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Tanguy BONNET [1]

Abstract

The aim of this paper is to investigate the links between strategic minerals - which are crucial in the transition to a low-carbon economy - and foreign investment flows. To this end, we consider a panel of 20 strategic minerals and 110 countries over the 1997-2020 period. Using a battery of panel data estimations to ensure the robustness of our results, we find that there is no FDI-resource curse for the strategic minerals production. Strategic minerals have a very strong force of attraction on foreign investments, which has many economic and geostrategic implications for both investing and producing countries.

Keywords : strategic minerals, foreign direct investments, resource curse.
JEL classification : Q4, F21, C23

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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, 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 fiscality, good network of infrastructures, and stability in institutions (see, e.g, Chakrabarti, 2001 ; Levasseur, 2002 ; Blonigen, 2005 ; Sahiti, 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 profit from and exploit 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 (ii) local violent conflicts, because of the coveting of resources, corruption, or the financing of rebel movements (Ross, 2002). According to the well-known *Dutch Disease*, 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 & Neary, 1982 ; Sachs & 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 instability, structural industrial imbalances, and the development of a low value-added activity (Davis & Tilton, 2005). In the empirical literature, the results regarding

the natural resource curse are mixed for certain countries. In particular, the quality of institutions is a key factor since, thanks to solid institutions, the negative effects of corruption and rent-seeking can be 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 & 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 foreign direct investments.

Indeed, this counter-intuitive negative relationship between natural resources and economic development also exists between FDIs and natural resources. Poelhekke & Van der Ploeg (2010) and Asiedu (2013) have shown that an endowment in natural resources may discourage investors and firms, leading to a negative relationship between the presence of natural resources and inward flows of FDIs. This is called the *FDI-resource curse.*
Poelhekke & 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 the presence of subsoil assets attracts the resource seeking FDI but crowds out the non-resource seeking FDI. The negative effect on non-resource FDI being stronger than the positive impact on resource-FDI, the aggregate effect is negative, highlighting a "resource curse for aggregate FDI". 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 dutch disease, which further undermines the non-resource tradable sector's attractiveness to foreign investments, leading to a vicious circle. 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 ac-

count FDI inflows from all foreign investors. She finds that natural resources have a negative effect on FDI, illustrating a FDI-resource curse.

A conceptual explanation can be found in Asiedu & Lien (2010). 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 FDI inflows.

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

So far, all these aforementioned papers focus on hydrocarbons, oil and gas. There also exists some studies dealing with minerals, and the obtained results are quite different. For example, Asiedu (2006) finds a positive relationship between natural resources and FDI for African countries only when using one natural resource variable gathering fuels and minerals. Anyanwu & Yamenogo (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, 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 minerals, which show mixed results : a very clear curse in the Democratic Republic of Congo (Otchia, 2015), a less marked curse in Australia (Koitsiwe & Adachi, 2015), and a positive effect in Chile (Maranon & Kumral, 2021). Although being interesting, this existing literature does not consider wide panels of countries, focuses on hydrocarbons 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 strategic minerals. The latter are of crucial importance as they are necessary for the development of the low-carbon technologies of the energy transition.

1.2 ...to strategic mineral resources

To fight against climate change, many countries around the world have committed themselves, especially at the time of the 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. [2] 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.

All countries committed to reduce their emissions have engaged, more or less strongly, in an energy transition. This transition makes it possible to reduce greenhouse gas emissions, while maintaining a certain level of energy production, thanks to the abandonment of carbon-based fossil fuels, replaced by renewable energies or low-carbon energies (solar, wind, hydro, nuclear, etc.). The exploitation of these energy sources requires various technologies necessary to produce energy, but also to store, transport or use it (solar panels, wind turbines, batteries, power grids, etc.). All these technologies are elaborated technological elements that require specific metals and minerals for alloys and chemicals properties. Indeed, these technologies are all downstream of a long value chain that begins with the extraction of strategic 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 components of low-carbon technologies (super-magnets, photovoltaic panels, batteries, electrical cable network). Thus, low-carbon technologies, including those related to the nuclear industry (in reactor construction), require very large quantities of metals and minerals that we will call "strategic metals and minerals for low-carbon technologies".

2. The details of the different commitments are displayed in Table 5 in Appendix.

As shown by Lepesant (2018), there has been a rapid and significant deployment of renewable energies these past years. As an example, in the European Union, the share of renewable energies in the energy mix went from 4% in 1990 to 20% in 2020. Within the year of 2016, both the USA and China have doubled their solar energy production. Lepesant (2018) notices that both public and private organisations, such as the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA) or Bloomberg Energy Finance, present optimistic and ambitious energy transition scenarios, and estimate that, by the year 2040, wind power and solar energies will represent 64% of the new installations for electricity production. These two energies should be predominant around 2030 and the renewables should represent 82% of the total electricity production. There is a similar vision for the transport sector with the example of electric cars : in 2016 there were 2 million of electric vehicles in the world, and this number could rise to 40 to 70 million by the year 2025 according to the IEA.

These evolutions have strong consequences for global metal demand and consumption. In its 2020 report, the World Bank presents global metal trends' predictions, based on different energy transition scenarios from organisations like the IEA, IRENA or the Energy Technology Perspective (ETP), concerning the development of wind power, solar photovoltaics and energy storage technologies. In a +2° scenario by the year 2050, the mineral demand is expected to increase very strongly. Compared to the 2018 production levels, the World Bank expects a rise from 100% to 200% for nickel, vanadium and indium, and an increase of almost 500% for graphite, lithium and cobalt, which are essential metals for storage and battery technologies.
In its 2021 report, the IEA also expects a huge increase in mineral demand. For a +2° scenario by 2050, demand will rise by four times (six times for an ambitious net zero emissions scenario), an increase mainly driven by the growth of electricity networks and the battery and storage technologies. [3]

These impressive figures are shared by other, independent, researchers. For example, Vidal & 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

3. It is difficult to find projections for the metal demand regarding the nuclear industry because the sector is protected by industrial secret. However the IEA and other international institutions foresee a steady and significant increase in the sector, although less than the dynamics of renewable energies.

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"*. IFPEN (IFP Energies Nouvelles) also produces predictions on global mineral demand based on official transition scenarios. According to Seck et al. (2020), Seck et al. (2021), and Hache et al. (2019), demand is expected to increase by a factor of 4 for nickel, 3 for copper, 2.5 for rare earth elements, and 1.5 for lithium.

Moreover, these different studies emphasize a number of significant limitations around global mineral demand growth. First, there are important geological limitations associated to the extraction of strategic minerals, depending on their abundance in the earth's crust. Moreover, there are concerns about geological criticality for some minerals, i.e., the increase in demand will be so important it could cause a risk of exhaustion, or at least significant tensions on geological reserves. The critical minerals are mainly copper, for which 89.4% of the identified global resources will be extracted in the $+2^{\circ}$ C scenario (Seck et al., 2020), cobalt, for which 83.2% of the identified global resources will be extracted in the $+2^{\circ}$ C scenario (Seck et al., 2021), as well as aluminium and nickel. As argued by Vidal et al. (2017), in the long-term, *"maintaining exponential trends is simply impossible in a finite world"*. Then, there are geostrategic risks concerning the supply of certain strategic minerals, as the extraction of some minerals can be very concentrated : more than 60% of world cobalt extraction is in Democratic Republic of Congo, more than 80% of world niobium extraction is in Brazil, almost all of the lithium extraction and reserves is divided in only few countries (Chile, Argentina, Bolivia, and Australia) and there is a huge lead of China on many metals at different levels of the value chain (Bonnet et al., 2022). Therefore, there could be supply risks due to geopolitical tensions between exporting and importing countries. [4] Finally, it is worth mentioning that there are critical social and environmental issues around mining operations throughout the world, raised by some associations or NGOs, such as SystExt or Mining Watch for example, or some authors such as Bassey (2020).

Despite these concerns, energy transition is needed, more or less already engaged, and low-carbon technologies are globally beneficial to the environment (compared to hydrocarbons), as shown by Hertwich & al. (2022) thanks to life-cycle assessment. The advanced countries are already engaged in such an energy transition, intensive in metals, and there is a political and economic will to conti-

4. 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.

nue in this way, at least in the short and medium term.

Despite the key role played by these metals and minerals, no studies 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 strategic minerals. To this end, we consider a panel of 110 countries over the 1997-2020 period and a selected sample of 20 strategic minerals. Specifically, we aim at answering the following questions. Do strategic minerals attract FDI ? Do countries producing strategic minerals escape the FDI-resource curse ? Which minerals attract FDI the most ? What are the economic and strategic stakes for the producing countries and the investing countries ?

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

2 Data analysis and methodology

2.1 Presentation of the variables

We consider a panel of 110 countries [5] from 1990 to 2020, corresponding to a total of 3410 observations. On these 110 countries, 52 are significant mineral producers (via extraction). Data for mineral production are available starting from 1994. After the data transformation and given that we will use lagged variables in the econometric analysis, our estimations will cover the 1997-2020 period.
Our explained variable is the FDI inflows, expressed in percentage of GDP. FDI data are extracted from the UNCTAD, and GDP data from the World Bank.

Turning to natural resources variables, we consider the rents in percentage of GDP for oil and natural gas. The data are from the World Development Indicators database of the World Bank. These variables allow us to test the efficiency of our model by checking if we find the results of the literature, i.e., a negative coefficient associated with these variables, testifying to a FDI-resource curse on hydrocarbons.

Regarding institutions' variables, we use the World Governance Indicators database from the World Bank and retain three indices of institutional quality :

5. The list of countries is given in Appendix.

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 Strategic minerals data

The COMES (Comity for Strategic Metals in France) defines "strategic metals" as metals or minerals that are "essential to the economic policy of a State, its defense, its energy policy or that of a specific industrial player". There are several lists of metals and minerals, depending on their uses, their geological criticality, and their geo-strategic interest. These lists are either official, made by public institutions, or drawn up by specialized researchers or institutions, and cover all kinds of sectors (health, armament, high-technology, food industry). We focus on minerals that play a role for the low-carbon technologies, i.e., for the energy transition. One of the main contribution of our study is to use a very large and precise sample of 20 minerals. To establish the list of selected minerals, we mainly rely on the European Union Commission communication : *Critical Raw Materials Resilience : Charting a Path towards greater Security and Sustainability.* We complete our list by relying on research and work done by some experts on strategic metals and low-carbon technologies such as Philippe Bihouix, Florian Fizaine, and IFPEN. We also rely on the 2021 Cyclope report's chapter on critical minerals and "electric metals".

The main obstacle 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 20 minerals. [6]
It is worth mentioning that this data allows us to focus on mining production, the extraction of minerals, i.e., the first stage of the long chain of transformation (refining, alloys, semi-finished products, components) around strategic metals and low-carbon technologies. This stage is extremely strategic as it is the basis of the whole value chain that follows.
Specifically, we consider the following minerals : antimony, bauxite, berrylium, cobalt, copper, germanium, graphite, lithium, manganese, molybdenum, nickel, niobium, palladium, platinum, rare earth elements (REE), rhenium, silicium, tunsgten, vanadium, and zirconium. [7]

Some of them are traditional industrial minerals, such as copper or aluminum, others are much more specific, like manganese, lithium, palladium or vanadium. Although these minerals are not equally used in low-carbon technologies, each of them plays an important role in the energy transition, from renewable energies technologies to nuclear industry with minerals like niobium or zirconium.
Moreover, the precision of our database allows us to disaggregate it between different minerals or sub-groups of minerals for a more detailed analysis :

- industrial minerals : more traditional and relatively more abundant minerals, with less specific but widespread uses in all industrial sectors. This group includes bauxite (aluminium), berrylium, copper, nickel, and molybdenum ;
- battery and storage minerals : for metals that play a predominant and very specific role in the development of battery and electricity storage technologies. This category comprises cobalt, lithium, manganese, and

6. The panel is unbalanced.
7. The main producing countries and principal uses are presented in Table 6 in Appendix.

nickel ;

- solar panel minerals : for metals that are necessary and precisely used in the photovoltaic solar panels technologies. antimony, germanium, and silicium belong to this group.
- wind turbines minerals : for metals that are necessary and precisely used in the wind turbines technologies. This category includes rare earth elements, vanadium, and copper ;
- minerals for Nuclear Energy : for highly resistant metals used in the installations of the nuclear power plant. niobium, rhenium, tungsten, and zirconium belong to this group.

For all minerals, we have aggregated the gross production, as well as the reserves. For the sake of completeness, we will also conduct regressions on these sub-groups of minerals. [8]
To our knowledge, this paper is the first to use data on strategic minerals production and reserves at such a complete and detailed level.

2.3 Preliminary analysis

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

8. We are aware of the limitations of using such aggregated data for gross production because minerals have not the same degree of scarcity, utility or monetary value, but this is the best way to keep a macro point of view on such a large panel of minerals.

	GDP	Inflation	Trade	Oil_pGDP	Rule_law	Control_corruption	Political_stab	FDI_inflows	Prod_mineral	Reserve_mineral
GDP	1									
Inflation	-0.0177	1								
Trade	-0.1679	-0.0216	1							
Oil_pGDP	-0.06	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_mineral	0.2484	-0.0203	-0.1780	-0.0570	0.1261	0.1481	0.0771	0.2609	1	
Reserve_mineral	0.0130	0.0053	-0.0507	-0.0938	0.0041	0.0451	0.0032	0.0580	0.6816	1

TABLE 1 – Matrix of correlations

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- and FDI-resource curse, oil rent is negatively correlated with both GDP and FDI inflows, although the correlations are very weak.

Mineral production and mineral reserves are positively associated with GDP and FDI inflows. These correlations are relatively important, about 24% between strategic minerals' production and GDP, as well as between reserves and GDP. Correlation between mineral production and FDI inflows is also quite significant, amounting to 26%. This may indicate a positive relationship between strategic minerals and FDI inflows. This very interesting result need to be confirmed by the econometric analysis.

Let us now discuss the expected results regarding the relationship between mineral resources and FDI inflows. It is worth mentioning that strategic minerals represent a particular natural resource, highly different from the other energy commodities, especially hydrocarbons and oil. Contrary to hydrocarbons, we may expect a positive relationship between mineral resources and FDI inflows because of (i) the interdependencies between the different countries, (ii) the relatively recent context of high demand for strategic metals, and (iii) the importance of the value chain around strategic metals and the importance of being as far upstream as possible.

First, the geographic distribution of production of minerals (mining extraction) appears to be very concentrated in one or few countries. [9] In many cases, one country is in dominant position on one metal. The most striking examples being, over the entire time sample, D.R. Congo with more than 60% of the world's production of cobalt, Brazil with more than 80% of the world's production of niobium, South Africa with more than 70% of the world's production of platinum, or China with almost 90% of the world's rare earth elements (REE) production. Thus, the production of strategic minerals is globally concentrated. However, such concentration concerns different minerals in different countries. Therefore, when all minerals are considered together as one natural resource, production is better distributed and less concentrated. From South-East Asia to Sub-saharian Africa and Latin America, many countries represent a significant share of the world production of strategic minerals. Moreover, even if few countries, like China, Russia or Australia, are important producers in several

9. See Figures 2 to 10 in Appendix.

different minerals,[10] there is no country in dominant position on the production of all 20 strategic minerals.
It is worth mentioning that it makes sense to consider all 20 minerals as a single natural resource because we consider the energy transition as a whole. 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, a windturbine, a smartgrid and electric batteries)... In addition there is, within the technologies themselves, a huge complementarity between the different metals. The technologies require various chemical properties obtained through alloys of different metals, often difficult to substitute or replace. The best example is the widely used Li-ion battery that requires cobalt, lithium, manganese, and nickel.
These interconnections between technologies and metals, where eventually each metal is necessary but insufficient, justify considering these 20 different minerals as a whole, i.e., as one natural resource. Besides, even if some countries have diverse and large productions, no country is in a dominant position on all the strategic minerals. Therefore, all countries are strongly interdependent to have access to all the metals necessary for a complete transition. Furthermore for strategic energy reasons, it is very important to be able to secure supplies, illustrating the interest to study FDI which can be seen as strategic placements toward mineral resources, in the mining countries.

Second, since the end of the 1990s, the general context is characterized by strong growth in demand for metals (Vidal et al., 2017) and significant increase in metal prices (see Figure 11 in Appendix). Thus there is not only a strategic interest, but also an important economic interest in investing in a booming sector with high profit possibilities. In the very near future, these stakes will become more and more important since hydrocarbons, which are an aging resource, are dedicated to decrease if the energy transition commitments of many countries are followed.

Finally, combining the two, it is worth recalling the importance of the value chain around strategic metals and low-carbon technologies. In this paper we purposely focus on mine production, the extraction of strategic minerals, which is the very first step of an important value chain, a transformation chain. After the extraction of the mineral ores, there are various stages of separation, refining, purification, and processing. The metals can then be used, very often in the form of alloys, for the production of components, semi-finished products and

10. On 20 minerals, China is in the top 5 producing countries for 13 minerals, Australia for 10 minerals, and Russia for 11 minerals.

ultimately, finished products, components for low-carbon technologies (supermagnets, photovoltaic plates, cables, batteries). If the first stage, extraction, is crucial from a strategic point of view, from an economic viewpoint it is above all in the following stages of the value chain with the most important added value. Hence the interest once again, for countries and companies issuing FDIs, to place themselves within mining countries, as far upstream as possible in the value chain, and then capture greater added value in the rest of the transformation chain, but also produce the strategic components of low-carbon technologies.

For all these reasons, the economic and geopolitical reading grid for strategic minerals is extremely different in comparison with hydrocarbons, explaining why we could expect very different results concerning the relationship between strategic minerals and FDI inflows. Due to the relative novelty and the rising economic strategic importance of these resources, it would make sense to find a positive relationship between strategic minerals production and FDI inflows, reflecting the fact that this resource does not obey the usual "rules" of natural resource macroeconomics.

2.4 Empirical methodology and unit root tests

As stressed above, our analysis covers a sample of 110 countries over the 1997-2020 period at an annual frequency. We consider the following general specification :

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

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-sectionnal dependence. Given the results presented in Table 8 in Appendix, we consider all the variables in first difference for the stake of consistency.[11] As the variables are either expressed in logarithm or percentages, we can ultimately interpret our first-differenced variables as growth rates.

11. 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.

3 Results and related comments

Table 2 reports the estimation results of Equation (1) using difference GMM and system GMM. [12]

12. For the sake of robustness, we estimated Equation (1) with several estimation techniques : Ordinary Least Squares estimations with pooled model, individual fixed effects model, time fixed effects model and individual and time fixed effects ; Generalised 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. All the methods lead to similar results (see Table 12 in Appendix), illustrating the robustness of our findings.

Table 2:

Variable	Difference GMM	System GMM
L.dFDI_pGDP	-0.291***	-0.326***
	(0.044)	(0.035)
L2.dFDI_pGDP	-0.057***	-0.093***
	(0.020)	(0.013)
dl_prod_total	-0.165	-0.014
	(0.265)	(0.165)
Inflation	0.000	0.001
	(0.006)	(0.006)
dOil_pGDP	-0.221***	-0.261**
	(0.084)	(0.108)
L.dOil_pGDP	-0.015	-0.012
	(0.048)	(0.048)
L2.dOil_pGDP	-0.139	-0.130
	(0.089)	(0.081)
D.NatGas_pGDP	-0.668*	-0.683**
	(0.366)	(0.328)
rule_law	-5.139*	-5.964*
	(2.892)	(3.086)
L.rule_law	10.058**	12.402*
	(4.835)	(7.013)
L2.rule_law	-5.109**	-5.095*
	(2.231)	(2.985)
political_stab	0.443	0.355
	(0.645)	(0.696)
L.political_stab	0.998	1.523
	(0.835)	(1.092)
L2.political_stab	-1.340*	-1.918**

Continued on next page

Table 2: (Continued)

	(0.730)	(0.836)
control_corruption	1.894	1.442
	(1.257)	(1.249)
L.control_corruption	-2.782	-2.880
	(2.389)	(2.651)
L2.control_corruption	0.982	0.319
	(1.006)	(1.086)
dl_GDP_curUSD	4.747**	5.299**
	(2.392)	(2.593)
D.Trade	0.134***	0.139***
	(0.042)	(0.042)
L.dl_prod_total	0.010	-0.010
	(0.068)	(0.084)
L2.dl_prod_total	0.311*	0.253*
	(0.179)	(0.137)
dl_reserve_total	0.311	0.326
	(0.223)	(0.216)
L.dl_reserve_total	-0.011	0.006
	(0.175)	(0.165)
L2.dl_reserve_total	0.009	0.018
	(0.148)	(0.196)
Constant	-0.425	-0.511**
	(0.320)	(0.246)
Observations	516	564

Standard errors in parentheses

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

Table 2 - Dynamic Panel Data regressions results

Before going further in the interpretation, we can see that there is indeed a positive relationship between the production of strategic minerals and the inflow of foreign direct investments (Table 2). [13]

We also find this positive effect by working on the subsample of producing countries or by removing China, a country that plays a very important role both as an investor and as a producer (Table 3). Our results thus "survive" the selection bias.

	All countries, 2 year lagged growth rate of production	**Mineral producing countries, 2 year lagged growth rate of production**	**All countries, less China, 2 year lagged growth rate of production**
Coefficient in the difference GMM DPD estimation	0.311	1.254	0.313

Table 3 - Comparison of coefficients (all significant) between groups of countries

The intuitions formulated above therefore explain these expected results. We also observe (see Tables 9 to 11 in Appendix) that, on average, mining countries benefit from a better macroeconomic context (stronger GDP) and institutional context (better institutional indices) than oil-producing countries, which may help to explain the absence of FDI resource curse.

3.1 General results, FDI-resource curse, and institutions

From a general viewpoint, our findings are in line with those of the literature. As shown in Table 2, we find a positive relationship between FDI inflows and economic growth, as well as trade openness. Both attract FDI inflows as they benefit investors and multinational companies (through the opportunities of a growing economy and the reduction of transaction costs). Inflation's coefficient is not significantly negative as it would be expected. Finally, lagged FDI inflows have a significant effect on present FDI inflows. When making an investment

13. The reference results are those from the difference-GMM equation, but it is important to note the strong robustness of our findings, since the same results are generally found in all of our regressions (see Figure 13 in Appendix).

decision, past values are examined, in addition to the delay between the decision and the actual investment.

Our results confirm the existence of the FDI-resource curse for hydrocarbons, i.e., for oil and natural gas (Figure 12 in Appendix). The growth rate of oil rents is significantly negative. When oil rents increase, then, on average, the share of aggregated FDI inflows in the GDP will decrease. This negative relationship is stable in time as shown by Figure 18 in Appendix.
The growth of the oil sector in a country attracts the resource seeker FDI but evicts the non-resource seeker FDI ; the aggregated effect is negative. Indeed, with the exception of the oil and/or gas sector, the structural economic imbalances caused by the resource curse negatively affect a country's attractiveness to FDI inflows. Our finding of the FDI-resource curse on hydrocarbons is in line with the literature. But, as noticed by Poelhekke and Van der Ploeg (2010) and Asiedu (2013), institutions play an important role and good quality institutions can mitigate the effects of the FDI resource curse.

We find mixed results regarding the quality of institutions. Recall that we consider three variables : indexes for rule of law, control of corruption, and political stability. Concerning control of corruption, it is non-significant. Turning to political stability it is not significant and can be negative for the two-year lagged coefficient, although this result is not robust. However we find significant and robust results for the rule of law index that appears to be positively linked to FDI inflows (in general, the positive effect of the two-year lagged coefficient offsets or outweighs the negative effects of other lags). As expected, a good rule of law increases the economy's general attractiveness to FDI.
Concerning the question asked by Asiedu (2013) : *Do institutions mitigate the adverse effects of natural resources on FDI ?*, we actually find similar results. In several estimations (Figure 16 in Appendix), the interaction variable between oil rents and rule of law or control of corruption is significant and positive. Therefore, good institutions can mitigate the FDI-resource curse as they can restore the attractiveness of the natural resource of a producing country.

Overall, our results are in line with the literature regarding the different considered variables and the existence of a FDI resource curse linked to oil and gas production. Let us now focus on the role of strategic minerals.

3.2 Strategic mineral production and reserves, escaping the FDI-resource curse ?

We now aim at answering the following question : Do strategic minerals attract FDI ? We will address the implications for the producing countries, but also what this means for (i) mineral resources as an energy raw material of global importance, and (ii) the companies and countries that invest in metal producing nations.

As shown in Table 2, we find a significant and positive relationship between FDI inflows and strategic minerals production growth rates. In other words, when metal production increases, the share of FDI inflows in GDP augments. The production of strategic minerals does attract investments from abroad. This is a novel and important result compared to the usual negative relationship found for oil and gas. The production of strategic minerals does not present an FDI-resource curse, which is a major difference with the natural resources studied so far. This finding confirms our intuitions that strategic minerals are not an energy raw material like the others, and therefore deserve a particular interest.

3.2.1 Economic implications

As shown, the production and development of strategic minerals mining represent a force of attraction for aggregated foreign investments, when considering all sectors together. Therefore, the strategic minerals exploitation may represent a *FDI-resource bless*. Let us recall that this effect is the sum of two opposite effects (Poelhekke and Van der Ploeg, 2010). There is a positive effect, an attraction effect for resource-seeking FDIs, and a negative effect, namely a crowding-out effect on non-resource seeking FDIs. So unlike the FDI-resource curse, the positive attraction effect of the FDI resource seeking prevails, resulting in a positive total effect. As we do not have disaggregated, sectoral, data on FDI, we can not explain which effect prevails (explaining the difference with hydrocarbons). We can however discuss some possibilities.

If the crowding out effect is weaker, this is positive for the global economy of the producing country because this would mean that production of strategic minerals attracts FDI in all productive sectors, contributing to the development of the whole economy. However, there is *a priori* no particular reason for this would be the case. Strategic minerals are still a natural resource that interest firms and countries' investors in their own, and there is no reason that does make all economic sectors attractive. The most likely reason may be that the attraction effect is strong enough to prevail on the crowding-out effect.

If the attraction effect on the "mineral seeker" FDI is stronger than the eviction effect on the "non mineral seeker" FDI, what are the implications for the local economy of the producing country ?
The consequences are rather ambiguous. This represents an economic opportunity, obviously for the metal producing sector, but probably not for the other producing sectors. Indeed, there is a risk of too much investment in the metal mining sector, making it hypertrophied in the economy of the producing country. The country would only sink into a dutch disease, with a structural imbalance between its different industrial sectors, which would be detrimental to its long-term growth and development. This positive effect could therefore prove to be temporary, but in the long term, there would be a risk that the producing countries would become locked into a dutch disease, which in the end would even have a negative effect on FDI inflows.
As a consequence, a FDI-resource curse may appear for the strategic minerals, as suggested by the results of a rolling regression we ran on a sliding window of eight years with the difference GMM estimator. As shown in Figure 17 in Appendix, the temporal evolution of the coefficient associated to the two-year lagged growth rate of metal production is positive and decreasing from 2002 to 2012, and then becomes non-significant. If this "trend" continues, one may expect to find a negative coefficient in the future, illustrating a FDI-resource curse associated with the strategic minerals production. Perhaps this positive aggregated effect on FDI inflows would only be temporary, due to the novelty of these metallic mining resources and the new rising economic stakes around these. But with time, if the producing countries lock themselves into a preponderance of their metal production and thus into a dutch disease, we could find a FDI-resource curse in the long term. [14]

These comments could however be nuanced by relying on institutional quality. Indeed, the good quality of institutions is supposed to mitigate the effects of both dutch disease (Van Der Ploeg, 2011) and FDI-resource curse (Asiedu, 2013). We ran estimations with interaction variables between quality of institutions and strategic minerals production, and the results, displayed in Figure 15 in Appendix, are quite unexpected. We find a negative effect of the interaction between metal production and institutions. Overall, good institutions seem to make the strategic metal mining sector less attractive to foreign investments.

14. This may suggest the presence of non-linearity. To address this hypothesis, we estimate a panel threshold model (PSTAR) model but no significant results were obtained.

Therefore, the effects of this *FDI-minerals bless* may be temporary, and apparently even good institutions do not seem to be able to preserve this attraction effect - the latter depending also on the type of minerals studied.

3.2.2 Geostrategic implications and minerals sub-groups analysis

The fact that the production of strategic minerals has such an attraction effect on foreign investments also illustrates their strategic importance. As stressed above, (i) some countries want to ensure a strategic supply of mineral resources and there is a strong interdependence between countries whatever their role, (ii) global demand for strategic metals low-carbon technologies, and the metal prices have exploded, and (iii) there are very strong economic and strategic interests in being upstream in the value chain of strategic metals and low-carbon technologies.
Indeed, in addition to the economic opportunities that this sector offers, FDI represents a desire to settle in on a long-term basis and to participate in the governance of mining operations. There are also global strategic issues and important national interests at stake. Sovereignty and energy security are crucial issues for the stability and prosperity of nations. Most of the investments in these sectors can be directly or indirectly under State control because, in most countries, the energy sector is strongly controlled by the State (often with public monopolies or important public-private partnerships). [15]

Moreover, if the aggregate effect is positive, it means that the attraction effect is stronger than the eviction effect, contrary to the case of hydrocarbons. The attraction dynamics exerted by strategic minerals is more pronounced than for hydrocarbons.

Thanks to our disaggregated data, we can investigate which minerals and which producing countries attract the most FDIs. To this end, we use the five groups of minerals defined in Section 2 : industrial minerals, battery minerals, solar panel minerals, wind turbine minerals, and nuclear energy minerals. The most striking findings concern minerals for batteries and storage technologies.

For the battery and storage minerals, the dynamic panel data regressions show that there is a positive effect of the lagged growth rate of production on

15. This is even more true for China where, in 2006, 82% of non-financial outward FDI was conducted by state-owned enterprises, and of the thirty largest companies ranked by outward FDI, all but two were state-controlled (Kolstad & Wiig, 2010).

the growth of the share of FDI inflows.[16] We find again this attraction effect, the *FDI-metal bless* : the minerals for battery and storage technologies positively attract the aggregated FDIs. The effect of FDI attraction is stronger for the battery and storage minerals production than the mean effect for all minerals (Table 4).

	All minerals, 2 year lagged growth rate of production	**Battery minerals, 2 year lagged growth rate of production**
Coefficient in the difference GMM DPD estimation	0.311	0.632

Table 4 - Comparison of significant coefficients (at a 10% level) between groups of minerals

The effect of attraction on FDIs is stronger for the minerals necessary for battery and storage technologies, and is quite stable over time (Figure 1).

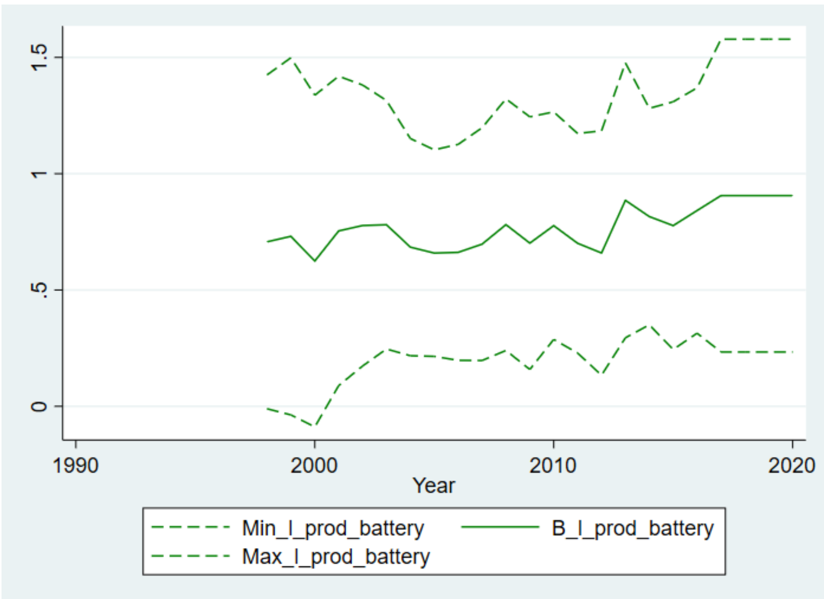

FIGURE 1 – Rolling difference-GMM regression for battery minerals production

Other notable results concern the minerals for wind turbines technologies and the nuclear industry. A positive relationship between these minerals and

16. This is a robust result, as illustrated by Figure 14 in Appendix.

FDI inflows is suggested by the positive effect of the growth rate of the wind turbine minerals reserves, and by the positive, and constant in time, effect of the growth rate of nuclear minerals in the difference GMM estimation (see Figure 19 in Appendix).

The metals used in the storage technologies and in the wind turbine or nuclear energy sectors (such as cobalt, lithium, rare earths or niobium) represent new stakes, and are at the center of strategic economic interests that are lively, both now and in the future. Indeed, the new generations of nuclear reactors and wind turbines are starting to be developed on a large-scale. In addition, the issue of electricity storage is central to an energy transition project with renewable energies. Indeed, whereas with hydrocarbons, energy is easily stored and transported, with renewable energies, electricity is produced and batteries are needed to store and transport it. It is worth mentioning that the production of high capacity batteries has recently developed a lot with the deployment of electric vehicles. [17] So, if these minerals are the ones that attract the FDIs more, it seems that they represent the stronger economic and strategic interests for the investor countries.

To sum up, our findings are very robust, and in accordance with the literature regarding the FDI-resource curse for oil, as there is a negative relationship between oil exploitation and FDI inflows.
Our main contribution is that we investigate for the first time the link between strategic minerals and FDI, and show that the former are highly specific resources. Indeed, the production of strategic minerals has a positive effect on FDI inflows. The strategic minerals and their producing countries escape the FDI resource curse.
Investors, multinationals, and, more generally, advanced countries, invest a lot in the producing countries to have access to strategic minerals and to take position on the value chain and benefit from a strong added value on the following stages even if there is a risk of macro-economic instability. So, the force of attraction of foreign investments is stronger for strategic minerals than for hydrocarbons. This shows that strategic metals may become the dominant energy raw material, leading to major macro-economic transformations.

17. Many advanced countries seem to be betting heavily on the development of electric vehicles, even though in truth this represents only a tiny part of the possible solutions and this sector is much criticised for its high consumption of metals and its significant rebound effects (connected, ever heavier and faster vehicles).

4 Discussion and conclusion

This paper investigates the links between FDI and strategic minerals. Relying on a panel of 20 minerals and 110 countries over the 1997-2020 period, we show that the FDI-resource curse does not apply to the production of strategic minerals, as the latter are so important that their power to attract investment predominates. The fact that strategic minerals attract so much foreign investment shows that this resource is highly coveted because it is crucial for the energy transition. Indeed, despite the potential economic risks, foreign countries and multinationals are investing in mining countries to gain access to these resources. This is due to the specificities of the host countries and the mineral resources studied, but it is mainly because these investments are a strategic way for foreign countries to secure their supplies, and also and above all, to take a position in the value chain, to ensure the following high value-added steps. These two objectives are clearly identifiable when studying China's strategy.

China is known for its quasi-monopoly on the production (extraction and refining) of rare earth elements, but it is also the leading country in the world production, at different steps of the transformation chain, of many other different strategic metals (Table 7 in Appendix). China's investments and direct imports allow the country to get access to minerals it does not even extract (or very little). China massively imports cobalt from R.D. Congo, lithium from Chile and Argentina, manganese from South Africa, Australia, Brazil and Ghana, nickel from Philippines, Indonesia and New-Caledonia, and copper from Chile and Peru (Chatham House Trade database). The same minerals are targeted by its investment strategy, as shown by Bonnet et al. (2021) : copper from Peru and Chile, lithium from Chile and Australia, Australian nickel, R.D. Congo's cobalt and South Africa's manganese. Through these coordinated import and investment policies, China secures its supply of minerals that it produces little or none.
China is thus meeting its colossal demand for minerals and metals, being the world leading consumer of metals, securing it supplies. It is also positioning itself in the value chain, in the high value-added stages. Indeed China has a strong dominant position in the market for renewable energy technologies and low-carbon technologies (Glachant & Touboul, 2021). This is in line with the evolution of China's industrial policy since 2010, with the production of increasingly more sophisticated goods, and the continuous increase of domestic added value (Goldberg, 2019).

But this Chinese domination has been made possible at a very high envi-

ronmental cost. The extraction of minerals and their transformation into metals have extremely heavy environmental costs, such as the destruction of the local environment, huge water and energy requirements, and the release of significant chemical pollution (radioactivity, toxicity, etc), in addition to potential social issues (child labor, destruction of local population environment, health issues for the miners, etc). This dilemma gives rise to very complex and interesting sociological and political issues within the countries concerned. In Latin America, the numerous debates and political choices around nationalization, extractivism, and environmentalism, described by Mariette & Poupeau (2021), clearly show the questioning around the exploitation of mining resources.
Another dilemma applies to the investor countries, especially the advanced economies, which must reconcile their climate objectives with their energy sovereignty objectives. Being dependent on imports of minerals, metals or low-carbon technologies is detrimental to this energy sovereignty, but necessary to reduce the carbon emissions. This may explain the strategy of the United States to revive mining operations on the ground, to take a place in the value chain by producing finished or semi-finished technologies, and to maintain strong trade relations with important partners such as Canada or Mexico. The European Union is also beginning to position itself more clearly with regard to these issues. Ursula Von Der Leyen, in her 2022 State of the Union speech, mentioned partnerships with several producing countries such as Chile, Mexico, New Zealand, Australia, and India, and also mentioned a "European sovereignty fund".

All these issues are crucial and show the great and growing importance of strategic minerals. This explains why their attractiveness for FDI is strong, leading mining countries to generally escape the FDI-resource curse.

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6 Appendix

6.1 Countries and minerals studied

List of 110 countries of the panel : Albania, United Arab Emirates, Argentina, Armenia, Australia, Austria, Azerbaidjan, Burundi, Burkina Faso, Bangladesh, Bulgaria, Bosnia, Belarus, Bolivia, Brazil, Botswana, Canada, Switzerland, Chile, China, Ivory Coast, Cameroun, Democratic Republic of Congo, Colombia, Czech Republic, Germany, Ecuador, Egypt, Espania, Ethiopia, Finland, France, Gabon, United-Kingdom, Georgia, Ghana, Guinea, Greece, Guatemala, Guyana, Honduras, Croatia, Hungary, Indonesia, India, Ireland, Iran, Israel, Italia, Jamaica, Jordania, Japan, Kazakhstan, Kenya, Kirghistan, South Korea, Laos, Sri-Lanka, Morocco, Moldavia, Madagascar, Mexico, Macedonia, Mali, Myanmar, Mongolia, Mozambique, Malawi, Malaysia, Namibia, New-Caledonia, Nigeria, Nicaragua, Norway, Netherlands, Pakistan, Peru, Phillipines, Papouasia-New-Guinea, Poland, Portugal, Roumania, Russia, Rwanda, Saudia Arabia, Senegal, Singapour, Sierra Leone, Serbia, Suriname, Slovakia, Sweden, Togo, Thailand, Tadjikistan, Turkmenistan, Tunisia, Turkey, Tanzania, Uganda, Ukraine, Uruguay, United-States, Uzbekistan, Venezuela, Vietnam, South-Africa, Zambia, and Zimbabwe.

Country	**Short-term commitment**	**Source**
European Union	Reach 45% of renewable energy in the energy mix by 2030 (this proportion is 22% in 2020).	REPowerEU Plan, Eurostat
France	Increase the share of renewable energy in gross final energy consumption to 33% by 2030 (it is 19% in 2020).	Ministry of ecological transition
United Kingdom	Reduce its greenhouse gaz emissions from the economy by at least 68% by 2030 from 1990 levels.	UK's Nationally Determined Contribution
United States	Reduce greenhouse gas emissions by 50% by 2030 compared to 2005.	US' Nationally Determined Contribution
Canada	Reduce its emissions by 45% by 2030 compared to 2005 levels.	Canada's Nationally Determined Contribution
China	Increase the share of non-fossil fuels in primary energy consumption to 25%, which is 11% today.	China's Nationally Determined Contribution, Statista
Russia	Reduce its emissions by 30% by 2030 compared to 1990 levels.	Russia's Nationally Determined Contribution
Japan	Reduce its emissions by 46% by 2030 compared to 2013 levels.	Japan's Nationally Determined Contribution

Table 5 - Countries' commitments for energy transition

Metal	Main producing countries in % of world production	Use
Antimony	China (84%)	Essentially lead-antimony car batteries, also photovoltaic panels
Bauxite	Australia (17%), China (12%), Guinea (11%), Brazil (7%), Indonesia (5%)	Transport, wind and solar energy infrastructures
Berrylium	USA (76%), China (16%), Russia (5%)	Transport and communication
Cobalt	D.R.Congo (52%), Zimbabwe (8%), Canada (8%), Russia (8%)	Batteries and power storage, superalloys
Copper	Chile (36%), USA (10%), Peru (9%), China (7%)	Transport, wind and solar energy, transport of energy
Germanium	China (82%), USA (14%)	Photovoltaic panels
Graphite	China (70%), Indonesia (12%)	Batteries, car-batteries
Lithium	Australia (40%), Chile (30%), China (10%)	Batteries, power storage
Manganese	South Africa (27%), Australia (18%), China (16%), Gabon (12%)	Ferro-alloys used in transport and infrastructures, batteries and storage

Molybdenum	China (33%), USA (25%), Chile (19%)	Super-alloys, power storage and transport
Nickel	Russia (17%), Indonesia (14%), Canada (12%), Australia (11%)	Power storage and batteries
Niobium	Brazil (91%)	Super-alloys in nuclear energy production
Palladium and Platinum	South Africa (57%), Russia (30%), Canada (6%)	Catalysts, fuel cells (hydrogene)
Rare earth elements	China (85%), USA (7%)	Super magnets for wind power energy, power storage
Rhenium	Chile (47%), USA (21%), Poland (8%)	Super-alloys, nuclear energy production
Silicium	China (59%), Russia (10%), Norway (6%)	Photovoltaic panels and semi-conductors, alloys for energy storage and transport
Tungsten	China (88%), Russia (5%), Australia (2%)	Super-alloys in mining, infrastructures and nuclear energy production
Vanadium	China (46%), South Africa (29%), Russia (23%)	Special-alloys, super-magnets
Zirconium	Australia (45%), South Africa (30%), China (8%)	Catalysts and nuclear energy production

Table 6 - Metal list, main producing countries and main uses. Source : United States Geological Survey

Top producing countries	**1**	**2**	**3**	**4**	**5**
Antimony	China	Russia	Tadjikistan	Bolivia	South Africa
Bauxite	Australia	China	Guinea	Brazil	Indonesia
Berrylium	USA	China	Russia	Brazil	Mozambique
Cobalt	Congo(DR)	Zimbabwe	Canada	Russia	Australia
Copper	Chile	USA	Peru	China	Australia
Germanium	China	USA	Russia		
Graphite	China	Indonesia	Brazil	Canada	Mexico
Lithium	Australia	Chile	China	Argentina	Zimbabwe
Manganese	South Africa	Australia	China	Gabon	Brazil
Molybden	China	USA	Chile	Peru	Mexico
Nickel	Russia	Indonesia	Canada	Australia	Phillipines
Niobium	Brazil	Canada	Australia	Mozambique	Congo(DR)
Palladium	South Africa	Russia	Canada	USA	Zimbabwe
Platinum	South Africa	Russia	Canada	Zimbabwe	USA
REE	China	USA	Australia	Indonesia	Russia
Rhenium	Chile	USA	Poland	Kazakhstan	Peru
Silicium	China	Russia	Norway	USA	Brazil
Tunsgten	China	Russia	Australia	Canada	Bolivia
Vanadium	China	South Africa	Russia	Brazil	USA
Zirconium	Australia	South Africa	China	USA	Indonesia

Table 7 - Top producing countries for each mineral. Source : United States Geological Survey

6.2 Geographic repartition of the production for sub-groups of minerals

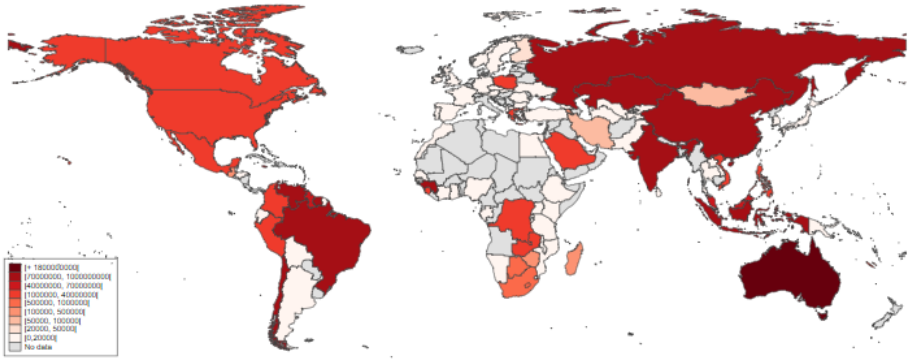

FIGURE 2 – Gross production of industrial minerals

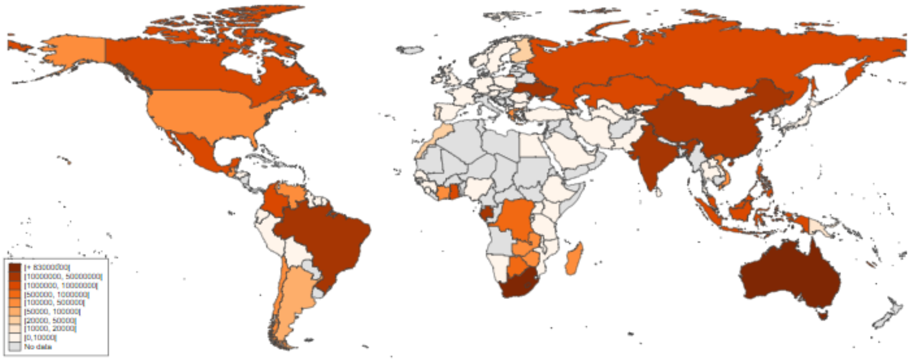

FIGURE 3 – Gross production of battery minerals

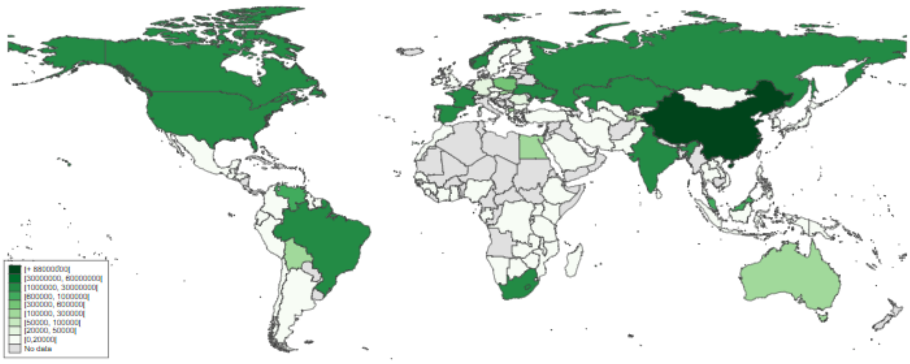

FIGURE 4 – Gross production of solar panel minerals

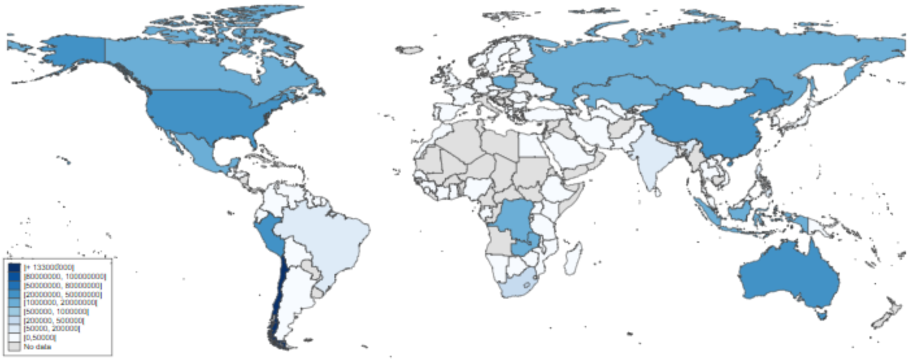

FIGURE 5 – Gross production of wind turbine minerals

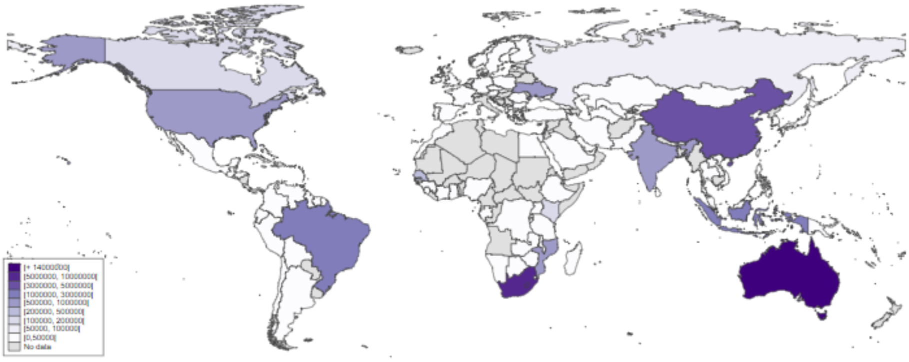

FIGURE 6 – Gross production of nuclear industry minerals

6.3 Minerals where top producing countries are not leading

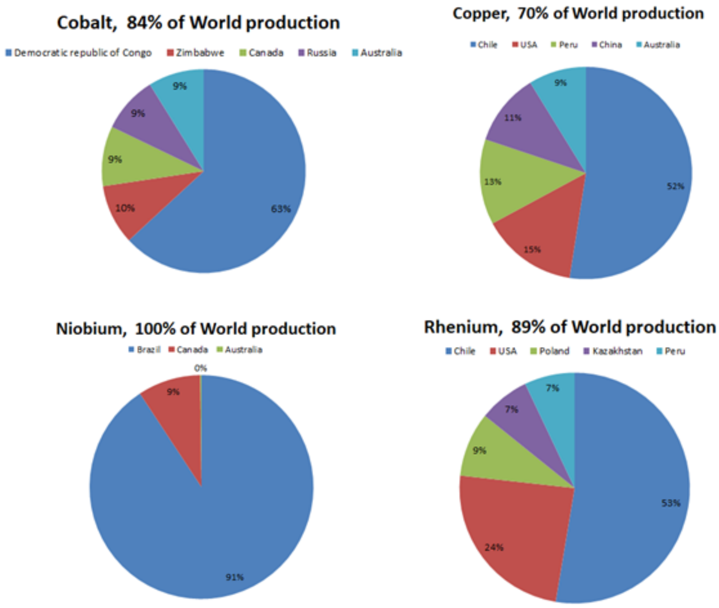

FIGURE 7 – Production of Cobalt, Copper, Niobium and Rhenium

6.4 Repartition of the sub-group minerals production

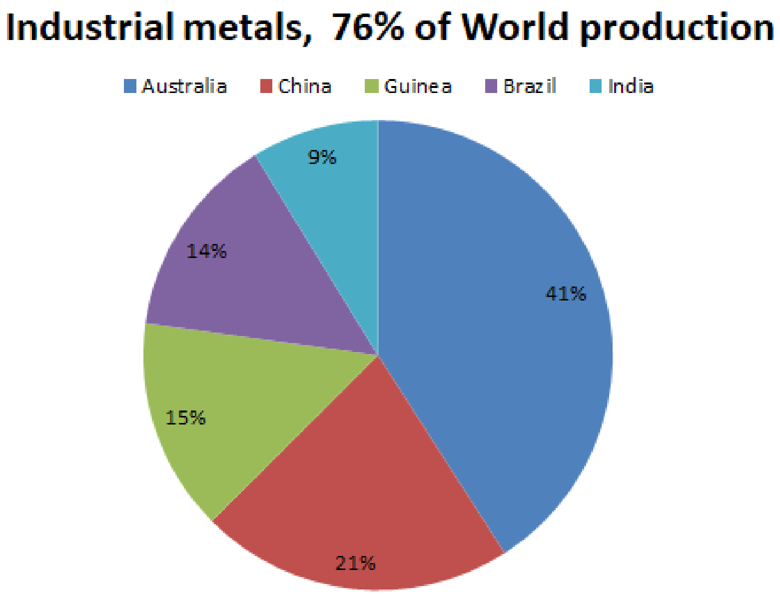

FIGURE 8 – Repartition of the production of industrial minerals

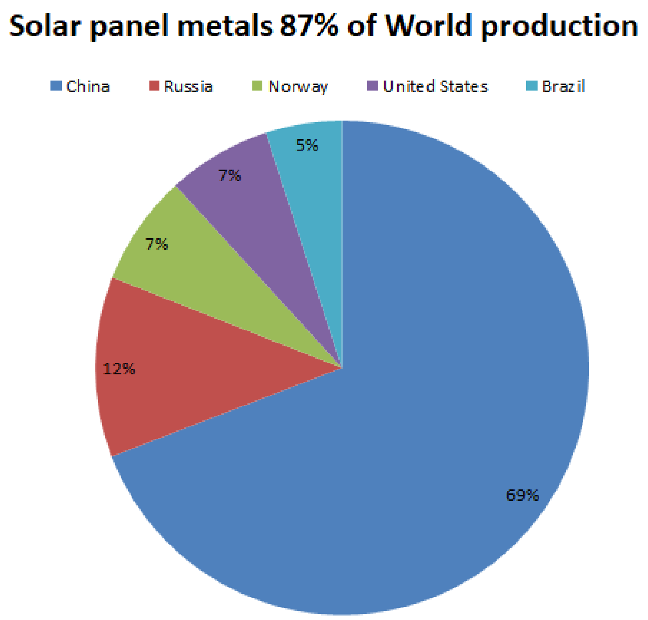

FIGURE 9 – Repartition of the production of solar minerals

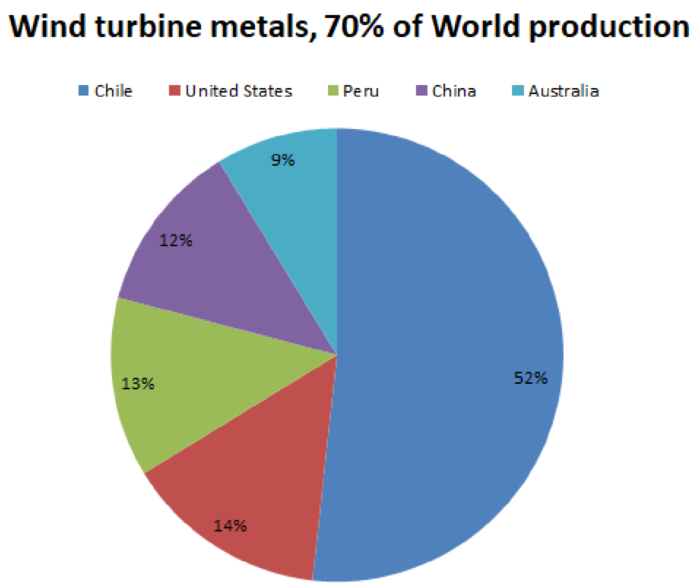

FIGURE 10 – Repartition of the production of wind turbine minerals

		FDI inflows pGDP	Oil pGDP	NatGas pGDP	Inflation
CIPS*	level	-2,4963	-2,193	-1,7559	-3,2839
p-value	level	0,01	0,015	0,465	0,01
CIPS*	1 diff	-4,0217	-3,5919	-3,434	-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	-2,771	-2,663	-1,7189	-1,6517
p-value	level	0,01	0,01	0,525	0,1
CIPS*	1 diff	-3,5126	-4,4596	-3,132	-2,7283
p-value	1 diff	0,01	0,01	0,01	0,03248

Table 8 - Unit root tests results

7 Descriptive statistics

	Obs	mean	Var	sd	min	max
FDI_inflows	3322	8.00e+09	6.91e+20	2.63e+10	-7.91e+10	4.68e+11
Oil_pGDP	3241	2.903559	50.29382	7.091814	0	55.38342
NatGas_pGDP	3235	.6124363	10.05898	3.171589	0	68.56375
Inflation	3050	38.97668	245716.9	495.6984	-11.68611	23773.13
rule_law	2398	-.0853036	.9496454	.9744975	-2.346105	2.129668
political_stab	2398	-.191459	.7967171	.8925901	-2.844653	1.755193
control_corruption	2398	-.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	1454	4312906	1.69e+14	1.30e+07	0	1.10e+08
reserve_total	1454	4.50e+08	1.73e+18	1.32e+09	0	7.40e+09
N	3399					

Table 9 - Descriptive Statistics for all countries (110 countries)

	Obs	mean	Var	sd	min	max
FDI_inflows	1574	1.08e+10	1.13e+21	3.37e+10	-2.83e+10	4.68e+11
Oil_pGDP	1540	.2951691	.3326406	.5767501	0	4.841347
NatGas_pGDP	1536	.1311298	.1602616	.4003268	0	4.399457
Inflation	1420	51.94138	491952.4	701.3932	-2.430968	23773.13
rule_law	1122	.1297222	1.017513	1.008718	-2.129996	2.129668
political_stab	1122	-.1032886	.8365422	.9146268	-2.844653	1.755193
control_corruption	1122	.1217658	1.028405	1.014103	-1.722926	2.464972
GDP_curUSD	1607	5.94e+11	3.89e+24	1.97e+12	3.49e+08	2.14e+13
Trade	1574	69.13543	1051.696	32.42986	13.75305	274.9731
prod_total	988	4419368	1.76e+14	1.33e+07	0	1.10e+08
reserve_total	988	5.50e+08	2.36e+18	1.54e+09	0	7.40e+09
N	1612					

Table 10 - Descriptive Statistics for mineral producing countries only (52 countries)

	Obs	mean	Var	sd	min	max
FDI_inflows	886	6.54e+09	3.16e+20	1.78e+10	-7.40e+09	1.49e+11
Oil_pGDP	861	10.29713	114.2562	10.68907	0	55.38342
NatGas_pGDP	861	1.948547	34.88937	5.906722	0	68.56375
Inflation	773	33.25948	46357.99	215.3091	-11.68611	4145.106
rule_law	638	-.5347235	.5384829	.7338139	-2.346105	2.036518
political_stab	638	-.448489	.5719712	.7562878	-2.374467	1.610245
control_corruption	638	-.5371449	.5383253	.7337065	-1.560315	2.294324
GDP_curUSD	884	3.45e+11	1.67e+24	1.29e+12	3.88e+08	1.47e+13
Trade	815	71.94974	1314.653	36.25814	20.72252	220.4068
prod_total	430	4429364	1.64e+14	1.28e+07	0	1.03e+08
reserve_total	430	2.59e+08	3.54e+17	5.95e+08	0	5.82e+09
N	899					

Table 11 - Descriptive Statistics for oil producing countries (29 countries)

Figure 11 - Evolution of the LME base metal index (aluminim (42.8%), copper (31.2%), zinc (14.8%), lead (8.2%), nickel (2%) and tin (1%))

8 Results

Variables/Estimator	OLS				
Specification	Pooled	FE N	FE T	FE N&T	Expected sign from the litterature
GDP	(+)***	(+)**	(+)*	(+)*	(+)
Inflation	(-).	(-).	(-).	(-).	(-)
Trade	(+)***	(+)***	(+)***	(+)***	(+)
Natural Gas	(-)*	(-)**	(-).	(-)*	(-)
Variables/Estimator	GLS				
Specification	Pooled	FE N	FE T	FE N&T	Expected sign from the litterature
GDP	(+)***	(+)***	(+)**	(+)**	(+)
Inflation	(-).	(-).	(-).	(-).	(-)
Trade	(+)***	(+)***	(+)***	(+)***	(+)
Natural Gas	(-).	(-).	(-).	(-).	(-)
Variables/Estimator	PCSE				
Specification	Pooled	FE N	FE T	FE N&T	Expected sign from the litterature
GDP	(+)***	(+)**	(+)*	(+)**	(+)
Inflation	(-).	(-).	(-).	(-).	(-)
Trade	(+)***	(+)***	(+)***	(+)***	(+)
Natural Gas	(-)**	(-)***	(-)*	(-)**	(-)
Variables/Estimator		DPD			
Specification		Diff-GMM	Sys-GMM		Expected sign from the litterature
GDP		(+)**	(+)**		(+)
Inflation		(-).	(-).		(-)
Trade		(+)***	(+)***		(+)
Natural Gas		(-)*	(-)**		(-)

Table 12 - General results for the control variables and natural gas rents.

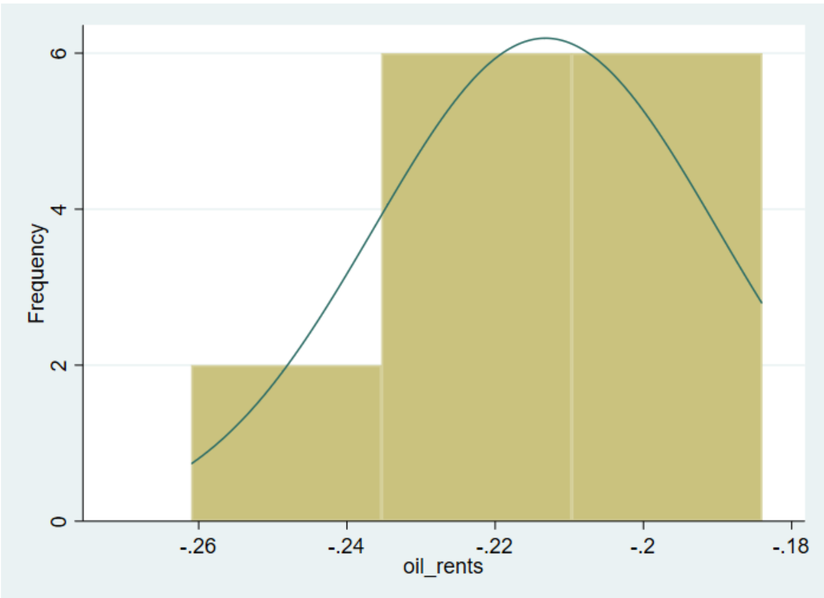

Figure 12 - Distribution of the coefficients (all significant at a 5% or 10% level) from the two year lagged growth rate of oil rents for OLS, GLS and PCSE with all different fixed effects specifications, and GMM estimations (differenced and system).

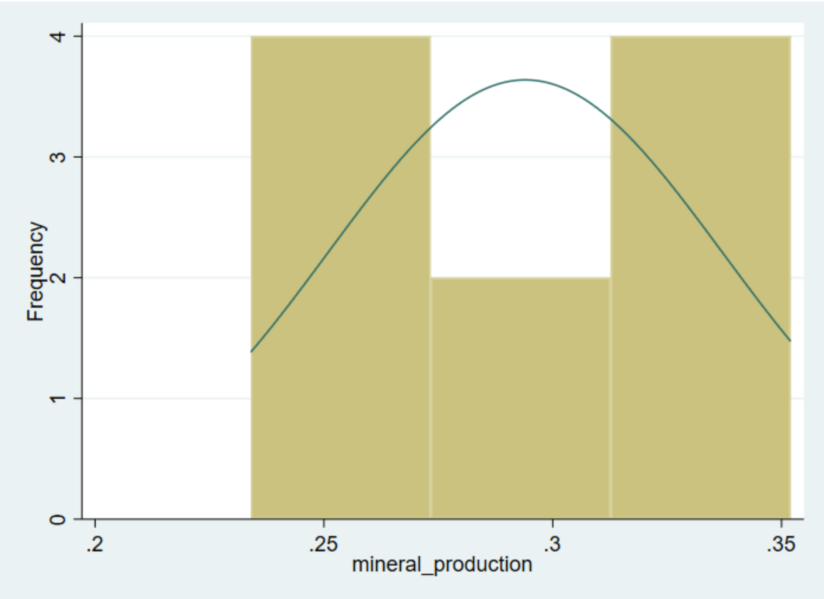

Figure 13 - Distribution of the coefficients (all significant at a 10% level) from the two year lagged growth rate of mineral production for OLS and PCSE (no significance in GLS) with all different fixed effects specifications, and GMM estimations (differenced and system).

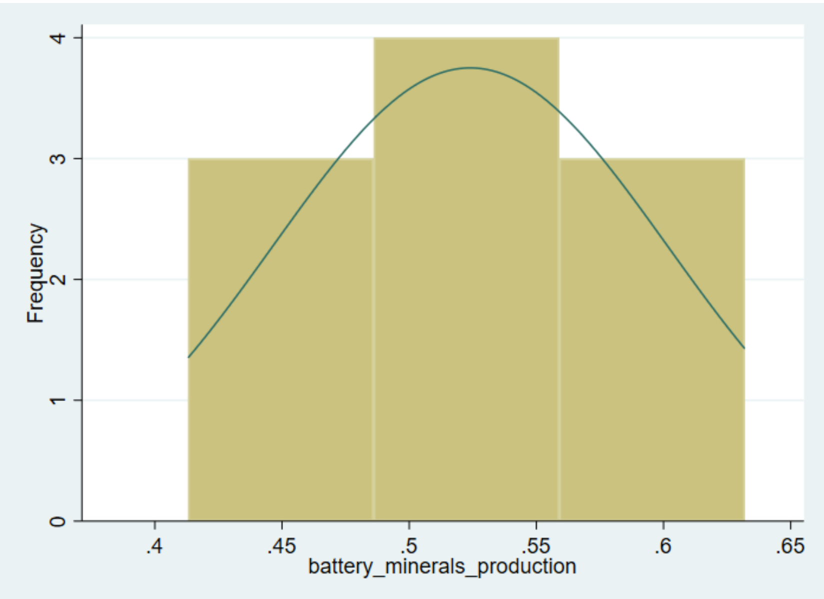

Figure 14 - Distribution of the coefficients (all significant at a 10% level) from the two year lagged growth rate of battery minerals production for OLS, GLS

and PCSE with all different fixed effects specifications, and GMM estimations (differenced and system).

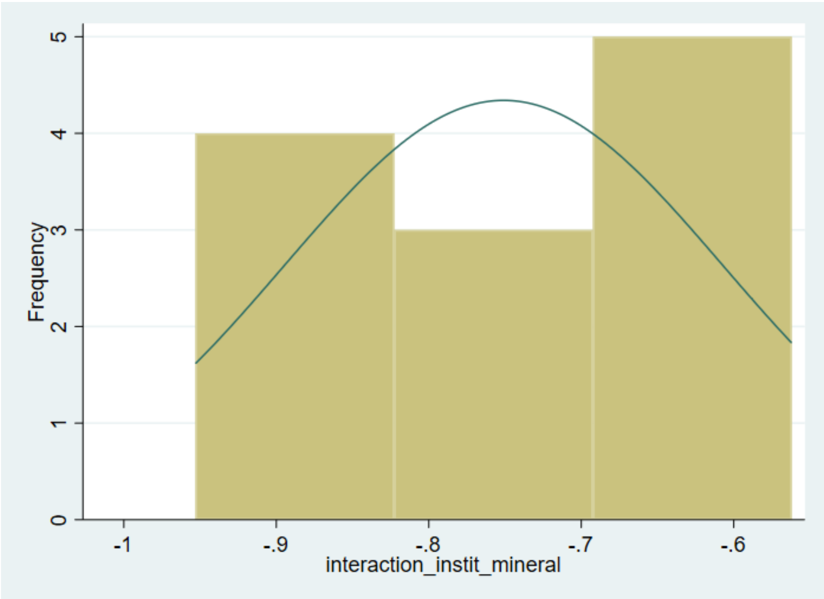

Figure 15 - Distribution of the coefficients (all significant at a 5% level) from the two year lagged interaction term between mineral production and the three institutions variables for OLS, GLS, PCSE, with all different fixed effects specifications and GMM estimations

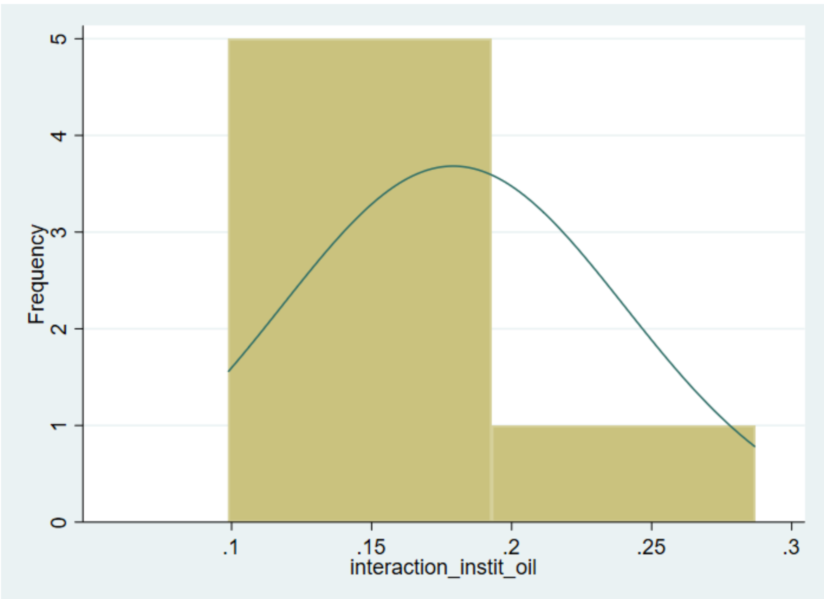

Figure 16 - Distribution of the coefficients (all significant at a 5% or 10% level) from the interaction term between oil rents and the three institutions variables for OLS, GLS, PCSE with all different fixed effects specifications and GMM estimations

8.1 Rolling regressions

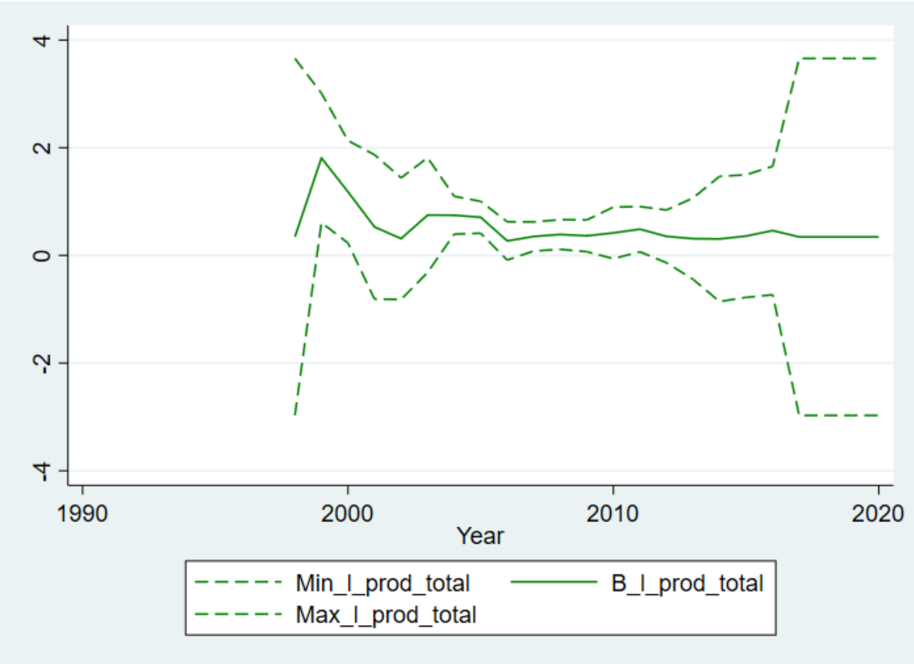

Figure 17 - Evolution of the coefficient for the 2-year lagged metal production growth rate, difference-GMM estimation

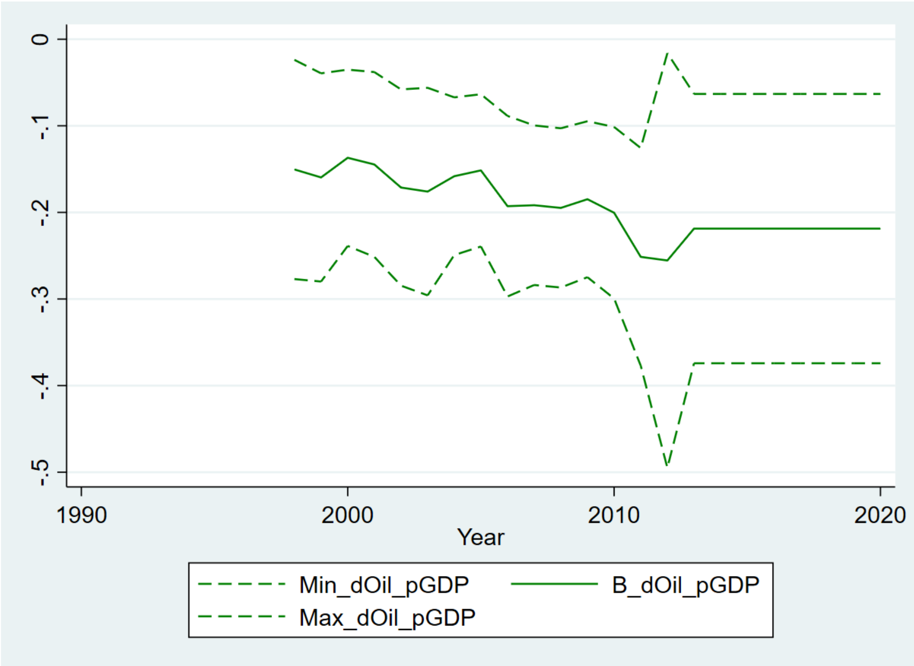

Figure 18 - Evolution of the coefficient for the oil rents/GDP growth rate difference-GMM estimation

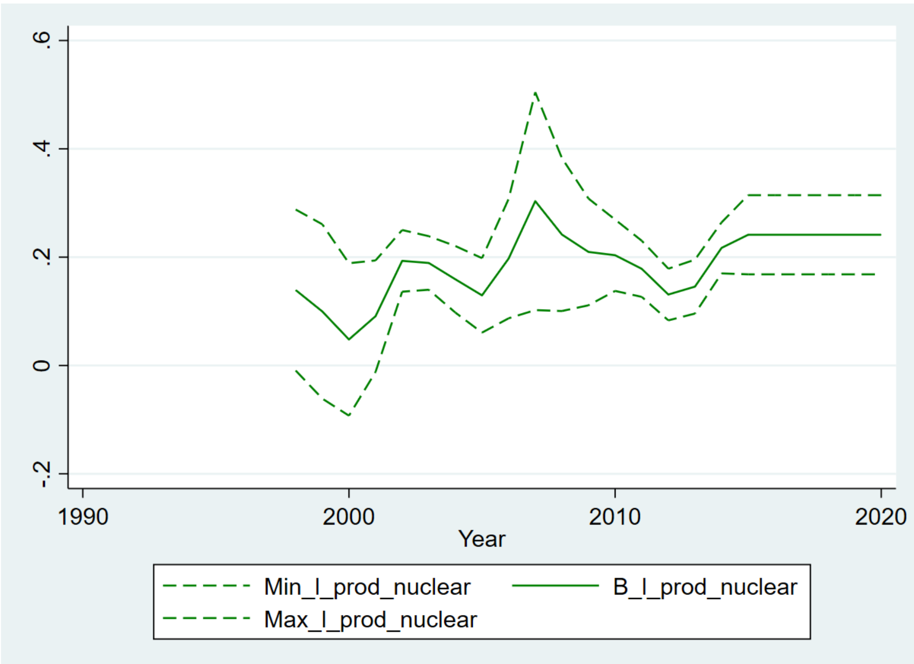

Figure 19 - Evolution of the coefficient for the nuclear metal growth rate, difference-GMM estimation