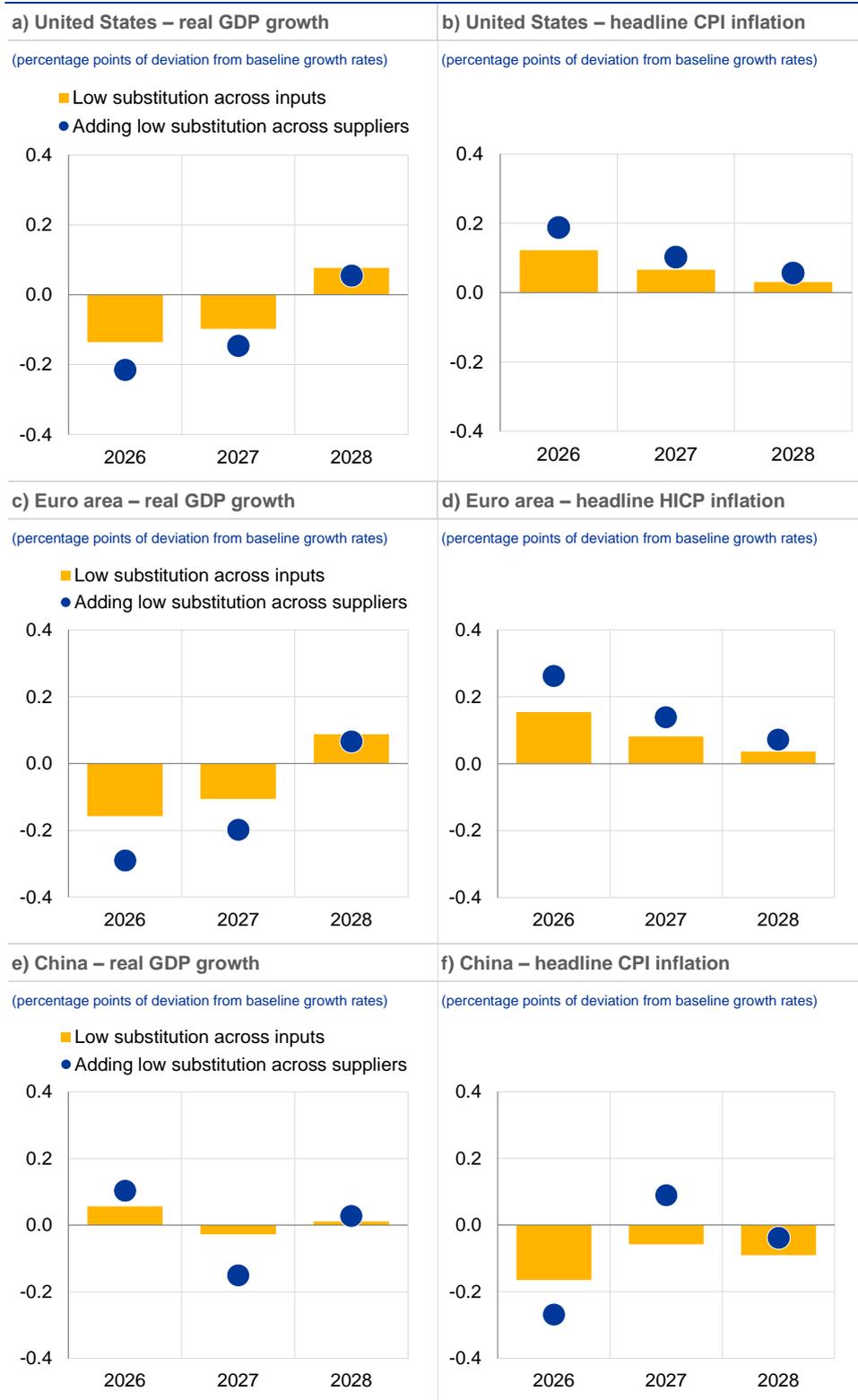
REE-importing economies like the United States and the euro area face a supply-driven contraction in output and a temporary cost-push increase in inflation (Chart 7, panels a to d). Export restrictions act primarily as an adverse supply disturbance. As REEs feed into a broad set of downstream industries and cannot be easily substituted, downstream production becomes constrained and demand for imported intermediates fall – a similar pattern as during supply chain disruptions in 2021-2022 (Attinasi et al., 2021). On the nominal side, the shock raises upstream production costs and increases inflationary pressures, as in Javorcik and Schweiger (2024), though this is partly offset by demand-driven disinflation as the shock weighs on activity.

¹⁷ More specifically, we use HS six-digit-level codes 280530 (“*Earth-metals, rare: scandium and yttrium, whether or not intermixed or inter-alloyed*”), 284610 (“*Cerium compounds*”), 284690 (“*Compounds, inorganic or organic (excluding cerium), of rare-earth metals, of yttrium, scandium or of mixtures of these metals*”), 360690 (“*Ferro-cerium and other pyrophoric alloys in all forms: articles of combustible materials not elsewhere classified in chapter 36*”), and 850511 (“*Magnets: permanent magnets and articles intended to become permanent magnets after magnetisation, of metal*”) as identified in Georgitzikis (2023) and U.S. Geological Survey (2025b). We use the most recent available year in the BACI dataset, which covers around 5,000 individual commodities – see Gaulier and Zignago (2010) for a description of the BACI methodology.

For China, the shock raises real GDP, because limiting foreign access to a globally scarce upstream input allows the supplier to capture part of the bottleneck rent (Chart 7, panels e and f). By restricting foreign access while maintaining domestic supply, China shifts part of downstream value added to its own economy and raises GDP – consistent with Alfaro and Chor (2025) and the broader literature showing that economies controlling bottleneck inputs can temporarily gain value added at the expense of downstream producers. Beyond the near term, however, China’s external position deteriorates due to lower foreign demand and a real appreciation induced by the relative strengthening of China’s economy. This is consistent with U.S. International Trade Commission (2009), which documents that the effects of export restrictions change over time, with short-run gains often dissipating. Finally, the appreciation of the renminbi and weaker foreign demand compress import prices and generate a mildly disinflationary effect. The downward impact of export restrictions on consumer prices is consistent with experiences with medical supplies during the COVID-19 pandemic and the use of export restrictions to contain domestic prices across emerging economies (e.g. OECD, 2010).

Chart 7

Macroeconomic impact based on an MCMS model (partial export ban)

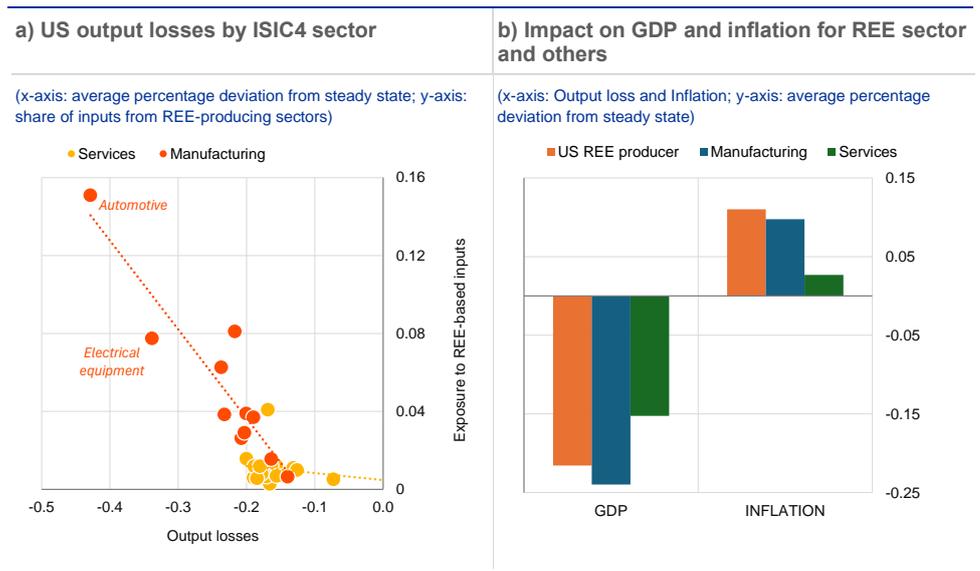


Sources: Aguilar et al. (2026b) and authors.
Note: Results are based on the MCMS-ONKIO

In REE-importing economies, the largest output losses arise in downstream industries that rely heavily on REEs. Output contracts in manufacturing industries using REEs as intermediate inputs, as foreign supply disruptions trigger severe margin losses downstream – in line with the dominant mechanism in Alfaro and Chor (2023). Sectors like automotive or electrical equipment experience the steepest losses (Chart 8, panel a), broadly in line with the mapping of REE-reliant sectors (Chart 1) and the sectoral impacts in U.S. Geological Survey (2025a). On the other end, services sectors display milder declines.

Beyond production and price effects, export controls on rare earths generate important demand-side feedback through international trade. By constraining production in REE-importing economies, the shock depresses foreign income and absorption, which in turn reduces demand for imported goods, including Chinese exports. As a result, China experiences a broad-based contraction in sectoral net exports, despite retaining domestic access to rare earth inputs. This mechanism highlights a “foreign income” or wealth effect: upstream export restrictions amplify downstream losses abroad, and these losses feed back to the exporter through weaker external demand. In general equilibrium, this channel prevents export controls from translating into an export-led expansion for the bottleneck supplier and contributes to a global contraction in trade volumes (Chart 8, panel a). Manufacturing sectors show higher exposure and larger contractions, consistent with the mechanism documented in Alfaro et al. (2025, 2025b), while service sectors are less exposed and more insulated; upstream REE-related sectors are comparatively less affected within manufacturing. Compared with manufacturing and services, the US REE sector shows smaller output losses than manufacturing on average but higher inflation, while services experience both smaller output declines and lower inflation (Chart 8, panel b).

Chart 8
US sectoral output losses in an MCMS model (partial export ban)



Sources: Aguilar et al. (2026b) and authors.
Notes: Results are based on the calibration of the MCMS-ONKIO with low substitution across inputs. Panel a) plots average sectoral output losses against exposure to REE inputs, where “exposure to REE-based inputs” accounts for both direct and indirect linkages.

6 Conclusion

This paper shows that Chinese export controls on REEs can generate output losses and inflationary pressures in REE-importing countries.

The low substitutability of REE-based inputs – most notably permanent magnets – combined with China's dominance over the REE supply chain creates vulnerabilities in production networks, particularly in high-tech and security-sensitive industries. While past episodes of export controls demonstrate China's willingness to leverage its dominant position in the supply chain, the implementation of severe and sustained bans would likely face practical and strategic constraints. In particular, a complete cut-off of Chinese REE supply could backfire by accelerating substitution efforts and alienating geopolitical allies. This suggests that export controls are best understood as strategic bargaining instruments: by creating visible and immediate disruption, partial restrictions can exert pressure on trade negotiations without permanently eroding long-run leverage. We calibrate a scenario of partial and temporary export restrictions and assess it using a combination of partial equilibrium, DSGE and multi-country multi-sector models. The results indicate that REE-importing economies such as the United States and the euro area would experience non-negligible output losses and inflationary pressures. Although China would benefit from a short-term boost to activity by capturing bottleneck rents, export restrictions would ultimately leave the global economy worse off, with output losses spread across countries.

Beyond the partial export restrictions examined in the baseline scenario, a near-total export ban would generate substantially larger effects, particularly if substitution possibilities were limited.

A more severe scenario could entail a near-total ban, which, despite being challenging to enforce in practice and potentially alienating China's strategic partners, would likely trigger large-scale substitution away from REEs over time. Such a severe scenario could also entail near-impossible substitution in the short-term, assuming REE-free alternatives are not scalable. Under this configuration, the Aguilar et al. (2026) model points to US output losses around 1.7% – broadly consistent with estimates from the partial equilibrium model, which range between 2.3% and 3.2%. In addition, beyond the scope of this paper, output losses could be even greater if export controls were extended to other critical minerals such as manganese or cobalt, where China also holds a dominant position in refining.

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Appendix

Table A1
Mapping of the rare earth supply chain

Sector (NAICS code)	Share in US output (%)	Intensity of rare earth use	Main rare earth uses and degree of substitutability
<i>First stage: rare earths mining and refining</i>			
Mining (212299)	0.08	High	Production of rare earths ores and concentrates; domestic output often dependent on China for refining
Inorganic basic chemicals (325180)	0.02	High	Processing of rare earths into oxides and carbonates; sensitive to bans on raw rare-earth minerals and on refining technology
<i>Second stage: production of functional rare earth-based products</i>			
Permanent magnets (332999)	0.01	High	Production of rare-earth-based permanent magnets (e.g. samarium, neodymium, terbium); dependent on rare earths inputs
Chemical catalysts and additives (325998)	0.17	High	Production of rare-earth-bearing catalysts (e.g. cerium, lanthanum) and of rare earths additives; dependent on rare earths inputs
Pigment manufacturing (325130)	0.02	High	Production of rare-earth phosphors (e.g. yttrium, europium, terbium, cerium); dependent on rare earths inputs
Non-metallic mineral products (327999)	0.09	Medium	Production of rare-earth-based coating products, polishing compounds, and advanced ceramics; dependent on rare earths inputs but modest volume of rare-earth based products within NAICS sector
Optical and precision glass (327212)	0.09	Medium	Production of rare-earth-doped glass (e.g. erbium, ytterbium); dependent on rare earths inputs but limited volumes of high-performance applications
Non-ferrous smelting, rolling, extruding (331410, 331491, and 331492)	0.25	Medium	Production of rare-earth-based metals and alloys (bars, sheets, wires, etc.) for downstream industries; dependent on rare earths inputs but limited volumes of high-performance applications
Iron, steel, and ferroalloy (331110)	0.02	Low	Production of rare-earth-based alloys with ferrous metals; dependent on rare earths inputs but for limited volumes of high-performance applications and possible substitution to non-rare-earth minerals (e.g. magnesium)
Batteries (335911 and 335912)	0.08	Low	Production of specialized batteries (e.g. Ni-MH) containing rare earths oxides; newer lithium-ion and mainstream alkaline batteries containing little to no rare earths
<i>Third stage: use of rare earth-based products in downstream industries</i>			
Motor vehicle and parts (336111, 336112, and 336120, 3363A0, 336310, 336320, 336350, and 336590)	1.68	High	Rare-earth-based permanent magnets essential in high-efficiency motors notably for electric and hybrid vehicles; use of rare-earth-based batteries in hybrid vehicles; use of rare-earth-based catalytic converters and exhausts in gasoline vehicles; more limited use in sensors, brake systems, power steering, adaptive suspension, actuators, and transmission systems; possible substitution with efficiency losses – but widespread use across sector and some designs centred around rare-earth-based components
Guided missile and space vehicle (336414 and 33641A)	0.35	High	Rare-earth-based permanent magnets in missile guidance systems and space vehicles; use of rare earths oxides in thrusters and engines; use of rare-earth-based lightweight heat-resistant alloys; limited substitution with no short-term alternatives for similar performances
Military vehicles and parts (336992)	0.02	High	Rare earths in propulsion, targeting, optics, and communication sub-systems; limited substitution with no short-term alternatives for similar performances
Turbine and power transmission (333611 and 333613)	0.28	High	Rare-earth-based permanent magnets in magnetic couplings, clutches, and gears; possible substitution (e.g. to gearboxes or ferrite magnets) with efficiency losses – but limited substitution for larger units

Sector (NAICS code)	Share in US output (%)	Intensity of rare earth use	Main rare earth uses and degree of substitutability
Search, detection, and guidance (334511)	0.02	High	Rare-earth-based specialized components (e.g. europium- and neodymium-doped laser crystals) in military radar, sonar, and avionics systems; limited substitution with no short-term alternatives for similar performances
Petroleum refineries (324110)	0.03	High	Use of Fluid Catalytic Cracking (FCC) catalysts for gasoline production; limited substitution with no short-term alternatives for similar performances
Semiconductors (334413)	0.01	High	Use of rare earths oxides for polishing wafers and rare-earth-based permanent magnets in lithography; limited substitution with no short-term alternatives for similar performances – notably for high-end semiconductors requiring precision polishing
Aircraft and parts (336411, 336412 and 336413)	0.18	High	Rare-earth-based permanent magnets in actuators, sensors, motors; rare-earth-based specialized components in radar and avionics; rare-earth-based lightweight heat-resistant alloys in airframes; possible substitution with efficiency losses – but widespread use across sector and limited substitution for modern fighter jets
Electromedical apparatus (334510)	0.01	High	Rare-earth-based permanent magnets in MRI scanners, rare-earth-doped crystals and glass in medical lasers; rare-earth phosphors and rare-earth-doped glass in X-rays detectors; limited substitution with no short-term alternatives for similar performances
Medical equipment (339112, 339114, and 339115)	0.31	High	Rare-earth-doped glass in surgical and diagnostic lasers, surgical fibre and high-refractive lenses; rare-earth phosphors in curing lights and whitening dental lamps; possible substitution with efficiency losses in some applications – but few substitutes with similar performance for high-end equipment
Optical instrument and lens (333314)	0.63	Medium	Rare-earth-doped glass in high-performance lenses (e.g. for cameras, telescopes, microscopes, etc.); rare earths oxides for polishing; mostly substitutable for polishings – but few substitutes with similar performance for high-end lenses
Communications equipment (334220 and 334290)	0.07	Medium	Rare earths for frequency tuning, antenna steering, and signal amplifiers; possible substitution with efficiency losses – but few substitutes with similar performance for high-end and defence-grade communications
Motor and generator (335312)	0.08	Medium	Rare-earth-based permanent magnets essential in high-efficiency motors; few substitutes with similar performance in high-end motors – but mostly substitutable in many standard motors (either not requiring rare earths or possible to revert to ferrite magnets)
Relay and industrial control (335314)	0.09	Medium	Rare-earth-based permanent magnets and phosphors critical in relays, sensors, and magneto-strictive actuators; possible substitution with efficiency losses
Pump and pumping equipment (33391A)	0.58	Medium	Rare-earth-based permanent magnets in high-performance motors, magnetic-drive couplings, and control sensors; possible substitution with efficiency losses
Audio and video equipment (334310)	0.04	Medium	Rare-earth-based permanent magnets in speakers, microphones, headphones; rare-earth phosphors and rare-earth-doped glass in displays; possible substitution with efficiency losses (ferrite magnets with lower performance) and rare-earth displays mostly substitutable
Computer storage device (334112)	0.03	Medium	Hard Disk Drive (HDD) containing rare-earth-based permanent magnets; limited substitution in HDD but industry moving to Solid-State Drives (SSD) containing little to no rare earths
Electronic computer (334111)	0.08	Medium	Rare earths in drives, capacitors, semiconductors, optical components, and batteries; possible substitution with efficiency losses – but few substitutes with similar performance for high-end computing
Magnetic and optical media (334610)	0.02	Medium	Rare earths in magneto-optical and rewritable media; use of rare-earth-based oxides for polishing; mostly substitutable (magneto-optical layer by phase-change alloys) and possible substitution for polishing compounds
Fibre optic cable (335921)	0.03	Medium	Rare-earth-doped glass for signal amplification; possible substitution with efficiency (and longevity) losses

Sector (NAICS code)	Share in US output (%)	Intensity of rare earth use	Main rare earth uses and degree of substitutability
Air conditioning and refrigeration (333415)	0.05	Medium	Rare-earth-based permanent magnets in motors, compressors, and control systems; possible substitution with efficiency losses
Ammunition, arms and ordnance (33299A)	0.09	Medium	Rare-earth-based permanent magnets used in targeting systems, actuators and sensors; rare-earth-doped glass for optics; specialized rare-earth-based alloys for heat resistance and weight; mostly substitutable for basic arms – but few substitutes with similar performance in advanced weapon systems
Household refrigerator and freezer (335222)	0.01	Medium	Rare-earth-based permanent magnets in compressors and fans; possible substitution with efficiency losses – but few substitutes with similar performance in high-end inverter models
Industrial variable instrument (334512, 334513 and 334519)	0.23	Medium	Rare-earth-based permanent magnets in magneto-strictive sensors and actuators; rare-earth-doped glass in lasers and optical filters; possible substitution with efficiency losses (lower precision, reliability, and harsh-environment operability)
Metal coating and engraving (332812)	0.03	Medium	Rare earths powders for metal coating used in downstream industries; limited rare-earth use and possible substitution with efficiency losses – but few substitutes with similar performance in high-end thermal barrier coatings (e.g. for aerospace or defence)
Other engine equipment (333618)	0.08	Medium	Rare earths used in high-efficiency electric machines, sensors, thermal coatings, lasers, and catalysts; limited rare-earth use and possible substitution with efficiency losses – but few substitutes with similar performance in high-end applications (e.g. aerospace)
Machine tool (333517)	0.12	Medium	Rare-earth-based permanent magnets in servo and linear motors, sensors, and control systems; possible substitution with efficiency losses
Other machinery (33329A and 33399A)	0.47	Medium	Rare-earth-based permanent magnets in high-efficiency motors, sensors, pumps; rare earths in thermal coatings; possible substitution with efficiency losses
Jewellery and silverware (339910)	0.02	Low	Rare earths in polishing and as decorative finishes; limited rare-earth use and mostly substitutable
Plumbing fixture fitting and trim (332913)	0.04	Low	Rare earths oxides used in polishing, coatings, and LED accents; mostly substitutable
Ship and boat building (336611 and 336612)	0.10	Low	Rare earths in propulsion, sonar, radar, lidar, navigation systems, and thermal coatings; limited rare-earth use and mostly substitutable in civilian and commercial ships – but few substitutes with similar performance in naval defence
Electric lamp bulb and lighting (335110)	0.02	Low	Rare-earth phosphors in lamp coatings; mostly substitutable to rare-earth-free lighting technologies (e.g. incandescent, halogen)
LCD screens and computer terminals (334118 and 334419)	0.36	Low	Rare-earth phosphors for white LED backlights; mostly substitutable to non-rare-earth phosphors (e.g. manganese-based) with efficiency losses
Farm and construction machinery (333111 and 333120)	0.04	Low	Rare-earth-based permanent magnets in electric drives, actuators and sensors; limited rare-earth use and possible substitution with efficiency losses
Industrial trucks and forklifts (333924)	0.11	Low	Rare earths in batteries, power and navigation systems; mostly substitutable in batteries and possible substitution (with efficiency losses) in navigation systems
Ceramics and refractories (327110 and 327120)	0.05	Low	Rare earths in ceramics (mainly for decoration); Rare earths in industrial refractories to improve heat-resistance and durability (e.g. additives, thermal coatings); mostly substitutable in ceramics and possible substitution (with efficiency losses) in refractories

Sources: Sources: Alfaro et al. (2025), International Energy Agency (2025a, 2025b), U.S. Geological Survey (2025a), U.S. Department of Energy (2023), US Bureau of Economic Analysis, and authors.

Notes: Share of US output based on detailed BEA input-output table. For NAICS codes 331491-331492, 332812, 334310, 334419, 335222, 33391A, 333924, 212299, 327212, 327110-327120, 335921, 334519, and 325998 the table reports the output share of a broader sector (NAICS codes 331490, 332800, 334300, 33441A, 335220, 333912-333914, 333920, 2122A0, 327200, 327100, 335920, 33451A, and 3259A0 respectively) due to insufficient granularity in BEA data. Sectors 212299 and 325998 are scaled down given the small share of rare earth-linked output out of a wider aggregate.

Table A2
DGSE model calibration

(calibrated on US economy)

Parameter	Description	Value
Preferences		
β	Discount factor	0.99
σ	Constant relative risk aversion (CRRA) on consumption	1.50
ψ	Frisch labour-supply curvature	2.50
χ	Labour disutility scale	1.00
r_π	Taylor-rule inflation coefficient	1.15
\bar{R}^n	Gross steady-state nominal rate ($1/\beta$)	1.01
Price-setting (Rotemberg)		
$\varepsilon^s, \varepsilon^o$	Dixit–Stiglitz elasticities ($markup = \varepsilon/(\varepsilon - 1)$)	6.00
ϕ^s, ϕ^o	Price-adjustment parameters	100
Non-REE-intensive sector (O)		
A^o	Labour productivity level	1.00
ζ^o	Labour-cost wedge in sector O ($effective\ wage = \zeta^o w$)	$mc_{ss}^o = mc_{ss}^s$
REE-intensive sector (S)		
v	Share of intermediate inputs bundle M	0.50
σ_R	Elasticity of substitution (R vs. X) in the intermediate inputs bundle M	0.10
α	Weight of R inside intermediate inputs bundle M	0.01
A^s	Sector productivity level	1.00
Aggregation weight		
s_Y	Weight of sector S in consumption, CPI, and output	0.07
Exogenous processes		
ρ_A^o, ρ_A^s	Persistence of sectoral TFP shocks	0.95
ρ_P^R, ρ_P^X	Persistence of input price wedges	0.95

Model description

Households. A representative household chooses consumption C_t , total labour supply H_t , and nominal one-period bond holdings B_t to maximise

$$\mathbb{E}_0 \sum_{t \geq 0} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{H_t^{1+\psi}}{1+\psi} \right)$$

where β denotes the discount factor, σ the parameter governing intertemporal substitution, χ the scale of labour disutility, and ψ the parameter determining the Frisch elasticity of labour supply. The household faces the following nominal budget constraint

$$B_t + P_t C_t = R_{t-1}^n B_{t-1} + W_t H_t + \Pi_t^S + \Pi_t^O$$

where R_t^n is the gross nominal bond return, W_t the nominal wage, and Π_t^j profit transfers from sector $j \in \{S, O\}$. Let Λ_t be the Lagrange multiplier, the first-order conditions are

$$C_t^{-\sigma} = P_t \Lambda_t$$

$$\chi H_t^\psi = W_t \Lambda_t$$

and the Euler equation

$$\beta \mathbb{E}_t \left[\frac{C_{t+1}^{-\sigma} R_t^n}{C_t^{-\sigma} \pi_{t+1}} \right] = 1$$

where $\pi_{t+1} \equiv P_{t+1}/P_t$ is gross inflation. Labour market clearing is $H_t^S + H_t^O = H_t$.

Pricing. Firms in each sector produce differentiated goods and incur Rotemberg price adjustment costs. With symmetry across firms, optimal marginal cost is

$$mc_t^j = \frac{1}{\mu^j} + \frac{\phi^j}{\varepsilon^j} \left[(\pi_t^j - 1) \pi_t^j - \mathbb{E}_t \left(\omega_t \frac{Y_{t+1}^j}{Y_t^j} (\pi_{t+1}^j - 1) \pi_{t+1}^j \right) \right]$$

where mc_t^j denotes the real marginal cost, μ^j the gross markup, ϕ^j the Rotemberg adjustment parameter, ε^j the demand elasticity, π_t^j sector-specific inflation, Y_t^j the sectoral output, and ω_t the stochastic discount factor.

Non-REE-intensive sector. Sector O uses only labour

$$Y_t^O = A_t^O H_t^O$$

where A_t^O is the sector-specific exogenous productivity. The real marginal cost is

$$mc_t^O = \zeta^O \frac{w_t}{A_t^O}$$

where $w_t \equiv W_t/P_t$ is the real wage and ζ^O a wedge.¹⁸ The sectoral resource constraint is

$$Y_t^O = C_t^O + \frac{\phi^O}{2} (\pi_t^O - 1)^2 Y_t^O$$

REE-intensive sector. Sector S combines labour and a composite intermediate input according to

$$Y_t^S = A_t^S H_t^S {}^{1-\nu} M_t^\nu$$

where A_t^S is the sectoral productivity, M_t is the composite input, and ν is its cost-share parameter. Cost shares satisfy

$$\frac{w_t H_t^S}{mc_t^S Y_t^S} = 1 - \nu$$

$$\frac{p_t^M M_t}{mc_t^S Y_t^S} = \nu$$

with p_t^M denoting the shadow unit cost of M_t . The composite input M_t aggregates REE R_t and other components X_t through a CES technology

¹⁸ ζ^O is chosen in steady state so that sector O 's marginal cost matches its targeted steady-state markup, given that common wage is determined by sector S .

$$M_t = \left[\alpha^{\frac{1}{\sigma_R}} R_t^{\frac{\sigma_R-1}{\sigma_R}} + (1-\alpha)^{\frac{1}{\sigma_R}} X_t^{\frac{\sigma_R-1}{\sigma_R}} \right]^{\frac{\sigma_R}{\sigma_R-1}}$$

where α is the share parameter on REE and σ_R is the elasticity of substitution between the two inputs. Firms take input prices p_t^R and p_t^X as given and face perfectly elastic supply for each. By duality, the shadow cost of the composite is

$$p_t^M = [\alpha p_t^R^{1-\sigma_R} + (1-\alpha) p_t^X^{1-\sigma_R}]^{\frac{1}{1-\sigma_R}}$$

Cost minimisation yields CES input demands

$$R_t = \alpha \left(\frac{p_t^R}{p_t^M} \right)^{-\sigma_R} M_t$$

$$X_t = (1-\alpha) \left(\frac{p_t^X}{p_t^M} \right)^{-\sigma_R} M_t$$

The sectoral resource constraint is

$$Y_t^S = C_t^S + R_t + X_t + \frac{\phi^S}{2} (\pi_t^S - 1)^2 Y_t^S$$

Monetary policy. Monetary policy follows the Taylor rule

$$R_t^n = \bar{R}^n \pi_t^{r_\pi} \exp(\epsilon_t^r)$$

where r_π governs the policy response to inflation, and ϵ_t^r is a monetary policy shock. All exogenous processes are AR(1).

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