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ABSTRACT

The aim of this paper is to investigate the links between energy transition critical minerals - which are crucial to the deployment of low-carbon technologies - and foreign direct investments. To this end, we consider the production of 8 energy transition critical minerals over the 1997–2020 period as an explanatory variable for FDI inflows, by using an original, complete, and precise database. Implementing a battery of panel data estimations to ensure the robustness of our results, we find that there is no FDI- resource curse for the energy transition critical minerals production. Unlike oil, energy transition critical minerals do generally attract foreign capital inflows, the positive attraction effect on resource seeker FDI likely dominates the negative eviction effect on non-resource seeker FDI; the minerals with the strongest FDI attraction effect being cobalt, lithium, and rare earth elements. These results confirm the important economic and strategic motivations of investing countries and companies, but also represent risks and opportunities for the host mining countries.

1. Introduction

1.1. Linking the FDI-resource curse

Foreign direct investments (FDI) play a key role for countries to develop their industry, trade, and production, contributing to their economic growth. It is also an important way for foreign investing countries and companies to strategically establish abroad, develop or gain access to certain markets or resources, and take position in global value chains. The literature usually identifies the following FDI determinants: the size of the economy, the stability of the macro-economic context, trade openness, cheap manpower, light fiscal policy, good network of infrastructures, and stability in institutions (see, e.g. [Chakrabarti, 2001](#); [Levasseur, 2002](#); [Blonigen, 2005](#); [Sahiti et al., 2018](#)). In this paper, we contribute to this literature by focusing on natural resources as a determinant of FDI. At first glance, we may expect that multinational companies want to establish themselves in countries that produce and export raw materials so that they can exploit and profit from these natural resources. However, this relationship is much more complicated because of the *natural resource curse* and the *FDI-resource curse*.

The *natural resource curse* has been the subject of a substantial literature which highlights the following, generally empirically verified, paradox: despite large amounts of natural resources, some countries

may experience weak growth performance and limited development. This phenomenon is realized through several different mechanisms and channels (social, political, and economic). For example, natural resource endowment can lead to (i) a political economy that promotes a rent-seeking elite, at the expense of efficiency for a long-term economic growth ([Auty, 1997](#)), and/or (ii) local violent conflicts, because of the coveting of resources, corruption, or the financing of rebel movements ([Ross, 2002](#)). The literature developed the well-known concept of *Dutch Disease*, when the strong development of the natural resources sector penalises the other exporting sectors because of the appreciation of the currency, but also the other industrial sectors of the country, because of the displacement of production capacities, notably the labor factor, towards the natural resources sector. One may add economic policies favouring the exploitation of natural resources to the detriment of policies for a diversified and structural economic development ([Corden and Neary, 1982](#); [Sachs and Warner, 1995](#)). Overall, the hypertrophy of the natural resources sector can lead a country to have short-termist corrupted rent-seeking economy, in addition to political instability, structural industrial imbalances, and the development of a low value-added activity ([Davis and Tilton, 2005](#)). Depletion of natural capital, bad terms of trade, and civil conflicts also weigh negatively on a balanced development ([Aknin, 2021](#)). In the empirical literature, the results regarding the natural resource curse are mixed for certain countries. In particular,

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the quality of institutions is a key factor since, thanks to solid institutions, the negative effects of corruption and rent-seeking can be mitigated or avoided and the income from natural resources can be reinvested in the rest of the economy (van der Ploeg, 2011).

More recent developments in this literature focus on the local aspects of the curse, studying the differences between resource-rich regions and resource-poor ones, at a subnational level. For some countries, such as Peru, resource-rich regions are substantially more prosperous than resource-poor ones, and these inequalities must be compensated by important redistribution arrangements (Loayza et al., 2013). However, at a larger scale, when more countries are considered, mixed results can be found. In some countries, the resource-rich regions may experience weak economic performance, worse than the resource-poor regions, especially concerning per capita income. This can be explained by rent capture or corruption, higher relative prices, labor market distortions, higher criminality, and environmental and social consequences (Cust and Viale, 2016). In this paper, we adopt a more global approach, at a worldwide macro-economic scale. Moreover, we focus on a sub-component of the natural resource curse as we investigate the links between natural resources endowments and attractiveness to FDI.

This counter-intuitive negative relationship between natural resources and economic development also exists between natural resources and FDI inflows. Poelhekke and van der Ploeg (2010) and Asiedu (2013) have shown that an endowment in natural resources may discourage foreign investors and firms, leading to a negative relationship between natural resources endowments and inward flows of FDI. This is called the *FDI-resource curse*. Poelhekke and van der Ploeg (2010) consider resource and non-resource seeking FDI inflows from the Netherlands toward 183 host countries. As suggested by the Hecksher-Ohlin model, they find that natural resources endowments attract the resource seeking FDI but crowd out the non-resource seeking FDI. The negative effect on non-resource FDI being stronger than the positive effect on resource-FDI, the aggregate effect is negative, highlighting a “resource curse for aggregate FDI”. Asiedu (2013) verifies the existence of this negative relationship at a macro-economic level by considering host countries’ aggregated net FDI/GDP positions, taking into account FDI inflows from all foreign investors. She finds that natural resources have a negative effect on aggregated FDI inflows, illustrating a FDI-resource curse.

A conceptual explanation can be found in Asiedu and Lien (2011). The authors explain that, for an economy that relies a lot on natural resources’ exploitation and trade, two effects are at play. First, the exchange rate appreciates with the demand for natural resources, penalizing the other non-resource tradable sectors, and crowding out the non-resource seeking FDI. Second, the instability on natural resources global markets leads to exchange rate instability, and the lack of trade diversification increases vulnerability to external shocks, discouraging foreign investments. Moreover, political instability and, especially, the potential corrupted short-termist rent-seeking character of the economy are not favorable to attract non-resource seeker FDI. Overall, the Dutch disease and the other factors of the resource curse generate general macroeconomic instabilities and imbalances that harm the attractiveness of the host country and, therefore, reduce aggregated FDI inflows. It is important to note that besides this negative total effect, it means that inside the existing FDI inflows, there is a predominant proportion of resource seeking FDI, digging the imbalances between the tradable sectors. It worsens the existing resource curse, which further undermines the non-resource tradable sector’s attractiveness to foreign investments, leading to a vicious circle.

In a sense, the FDI resource curse is both the consequence and a component of the general resource curse on growth and development.

In addition to Poelhekke and van der Ploeg (2010) and Asiedu (2013), other papers find evidence of a FDI-resource curse: Okafor et al. (2015) and Jumanne and Keong (2018), for Sub-Saharan countries; Elheddad (2016), for Gulf Cooperation Council countries; and Asiedu and Lien (2011), who study the link between FDI, democracy, and

natural resources. These papers focus on hydrocarbons, mainly oil and secondarily gas, and show that oil activities in producing countries, that might undergo the natural resource curse, have a negative effect on aggregated FDI inflows, as they only attract investments in the oil sector while strongly crowd out investments toward other economic sectors.

There also exists some studies dealing with minerals, and the obtained results are quite different. For example, Asiedu and Lien (2011) finds a positive relationship between natural resources and FDI for African countries only when using one natural resource variable gathering fuels and minerals. Anyanwu and Yameogo (2015) find a positive effect when the host country is endowed with mineral resources. Finally, Oro & Alagidede (2021) find a FDI-curse for hydrocarbons, but a positive relationship between FDI and mineral ore exports. The main limit of these papers is that the mineral resources studied are unspecified and imprecise, as the different metals and minerals are not detailed.

There also exist studies on specific countries dealing with the natural resource curse in the case of mine-rals, which show mixed results: a very clear curse in the Democratic Republic of Congo (Otchia, 2015), a less marked curse in Australia (Koitsiwe and Adachi, 2015), and a positive effect in Chile (Marañon and Kumral, 2021). However, this literature does not consider wide panels of countries, primarily focuses on oil and fuel resources, and generally ignores FDI.

Falling into this strand of the literature, we go beyond the general scope of the previous studies by paying particular attention to FDI and considering the case of critical minerals necessary for the development of low-carbon technologies for the energy transition.

1.2. To strategic mineral resources

To fight against climate change, many high-income economies and industrialized countries have committed themselves, especially at the time of the different COP (Conference of the Parties), to greatly reduce their greenhouse gas emissions. For example, the United Kingdom, United States, Canada, Russia, and Japan have committed to reduce their greenhouse gas emissions from 30 % to 68 % by 2030 compared to the late 1990s or early 2000s. China has committed to peak its carbon emissions by 2030 and to increase the share of non-fossil fuels in energy consumption to 25 %, compared to 11 % today. Finally, the European Union committed to reach 45 % of renewable energies in the energy mix by 2030 (against 22 % in 2020). The long-term commitments are even stronger for many advanced and emerging countries, which are looking for carbon-neutrality in 2050 or 2060.¹

In order to reduce their emissions, these countries have engaged, more or less strongly, in an energy transition. The aim of such a transition is to reduce greenhouse gas emissions, while maintaining a certain level of energy production, by abandoning the use of carbon-based fossil fuels (mainly coal, oil and gas) and replacing them with carbon-free energies (solar, wind, hydro, nuclear, natural gas and hydrogen). The exploitation of these energy sources requires various technologies necessary to produce energy (electricity or hydrogen), but also to store, transport or use it (solar photovoltaic panels, wind turbines, batteries, electric vehicles, hydrogen fuels, power grids, etc.). These “low-carbon technologies” include elaborated technological elements that require specific metals and minerals for alloys and chemical properties. Indeed, these technologies are all downstream of a long value chain that begins with the extraction of specific minerals, which continues in refining, separation, and transformation into metals; metals that are used, most of the time in the form of alloys, in the manufacturing of components for low-carbon technologies (super-magnets, photovoltaic panels, batteries, electrical cable network, hydrogen electrolyzers). Thus, low-carbon technologies require very large quantities of energy transition critical minerals which will be referred as ETCM.

¹ Sources and details of the commitments for several countries are displayed in Table 5 in Appendix.

Such a transition is already engaged, even if it is far from being totally accomplished, and for now, the situation is still characterized by an energy accumulation (Fressoz, 2020). The fact is that there has been a rapid and significant deployment of low-carbon technologies these past years, especially in the wealthiest countries. According to the International Energy Agency (IEA) energy statistics data, World's solar PV electricity generation grew from 32 Twh in 2010 to 1020 Twh in 2021 (mainly driven by Europe, USA and China, respectively 199 Twh, 148 Twh and 327 Twh in 2021) and World's wind electricity generation grew from 342 Twh in 2010 to 1864 Twh in 2021 (once again due to Europe, USA and China respectively 500 Twh, 382 Twh and 656 Twh in 2021) (IEA, 2023). Despite these advances, in 2021, wind and solar only accounted for 10.11 % of World's total electricity generation (and only 2.7 % of total energy supply). Therefore, this deployment is expected to continue for wind and solar to reach 25 % of World's total electricity generation by 2028, according to IEA's main case scenario (which considers existing policies and market conditions) (IEA, 2024a,b,c,d). It should also go with the electrification of the economy and the deployment of electricity storage batteries and electric vehicles (EV). Global electricity grid went from 60 million km in 2010 to almost 80 million km in 2021 and should reach 110 million km in 2035 according to IEA's Announced Pledges Scenario (APS) (IEA, 2023). EV world stock share went from 0.8 % in 2020 to 3.2 % in 2023 and should reach 34 % in 2035 according to IEA's APS (IEA, 2024a,b,c,d).²

These past and future developments have strong consequences for global mineral demand. Regarding wind and solar power, EVs, battery storage and electricity networks, global mineral demand for the related technologies went from 4.5 Mt in 2010 to 6.7 Mt in 2020 (IEA, 2021). For these same critical minerals, the demand projections can be dizzying. For example, according to the IEA's APS, demand relative to low-carbon technologies in 2040, relative to 2021 levels, should be higher by a factor of 32 for lithium (used for EV batteries), 18.5 for graphite (used for EV batteries) 14 for nickel (used for EV batteries and hydrogen electrolyzers), 7 for cobalt (used for EV batteries), 6 for REE (used for permanent magnets in EVs and wind turbines) and 3 for copper (used in all technologies and electricity grids) (see Table 8 in Appendix) (IEA, 2024a,b,c,d).

Different studies emphasize a number of significant limitations around global mineral demand growth. First, on the short run, there are geopolitical risks concerning the supply of certain ETCM, as the extraction of some minerals can be very concentrated. The World mining production has been quite concentrated since 1997. For many ETCM, only 2 or 3 countries has ensured more than half of the global mining production. Moreover, in the past years this concentration has actually increased, sometimes sharply, for most minerals. Striking examples, for the year 2020, are D.R. Congo that has ensured 73 % of World's cobalt extraction or China that ensured 79 % of World's graphite extraction, 57 % of World's REE extraction and 70 % of World's silicon extraction (see Table 6 in Appendix). Indeed, China has a huge lead for many metals and technologies all along the value chain (Bonnet et al., 2022). Therefore, there could be supply risks due to geopolitical tensions between exporting and importing countries.³ Then, there are technical limits to

extraction, because of mining lead times, energy cost of mining and technical capacities to run operating mines. Therefore, according to the IEA, committed mine production will no longer be able to meet projected demand from 2026 onwards for copper, and 2028 for lithium and cobalt (IEA, 2021). There are also, in the longer term, important geological limitations associated to the extraction of ETCM, depending on their abundance in the earth's crust, and the depletion of resources (ore grades decline). The increase in demand will be such that it could cause a risk of exhaustion, or at least significant tensions on geological reserves. The most critical minerals on a geological point of view are mainly copper for which 89.4 % of the identified global resources in 2010 might be extracted in 2050 in a +2 °C scenario (Seck et al., 2020), and cobalt for which 83.2 % of the identified global resources in 2013 might be extracted in 2050 in a +2 °C scenario (Seck et al., 2021). Moreover, depletion of resources, which is ultimately unavoidable, means more mining activity, leading to more local environmental degradation, mining wastes, water use, land use and energy consumption, for the same amount of viable mineral in the end. These ecological costs (SystExt reports,) can also represent limits to mining exploitations (IEA, 2021).

Indeed, on a more general point of view, Vidal et al. (2017) show that since the industrial revolution, mineral and metallic resources have been experiencing a very strong and uninterrupted growth, today's levels of mineral resources consumption being higher than ever. To this existing trend must be added the legitimate industrial and technological development objectives of developing countries, but also all the objectives concerning the energy transition and the deployment of low-carbon technologies for both advanced and developing economies. Therefore, Vidal et al. (2017) also end up predicting huge increases in the metallic resources' demand: "In order to meet this demand, more metals will have to be produced by 2050 than over the last 100 years" and argue that, in the long term, "maintaining exponential trends is simply impossible in a finite world".

Finally, there are economic risks associated to mining extraction, in relation with Dutch Disease and resource curse, that we will discuss in subsection 4.2.

Even with these concerns, such a mineral intensive energy transition is considered as a necessity for the countries engaged and there is a political and economic will to continue in this way, at least in the short and medium term.

Despite the key role played by these ETCM, no global macroeconomic study have been conducted - to the best of our knowledge - on their link with FDI. We fill this gap in the present paper by investigating the FDI resource curse in the specific case of ETCM. To this end, we consider a panel of 117 countries over the 1997–2020 period and a selected sample of 8 minerals. Unlike oil activity, we find evidence of a robust positive relationship between ETCM production and aggregated FDI inflows, highlighting a dominant positive attraction effect on mineral seeker FDI. Rare earth elements are amongst the minerals that attract FDI the most, possibly because of the need to promote and diversify mining suppliers.

The rest of the paper is organized as follows. Section 2 presents our variables, the data used and the empirical methodology. Section 3 displays our results. Section 4 discusses the implications and concludes.

2. Variables, data and methodology

2.1. Presentation of the variables

We consider a panel of 117 countries.⁴ On these 117 countries, 52 can be considered as significant ETCM producers (see Table 7).⁵ Data for

² There is no APS for wind and solar share in World's total electricity generation in the IEA, 2024a,b,c,d Renewables report, only the main case scenario (which considers existing policies and market conditions). Regarding electricity grid and EVs, projections are made according to the IEA's APS which accounts for announced ambitions and targets. "It includes all recent major national announcements as of the end of August 2024, both 2030 targets and longer-term net zero or carbon neutrality pledges, regardless of whether these announcements have been anchored in legislation or in updated Nationally Determined Contributions."

³ A recent example is China which, in 2010, blocked its exports of rare earths to Japan during the diplomatic crisis due to maritime tensions, which had serious economic consequences on some Japanese companies. This event is now referred as the "rare earth crisis".

⁴ The list of countries is given in Appendix.

⁵ Any country that has represented at least 1 % of the World production of at least one TCM during at least one year.

mineral production are available starting from 1994. After data transformation and given that we will use lagged variables in the econometric analysis, our estimations will cover the 1997–2020 period. Moreover, the panel being unbalanced, some individuals with too much missing observations will be dropped by the estimations resulting in shorter samples that will be precised for each estimations.

Our explained variable is the net FDI inflows expressed in percentage of GDP. FDI data are extracted from the UNCTAD, and GDP data from the World Bank. We also use the American Enterprise Institute China Global Investment Tracker data and Bureau of Economic Analysis data to conduct a detailed analysis on Chinese and US FDI.

For hydrocarbon natural resources, we consider the rents in percentage of GDP for oil, in line with the literature. The data are from the World Development Indicators database of the World Bank. This variable allows us to test the relevance of our model by checking if we find the same results as the literature, i.e., a negative coefficient associated with this variable, testifying to a FDI-resource curse on oil.

Regarding institutional variables, we use the World Governance Indicators database from the World Bank and retain three indices of institutional quality: rule of law, control of corruption, and political stability. These three indexes range from -2.5 to 2.5 , from worst to best. Rule of law represents the confidence and the respect of the agents in the laws and rules of a given country. It testifies of the solidity of the contracts, the property rights, the quality of the police and justice. For the control of corruption, the index measures the reputation of a State in its fight against corruption, and against the “capture” of wealth by an elite and by private economic interests. Finally, the political stability index measures the perception on the stability of the political regime and/or the politically-motivated violence, in addition to the risk of terrorism. All these institutional variables are expected to have a positive effect on FDI inflows in that they promote stable economic growth and guarantees in terms of physical and legal security.

Finally, we consider the traditional determinants of FDI, all these control variables being extracted from the World Development Indicators database of the World Bank. We use the Gross Domestic Product in current US dollars to measure economic activity, the inflation rate, and trade openness defined as the sum of exports and imports of goods and services expressed in percentage of GDP. These control variables capture what traditionally determines FDI inflows, namely good growth, openness to trade, and a stable macroeconomic framework that will attract FDI by ensuring the most attractive and least risky business climate possible.

2.2. ETCM selection and data

“Strategic metals” or “critical minerals” are metals or minerals that are generally considered as essential to certain specific sectors and/or to State’s industrial policy or material/energy/defense security, while being “critical”, i.e., subject to significant supply risks from various sources (geologic, geopolitical, economic or environmental). Several lists of strategic or critical materials have been drawn up, mainly by public institutions (US government, EU commission, World Bank, IEA, French COMES) but also by specialized researchers or institutions. These classifications have multiplied in recent years and may differ more or less depending on the sectors covered (energy, health, armament, high-technology, food industry), the measure of criticality (the consideration and weight given to the different supply risks origins) and the differences between each country drawing official lists and that might not have the same industrial/security objectives or the same supply sources.

In this paper, we focus on minerals necessary for low-carbon technologies, i.e., for the energy transition. Starting from the critical minerals for the renewable energies sector in the list of the European Union Commission communication (*Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability*) and the 2023 US Department of Energy Critical Materials List, we then refine this selection by retaining only the minerals that represent the highest shares in

mineral demand, according to the IEA’s Critical Minerals Data Explorer, specifically for each of the main low-carbon technologies: wind turbines, solar photovoltaics panels, electric vehicles, battery storage, hydrogen electrolyzers and electricity grids. By doing so, we select the most important minerals for the deployment of low-carbon technologies, those with the strongest demand trends. 8 critical minerals are retained for this study: bauxite, cobalt, copper, graphite, lithium, nickel, rare earth elements (REE), and silicon.⁶

Usually, the main obstacle to study critical minerals lies in the difficulty of accessing the data. There are very few data sources and there is no database built, complete and accessible. The United States Geological Survey (USGS) stands as the reference for data and statistics on minerals and metals from around the world. However the data presentation is not adapted at all for statistical and econometric analysis because there is no time-series database, and even less panel data, available. To fill this gap we construct a database for a panel of 52 producing countries, for 27 years, from 1994 to 2020, with gross production (extraction) and reserves, both expressed in metric tons, for these 8 selected minerals.⁷

The 8 retained minerals are considered critical by the European Commission and the US DoE, and will be the most widely used (demanded and extracted) in the main low-carbon technologies for generation, storage and transport of electricity, according to the IEA. The relevance of this selection and the quality of the database constitute one of the contribution of this paper. We will now refer to energy transition critical minerals (ETCM) to speak of this selection of minerals.

2.3. Preliminary analysis and expected effects at play

To provide a first insight, let us now investigate the correlations between the different variables.

As shown in Table 1, the quality of institutions is positively associated with both GDP and FDI inflows with moderate correlations (between 13 % and 30 %). As expected, GDP and FDI inflows are positively linked as well, with a strong correlation of 79 %. In line with the natural resource curse and FDI-resource curse, oil rent is negatively correlated with both GDP and FDI inflows, although the correlations are very weak.

Mineral production is positively associated with GDP and FDI inflows. These correlations are relatively important, almost 25 % between ETCM’ production and GDP, and almost 26 % with FDI inflows. This may indicate a positive relationship between ETCM and FDI inflows. This very interesting output needs to be confirmed by the econometric analysis.

Before discussing the expected results regarding the relationship between critical minerals production and FDI inflows, let us recall the characteristics of the 8 minerals retained. Extraction is highly concentrated geographically. For 3 of them, more than 70 % of 2020 world production is in only one country (cobalt in D.R. Congo, graphite and silicon in China). For the 5 others, more than 50 % of 2020 world production is in only two or three countries (see Table 6 in Appendix). Extracting countries are quite heterogeneous. For the main extracting countries of the minerals retained, only Australia is a high income country, where China, Russia and Chile are upper middle, and Indonesia or D.R. Congo are lower middle or low income countries (according to the World Bank classification). The minerals can also have differences regarding their prices, their extraction techniques, their criticality, their uses and how long they are being exploited.

However, these minerals are also characterized by a very high degree

⁶ The main producing countries and uses in low-carbon technologies are presented in Table 6 in Appendix. USGS’ data for REE includes all 15 lanthanides as well as yttrium but excludes scandium.

⁷ The panel is unbalanced. The database is available here and for a larger selection of 20 minerals: <https://pladifex.institutlouisbachelier.org/critical-metals/>.

Table 1
– Matrix of correlations based.

	GDP_curUSD	Inflation	Trade	Oil_pGDP	Rule_law	Control_corruption	Political_stab	FDI_inflows	Prod_total	Reserve_total
GDP_curUSD	1									
Inflation	-0.0177	1								
Trade	-0.1679	-0.0216	1							
Oil_pGDP	-0.0600	0.0322	0.0221	1						
Rule_law	0.2929	-0.0911	0.2024	-0.2124	1					
Control_corruption	0.2704	-0.0723	0.2049	-0.2054	0.9569	1				
Political_stab	0.1376	-0.0911	0.3343	-0.1032	0.7471	0.7321	1			
FDI_inflows	0.7940	-0.0219	-0.0294	-0.0527	0.3212	0.3091	0.1634	1		
Prod_total	0.2474	-0.0207	-0.1740	-0.0626	0.1250	0.1481	0.0766	0.2590	1	
Reserve_total	0.0103	0.0051	-0.0459	-0.0941	0.0029	0.0446	0.0044	0.0548	0.6817	1

of complementarity. To carry out a full and complete energy transition project, it is necessary to set up and articulate different and interdependent technologies of production, transport, storage of electricity (for example, wind turbines, a distribution grid and power storage batteries, etc.). In addition, there is, within the technologies themselves, a huge complementarity between the different minerals. The technologies require various chemical properties obtained through alloys of several different metals, often difficult to substitute or replace (see IEA's critical minerals data explorer for the composition of technologies). These interconnections between technologies and minerals, where eventually each mineral is necessary but insufficient, justify considering these 8 different minerals as a whole. Therefore, we will aggregate the extractions and reserves for these 8 minerals for the first series of estimations, and study them individually as explanatory variables for further estimations.

Moreover, even if some countries have diverse and large productions, no country is in a total dominant position for the extraction of all ETCM. Consequently, all countries are ultimately interdependent to have access to these resources necessary for a complete energy transition. Hence the interest of studying FDI which can be seen, beyond the economic interest, as strategic placements in mining countries, in order to secure supplies and for strategic material and energy imperatives.

Regarding the expected effects of mineral exploitation on FDI inflows, just like the literature showed for hydrocarbons exploitation, two effects should be at play. One negative effect crowding out non-resource seeker FDI and one positive effect attracting resource seeker FDI.

Let us discuss the mechanisms that could explain the negative crowding out effect on non mineral seeker FDI. First, mineral extraction comes with huge ecological costs as mining activities destroy local environments, use and pollute water, can cause deforestation and generate chemical pollution and important mining wastes (SystExt reports,). Then, mineral extraction also comes with economic risks as, just like any other natural resource exploitation, it can be the source of a Dutch Disease or a broader natural resource curse. Resource curse authors,⁸ or even the World Bank in its 2024 World Development report, highlight a new or increased risk of resource curse for mining countries in the context of energy transition and soaring demand for critical minerals. Hache et al. (2023), who refer to a potential "energy transition curse", show that developing mining countries such as Chile, Argentina and D.R. Congo have experienced weak growth since 2010 despite being the World's main lithium and cobalt producers. This would be explained by the fact that these countries know weak institutions, social oppositions or even armed conflicts, as well as a liberal economic and fiscal framework that favors extrovert extractivism by private and often foreign companies. These factors do not permit a sufficient redistribution of the mining revenues to the rest of the economy, and/or prevent the development of a national industrial strategy aimed at moving downstream global value chains, to capture more added value in the stages following mining (metallurgy, refining, manufacturing

technologies, etc.).

The natural resource curse can be mitigated or even avoided, including for mining countries, and it depends on the political and economic strategies and structures of the latter. For example, China has turned its mining activities into a powerful economic asset, precisely by positioning itself across the entire value chain and becoming the world leader in metallurgical activities and in the manufacture of low-carbon technologies (Bonnet, et al., 2022) (even if it seems to be suffering from a kind of internal curse, with strong inequalities between the extractive provinces and the provinces that provide high value-added activities, as shown by Hache et al. (2023)). Australia is another striking example of a major mining country that has nonetheless achieved a high level of economic development and growth thanks to economic diversification and a balance between its various sectors (Ville and Wicken, 2013).

Beyond these cases, it is reasonable to assume that, generally, a number of mining countries face a significant risk of resource curse linked to critical minerals in the current context of exploding needs. This risk could result in mineral extraction having a negative impact on the attractiveness of mining countries to non-resource seeker FDI, and therefore a negative crowding-out effect on aggregated FDI.

On the other hand, a positive attraction effect on mineral seeker FDI should be at play, as for foreign investing countries, critical minerals represent a huge economic opportunity as well as an important strategic resource regarding energy and material security issues.

First, as we mentioned earlier, global mineral demand is characterized by an important growth and goes together with a general increase in metal prices (see Figs. 1 and 2 in Appendix), both being strongly supported by the huge needs for the deployment of low-carbon technologies and the energy transition to come. These dynamics represent important economic guarantees and opportunities for investing foreign countries and foreign capital are very likely to export itself toward such a booming sector.

Then, there are motivations for FDI toward mining countries from a strategic point of view and for a material security objective. As we previously noticed, countries aiming at a massive deployment of low-carbon technologies face huge critical minerals needs that will mostly be met by a sharp increase in mining activity worldwide. Indeed, the recycling is an interesting alternative to mining to ensure a secondary source of supply. However, as of right now recycling is very limited in terms of volumes of production, and even with ambitious recycling rates by 2050, most of the supply would still come from mining and new investment in such sector would still be needed (IEA, 2021; Hund et al. (2020). At a shorter term, by 2030, mining, primary supply, should stay by far the main supply source for ETCM. Therefore, as FDI can be an economic tool in favor of a political transformation, within host countries, toward a market economy (Bürbaumer, 2024), such investments are a means to promote resource extraction and potentially secure supplies from a host country. It is therefore in the interest of the generally richer non-mining countries to export capital within generally less rich mining countries in order to (i) at short term, secure supplies with partnerships or mining operations abroad and (ii) at a longer term,

⁸ <https://cepr.org/voxeu/columns/new-curse-critical-minerals>.

ultimately increase global extraction levels to meet with global mineral needs associated with electrification and decarbonization.

For foreign investing countries and companies, the stakes are twofold, with economic benefits expected from a booming sector, and material benefits expected from the extraction of raw materials critical to technological and energy projects. These motivations should result in a positive impact of mineral extraction on the attractiveness of mining countries to resource seeker FDI, a positive attraction effect.

Therefore, two contradictory effects are at play and it is necessary to determine which effect is stronger. The literature has shown that the crowding out effect dominates for oil, resulting in a negative relationship between oil resources and aggregated FDI inflows, highlighting an oil FDI resource curse. Regarding transition critical minerals extraction and aggregated FDI inflows, our results will determine which effect is stronger. This is the subject of the following section, in which we present the results of our estimations.

2.4. Empirical methodology and unit root tests

As stressed above, our analysis covers a sample of 117 countries over the 1997–2020 period at an annual frequency. We consider the following general specification:

$$FDI_{i,t} = \beta_0 + \beta_1 FDI_{i,t-1} + \beta_2 OilRents_{i,t} + \beta_3 Institvariables_{i,t} + \beta_4 Control_{i,t} + \beta_5 MineralProd_{i,t} + \beta_6 MineralRes_{i,t} + \epsilon_{i,t} \quad (1)$$

Before estimating this specification, we apply the CIPS unit root test to ensure the stationarity of our variables. This second-generation panel unit root test developed by Pesaran (2007) allows for heterogeneity regarding the presence of a unit root and accounts for cross-sectional dependence. Given the results presented in Table 9 in Appendix, we consider all the variables in first difference for the sake of consistency.⁹ As the variables are either expressed in logarithm or percentages, we can ultimately interpret our first-differenced variables as growth rates.

We will drop individuals with too many missing observations from the estimations, and display the number of countries and observations for each estimation. Since we consider dynamic panel data regressions, we use difference GMM and System GMM, in line with the literature. For the sake of robustness, we also estimate Equation (1) with several estimation techniques.¹⁰ All the methods lead to similar results (see Tables 8–10 in Appendix), illustrating the robustness of our findings. We also run estimations for disaggregated minerals productions, took individually as explanatory variables.

3. Results and related comments

Table 2 reports the estimation results of Equation (1) using difference GMM and system GMM.

The results of the several estimations conducted for robustness are available in Appendix (Tables 8–10).

Before discussing these results in details, let us mention that three outputs are worth noting: (i) the findings are robust throughout the different estimation methods, (ii) the findings are in line with the known results of the literature, testifying the relevance of the estimations and (iii) the relationship between ETCM and FDI inflows is positive, showing the domination of the attraction effect on mineral seeker FDI over the crowding out effect on non-mineral seeker FDI, a singular finding that

⁹ We do not conduct tests on institutional quality indices or on metal reserves because these are series with very little volatility and amplitude, so there is no risk of a unit root.

¹⁰ I also conduct estimations with Ordinary Least Squares; Generalized Least Squares, robust to residuals' autocorrelation; and Panel Corrected Standard Error regressions, robust to residuals' heteroscedasticity; each time with pooled regression, individual fixed effects, time fixed effects and individual and time fixed effects.

Table 2
Dynamic Panel Data regressions results.

Variable	Difference GMM	System GMM
L.dnet_FDI_inflows_pGDP	−0.540*** (0.0814)	−0.515*** (0.0745)
L2.dnet_FDI_inflows_pGDP	−0.182*** (0.0520)	−0.162*** (0.0495)
dl_prod_total	−0.170 (0.180)	−0.249 (0.180)
Inflation	−0.0105** (0.00501)	−0.00687 (0.00526)
dl_GDP_curUSD	−0.392 (1.345)	−0.498 (1.514)
dOil_pGDP	−0.229* (0.124)	−0.264* (0.138)
L.dOil_pGDP	−0.183 (0.114)	−0.219* (0.115)
L2.dOil_pGDP	−0.174** (0.0729)	−0.205** (0.0862)
L.Inflation	0.0869* (0.0506)	0.0634 (0.0467)
L2.Inflation	−0.00373 (0.0347)	−0.0222 (0.0348)
rule_law	−2.128 (2.115)	−2.432 (2.107)
L.rule_law	4.576* (2.578)	5.230* (2.841)
L2.rule_law	−2.447 (1.542)	−1.938 (1.518)
political_stab	0.0565 (0.669)	−0.0618 (0.762)
L.political_stab	0.0353 (0.664)	0.279 (0.666)
L2.political_stab	−0.0637 (0.697)	−0.564 (0.715)
control_corruption	2.001 (1.411)	1.915 (1.428)
L.control_corruption	0.0101 (1.665)	−0.581 (1.993)
L2.control_corruption	−1.340 (1.041)	−1.751* (1.047)
L.dl_GDP_curUSD	1.127 (0.968)	1.685* (0.902)
L2.dl_GDP_curUSD	0.848 (0.663)	1.121 (0.742)
dTrade	0.198*** (0.0509)	0.191*** (0.0486)
L.dTrade	0.0638*** (0.0235)	0.0558*** (0.0214)
L2.dTrade	0.0371 (0.0259)	0.0291 (0.0268)
L.dl_prod_total	−0.00433 (0.156)	−0.0103 (0.142)
L2.dl_prod_total	0.347** (0.171)	0.391** (0.167)
dl_reserve_total	0.506 (0.352)	0.692* (0.409)
L.dl_reserve_total	−0.162 (0.219)	−0.0821 (0.198)
L2.dl_reserve_total	−0.309 (0.196)	−0.311 (0.211)
Constant	−0.642** (0.290)	−0.624** (0.280)
Observations (groups)	340 (31)	372 (32)

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

we will discuss further.

3.1. Traditional determinants, institutions and FDI oil curse

Regarding traditional determinants of FDI (Table 11), we find a very robust positive relationship between FDI inflows and trade openness, as well as important positive effects of GDP growth. Both attract FDI inflows as they benefit investors and multinational companies (through the opportunities of a growing economy and reduced transaction costs).

As expected, inflation's coefficient is significantly negative but weak and not very robust.

Regarding the quality of institutions (Table 12), we consider three indexes for rule of law, control of corruption, and political stability. The only robust finding is a strong positive relationship between rule of law and FDI inflows. As expected, a good rule of law increases the economy's attractiveness to aggregated FDI. The coefficients of the two other indexes for institutions are not significant. We find the same general results by using only the rule of law index.

Then an important output is that our results confirm the existence of the FDI-resource curse for oil (Table 13). The coefficient for the growth rate of oil rents is significantly negative in almost all estimations. When oil rents increase, then, on average, the share of net FDI inflows in GDP will decrease.

Indeed, because of the structural economic imbalances of an oil producing country (a component of the resource curse), the growth of the oil sector attracts FDI toward the oil sector but evicts FDI toward other sectors. This negative effect of eviction of non-oil seeker FDI dominates the positive effect of attraction of oil seeker FDI.

Overall, our results are in line with the literature regarding the traditional determinants of FDI and the existence of a FDI oil curse. Let us now focus on the role of ETCM.

3.2. ETCM production relationship with FDI inflows

As shown in Table 13, we find a robust, significant and positive relationship between ETCM production growth rates and net FDI inflows on GDP, especially for a two year lag. When mineral extraction increases, the share of foreign capital in the economy rises later on. No significant coefficients are found for critical mineral reserves.

From the two possible opposite effects at play presented earlier, the positive attraction effect largely prevails. Critical minerals seeker FDI's strong positive dynamic, driven by economic and strategic interest, exceeds the crowding out effect on FDI aimed at the rest of the economy, fearing the potential structural imbalances and instability of a mining country.

This result contrasts sharply with the negative relationship between oil activity and aggregate foreign capital inflows. The FDI-oil curse testifies that the oil seeker investments dynamic is not strong enough to compensate the crowding out effect on other FDI. Therefore two observations can be made from this result differing from the findings on oil. First, ETCM are a singular raw material and must be the subject of its own studies and analyses as they might not "obey" the traditional "rules" of natural resource macroeconomics, i.e., they might not exactly follow the traditional observations made by the literature on natural resources. Either because structurally, minerals are different from hydrocarbons because of their plurality, their complementarity, the complexity of the associated value chain, and the geographical distribution of resources. And/or because these minerals are in a relatively recent context (compared to hydrocarbons) of exploding production, demand and use, with a trend towards higher prices and growing strategic interests. Second, the investments dynamics in the mining sector are stronger than in the oil sector, and/or resource curse in oil countries could be more severe, leading to a stronger crowding out effect.

This result, on a large time sample between 1997 and 2020, is in line with the more recent analysis around the reconfiguration of global investment patterns in the different natural resources sectors in the context of the energy transition. Indeed, as shown in the UNCTAD's 2024 World Investment Report, the number of announced greenfield projects in critical minerals (including processing) around the world largely increased between 2022 and 2023, from 61 projects (for 30,396 millions of dollars) in 2022 to 114 projects (for 57,964 millions of dollars) in 2023. On the contrary, for oil and gas, announced greenfield projects worldwide decreased between 2022 and 2023 from 58 projects (for 89,567 millions of dollars) in 2022 to 47 projects (for 25,850 millions of dollars) in 2023 (UNCTAD, 2024). These important dynamics

may indicate a sort of shift, at least in the economic and financial sphere, from oil to critical minerals as the new main energetic raw materials, leading to many huge implications.

Thanks to the disaggregated critical mineral production data used, we also conduct estimations for each mineral production and reserves as explanatory variables individually to compare their force of attraction on FDI. The three minerals with the strongest and most robust positive effect on FDI inflows are cobalt, lithium, and REE (see Table 3).

3.3. Cobalt and lithium, minerals for electric vehicles' batteries

Table 14 displays results regarding extraction of cobalt, lithium and REE. Cobalt production has a strong attraction effect on foreign capital. Cobalt is indeed a critical component of storage batteries technologies for which demand is soaring in relation with electric vehicles. The main producing country in the world is the D.R. Congo. Despite the political instabilities in the country, and the conflicts related to cobalt, it is an important host for several multinational mining companies (Glencore, Eurasian Natural Resources, China Molybdenum ...) that share cobalt production while the state-owned company Gécamines weighs very little (Leruth et al., 2022). It is important to note that if we exclude DRC from the host countries panel, the coefficient is still significantly positive and is only slightly weaker (2.34**).

Regarding lithium, once again the strong attraction effect is linked to criticality of lithium in all storage batteries technologies. With cobalt, it is one of the minerals with the strongest recent and future demand and production trends. The top producing countries are Australia and Argentina, all very open to foreign capital, especially Chinese, in the mining sector. There is also Chile, for which lithium production has been ensured by the US company Albermale (owned by Blackrock and Vanguard) and SQM (owned by Pampa, a Chilean group, and Tianqui, a Chinese company) (Leruth et al., 2022), but the government recently announced the creation of a state-owned company to exploit and progressively nationalize lithium resources which we will discuss in subsection 4.2. Indeed, the largest reserves of lithium are in "the lithium triangle" in Argentina, Chile and Bolivia, the latter has decided to totally nationalize its lithium reserves to develop a national industry along the entire value chain, testifying of the different national strategies and policies in this region (Bastida et al., 2024).

3.4. REE, minerals for wind turbines and electric vehicles

REE production also has a significant positive effect on FDI inflows that we will assess in details. Indeed, REE represent a specific case for two reasons, the evolution of the concentration of the world production, and the fact that these minerals revealed and crystallized the geopolitical issues around critical minerals.

Since the 2000s, REE production has been largely dominated by China as a result of a national strategy to develop domestic extraction in order to "fuel" the growing domestic sectors of low-carbon technologies, but also high-tech digital technologies, and at the cost of massive and dramatic pollution associated with extraction of such materials (Seaman, 2019). Between 2000 and 2010, China represented more than 80 % of world production. Then in 2010–12 during the well-known "rare earth crisis", it has been considered that China used its quasi-monopoly on REE as a "geopolitical weapon" to settle a maritime conflict with Japan. At that time Japan faced important but short-termed economic consequences because of the disruption of trade flows and price increases penalizing the Japanese REE-dependent industrial sectors. But

Table 3

Coefficients for the lagged growth of extraction in the difference GMM estimations for each mineral took individually as an explanatory variable.

Variables/Estimator	All minerals	Cobalt	Lithium	REE
Difference GMM coefficient	0.347**	2.614***	1.244***	0.348*

with hindsight, the main effect of this event may well have been to trigger the growing awareness, on the part of Japan, the US and the EU, of the need to reduce reliance on China for REE (but also ultimately for other critical minerals for which China dominates, from extraction to refining and transformation) (Bonnet et al., 2022). REE are indeed essential to super magnets for wind turbines or electric vehicles, the same minerals are also vastly used in high-tech digital products or advanced military technologies, the latter being national security priority for the US.

Therefore, we exclude China from the panel of host mining countries, and we actually find a significant and stronger positive effect (see Table 4). This result is very interesting as it testifies the will from many investing and demanding countries to decouple from China and promote alternative REE producing countries. This is in line with the observed geographical deconcentration of the world REE production between 2010 and 2020, a singular observation as for other minerals (cobalt, lithium, nickel) there has been a significant geographical concentration of the production these past years. Regarding REE, China represented around 90 % of world production in the early 2000s, and “only” 57 % in 2020.

In reaction to the 2010-12 REE crisis, important alternative producing countries developed REE mining, especially in USA and in Australia for which REE production has exploded since 2012 (see Fig. 3 in Appendix) representing respectively 16 % and 8.6 % of the world production in 2020.¹¹ Notably, Mountain Pass in California - the historical REE mining site that dominated world production in the 1970s and the 1980s - was closed in 2002 but reopened in 2012, raised as a symbol of the domestic mining revival in the US. Regarding Australia, mining is by far the most attractive sector toward FDI and the top investing countries are generally USA, Great Britain, the EU or Japan.¹² Precise data on FDI toward mining and REE Australian sector are not available but even these limited data corroborate our results, Australia's mining and REE production would attract FDI from western countries willing to reduce reliance on China.

However, this deconcentration is limited, insufficient, and China still largely dominates the downstream REE global value chain, from refining to transformation of REE and associated technologies manufacturing. Hence the will to also develop on these segments, like in the US with a partnership between the US Department of Defense and the Australian company Lynas Rare Earths to develop a REE treatment facility in Texas.¹³

4. Discussion

Regarding foreign investing countries and companies, this positive relationship between critical minerals and FDI clearly shows the interest in this sector, i.e., in these resources. This sector is attractive from

Table 4

Coefficients for the lagged growth of REE extraction in the difference GMM estimations with and without China as a host country.

Variables/Estimator	REE	REE (without China as host country)
Difference GMM coefficient	0.348*	0.962***

¹¹ Myanmar also appeared as an important REE producer (12.7 % of world production in 2020). Extraction takes place in Kachin state on the border with the Chinese Yunnan Province (Chinkaka et al., 2023). But this activity is very recent, unstable and insecure.

¹² (Between 2019 and 2023, the mining and quarrying sector accounted for an average of 34 % of total FDI inflows. The same period, on average, US accounted for 24.6 %, UK for 18.7 %, EU for 17.6 % and Japan for 6 % of total FDI inflows toward Australia in general (Australian Bureau of Statistics, (2023)).

¹³ <https://www.ft.com/content/20badb28-7a9d-11e9-81d2-f785092ab560>.

an economic viewpoint as it is a growing sector with a supported soaring demand as well as generally rising prices, but also for strategic, material and energetic objectives. As stressed above, FDI can be a strategic economic tool to support a political transformation in the host country, to promote the development of a market-based and extractive economy, as well as a way of ensuring economic profits and/or direct or indirect supply or trade partnerships. We will detail some of the global FDI strategies from demanding and investing countries and companies that explain and illustrate this positive relationship between ETCM and FDI inflows.

4.1. The role of FDI in the international strategies of ETCM demanding countries

As illustrated by our results, the REE have revealed and crystallized the geopolitical issues around critical minerals and China's dominance, and the crucial role of FDI to promote extraction in host countries. But besides REE, these geopolitical issues quickly expanded to the other critical minerals, and demanding countries have set up international strategies to secure the best position in the global supply chains of several ETCM. Recent studies have focused on mine ownership and investment strategies worldwide and highlight the predominance of mainly China and the US in capital holding of ETCM mining companies (Bonnet et al., 2022; Leruth et al., 2022; Faubert et al., 2024).

Indeed China has a global leadership not only on the REE value chain but on several other ETCM, and FDI outflows is an important part of its global strategy. First, China is a major mining country, dominating world extraction for REE but also for graphite and silicon, in addition of a significant national primary production of bauxite, copper and lithium (see Table 6 in Appendix). Besides this strong position on primary production, and in order to fill the gaps, China has set up an important global strategy to secure supplies to minerals it extracts little or none. In the context of the Belt and Road Initiative (BRI) - and coupled with bilateral partnerships, infrastructure investments, collateralized loans to mining operations - China has multiplied FDI to the top mining countries that precisely extract minerals it lacks the most. Hence, China massively invests in the mining sector of Argentina, Chile and Peru producing copper and lithium, D.R. Congo producing cobalt, Australia producing lithium, and Indonesia producing nickel (Bonnet et al., 2022). As a result, Chinese firms and investors' holdings account for around 18 % of copper, lithium and nickel world production, for 28 % of cobalt world production and 73 % of REE world production (Faubert et al., 2024). Following this, China massively imports ETCM from these countries, for example for each bauxite, cobalt, copper, lithium and nickel, Chinese imports of ores and concentrates represented between 50 % and 85 % of global trade in 2022 (Chatham House, 2024) and mainly from these same countries. As a result, for almost all ETCM then, China has a clear dominant leadership for refining (Bonnet et al., 2022).

China is therefore the illustration of the strategic role of FDI as a means to take position in a foreign mining country in order to secure supplies and promote emerging mining activities. Global FDI has been a pillar of this far-sighted, albeit criticizable, strategy.¹⁴

The US on its side are trying to catch up with China. Regarding domestic extraction, since 2017, and continuously under the Trump and Biden administrations, there is a political will to revive the domestic mining sector through flexible regulations (mining sector added to the

¹⁴ On the sole criterion of securing supplies, this strategy is undoubtedly very effective. However, several criticisms can be made on the socio-political and environmental fronts. A number of arguments can be put forward highlighting an imbalanced relationship between China and some mining supplier countries, which could even reveal a Core-Periphery relationship and the realization of an ecologically unequal exchange between China and certain mining countries. Such problematics are out of scope of this paper and will be the object of future research.

FAST-41 fast track permitting law) and massive public spending especially under the Inflation Reduction Act.¹⁵ Nonetheless, domestic extraction faces important socio-environmental and geological limits (Boyer et al., 2017; Rodeiro, 2023; Hammond and Brady, 2022).

Therefore, the US will still greatly rely on foreign supplier countries, but with the will to better decide and control its reliance. Indeed, in addition to the reshoring strategy, the US relies heavily on a friendshoring strategy. The most striking example is the critical materials requirement for the IRA consumer subsidy on electric vehicles. The tax credit grant is conditioned by the domestic assembly of the vehicle and its battery, and by the origin of the critical minerals composing it. There is a complete ineligibility for the credit if materials are originated from “foreign entity of concern”, i.e. any companies “significantly influenced by the governments of China, Russia, North Korea, or Iran” (Congress Research Service, 2024). However, there is a total eligibility for critical materials from countries that have signed a free trade or a critical minerals agreement, regarding mineral supplying countries it concerns Australia, Canada, Chile, Mexico, Peru and Japan.

In addition of this protectionist strategy on the trade side, the US also rely on FDI toward mining countries. Historically the main host countries for US FDI toward the mining sector are by far Australia and Canada, mainly for industrial metals and coal exploitation. FDI toward mining in these two countries have significantly decreased since ten years, however US FDI toward the mining sectors of other countries have increased steadily since then, especially in Latin America (Brazil, Chile, Peru) producing copper and lithium and in Indonesia producing nickel (see Fig. 4 in Appendix). Indeed, US companies have progressively increased their holdings to ultimately account for around 16 % of world production of nickel, and around 39 % of world production of copper and lithium (Faubert et al., 2024). Regarding REE, the US’ holdings accounts for approximately 16 % of World production but it is not really related to a global FDI strategy, and holdings on operations abroad. However, it is rather due to the re-shoring strategy and the domestic exploitation of Mountain Pass in California, which accounts for such share of the world REE production, as explained above.

Finally, regarding other of the richest and highly demanding countries susceptible to develop global FDI strategies to access ETCM, Australia and Canada are major mining countries with several of the biggest mining transnational companies (PwC, 2023). However, they are more focused on the exploitation of coal, gold and industrial metals, less specialized on ETCM extraction. Cobalt and nickel mining are underdeveloped in Canada, and if Australia is geographically the top world producer of lithium, the latter is operated mainly by state-owned Chinese companies such as Talison lithium (Leruth et al., 2022). The existence of several transnational mining companies is still an asset and let the possibility to diversify the production toward other materials. The European Union on its side does not domestically produce ETCM, does not have many transnational mining companies, and its ownerships in foreign companies or operations are very limited (Faubert et al., 2024). The EU faces a challenge trying to catch up with China and the US, as the domestic extraction potential is very limited, it will likely rely on trade partnerships to secure supplies but also bet on developing recycling capacities and boost sufficiency to reduce consumption levels (Nobletz et al., 2024).

¹⁵ Under the IRA, 250 M USD is granted to the DoD, to invest in critical mineral mining or processing projects; the Department of Exterior is instructed to ensure 40B USD of loans; and the Department of Treasury to ensure a 10 % tax credit, for critical minerals mining and processing (IRA guidebook, 2022). Under the Infrastructure, Investment and Jobs Act now, 500 M USD is granted to the USGS for research, mapping and documentation on critical minerals (IIJA guidebook, 2022). Finally, the Congress has voted a 218M USD budget for the National Defense Stockpile for new acquisitions in 2022 and 2023, it’s a first since 1969 (since it usually funds itself through sales) (Congress Research Service, 2023).

Therefore, China and the US are the two predominant players in global FDI dynamics around ETCM, we can confirm it by running side estimates to check for the effect of China and the US as major global investors. We run regressions using Chinese FDI data from the American Enterprise Institute China Global Investment Tracker, and US FDI data from the Bureau of Economic Analysis. For each country, we subtract the Chinese/US FDI inflows amounts from the total FDI inflows data, in order to create a FDI inflows variable without China or without the US as investing countries. Two regressions are run using these variables, the positive relationship between critical mineral production and FDI inflows is still verified, however the coefficients are changed (see Table 15 in Appendix). The coefficient is only slightly weaker when excluding FDI inflows from the US, but significantly weaker when excluding FDI inflows from China, confirming the important role of the US, and the even stronger role of China, as global investors in mining countries. However, it also shows that critical minerals do attract non-Chinese or non-US investments, corroborating their major, but not exclusive, role in determining global FDI flows toward mining countries, and adding robustness to our general finding of a positive relationship between these two variables.

An important point marks a major difference between the Chinese and the US strategies. 76 % of Chinese mining investments abroad are made by state-owned enterprises (Ufimtseva et al., 2024). The main Chinese companies operating in China and abroad are therefore likely to act in line with strategic political longer-term objectives, with interests for securing material supplies. On the other hand, national and transnational US-based mining companies are largely held by private funds (Leruth et al., 2022), more likely to act in line with private shorter-term economic objectives, with interests for profit. The motivations might not be the same and it may determine these FDI dynamics. China’s strategy could be more long-term oriented and less sensitive to price variations in addition to registering in a global investment, infrastructures and trade strategy within the BRI.

On the other hand, host countries are aware of the predominant role of the Chinese government and can therefore decide to practice screening policies on Chinese FDI for geopolitical and national security reasons, as it is starting to be done in Australia, Canada and the US, as a part of the objectives of decoupling from China, in line with trade distortive measures, and in parallel of developing friendshoring strategies, through trade and investment partnerships (Ufimtseva et al., 2024). If the US governments have really grasped the strategic and material stakes involved in securing supplies, they can only try to encourage, incite or support private mining companies (and more are being done in this sense), whereas China’s government may actively control and direct most of its mining companies.

4.2. Risks, opportunities and national strategies of ETCM mining countries

Whatever the motivations of the investing countries and companies, whether it be for securing material supplies or to pursue economic interests, the outcome is the same: FDI strategies are taking form to promote the extraction of ETCM within host countries. Therefore, we must now focus on the consequences of these dynamics for the host, mining and mainly developing countries. The rise of foreign capital inflows and the development of mining activities can represent both risks and opportunities for the different mining countries which face up to it alongside public policy choices and national strategies implementations. These risks could, at term, penalize the attractiveness toward foreign capital inflows and therefore mitigate the positive effect found by our estimations.

In a paper on development and sustainability, Goutte and Sanin (2024) explain that FDI inflows are a significant driver of economic growth and development. In the same paper, they explain that the extraction of critical minerals comes with socio-environmental costs, regarding water, biodiversity and labor conditions. When applied to

mining countries hosting FDI, these two points show the complexity of the situation. Therefore, we will discuss the different risks and opportunities for such countries regarding the mining sector, the related FDI inflows benefits, and the related socio-environmental costs.

First, there is a structural risk of growing a mineral resource curse at a longer term. Critical minerals' strong effect of attraction on FDI may surely benefit to the mining sector, but the large capital inflows toward the latter could lead to its hypertrophy increasing the risks associated with the natural resource curse: imbalances with the other tradable sectors because of the Dutch Disease (currency overvaluation and instability, displacement of labor factor), rent-seeking and/or corrupted economic elites, lack of diversification, extractivism (in the sense of low value-added raw materials exports, with the capture of the value-added downstream of the value chain by foreign companies), etc.

Indeed, a crucial economic stake lies around the issues of taxation of the mining sector in order to capture fiscal revenues, necessary to conduct the fiscal policy and promote economic diversification and public spending in other sectors. There are inherent difficulties in the design of fiscal policies for the extractive sectors of FDI host countries. First, the fiscal regime must be balanced, strong enough in order to capture significant revenues, and competitive enough in order to attract foreign companies and investments. Then, a fiscal regime must be stable in the long-term in order to offer guarantees and visibility for investors, while at the same time mining revenues can be quite volatile depending on the evolution of minerals and metals market prices. Finally, mining countries from emerging economies can have difficulties to enforce fiscal rules and actually capture revenues because on weaker institutions and governance (Gourdon and Lapeyronie, 2024).

Therefore, there are evidences of important fiscal evasion and tax avoidance in the mining sector. Multi-national mining companies avoid taxes via fiscal optimization and profit transfers to off-shore subsidiaries. It is an important issue and a heavy loss of potential income for mining countries hosting FDIs, especially emerging economies (Heidrich, 2013; Albertin et al., 2021; Beer and Devlin, 2021; Gourdon and Lapeyronie, 2024).

Moreover, in a context of energy transition and soaring ETCM extraction, the increase of fiscal evasion and the resulting loss of earnings from mining activities is a real threat to the "fair" character of such transition, as mining taxes can be seen as a way to compensate the depletion of finished resources, of natural capital, as well as a way to compensate, even imperfectly, for the negative socio-environmental consequences of mining activities (Gourdon and Lapeyronie, 2024; Le Billon, 2024), a fair fiscal policy on mining profits enabling a balanced repatriation of revenues, with a view to justice, equity and redistribution.

Indeed, there are also socio-political risks that come with the increase of mining activities, from social conflicts with workers, to armed conflicts between different actors. An important example of a mining country knowing dramatic armed conflicts around its mineral resources is D.R. Congo (Prause, 2020). But historically mining has been linked to more or less violent conflicts around the world (Martinez-Alier, 2012). A comprehensive survey of conflicts has been made resulting in the Environmental Justice Atlas (Temper et al., 2018). Using the latter, the authors highlight mining as the most frequently reported sector, but also the most violent as mining related conflicts are significantly deadlier compared to other sectors on average, even more when Indigenous groups are involved (Scheidel et al., 2020). These results also highlight the persistence of colonial violence in several cases, and this issue is likely to recur as "the majority of the world's Energy Transition Minerals projects are located either on or near Indigenous Peoples' or Peasant lands with adverse conditions for human rights-compatible permitting, consultation, and consent" (Owen et al., 2022).

These social conflicts are often linked or caused by the major environmental costs associated with mining (Worlanyo and Jiangfeng, 2021; SystExt reports,) highlighted by a large literature (Lapeyronie and Espagne, 2023). Mine-ral extraction necessarily destroys its local environment as it expands on the surface and sinks deeper underground to

exploit deposits. Moreover, these deposits become less and less concentrated as they are exploited, mines expand and sink deeper, generating considerable quantities of mining waste - often toxic or radioactive due to the presence of chemical substances, both natural and resulting from extraction techniques. Mining also consumes a great deal of energy and carbon, and is therefore responsible for significant greenhouse gas emissions. In fine mining activities destroy or pollute soil, biodiversity, water and forest. The volumes involved are staggering - surface area of mines (Maus et al., 2022), quantities extracted, moved, stored as waste - and the timeframes are long, with industrial mines generally operating for several decades.

Hence, it would be inappropriate to speak of a "mineral blessing" because if FDI inflows promote mining activities, as the latter keep developing, these economic and socio-environmental risks will increase and mining countries will likely face more of these negative externalities. At a longer-term this may not necessarily benefit the whole economy, as Asiedu (2013) explains: "reaping the benefits that accrue from FDI may be more difficult than attracting FDI", and at a longer term one can therefore expect this positive effect to fade out. Indeed, economic instability, industrial imbalances, political and social conflicts, physical violence and environmental destruction could ultimately harm the country's overall attractiveness to foreign investment, or even discourage investors from investing in the mining sector if these externalities become too strong, especially private profit-seeking companies.

Therefore, with the risks faced by mining countries also come challenges and opportunities, to stabilize and sustain foreign capital inflows, while at the same time keeping a degree of sovereignty over mineral resources and their exploitation in order to turn them into an economic and geopolitical asset. The challenge for host mining countries is to manage these risks and mitigate the negative consequences, to turn the foreign capital fueled mining sector into a true asset for a balanced economic development, in addition to a geopolitical asset and a stepping stone toward technological material development.

First, as explained earlier there is a very strong stake in capturing tax revenues from mining industry profits, to unlock fiscal space of mining countries in order to spend on public policies, national strategies and diversification. To do so, efforts must be made in terms of governance, institutions and law enforcement. Investment must be made in research in the mining sector in order to reduce the information asymmetries that enable multinational companies to avoid taxes. And regional cooperation in terms of fiscal regime can be made between different mining countries, in order to avoid fiscal competition (Gourdon et al., 2024).

Then, it seems necessary to follow a national industrial strategy to develop the other mining-related sectors and cover a larger share of the value chain. Diversification is a means to avoid the natural resource curse, Australia being an example (Ville and Wicken, 2013), as well as China who leads on all stages of the global value chain of ETCM and low-carbon technologies (Bonnet et al., 2022). Countries therefore need to put in place the means to capture a portion of mining revenues and reinvest them in other sectors, via taxes or joint ventures between private and public companies, quotas on raw materials or refined materials exports, or policies to attract or to divert FDI to other sectors related to mining or not. The stakes are huge since regarding critical minerals, much added value lies in the following stages of metallurgy and especially the booming sector of advanced and low-carbon technologies. There are some important, albeit imperfect, examples of steps made in that direction. This is the case in Chile with the creation of the state-owned National Lithium Company in order to partially and progressively nationalize the lithium production, as it did with copper, Codelco being a fully state-owned company and one of the world's largest copper mining company (in terms of production).¹⁶ In Indonesia, exports of raw nickel ore have progressively been banned in order to promote the development of metallurgical sectors, to capture more

¹⁶ <https://www.iea.org/policies/17958-national-lithium-strategy>.

added value and export refined and transformed nickel metal.¹⁷

However, such strategies can come close to resource nationalism by limiting, selecting or evicting foreign participation. In this sense the case of Bolivia is interesting. Mariette (2021) explains the national Bolivian strategy around lithium which nationalized production and only accepts selected and limited international partnerships, and learned by doing, not without technical or political difficulties, to develop a production, albeit very small, but sovereign and national battery-grade lithium. Nickel production is also at the center of the strategy for political and economic independence of the Kanak people in New Caledonia. The “nickel doctrine”, while facing several difficulties or failures, aims at maximizing domestic added-value by developing metallurgical activities to export refined or transformed metal, and diversify the local economic sectors to prepare for a “post-nickel” economy (Demmer, 2018). Resource nationalism has therefore an obvious negative effect on general FDI inflows but besides few striking examples like Bolivia or New-Caledonia, it is still very limited in mining countries in general.

Besides the industrial development on the following stages of the value chain, there is also opportunities to develop other sectors and especially the transports infrastructures. Indeed, the mining sector requires colossal transport infrastructures to transport the materials extracted toward refining and transformation sites and/or in order to export such materials abroad. Therefore, there are potential spillovers between FDI inflows in shipping, road and freight infrastructures, and the mining sector. This complementarity could explain how the mining sector generally attracts FDI, as the latter can attract FDI in such necessary infrastructures. For example, the above-mentioned Chinese BRI lead important investments targeting transport infrastructures in mining countries, in order to guarantee the transport and the export toward China (Dahir, 2019). Such infrastructures surely benefit the others tradeable sectors and potentially rest of the economy.

Therefore, mining countries face a challenge and will have to implement calibrated and nuanced policies if they want to continue to attract FDI, while at the same time guarantee a balanced economic development and maximize the domestic added value. Moreover, in addition of these economic opportunities, ETCM endowments and production, as well as a strong positioning on global value chains, could represent a clear geopolitical asset for developing mining countries, as discussed earlier with China.

Regarding the negative social consequences of mining, some policies can be implemented to mitigate the latter, by improving work conditions, by ensuring dialogue, social and economic guarantees, as well as material or technological benefits, or democratic decision-making with workers and local populations. Institutions should play the role to avoid violent conflicts and respect Indigenous’ peoples sovereignty. Regarding environmental consequences, they are more irreducible, and if “sustainable mining” seems unattainable (SystExt reports,) there is still

room to implement environmental standards for a better management of these consequences and guarantee the best post-mining restoration policies. However, the imposition of high socio-environmental standards for mining activities could also crowd out foreign investments as it represents a number of constraints.

Once again, for mining the countries, the challenge is to reconcile two potentially contradictory objectives, to maintain a sustainable attractiveness to foreign capital, while at the same time ensuring a diversification of the economy, domestic revenues and value-added as well as better socio-environmental mining standards.

4.3. Conclusion

This paper investigates the existence of a FDI-resource curse for the ETCM through the use of a complete and precise mining extraction database built from USGS reference data. We find evidence of a robust positive relationship between critical mineral production and aggregate FDI inflows. Unlike oil, critical minerals generally attract FDI, illustrating the dominance of the positive attraction effect on mineral seeker FDI over the negative crowding-out effect on non-mineral seeker FDI. This result highlights the strong dynamics of FDI toward critical mineral resources, which can be explained by the important economic and strategic interests of countries and foreign investor companies. Nevertheless, for the various mining countries, these capital inflows motivated by mineral endowments represent both an opportunity and a risk: an opportunity to develop the mining sector, and a risk of a potential Dutch disease or a mineral resource curse, eventually becoming a burden for the balanced structural development of the economy.

Cobalt, lithium and REE are key minerals as they attract FDI the most, possibly because of the explosion of their demand and the technologies using them (electric vehicles batteries for lithium and cobalt), but also possibly because of the need to promote and diversify the mining suppliers (regarding REE). More detailed, qualitative case-by-case analyses of the main countries and mining projects for these materials would be interesting, as well as the possibly diverting interests and strategies between (i) demanding investor countries and companies and (ii) mining host countries. Finally, the shift from one dominant energetic raw material to another, namely from oil to ETCM, suggested by the results of this paper should be investigated furthermore as it would have huge macro-economic consequences.

Declaration of competing interest

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Appendix

Countries and minerals studied

List of 117 countries of the panel: Angola, Albania, Argentina, Armenia, Australia, Austria, Azerbaijan, Burundi, Benin, Burkina Faso, Bangladesh, Bulgaria, Bosnia and Herzegovina, Belarus, Bolivia, Brazil, Bhutan, Burundi, Botswana, Canada, Switzerland, Chile, China, Côte d’Ivoire, Cameroon, Democratic Republic of the Congo, Colombia, Cuba, Czech Republic, Germany, Dominican Republic, Ecuador, Egypt, Spain, Ethiopia, Finland, France, Gabon, United Kingdom, Georgia, Ghana, Greece, Guatemala, Guyana, Honduras, Croatia, Hungary, Indonesia, India, Ireland, Iran, Iceland, Israel, Italy, Jamaica, Jordan, Japan, Kazakhstan, Kenya, Kyrgyzstan, South Korea, Laos, Sri Lanka, Morocco, Moldova, Madagascar, Mexico, North Macedonia, Mali, Myanmar, Mongolia, Mozambique, Malawi, Malaysia, Namibia, New Caledonia, Niger, Nicaragua, Norway, New Zealand, Pakistan, Peru, Philippines, Papua New Guinea, Poland, North Korea, Portugal, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Singapore, Sierra Leone, Serbia, Suriname, Slovakia, Sweden, Togo, Thailand, Tajikistan, Turkmenistan, Tunisia, Turkey, Tanzania, Uganda, Ukraine, Uruguay, United States,

¹⁷ <https://www.iea.org/policies/16084-prohibition-of-the-export-of-nickel-ore>.

Uzbekistan, Venezuela, Vietnam, South Africa, Zambia, Zimbabwe.

Table 5

Countries' targets for greenhouse gas emissions reduction. Nationally determined contribution are taken under the United Nations Framework Convention on Climate Change.

Country	Greenhouse gas re-duction targets	Sources (available in bibliography)
European Union	Reach 45 % of renewable energy in the energy mix by 2030.	RePowerEU Plan, European Commission "Renewable Energy Directive" (European Union Commission Renewable Energy Directive)
United Kingdom	Reduce all green- house gas emissions by at least 81 % by 2035, compared to 1990 levels.	United Kingdom's Nationally Determined Contribution (UNFCCC United Kingdom's NDC)
United States	Reduce greenhouse gas emissions by 61–66 % by 2035 com-pared to 2005 levels.	United States' Na- tionally Determined Contribution (UNFCCC United States' NDC)
Canada	Reduce greenhouse gas emissions by 40–45 % by 2030 com-pared to 2005 levels.	Canada's Nationally Determined Contri- bution (UNFCCC Canada's NDC)
China	Reduce greenhouse gas emissions (per unit of GDP) by 65 % by 2030 compared to 2005 levels.	China's Nationally Determined Contri- bution (UNFCCC China's NDC)
Russia	Reduce greenhouse gas emissions by 70 % by 2030 compared to 1990 levels.	Russia's Nationally Determined Contri- bution (UNFCCC Russia's NDC)
Japan	Reduce greenhouse gas emissions by 46 % by 2030 compared to 2013 levels.	Japan's Nationally Determined Contri- bution (UNFCCC Japan's NDC)

Table 6

Transition Critical Minerals list, main producing countries and main uses. Source: United States Geological Survey for production data; International Energy Agency for uses

Metal	Main producing coun- tries in % of world pro- duction, total on the 1997–2020 period	Main producing coun- tries in % of world pro- duction, for the year 2020	Main uses in low carbon technologies
Bauxite	Australia (17 %), China (12 %), Guinea (11 %)	Australia (27 %), China (24 %), Guinea (23 %)	Wind and solar energy infrastructures, electricity networks
Cobalt	D.R.Congo (52 %), Zimbabwe (8 %), Canada (8 %), Russia (8 %)	D.R.Congo (73 %), Russia (7 %), Australia (4 %)	Power storage batte- ries for electric ve- hicles
Copper	Chile (36 %), USA (10 %), Peru (9 %), China (7 %)	Chile (32 %), Peru (12 %), China (9 %)	Electricity networks, wind turbines and solar PVs, electric vehicles
Graphite	China (70 %), Indonesia (12 %)	China (79 %), Brazil (6.5 %)	Power storage batte- ries for electric ve- hicles and storage grids
Lithium	Australia (40 %), Chile (30 %), China (10 %)	Australia (48 %), Chile (26 %), China (16 %)	Power storage batte- ries for electric ve- hicles and storage grids
Nickel	Russia (17 %), Indonesia (14 %), Canada (12 %), Australia (11 %)	Indonesia (36 %), Phillipines (16 %), Russia (13 %)	Power storage bat- teries for electric vehicles, hydrogen electrolysers
Rare earth elements	China (85 %), USA (7 %)	China (57 %), USA (16 %), Myanmar (13 %)	Wind turbines, elec- tric vehicles
Silicon	China (59 %), Russia (10 %), Norway (6 %)	China (70 %), Russia (7 %), Brazil (5 %)	Solar PVs, electric vehicles

Table 7

Share of World production by country and by TCM (total 1994–2020, rounded) (USGS data)

Country	Bauxite	Cobalt	Copper	Graphite	Lithium	Nickel	REE	Silicon
Argentina	.	.	.	.	8	.	.	.
Australia	33	8	6	.	41	12	4	.
Brazil	12	1	.	8	1	5	1	4
Botswana	.	.	.	.	.	1	.	.
Canada	.	8	4	3	2	13	.	1
Chile	.	.	37	.	31	.	.	.
China	17	4	8	68	12	5	85	60
DR Congo	.	54	3	.	.	.	.	.
Colombia	.	.	.	.	.	4	.	.
Czech Republic	.	.	.	.	.	.	.	.
Egypt	.	.	.	.	.	.	.	.
Spain	.	.	.	.	.	.	.	1
Finland	.	.	.	.	.	.	.	.

(continued on next page)

Table 7 (continued)

Country	Bauxite	Cobalt	Copper	Graphite	Lithium	Nickel	REE	Silicon
France	.	.	.	.	.	.	.	3
Guinea	12	.	.	.	.	.	.	.
Greece	.	.	.	.	.	1	.	.
India	7	.	.	14	.	.	2	1
Indonesia	3	.	5	.	.	16	.	.
Jamaica	6	.	.	.	.	.	.	.
Kazakhstan	1	.	2	.	.	.	.	1
Madagascar	.	1	.	1	.	1	.	.
Mexico	.	.	3	2	.	.	.	.
Mozambique	.	.	.	1	.	.	.	.
New Caledonia	.	2	.	.	.	9	.	.
Norway	.	.	.	.	.	.	.	7
Peru	.	.	9	.	.	.	.	.
Philippines	.	2	.	.	.	12	.	.
Poland	.	.	3	.	.	.	.	.
Portugal	.	.	.	.	1	.	.	.
Russia	2	8	5	1	1	18	1	10
South Africa	.	1	.	.	.	2	.	2
Ukraine	.	.	.	1	.	.	.	2
United States	.	.	10	.	.	.	7	6
Venezuela	2	.	.	.	.	.	.	1
Zambia	.	8	4	.	.	.	.	.
Zimbabwe	.	.	.	.	2	.	.	.

Table 8

Estimated demand for key critical minerals in the Announced Pledges Scenarios of the IEA, 2024a,b,c,d Global Critical Minerals Outlook

Mineral	Demand Type	2021	2023	2030	2040	Growth Factor 2021–2040
Copper	Cleantech demand	5380	6311	12,001	16,343	×3.04
	Other uses	19,548	19,543	19,127	20,036	×1.03
	Total demand	24,928	25,855	31,128	36,379	×1.46
Lithium	Cleantech demand	38	92	442	1203	×31.7
	Other uses	63	73	90	123	×1.95
	Total demand	101	165	531	1326	×13.1
Nickel	Cleantech demand	240	478	1953	3381	×14.1
	Other uses	2519	2627	2802	2857	×1.13
	Total demand	2759	3104	4754	6238	×2.26
Cobalt	Cleantech demand	36	64	177	260	×7.22
	Other uses	145	150	167	194	×1.34
	Total demand	181	215	344	454	×2.51
Graphite	Cleantech demand	532	1292	6013	9839	×18.5
	Other uses	3388	3340	4406	6185	×1.83
	Total demand	3920	4632	10,419	16,023	×4.09
Rare Earths	Cleantech demand	11	16	46	64	×5.82
	Other uses	67	76	87	105	×1.57
	Total demand	78	93	134	169	×2.17

Table 9

Unit root tests results

		FDI inflows pGDP	Oil pGDP	NatGas pGDP	Inflation
CIPS*	level	−2,4963	−2193	−1,7559	−3,2839
p-value	level	0,01	0,015	0,465	0,01
CIPS*	1 diff	−4,0217	−3,5919	−3434	−3,5977
p-value	1 diff	0,01	0,01	0,01	0,01
		log GDP cu-rUSD	GDPPC Growth	Trade	log prod total
CIPS*	level	−2771	−2663	−1,7189	−1,6517
p-value	level	0,01	0,01	0,525	0,1
CIPS*	1 diff	−3,5126	−4,4596	−3132	−2,7283
p-value	1 diff	0,01	0,01	0,01	0,03248

7 Descriptive statistics

Table 10
Descriptive Statistics for all 117 countries

	Obs	mean	Var	sd	min	max
net_FDI_inflows_pGDP	2769	2.214132	19.44064	4.408919	-37.30209	43.00372
Oil_pGDP	3241	2.903559	50.29382	7.091814	0	55.38342
Inflation	3050	38.97668	245716.9	495.6984	-11.68611	23773.13
rule_law	2398	-0.0853036	0.9496454	0.9744975	-2.346105	2.129668
political_stab	2398	-0.191459	0.7967171	0.8925901	-2.844653	1.755193
control_corruption	2398	-0.0876329	1.002008	1.001003	-1.722926	2.464972
GDP_curUSD	3362	4.50e+11	2.54e+24	1.59e+12	3.49e+08	2.14e+13
Trade	3186	74.2077	2020.897	44.95439	11.8554	437.3267
prod_total	1587	3734443	1.47e+14	1.21e+07	0	1.06e+08
reserve_total	1587	4.01e+08	1.58e+18	1.26e+09	0	7.40e+09
N	3399					

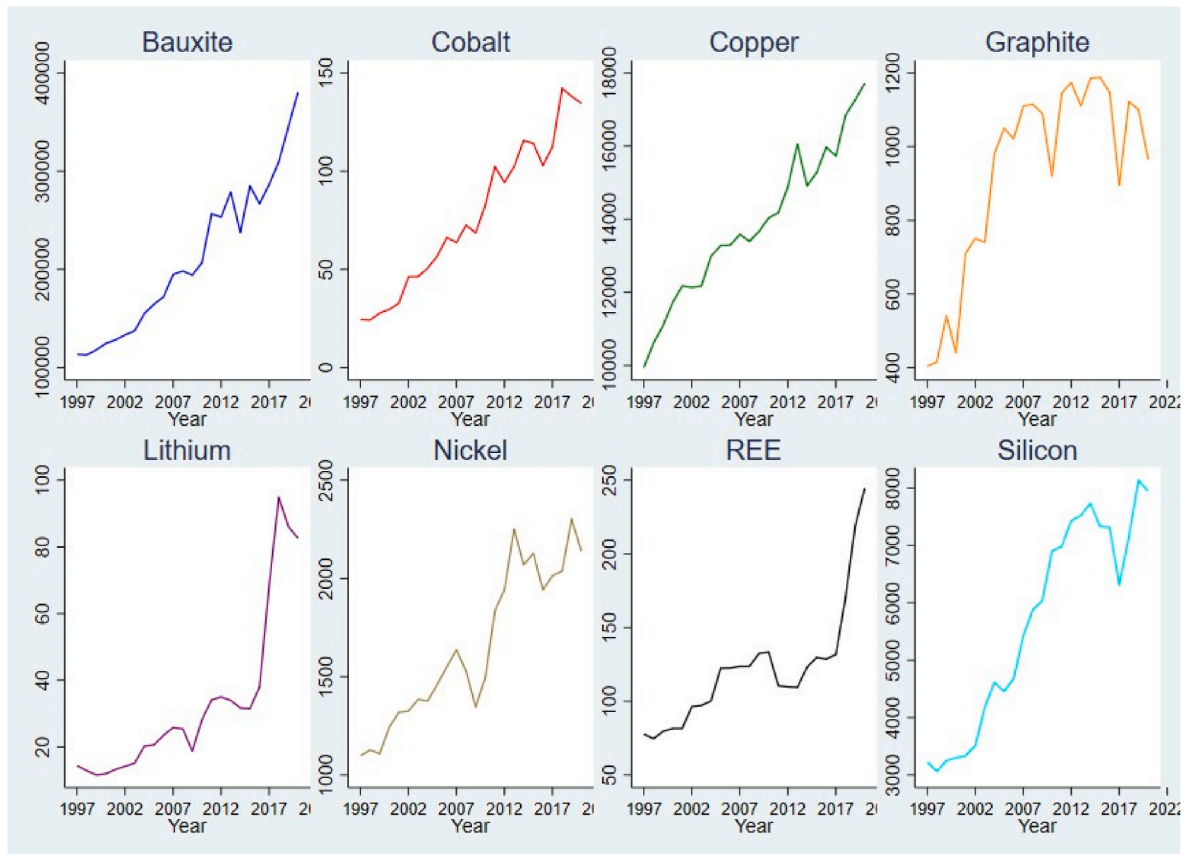


Fig. 1. Evolution of the World Critical Minerals Production (in thousand tons), source: USGS.

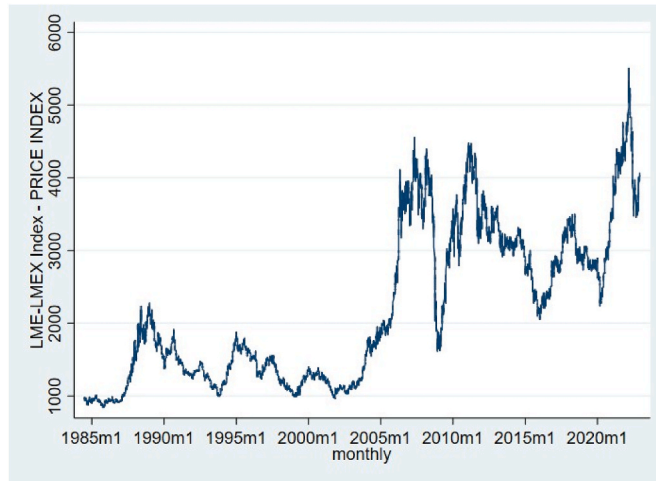


Fig. 2. Evolution of the LME base metal index (aluminum (42.8 %), copper (31.2 %), zinc (14.8 %), lead (8.2 %), nickel (2 %) and tin (1 %)).

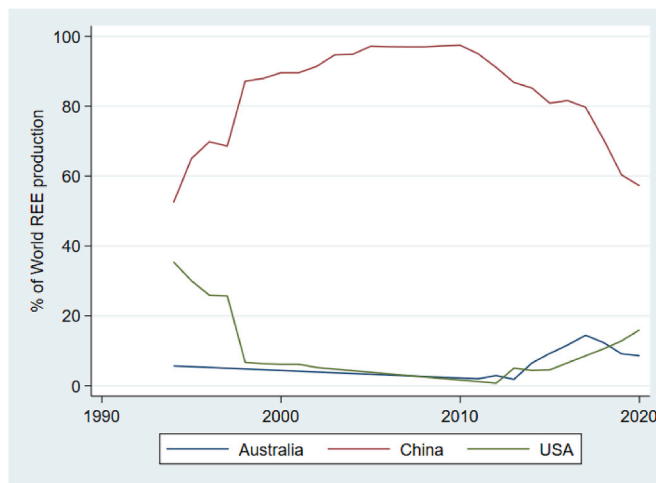


Fig. 3. Evolution of the share in the world REE production for the top three mining countries.

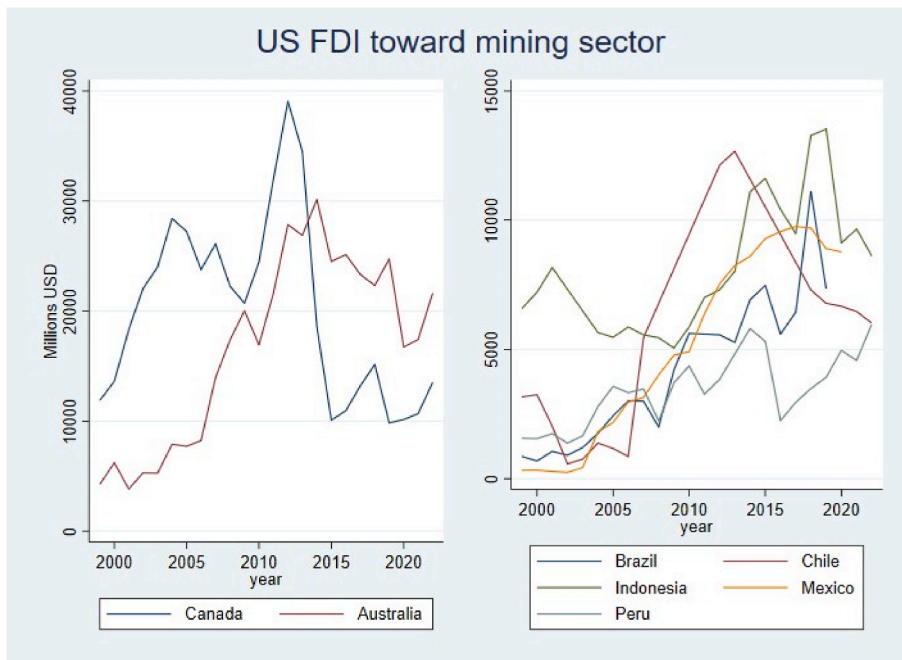


Fig. 4. Evolution of US FDI outflows toward mining sectors of top host countries.

8 Results

Table 11

Base equation estimations' coefficients at t , 372 observations for 32 countries for all but Diff-GMM with 340 observations and 31 groups. OLS: Ordinary Least Squares; GLS: Generalized Least Squares; PCSE: PanelCorrected Standard Errors; FE N and/or T: individual and/or time fixed effects; DPD: Dynamic Panel Data, difference and system GMM: Generalized Method of Moments

Variables/Estimator	OLS				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
GDP growth	-0.333	-0.392	2.056	2.849*	(+)
Inflation	-0.00564	-0.0105**	-0.00463	-0.00998**	(-)
Trade openness	0.163***	0.198***	0.184***	0.228***	(+)
Variables/Estimator	GLS				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
GDP growth	-0.333	-0.392	2.056	2.849**	(+)
Inflation	-0.00564	-0.0105	-0.00463	-0.00998	(-)
Trade openness	0.163***	0.198***	0.184***	0.228***	(+)
Variables/Estimator	PCSE				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
GDP growth	-0.566	-0.455	1.872	2.309*	(+)
Inflation	-0.00484	-0.00826	-0.00322	-0.00761	(-)
Trade openness	0.175***	0.206***	0.198***	0.233***	(+)
Variables/Estimator	DPD		Sys-GMM		Expected sign
Specification	Diff-GMM		Sys-GMM		
GDP growth	1.127		1.685*		(+)
Inflation	-0.0105**		-0.00687		(-)
Trade openness	0.198***		0.191***		(+)

Table 12

Base equation estimations' coefficients at lag 1, 372 observations for 32 countries for all but Diff-GMM with 340 observations and 31 groups. OLS: Ordinary Least Squares; GLS: Generalized Least Squares; PCSE: PanelCorrected Standard Errors; FE N and/or T: individual and/or time fixed effects; DPD: Dynamic Panel Data, difference and system GMM: Generalized Method of Moments.

Variables/Estimator	OLS				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
Rule of law	4.811*	4.576*	4.955*	4.418*	(+)
Control of corruption	-0.464	0.0101	-0.978	-0.315	(+)
Political stability	0.175	0.0353	-0.0166	-0.259	(+)
Variables/Estimator	GLS				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
Rule of law	4.811**	4.576**	4.955**	4.418**	(+)
Control of corruption	-0.464	0.0101	-0.978	-0.315	(+)
Political stability	0.175	0.0353	-0.0166	-0.259	(+)
Variables/Estimator	PCSE				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
Rule of law	4.644***	5.193***	4.799**	4.789**	(+)
Control of corruption	0.128	0.274	-0.752	-0.203	(+)
Political stability	0.473	0.219	0.140	-0.0609	(+)
Variables/Estimator	DPD		Sys-GMM		Expected sign
Specification	Diff-GMM		Sys-GMM		
Rule of law	4.576*		5.230*		(+)
Control of corruption	0.0101		-0.581		(+)
Political stability	0.0353		0.279		(+)

Table 13

Base equation estimations' coefficients at lag 2, 372 observations for 32 countries for all but Diff-GMM with 340 observations and 31 groups. OLS: Ordinary Least Squares; GLS: Generalized Least Squares; PCSE: PanelCorrected Standard Errors; FE N and/or T: individual and/or time fixed effects; DPD: Dynamic Panel Data, difference and system GMM: Generalized Method of Moments.

Variables/Estimator	OLS				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
Oil rent	-0.112	-0.174*	-0.192*	-0.226**	(-)

(continued on next page)

Table 13 (continued)

Variables/Estimator	OLS				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
Mineral extraction	0.284*	0.347**	0.208	0.281**	(?)
Mineral reserve	-0.163	-0.309	-0.0996	-0.255	(?)
Variables/Estimator	GLS				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
Oil rent	-0.112	-0.174*	-0.192**	-0.226**	(-)
Mineral extraction	0.284	0.347**	0.208	0.281*	(?)
Mineral reserve	-0.163	-0.309	-0.0996	-0.255	(?)
Variables/Estimator	PCSE				Expected sign
Specification	Pooled	FE N	FE T	FE N&T	
Oil rent	-0.118	-0.186*	-0.201*	-0.228**	(-)
Mineral extraction	0.278**	0.348**	0.228*	0.296**	(?)
Mineral reserve	-0.159	-0.321	-0.0916	-0.262	(?)
Variables/Estimator	DPD		Sys-GMM		Expected sign
Specification	Diff-GMM		Sys-GMM		
Oil rent	-0.174** 0.347**		-0.205** 0.391**		(-)
Mineral extraction	-0.309		-0.311		(?)
Mineral reserve					(?)

Table 14

Side equations estimations' coefficients at lag 1. For each set of estimations, cobalt, lithium and REE are considered individually as an explanatory variable. Each estimations has respectively 106, 83 and 60 observations each time. OLS: Ordinary Least Squares; GLS: Generalized Least Squares; PCSE: PanelCorrected Standard Errors; FE N and/or T: individual and/or time fixed effects; DPD: Dynamic Panel Data, difference and system GMM: Generalized Method of Moments.

Variables/Estimator	OLS			
Specification	Pooled	FE N	FE T	FE N & T
cobalt extraction	2.137**	2.614**	2.177*	2.892*
lithium extraction	0.993*	1.387**	0.184	0.682
REE extraction	0.0858	0.270	-0.0157	0.189
Variables/Estimator	GLS			
Specification	Pooled	FE N	FE T	FE N & T
cobalt extraction	2.137***	2.614***	2.177**	2.892***
lithium extraction	0.993**	1.387***	0.184	0.682
REE extraction	0.0858	0.270	-0.0157	0.189*
Variables/Estimator	PCSE			
Specification	Pooled	FE N	FE T	FE N & T
cobalt extraction	2.179***	2.541***	2.234***	2.785***
lithium extraction	1.078**	1.417***	0.239	0.731
REE extraction	0.138	0.246	-0.0230	0.196*
Variables/Estimator	DPD		Sys-GMM	
Specification	Diff-GMM		Sys-GMM	
cobalt extraction	2.614***		2.276***	
lithium extraction	1.387***		1.096***	
REE extraction	0.348*		0.107	

Table 15

Mineral extraction effect on FDI inflows with and without China and the US as investing countries.

Variables	Coefficient
Coefficient for two year lagged growth rate of mineral extraction in difference GMM estimate	
First difference of net FDI inflows per GDP (1997–2020) (base equation)	0.347**
First difference of FDI inflows per GDP (1997–2020) (robustness check)	0.339***
First difference of FDI inflows per GDP (2005–2020) (sub time sample)	0.342***
First difference of FDI inflows per GDP without Chinese inflows (2005–2020)	0.277*
First difference of FDI inflows per GDP without US inflows (2005–2020)	0.328*

Data availability

Data will be made available on request.

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