How does new demand for a natural resource impact the economic growth of developing countries endowed with it?

Case study of lithium and rare earth elements

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Introduction

The new-technology era that we are facing today is having a major impact on economies and especially on developing economies. We need to understand more clearly how these technologies may affect our economy and our welfare. The use of extensive natural resources for these technologies will undeniably affect our economies. We can observe movement in natural resource demand. Consequently, some natural resources (such as crude oil and gold) are having less impact, while other natural resources emerge to respond to new consumer preferences (such as lithium and rare earth). Our goal in this thesis is to describe and explain the main literature of natural resource economics and their potential influences on growth. Thanks to this literature analysis, we will be able to perceive if and how these new demands for lithium (or sometimes called "white petroleum") and rare earth elements can affect developing countries. In addition, we will try to assess the impact of such a change on economic growth and to observe if, after all, it really affects a developing economy. In this entire thesis, we will keep in mind and try to respond to the question: "*How does new demand for a natural resource impact the economic growth of developing countries endowed with it?"* As many have focused on economic dependence on "old" natural resources, there is very little literature about these "new" natural resources and their effect on the economy, and we will seek to take this a step further. Rather than observing if the resource curse is "real", as many did, we intend to develop a growth model to judge the impact of such new natural resources increases in developing countries.

To that end, our work will be divided into two parts and six chapters. It will be articulated as follows: the first part constitutes a review of the existing literature on natural resource impact: the blessing and the curse; whereas the second part contains our theoretical and empirical (econometric) contribution to the literature. As this model is restrained, we will include a limitation section to discuss the existing problems and the possible remedies for potential solutions.

The main literature usually attributes a negative effect on economic growth to natural resource endowments (Sachs and Warner [1999]). Natural resource endowment affects the economy through several channels: real exchange rate, politics and politicians, price volatility, instability in work, civil war, and conflict. Even though many scholars agree on a "resource curse", one must remain careful as there are many elements that need to be taken into account, and the literature has not actually observed a country that is truly cursed. Actually, some potential solutions exist: development in institutions, sovereign wealth funds, and potential positive externality.

Our thesis is based on data from the U.S. Geographical Survey and the World Bank database to determine the annual production and the economic indicator of each country that we analyze. To compare how lithium and rare earth country producer react to the increase of demand, we used the proxy of production and we compare our economic indicator with similar countries. In addition, we have used a dynamic panel data with time-fixed-effects model in order to remove the effect of time-invariant characteristics, so we can assess the net effect of the explanatory variable. We also use random-effects model for estimating the economic indicator that could be affected by lithium and rare earth production.

With the rise in demand for "white petroleum" and rare earth to respond to the growth in battery production, we observe that developing countries and developed countries are reacting positively to this increase. Indeed, the increase in these natural resource productions seems to have a positive impact on the gross domestic product evolution. As a matter of fact, we notice that foreign direct investment is higher when lithium is produced in larger quantities. However, we perceive that the extraction of lithium and rare earth elements has a negative effect on consumption expenditures. Moreover, when the price of lithium rises we observe that the growth is affected negatively due to the availability of substitutes.

Literature Review

This part will be devoted to an analysis of the potential pitfalls that developing countries can fall into when a new demand for a natural resource emerges and they are endowed with this resource. Throughout time, a large number of scientific papers and economic research have proven those pitfalls to be real. Despite the related caveats, empirical studies have proven that, with the right policies, potential benefits for developing countries through a new demand for a natural resource do exist. Consequently, we will divide this part into three chapters: the literature on the pitfalls, the literature on the benefits of a new demand for a natural resource, and the evolution of the demand for new minerals. Thanks to the literature, we shall grasp the different impacts on the economic growth of a new demand for natural resources on developing countries which both extract and are endowed with this natural resource.

Chapter I The Pitfalls of a New Demand for a Natural Resource

There has been a growing body of literature inquiring into the positive externalities of a well-endowed economy with natural resource relative to other factors of production (see Auty [1997]; Rodrik [1999]; Rodriguez and Sachs [1999]; Sachs and Warner [1999]; Isham et al. [2005]). However, prior to the late 1980s, it was commonly believed that a large endowment in the natural resource would be beneficial in terms of economic development to countries endowed with the resource in question. In the 1950s, most economists agreed that a significant endowment in natural resources eased positive economic growth of any such country. Even the geographers approved: "*the possession of a sizable and diversified natural resource base is a major advantage to any country embarking on a period of rapid economic growth*" (Ginsburg, 1950) (As cited in Rosser, 2006).

Walter Rostow (1959) claimed that natural resource endowments would permit to developing countries to make a shift from underdevelopment to industrial. The mainstream idea arising from this literature could be summarized as: natural resources were a blessing.

Conversely, in the late 1980s, the literature challenged this received wisdom by suggesting that a country well-endowed in natural resources would have an increased probability of experiencing negative economic growth. This paradox, as we might say, has been broadly recognized by economists and researchers. It all started with the development of the notion of the "resource curse" by Auty (1993) and later on by Sachs and Warner (1995), founding a negative correlation between the natural resource intensity and growth. They proved this result with an elaborate empirical study. This evident paradox was a phenomenon of interest and has been investigated in depth by numerous researchers. In our case, where a new demand rises, we do not try to prove a resource curse but rather to show how the specific resource boom will impact the economic growth of particular developing countries. The literature identifies five different situations/models that are unsafe when a natural resource booms. Those are closely linked to this apparent resource curse: the so-called "Dutch Disease", volatility in commodity prices, the probability of undermining democratic rule, the type of resource *per se*, and finally conflict for access to such natural resources.

I.1 The Dutch Disease

The very first negative externality of an increase of the demand for a natural resource will be the Dutch Disease: an economic phenomenon in which real appreciation, which is triggered by a resource boom, crowds out manufacturing and other exports (Beck et al., 2007, p. 6). Indeed, in the late 1950s, the discovery of large natural gas reserves in the Netherlands resulted in raised gas exports, which led the exchange rate of the Netherlands currency to appreciate and increased wages[1] quicker than the productivity gain in other sectors of the

[1] Due to the resource booming, the sector is obligated to offer workers higher wages to attract the labor it needs

economy. Those two developments hit, in particular, the manufacturing sector, which therefore has to compete domestically with foreign markets. An excessively appreciated currency leads to manufactured goods becoming overpriced and hence uncompetitive. Nonetheless, it is worth reflecting whether this is a real disease. One interpretation is that, if the complete cycle is not well thought through, when commodity prices fall there is a risk of painful reversal (Frankel, 2010). Each of the studies by Krugman (1987), Matsuyama (1992), Sachs and Warner (1995) showed that the exploitation of more natural resources reduces the industrial sector, and has undesirable long-term economic consequences. This literature has been influential in explaining why a resource boom may lower growth.

To deepen this literature, let us use a simplification of the main Dutch Disease model given by Corden and Neary (1982). This model theorizes a three-sector economy: a booming natural resource sector (R), a non-traded sector (N) and manufacturing as well as the agriculture sector (MA). With different assumptions, where labor is the only mobile and factor prices are not distorted, the natural resource boom will have two different effects on the manufacturing sector: the resource movement effect and the spending effect. On the one hand, the resource movement effect designates the migration of labor from (N) and (MA) to the booming sector (R). On the other hand, the spending effect constitutes a rise in the price of the non-traded sector due to the increase of income from (R) that they will spend on (N). Because of those reduced assumptions, a resource boom will lead to an unequivocal decrease in output of (N) and (MA) sector, leading to what Corden and Neary call “deindustrialization”; that is to say a decline in the non-booming sector, assumed here to be manufacturing (Corden and Neary, 1982, p. 841).

This phenomenon, even if modeled, has to be answered empirically. Ismail (2010) found that oil booms have the effect of reducing manufacturing output and a stronger impact on the economy’s openness to foreign investment. Smith (2014), through an empirical study, could not contradict the core Dutch Disease model. In other words, he agreed on an ambiguous effect of an oil boom on the other sectors. Moreover, he could not imply that the mechanisms (resource movement and spending effects) are not present. Even if this pitfall has been demonstrated, there exist several counter examples. With the right policies, it is possible to decrease the negative impact of natural resources boom while permitting an expansion of tradable production. As Stiglitz (2004) mentioned, in principle it seems quite easy to avoid currency appreciation by keeping the foreign exchange earning from natural resource exports out of the country and investing them in the safest countries (such as Europe and the U.S.) and then bring them back gradually. However, most countries believed that such a policy would not help their own economy but someone else's economy. For him, the Dutch Disease is a matter of political will.

I.2 Volatility in Commodity Prices

We will now move on to the literature that addresses the problem of volatility in commodity prices. When new demand for a natural resource rises, we can ask ourselves about the impact of the high volatility in the prices of such natural resources, especially for developing economies.

First, there is a consensus between economists on the fact that mineral commodities and commodities in general are much more volatile markets than manufactured markets (see Ross [2001]; Radetzki [2008]; Jacks [2011]). In this literature, many suggest that there is a high probability that the volatility of natural resources prices will be bad for economic growth (see Davis and Tilton [2005]; Blattman et al. [2007]; Poelhekke and Van der Ploeg [2008]). In our case, mineral commodities, the volatility arises primarily from a larger fluctuation in demand over the business cycle. Davis and Tilton (2002) argue that when an economy is flourishing, the sectors that consume most mineral commodities, namely construction, transportation and consumer durables, are developing even faster than the economy. Oppositely, when the economy is in a recession, they affirm that those sectors are even more depressed. In other terms, there is a shift in demand rather than in the supply, and it is this that explains the price variation. This situation will induce a high volatility in government revenue (from taxes on company profits) which will be detrimental to the effectiveness of planning, spending, and aligning public finance revenues and expenditures.

According to Davis and Tilton (2005), the volatility in these sectors can also reduce the possibility of using a counter-cyclical expansionary monetary policy when it is the most needed; i.e. when recession affects these sectors. Moreover, Van der Ploeg (2011) notes that when commodity prices are elevated, countries endowed with many natural resources tend to borrow from abroad, intensifying the boom. But from panel data estimation, commodity-rich countries are led into debt crises when the commodities' price falls.

Empirically, Blattman et al. (2007) show that if Indonesia had experienced fewer terms of trade volatility[2] than Canada, then Indonesia would have grown faster by about 0.3 of a percentage point and thus decreased the growth rate gap between them by a third. Van der Ploeg and Poelhekke (2009) show a causal link between the high volatility of natural resources prices and the output per capita growth in countries that depend heavily on natural resources. They also present evidence of a robust negative effect of volatility in unanticipated output growth on long-run growth. Therefore, we can assume a causal link between price volatility and growth. This effect is not limited to countries that produce oil but also for exporters of copper, coffee, food, etc. However, for the authors, the countries are not doomed to negative growth. Indeed, they can substantially reduce volatility with lower capital restrictions, openness and physical access to world trade. As discussed in the previous section (I.1), it is not only the volatility of natural resources prices that affects the economic growth of developing countries. For instance, Aghion et al. (2009) found out using cross-country panel datasets that a high level of real exchange rate volatility (which could be due to the Dutch disease) could stunt growth.

[2] A ratio of an index of a country's export prices to an index of its import prices

I.3 Probability of a Deterioration in Political Institutions and the Rent-Seeking Theory

Although political institutions may affect the way an economy's country responds to a natural resource endowment, many suggest that the natural resource endowment alters a country's political institutions. When new demand for a natural resource arises, it will unquestionably alter the democracy, political stability and property rights. The literature has responded to this through a theoretical explanation: rent-seeking, or as described by Lam and Wantchekon (2002) "Political Dutch Disease".

As the revenues from natural resources increase thanks to a natural resource boom, there is an expansion in the availability of resource rents. Investment in this natural resource rent appears to be much more lucrative than investments in production. Nevertheless, we may wonder why rent-seeking behaviour is more common in countries that have a large natural resource endowment. The response is quite straightforward: the extraction of natural resources is mostly controlled by huge firms or state organizations and thus these resources are not extracted or produced in a competitive market. The many barriers to market entry do not allow small or medium investors to start up a natural resource extraction business which enables a monopoly position or cartels to develop in such markets. The structure of a natural resource market (monopoly, cartel, tariffs) makes it possible for different stakeholders to extract rent.

Let us explain this with the basic theory of the rent-seeking developed by Tullock (1967). Initially developed to explain social welfare losses—due to the establishment of monopolies, tariffs and subsides—the theoretical framework could help to elucidate the risk of the deterioration of political institutions.

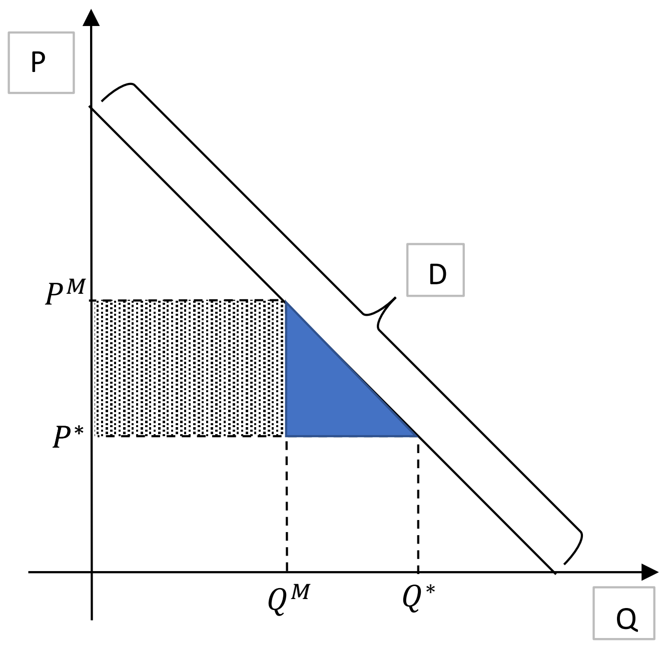

Figure I.1 — Social lost from a monopoly, tariffs or taxes

As we observe on Figure I.1, there is a demand curve (D) of a good depending on the quantity sold (Q) (horizontal axis) and the price of this good (P) (vertical axis). Under perfect competition assumptions, Q^* units of the good will be sold at price P^*. While, if we observe a monopoly, the result is quite different: Q^M units will be sold at a price P^M. Following the classical economic theory, the deadweight loss (the blue triangle) from the monopoly denotes the consumer surplus that would have been gained if the price had been lower than P^M. Contrarily, the dotted rectangle represents the monopoly rents. One would think of this as a simple transfer of surplus from consumers to monopolists. However, the core belief of rent-seeking is that the net social loss from monopolies, taxes, tariffs or even subsidies is in fact much larger than deadweight loss and includes the dotted rectangle. How to explain it? According to the classical theory, a monopoly is created without cost. However, for Tullock (1967), creating a monopoly occurs to be a competitive industry which is costly to secure, and thus the cost is much higher. From this basic framework, researchers have developed three alternative types of rent-seeking that have been recognized over time (Ross, 2001).

- Rent creation: firms search for rents created by states, by bribing politicians and public officials;

- Rent extraction: politicians and public officials search for rent held by firms, by threatening firms with tariffs and taxes;

- Rent seizing: state actors search for rent held by state institutions, by dismantling the rule of law that obstructs the rent-seeking process.

As one can see, rent-seeking may take different forms, such as tariff protection or outright corruption. With these three types in mind, we are now able to understand how a government that has recourse to tax or tariff mechanisms, a firm that bribes politicians, or a state actor that dismantles legal rules as a result of an increase in rent generated by new demand for a natural resource will probably lead to a decrease in the net social losses and in the deterioration of political institutions. For instance, Robinson et al. (2006) show that a resource boom often creates inefficiency due to the rent-seeking behavior of politicians who engage in inefficient redistribution to influence elections. Another example of rent-seeking given by Polterovich (2010) is when governments tax natural resource producers and use this money to invest in other industries. This leads to business failure because the selection of industries is influenced by lobbying or cronyism. The rent-seeking theory also explains the deterioration of human capital and increase in inequality. For example, Torvik (2002) developed a model where a larger natural endowment increases the number of social actors involved in rent-seeking while it reduces the numbers of those running productive firms. The rent-seeking framework and literature show that new demand can alter a country's democracy, political stability and property rights. Empirically, Sala-i-Martin and Subramanian (2013) as well as Isham et al. (2005) have demonstrated the link between natural resource and a deleterious impact on institutional quality.

In addition to this, natural resource revenues can be considered as one of the main sources of conflict between politicians and citizens (Collier and Hoffler [2002]; urshed [2002]; Sala-i-Martin and Subramanian [2013]). All of them find that a country's resource-dependence (especially in oil and mineral wealth) tends to be correlated with civil war. However, they are not unanimous on the direction of causality (Frankel, 2010). Brunnschwelever and Bulte (2009) found that civil war increases dependence on resources, while Humphreys (2005) established that the reason why natural resource conflicts end in a military victory (rather than with a settlement) is the presence of sizeable resources.

To conclude this section, we have seen that the literature gives many examples where a new demand for natural resources can disrupt political institutions. For instance, Congleton et al. (2008), affirm that without property rights the natural resource endowment and wealth will only be a rent-seeking prize. Even if scholars don't agree on how it will affect all the various political institutions, there is a consensus on the way that a natural resource boom tends to distort economic growth and impact on political institutions, especially if institutional quality is poor (see Stijns [2005]; Sala-i-Martin and Subramanian [2013]).

I.4 Type of Resource

We have seen in the last three sections many pitfalls that a growing economy can fall into when faced with a rise in the demand for a natural resource. However, all of the above are, in a certain way, not a definitive meltdown and can be countered with the right policies and right institutions. This section treats another difficulty identified in the literature that is much harder to counter. The particular type of natural resources may affect in a different way the growth and the development of an economy. Indeed, many scholars have offered evidence claiming that the main problem is not natural resource abundance *per* se but rather an abundance of a particular type of natural resource (Auty [2001]; Lay [2004]; Mavrotas et al. [2012]).

The literature contrasts two different types of natural resource: point-source resources (sometimes called concentrated resources) and diffused resources. On the one hand, point-source resources are extracted from a narrow geographic or economic base, such as minerals and oils. On the other hand, diffused resources are resources that are not concentrated in one place, such as soils, fisheries, forestry and agricultural products. Another characteristic for distinguishing the two natural resources is the ease of taxing them. Point-source resources are easily taxed while diffused resources such as agricultural products are much less taxed due to the lower profit margins and the wider range of private actors. The point-source resources are much more exposed to rent-seeking, mismanagement, poor public institutions, slower growth and conflict (Addison et al. [2002]; Roy [2003]; Murshed [2004]). The explanation behind this is the following: when resources are close and concentrated, the cost of protection and control is relatively low. In other terms, the resource can be more easily expropriated. A market that can be easily at low cost will result in a wasteful rent-seeking game where the only goal of the contest is to be the one to capture the resource rents (Murshed, 2004). As Mavrotas (2011) pointed out in his paper, point-source economies depend on the quality of institutions, and the quality of institutions could be affected in parallel by resource dependence. To truly understand how the type of resource affects a developing country and its growth, we have to look at all the pitfalls at stake: rent-seeking, resource-dependence, volatility, real exchange rate, etc. We then understand how closely linked all of these factors are and how one can affect another.

Empirically, there are many studies that have studied the type of resource and its effect. For example, Isham et al. (2002) show that during the 1980s and 1990s point-source economies had a tendency to grow slower than diffused economies. Mavrotas (2011) demonstrated that point-source economies have a worse impact on governance, which in its turn will affect growth. Probably one of the most complete papers about resource types is that of Boschini (2007), which shows that a country's development and growth depend crucially on the types of resource that the country is endowed with and the institutional setting. This study showed that mineral-rich countries (point-sourced resources) will be "cursed" only if the institutions are at a low level but the “curse” can nevertheless be reversed if the institutions are good enough.

I.5 Conflict for Access to the Natural Resource

As we have mentioned previously, natural resources are a worldwide reason for conflict. Theoretically, the reasons why conflict is emboldened in resource-rich countries are multiple. However, the literature divides these into three main categories. The first reason is the rent-seeking behaviors mentioned in section 0: the opportunity of seizing a “prize” will motive people to improve their welfare. Another second explanation, from Collier, Hoeffler and Rohner (2009) is that rebellion becomes much more feasible with the extraction of natural resources. Indeed, a large windfall relaxes credit constraints and facilitates other elements necessary to set up a rebel movement. Thirdly, a final justification sees natural resources as generating separatism in certain cases where the natural resource is unequally distributed within the country and gives the opportunity for ethnic minorities which are endowed with those natural resources to gain the upper hand and “emancipate” themselves from the nation (Morelli and Rohner, 2015).

Empirically, Berman et al. (2015) estimate that a steep increase in mineral prices between 1997 and 2010 accounts for 13 to 21% of the average violence for the African countries that were observed during this period. They also found a significant and quantitatively large impact of mining activities on the likelihood of conflict occurring in the same area. Correspondingly, Couttenier, Grosjean and Sagnier (2017) observe a “homicide resource curse” in the context of mineral discoveries and weak politics. However, as Oliver Vanden Eynde (2016) noted in the case of the conflict with rebels for control of India’s naxalite, there are different counter-policies that can be particularly effective at restraining the fighting capacity of rebels against the government in mineral-rich areas.

As we end this first chapter, we have observed different phenomena that affect a developing economy when a demand for a natural resource is fostered, and "how" it can be affected. Nevertheless, there are many other "hows" that we did not address and which have a negative effect on economic growth. For instance, how social factors such as sloth and laziness may affect the behaviour of a country and a government when they have an abundance of natural resources (Sachs and Warner [1995]) or how the citizens of a mineral resource-rich state may develop more individualistic sentiments and seek less redistribution (Couttenier and Sangnier [2010]). The main goal was to introduce the wide range of literature on the negativity for a country of new demand for a natural resource: real exchange rates, unemployment, instability in work, corruption, instability in political institutions, civil war and so on. Even though many scholars agree on a "resource curse", one must remain careful to distinguish the many elements to need to be take into account when assessing the impacts of such change on economic growth.

Chapter II The Potential Benefits of New Demand for a Natural Resource

Thanks to the analyses presented in the first chapter, we can grasp and begin to identify the different types of factor at stake and how these will affect developing countries when demand for a natural resource increases. However, there is evidence that high institutional quality and above all, public policies can overcome the pitfalls that we are aware of. In this chapter, we will present several examples of benefits and seek to set out the main reasons for such benefits. According to the OECD (2011), sustainable management of natural resources allows resource-rich countries to develop and establish the foundations for long-term development and growth and, at the same time, to alleviate poverty. The main benefits of a natural resource come from the current and potential flows of income. The rise in revenues from natural resources generated by new demand enables the government—or any other stakeholder—to play with many factors. For instance, poverty reduction, development of human capital, job creation. However, to do so, they often need to adopt public policies, to develop institutions and transparency, to have multi-stakeholder participation and so on.

As we said, the benefits are many but they are highly dependent on how the resources are managed. In this chapter, we will explain the opportunity for benefits and what they rely on if they are to be obtained. For this purpose, we have decided to split our analysis into three separate sections: the opportunity for institutional development, the positive externalities of new demand, and the creation of stabilization funds to boost the real benefits. In addition, we will present various examples of how to overcome the pitfalls to obtaining benefits.

II.1 Opportunity for Institutional Development

As we have mapped out in section 0, new demand can produce negative effects on political institutions, such as corruption, civil war, democracy, etc. (Murshed [2002]; Isham et al. [2005]; Sala-i-Martin and Subramanian [2013]). For instance, Vardy (2010) argues that without any major bound in institutional quality, it will be impossible for countries that are well endowed in natural resources but with poor institutions to move to a good equilibrium where resource endowment, good institutions, and growth reinforce each other. Nonetheless, one can find counter-examples with poor institutional quality where they improve their financial transactions, efficiency and corruption index.

Sinnott, Nash, and De La Torre's book (2010)[3] concludes that "*some studies provide evidence that the growth benefits of natural resource abundance are greater, on average, for countries with weak institutions*". Indeed, if we examine the economic paper of Brunnschweiler (2008) Alexeev and Conrard (2009), we can observe that weak institutions do not determine the growth benefits for resource-rich countries. Brunnshweiler (2008) found no evidence of a negative growth effect of natural resource abundance, especially when concentrating on mineral resources. The explanation, according to him, is a catch-up effect or in other terms countries with weaker institutions tend to benefit more in growth because they were simply catching up on the others.

Government must use the income flow to improve governance and the economic sustainability[4], by transforming the management of resources. To do so, they need to modify the institutions itself. There is a need to shift from "*government to governance*" (OECD, 2011). To be sustainable, they need to keep the nation's capital intact; that is to say to aim for a constant future income stream (Hartwick's rule). For Havro and Santiso (2008), Norway and Chile have been able to take advantage of their natural resource booms (respectively oil and copper) by

[3] Sinnott, E., Nash, J., & De la Torre, A. (2010), Natural resources in Latin America and the Caribbean: beyond booms and busts?, World Bank Publications.

[4] If future generations are able to enjoy the same standard of living as the current one, then the economy is considered as sustainable

implementing practical policies that were designed to offset the tendency towards economic unsustainability. As Ripley and Roe (2012) set out, there are different examples of government initiatives capable of overcoming the risk of corruption and decreased efficiency. Particular examples include the Audit Commission created in the Philippines or the Cooper Department set up by the Chilean government to monitor the flow of investment and copper with the goal of deterring corruption.

It is clear that it is not necessarily easy for a government and institutions to develop themselves in a resource boom but there is still the possibility for progress. The main contrast between this section and the first chapter is that weak institutions do not necessarily lead to bad management of the natural resource revenues.

II.2 Positive Externalities of New Demand for a Natural Resource

At first, let us remind ourselves what an externality is. It is the consequence of an economic agent's action that directly affects another economic agent's welfare without being reflected in market prices. An academic example of positive externalities are those that derive from vaccination. With a larger population of people vaccinated, the risk of the disease spreading is decreased, which thus reduces the risk to those who did not benefit directly from this protective measure itself. New demand implies a response in output and production technology. A technological development has several positive externalities, such as spin-off industries, investment in education, new technological skills, higher wages with the newly skilled jobs, and so on (Ripley and Roe [2012]). For our case study, mining often needs spin-off industries that create many jobs and require skilled workers. Rocha (2010) finds evidence that natural resource exports provide positive spillovers to the domestic sector and that productivity and spillovers to the economy are at least as high as those given by the export manufacturing sector. Other natural resources also have their positive externalities: watersheds can provide water filtration and purification for wetlands, oil wealth attracts foreign direct investment including the construction of pipelines, and oil transformation engenders positive externalities for the whole economy.

Nonetheless, it must be recognised that not only positive externalities that can come out of a new demand for a natural resource and it can have a catastrophic economic and social impact. A notable example of this problem is Nigeria. This country is one of the largest oil-producing countries. However, because of the lack of oil-related infrastructure, they are obliged to export the crude oil. Without the necessary complete infrastructure, the country cannot benefit from skilled jobs, high salaries, spin-off industries and any other positive externalities. In addition to this, natural resource extraction might produce negative externalities, such as water and air pollution, and soil erosion. Most of the time, those negative externalities are borne by the poorest. For our case study, rare earth elements and lithium are two elements that are used on goods that are not for the most part are recyclable (electric cars, phones, etc.), and this brings with it a problem of sustainability as this resource is non-renewable and mostly non-recyclable for future generations and this can be considered as a negative externality.

II.3 Creation of a Sovereign Wealth Fund to Boost the Real Benefits?

An increase in the demand for natural resources will create a windfall for a country and as we stated previously, it is most important to properly manage this windfall in order to avoid future uncertainty. We mentioned in II.1 and II.2 different opportunities and positive externalities if the right policies and the right actions were implemented. However, the literature is quite divided about the right action to administer in that situation. In this section, we will examine further the literature on one solution proposed: the Sovereign Wealth Fund (SWF). The International Fund Monetary has recommended that resource-rich countries put their windfall profits into a SWF (Davis, 2001). One definition of a SWF according to ECB (2008, p. 6) is the following: "*public investment agencies which manage* *part of the (foreign) assets of national states".* We can add to this that they are independent from foreign reserves, and most SWF are funded by income from commodity exports. The best known and most successful SWG is the Government Pension Fund of Norway which is used to preserve the surplus wealth from petroleum revenue for future generations. Nowadays, Wills (2016) have observed that 60% of resource-dependent countries have established some form of funds. The IMF (2008) distinguished five types of SWF: stabilization funds, savings funds, development funds, pension reserve and reserve investment corporations. Ripley and Roe (2012) observe that SWFs can assist government in a number of creative ways, depending on their specific needs. However, we shall focus only on three types: intergenerational funds (or savings funds), development funds (also called parking funds) and stabilization funds. All have proven efficient in certain ways but we shall observe what the literature assumes to be wiser for developing countries.

II.3.1 Intergenerational Fund

This kind of fund aims to transfer the natural resource wealth earnings into a long-term financial wealth. These funds are a way to manage the long-term revenue of the natural resource (Torvik, 2016). The intergenerational fund is designed to overcome the brevity of a finite stream of revenues from a natural resource that is exhaustible (Wills, 2016). In other terms, they seek to convert the windfall of the non-renewable resource into an asset that will give income for the future when the resource is exhausted. The main difference between this fund and the others is the long-term investment strategy (Sinnott, Nash and De La Torre [2010]). However, for Wills (2016), this fund is most relevant for developed countries rather than developing countries. According to the author, the welfare of developing countries' future generations is better served with the prioritization of domestic investment. Consequently, developing countries should focus on the two other funds (Development and Stabilization funds) in order to avoid the pitfalls of a new demand for a natural resource. For instance, van der Ploeg and Venables (2011) found results on savings and investments to suggest that resource revenue should be used to accelerate growth in the non-resource economy and not to transfer resources rent to future generations. However, we must observe that for developed countries with high-performing institutions, there are several examples that prove the efficiency and the benefits of such a fund (Norway's Pension Fund, Kuwait's Reserve Fund).

II.3.2 Development Fund

The point of this type of fund is to invest domestically using natural resource income but in an efficient way. The development fund will help to create domestic socioeconomic projects, such as education, infrastructure, health and social assistance with high potential payoffs. The reserves from the development fund will be released for investment when viable commercial opportunities arise in the country (Dixon and Monk [2011]). However, there is a need to invest gradually so as not to overheat the economy and cause the real exchange rate to appreciate. Moreover, Ghahramani (2013) argues that development funds can overcome the Dutch Disease by supporting other industries at the right time. To work efficiently, the Development Fund needs to be established as a separate entity and with professional investment managers that are not corrupted or under political sway (Dixon and Monk [2011]). To sum up, the main objective of this SWF is to hold the revenue of natural resources by holding other assets abroad and to release the revenue into more efficient domestic investments at the right time.

II.3.3 Stabilization Fund

The goal of a stabilization fund is to prevent short-term fluctuation in revenues resulting from the high volatility of commodity prices (Torvik, 2016). In other words, the point is to protect the domestic economy against cyclical movements and the instability of commodity prices (Jen, 2007). For Davis and Tilton (2005), such a fund should enable governments to withdraw the accumulated revenues to support government programmes when the natural resource market is depressed. The negative effect of the market will be then restrained. As Sinnott Nash and De

La Torre (2010) mentioned it, a stabilization fund can contribute to a more effective counter-cyclical fiscal policy function with an expenditure stabilization function. The way it works is the following: it accumulates reserves when the commodity price is higher than the reference value and invests in low risk liquid assets (Heuty and Aristi [2009]). Conversely, it will contribute to budgetary resources when prices are lower than the reference value. The main challenge in this situation remains how to choose correctly the reference value of the commodity. Thanks to Table 1 (cf. appendices), we can clearly grasp the difference between stabilization funds and intergenerational funds (or saving funds). Many examples of such funds do exist: Alaska, Canada, Chile, Ghana, Norway, Papua New Guinea and Venezuela. Even if the results of these stabilization funds have been mixed (cf. Venezuela), it remains a leading solution for many stakeholders to face the many risks arising from new demand for a natural resource. Nevertheless, other solutions exist to address the pitfalls of a natural resource windfall. Frankel (2010) enumerates some: reserve accumulation by central banks, reducing net private capital inflows during booms, lump-sum distribution.

The creation of SWFs as recommended by IMF has often advantaged developed countries. However, there are several examples where developing countries have profited from such funds. We cannot affirm with any certainty whether this will be bad or good for a developing country over time, but Sala-i-Martin and Subramaniana (2013) and Van der Ploeg (2011) argue that the results of such funds mainly depend on the non-economic factors in a country. For instance, if the institutions are weak, this will lead the sovereign wealth fund being ineffective. There is no clear consensus in the literature on how and which funds to use to provide the best tools to face a natural resource boom. Wills (2016) suggests that developing countries should implement a stabilization and developing fund, while Dixon and Monk (2011) advise using the three separate SWF over time but starting with a stabilization fund. On the contrary, Torvik (2016) proposes investing in human capital and domestic infrastructure instead of using a fund in countries with low initial institutional performance levels.

Chapter III The Evolution of Demand for New Minerals

To empirically test the question posed, we first need to find natural resources where world demand has been and remains upward. As S. Kesler (2007) stated, mineral consumption is growing faster than the number of people since more consumers enter in the market for minerals as global living standards increase. Our focus is not minerals in general, but rather minerals that face or will face a sharp increase in demand for the near future. As life styles evolve and consumer preferences are shifting toward high-tech and new "green" products, some minerals will be produced in much larger amounts (De Lima and Filho, 2016).

Even though other minerals are used for green and high-tech goods, we will concentrate our analysis on two minerals: lithium and rare earth elements. As you may know, demand for lithium is rising with the use of advanced batteries (their main use) while rare-earth prices have risen in recent years[5] and there are many countries that are pursuing the development of new deposits (World Bank, 2013). Both of these minerals have many applications (e.g. glasses, air conditioning, TVs, computers, smartphones, and more especially batteries). Besides, lithium is often combined with rare earth elements for the production of renewable energy sources which is why it is interesting to study empirically both of these natural resources (Doyle, 2015).

The two following graphics that we compiled from USGS time series will show how lithium and rare earth elements (REEs) production has grown from the 1900s up until the present.

[5] Even though they have stabilized by now

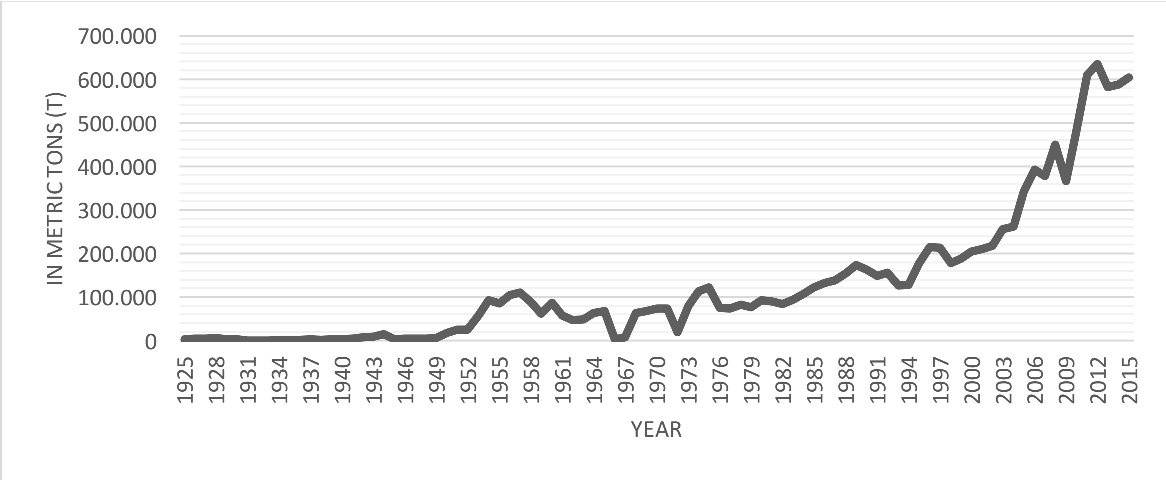

Figure III.1 — Evolution of world production of lithium by metric tons
(Source: USGS, Data series 140)

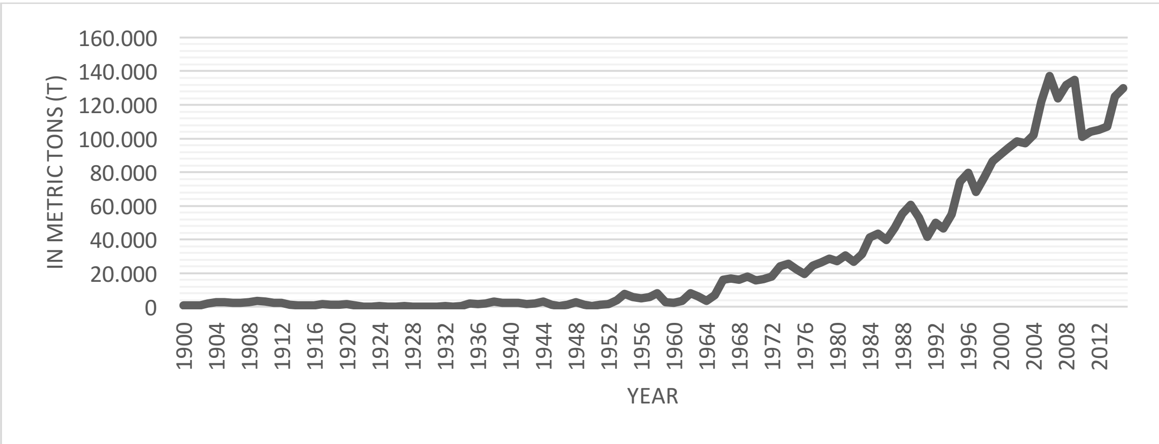

Figure III.2 — Evolution of world production of rare-earth elements by metric tons
(Source: USGS, Data series 140)

The increase in lithium and REEs production is largely explained by new types of goods and production. According to Credit Suisse (2014), lithium demand is likely to grow by 12% annually compounded looking out to 2020 driven by battery usage and electric vehicles. For them, much of that growth will come from lithium batteries. According to USGS (2017), the two biggest producers in Chile and Argentina announced plans to further expand their lithium production in order to meet the increasing demand for batteries in electric vehicles. If we look at Figure 1 (cf. appendices), we can see that the growth rate for the last 20 years of lithium and rare earth elements is quite elevated in contrast to the other main known minerals. Moreover, we can tell from the U.S. Geological Survey National Minerals Information Center that the growth rate for the last twenty and five years for lithium and REEs is higher than the mineral average (cf. Table 2, appendices).

Empirical Part

Chapter IV Methodology

The goal of this empirical part is to assess the impact of an increase in lithium and rare earth elements demand on economic growth. The literature indeed suggests that it can affect economic growth in several ways. For this assessment, we shall use a proxy for demand: the output of lithium and REEs by country and its impact on economic growth. Indeed, when there is a change in one of the factors of demand (in our case: consumer preferences towards green products and new technology), there will be a shift in the demand curves to the right. *Ceteris paribus*, it will lead to a higher quantity being produced and consumed. Rather to verify the different pitfalls and benefits set out and shown in the literature, we will provide a critical commentary on how higher commodity output may affect the long-run growth of developing countries endowed with these resources.

As I. Coxhead and S. Jayasuriya (2008) mentioned, commodity extraction and production have strong environmental impacts, especially in the case of market failure and weak institutions, and it may have serious growth and equity consequences. While studies have demonstrated that a large and sharp increase in the commodity price is ambiguous in the long-run growth of commodity exporters but will raise income in the short run (Collier and Goderis, 2012), it is worth considering how a variation in the production of a commodity will affect a developing economy and its growth.

IV.1 Choice of Data

The database that we are going to use (named "lireeDATA") is a merge between the database of lithium and rare earth production by countries from 1998 to 2014 from the U.S. Geographical Survey and economic indicators selected from the World Bank database. The economic indicators are selected according to previous and similar empirical papers (Gokovali and Bahar [2006]; Torres et al. [2009]; Downes et al. [2014]; Gaspart and Pecher [2015]).

To investigate the link between natural resources production and economic growth, we take data from eight lithium and/or REE country producers (of which six are developing countries[6] and two developed countries[7])[8] and eight similar countries but non-producers of lithium or rare earth elements. We chose these similar countries in accordance with the geography, the size, the GDP, and the economic complexity index (ECI)[9]. Each producer-country and non-producer-country but similar is listed in the appendix (cf. Tables).

In our database, we selected 14 variables including the gross domestic product (hereafter GDP) per capita based on purchasing power parity (PPP), the lithium production, the REE production, the REE and lithium price[10], the lithium and rare earth reserve, a binary variable if the country is a producer of both lithium and rare earth, etc. All variables that we selected are from USGS and World Bank. They are available in the following page with their code and their description.

[6] Argentina, Brazil, Chile, China, Malaysia and Zimbabwe
[7] Australia and Portugal
[8] According to IMF
[9] ECI allows one to explain international variations in in income inequality by considering the total exports of a country and the difficulty of exporting each product
[10] The unit value in dollars of 1 ton of rare earth oxide apparent consumption with conversion according to the consumer price index taking 1998 as the base year

Variables	Code	Description	Source
Explanatory variables			
Lithium production	*LIprod*	Estimation of lithium minerals and brine production (in metric tons, gross weight)	USGS, Minerals Yearbook
Lithium reserve (in metric tons)	*LIreserve*	The part of the reserve base, which could be economically extracted or produced at the time of the determination (2014). For further information: https://minerals.usgs.gov/minerals/pubs/mcs/2015/mcsapp2015.pdf	USGS, Mineral Commodity Summaries
REE production (in metric tons)	*REEprod*	Estimation of rare earths production (in metric tons, gross weight) with only the official production quota. Illegal production could not be quantified	USGS, Minerals Yearbook.
REE reserve	*REEreserve*	The part of the reserve base, which could be economically extracted or produced at the time of the determination (2014). For further information: https://minerals.usgs.gov/minerals/pubs/mcs/2015/mcsapp2015.pdf	USGS, Mineral Commodity Summaries
Lithium and REE production	*LIRANDEE*	Binary variable, 1 if the country produces lithium and production, 0 otherwise	Author
Lithium or REE production	*LIORREE*	Binary variable, 1 if the country produces either lithium or rare earth elements, 0 otherwise	Author
Demand-level control variable			
Lithium price (base year 1998)	*price98LI*	Unit value of 1 metric ton (t) of lithium apparent consumption. The price series for lithium carbonate was used to estimate unit value for lithium. The Consumer Price Index Conversion factor, with 1998 as the base year, was used to adjust the unit value in current U.S. dollars to unit value in constant 1998 U.S. dollars.	USGS, Data Series 140
REE price (base year 1998)	*price98REE*	Unit value of 1 metric ton (t) of REO apparent consumption. Unit value was estimated for the United States in actual dollars by a weighted average of imports and exports. The Consumer Price Index Conversion factor, with 1998 as the base year, was used to adjust the unit value in current U.S. dollars to unit value in constant 1998 U.S. dollars.	USGS, Data Series 140
Country-level control variables			
Foreign direct investment, net inflows (% of GDP)	*FDI*	Foreign direct investment is the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor.	WorldBank, Indicator Code: BX.KLT.DINV.WD.GD.ZS
Consummation rate (% of GDP)	*CONS*	Final consumption expenditure (formerly total consumption) is the sum of household final consumption expenditures (private consumption) and general government final consumption expenditure (general government consumption).	WorldBank, Indicator Code: NE.CON.TETC.ZS
Exports of goods and services (% of GDP)	*EXP*	Exports of goods and services represent the value of all goods and other market services provided to the rest of the world.	WorldBank, Indicator Code: NE.EXP.GNFS.ZS
General government final consumption expenditure (% of GDP)	*GOV*	General government final consumption expenditure (formerly general government consumption) includes all government current expenditures for purchases of goods and services (including compensation of employees).	WorldBank, Indicator Code: NE.CON.GOVT.ZS
Dependent variables			
GDP per capita, PPP	*GDPpc*	GDP per capita based on purchasing power parity (PPP). GDP is gross domestic product converted to international dollars using purchasing power parity rates.	WorldBank, Indicator Code: NY.GDP.PCAP.PP.CD
Logarithm of GDP per capita, PPP	*lGDPpc*	Use of the log function on GDP per capita for the creation of this variable	WorldBank, Indicator Code: NY.GDP.PCAP.PP.CD

Table IV.1 — Description, code and source of each variable for the empirical analysis

More specifically, for the two variables linked to production, we based our analysis on the estimation made by the U.S. Geological Survey (USGS). For lithium production, they only take into account the production from subsurface brine and concentrates (therefore, USGS excludes any recycled production process, such as found in Belgium). Similarly, for rare earths mine production, the USGS rely only on trustworthy estimates and information. However, one must remain prudent, since they could not be precisely quantified and may include illegal production. Indeed, with official production quotas (especially for China's case), some people are tempted to illegally produce more REE than announced. Indeed, illegal extraction plays an important role in China (Pothen and Fink, 2015).

Since we only possess enough information after 1998, we cannot have a larger time series. In our analysis, we are constrained by the number of observations. Indeed, we are limited to 17 observations per country. Such a small amount of observation makes it impossible for time series[11], while cross-sectional data is not possible given the small number of countries that produce lithium or rare earth elements. This is one of the main reasons we will deal with a panel dataset of i=16 and t=17.

Thus, we will use cross-sectional time-series data[12] in this analysis. Cross-sectional time-series (or sometimes-called panel data or longitudinal time-series) are datasets in which the behavior of entities (in our case countries) are observed across time[13]. Why use panel data? Baltagi (2008) enumerated a comprehensive list of all the advantages and disadvantages of cross-sectional time series. We will summarize the pros and cons with the following Table IV.2:

[11] Many consider that one needs to have at least 30 observations at different times for a time series
[12] This approach is similar to previous similar empirical papers
[13] Different from pooled data where the observations do not necessarily refer to the same unit

Advantage of data panel	*Disadvantage of data panel*
Controlling for country heterogeneity (which is not the case for time-series and cross-section)	Cross-country dependency in the case of macro panels
Give more informative data, more variability and less collinearity among the variables	Sampling, design and coverage, non-response in the case of micro panels
Macro panel have longer time series and it will permit to avoid the problem of nonstandard distribution typical of unit roots test in time-series analysis	

Table IV.2 — Advantages and disadvantages of data panel (Source : Baltagi, 2008)

IV.2 Econometric Approach

As we mentioned earlier, we are dealing with a balanced panel dataset. Our estimation technique must be in agreement with our data. There exist two different models and structure for panel data: fixed-effects and random-effects (Torres-Reyna [2007], Greene [2010]).

The first step in executing a panel data regression will be to define whether we should use a fixed-effect or a random-effect model:

- **Fixed-effects model**: this model is used when one is interested in analyzing the impact of variables that vary over time. The fixed-effect model seeks to establish the relationship between the explanatory and dependent variables within a country. Fixed-effect models will remove the effect of time-invariant characteristics so it is possible to assess the net effect of the explanatory variables on the dependent variables. One main assumption of the fixed-effect model is the non-correlation of those time-invariant characteristics with other individual characteristics. For this model, each entity is different and therefore it is expected that the error term is not correlated within each entity. The following sentence summarizes well what fixed effects model are used for: "*Substantively, fixed-effect models are* *designed to study the causes of changes within a person. A time-invariant characteristic cannot cause such a change, because it is constant for each person.*"[14]

- **Random-effects model:** contrary to the fixed-effects model, the variations across entities are assumed to be random and uncorrelated with the explanatory variables included in the model. If we think that some difference has some influence across entities on our dependent variable, then we should use the random-effects model. An advantage of random effects is the fact that we can include time-invariant variables (in our case lithium and production reserve) while in the fixed-effects model those variables will be absorbed by the intercept.

To choose between fixed or random effects, it is widely accepted to run a Hausman test[15]. The Hausman test examines if the errors are correlated with the regressors. However, if we have reason to think that some omitted variable can be constant over time but vary between cases, and others may be fixed between cases but vary over time, then we can use a random-effect estimator which is a weighted average of fixed and between effects.

It is commonly known that fixed-effect models give more consistent results, yet they may not be the most efficient model to use. Statistically, if we are able to justify it we will use a random-effect model (as it gives better p-values and more efficient estimator).

When we conducted the Hausman test (cf. Tables, appendices), we observed that the null hypothesis is rejected with a p-value inferior to 0.05. As the null hypothesis states that the unique errors are not correlated with the regressors, we use the fixed-effects model. Afterwards, we run a test to know if we need to use time-fixed-effect models (Breusch-Pagan and Test of time effects). Once again, our

[14] Kohler, Ulrich, Frauke Kreuter, Data Analysis Using Stata, 2nd ed., p.245
[15] Where the null hypothesis is that the best model is random-effects

p-value is inferior to 0.05 (cf Tables), we will then use the time-fixed effects, as the null hypothesis is that no time-fixed-effect is needed.

Now that we have explained the estimation technique, our purpose is to estimate the effect of REE and lithium production, together and by type, on economic growth by means of panel data time-fixed-effects, having the general specifications as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + B_2 Z_{it} + \alpha_i + \zeta_t + \varepsilon_{it} \tag{4.1}$$

Where $i = 1,2,\dots,8,\quad t = 1998,1999,\dots,2014,$ Y denotes the dependent variables, respectively the logarithm of the gross domestic product. X represents the explanatory variables, it is to say the REE and lithium production (overall and by type), Z represents the country-level control variables, α is country fixed-effect that is useful for diminishing the omitted variables bias. β_1 and β_2 are the parameters. ζ_t is the year fixed-effects, and finally ε is the idiosyncratic errors (which characterizes the unobserved factors that affect the dependent variables and change over time).

The year fixed-effects (ζ_t) is quite important as it incorporates the cyclicality at the level of the country and will decrease the concern that arises when we use a yearly panel (Gaspart and Pecher, 2015)[16]. Our main goal is to observe and analyze the parameters β_1 for a negative or positive effect on economic growth according to the country type.

[16] We do need to control for time effects as special events may induce unexpected variation (i.e inflation in Zimbabwe)

Chapter V Estimation Results

In this chapter, we present an empirical investigation of lithium and rare earth production on economic growth in developing countries. To face potential econometric issues, we estimate dynamic panel data growth models with time-fixed-effects model.

V.1 Descriptive Statistics

Hereafter, you will find the main descriptive statistics of the different variables. The following table synthesizes all the statistical functions necessary to analyze a vector of data. It will go to the number of observations, standard deviation, minimum, maximum, skewness and kurtosis of each variable. The skewness represents the measure of the asymmetry of the probability distribution in a set of statistical data while the kurtosis measures if the grouping is near or far from the center of the data probabilities.

Descriptive statistics

Variables	N	Mean	St. Dev.	Min	Max	Skewness	Kurstosis
LIprod	272	1,324.4	2,812.5	0	13,300	3.57	10.01
LIreserve	272	901,937.5	1,940,717.0	0	7,500,000	2.70	8.57
REEprod	272	6,219.0	24,268.4	0	133,000	2.51	16.85
REEreserve	272	4,339,375.0	11,560,004.0	0	44,000,000	3.88	9.08
LIANDREE	272	0.1	0.3	0	1	2.71	1
LIORREE	272	0.5	0.5	0	1	0	6.14
price98LI	272	2,742.9	1,072.4	1,220	4,480	2.08	1.79
price98REE	272	11,330.6	10,676.1	3,150	42,100	-0.00	5.96
FDI	272	0.04	0.04	-0.04	0.4	5.16	39.68
EXP	272	0.3	0.2	0.1	1.2	2.29	8.94
CONS	272	0.8	0.	0.5	1.2	0.08	4.55
GOV	272	0.2	0.04	0.02	0.3	-0.20	2.90
GDPpc	272	14,555.7	10,742.9	412.3	46,446.0	0.74	2.80
lGDPpc	272	9.2	1.1	6.0	10.7	-1.03	3.57

Table V.1 — Descriptive statistics for all variables

The data collected for 16 countries from 1998 to 2014 seems to be highly skewed[17] and have kurtosis higher than three[18]. This indicates that the series are not being normally distributed. Indeed, it seems like the sample has a rather asymmetric distribution and a fatter tail than normal. However, one must remain careful, as we do not have data for the whole population. Thus, we cannot suppose the same skewness and kurtosis in the sample as in the population. Thanks to the descriptive statistics, we can perceive much better the data that we possess. Now, we discern that we are dealing with continuous data (except for the two binary variables) and that the sample is skewed and has a fat tail.

[17] According to Bulmer (1979) rule

[18] A normally distributed variable has a kurtosis of 3

Now, if we create a subset of the sample by lithium and/or REE producers, and non-producer but similar country, we observe a difference in one of the economic indicators:

Variables	Summary statistics with subsamples	
	Country type	
	Median for Country-Producer	Median for Not-Country-Producer
EXP	0.288	0.294
CONS	0.793	0.803
GOV	0.159	0.159
FDI	0.035	0.019

Table V.2 — Descriptive statistics for economic indicators by country type

We observe for lithium and rare earth country producers that the mean and median of the foreign direct investment (FDI) is much higher, whereas it is much lower for non-producer countries. The other economic indicators are quite similar in both cases. The production of lithium and rare earth elements could affect positively the foreign direct investment.

V.2 Correlation Matrix and Scatterplot

In addition to descriptive data, it is also interesting to focus on the correlations within each variable that we possess. The closer the correlation is to one to the logarithm of GDP per capita (lGDPpc), the more interesting the variables may be for our statistical model. Thanks to RStudio, we will use a correlogram to represent the correlation matrix graphically. In addition to this, the correlogram allows us to determine if there is a multi-collinearity between some of the explanatory variables. The correlogram will emphasize the most correlated variable in our dataset. The following figure is for the whole sample (including developing and developed countries).

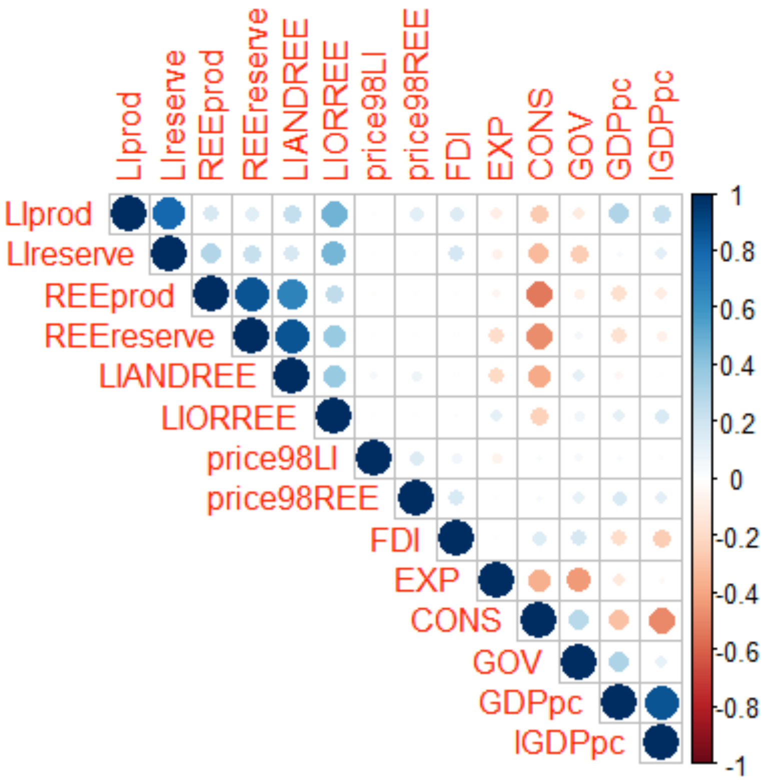

Figure V.1 — Correlogram of All the Variables

As we can observe in figure V.1, lGDPpc is not highly correlated with any variables (except GDPpc). Nevertheless, we can discern that lithium and REE production (and reserve) have a small correlation with lGDPpc, positive correlation for lithium production and negative correlation for rare earth production. Moreover, it seems that the production and reserve of lithium of a country is positively correlated with the FDI while the rare earth production and reserve seems to be negatively correlated with the consumption expenditure rate. On the contrary, the annual price of lithium and rare earth does not seem to be correlated with any of the variables. However, it is important to keep those two variables in our model as it may greatly affect the output. Logically, REE and lithium production are highly correlated to their reserve.[19] Furthermore, if we set subsamples by the type of country (developed or underdeveloped), we distinct that the correlation matrix will be quite different (cf. Figures in Appendix). For developed countries, we observe that lGDPC is positively correlated with lithium and REE production, while

[19] We will employ these variables within distinct panel data regression models in order to avoid the multi-collinearity issue

lithium and REE production is barely correlated with lGDPC for developing countries. Shockingly, lithium and REE production (as reserve) are highly and negatively correlated with consumption and exports rates for developed countries. The binary variable that says if a country is either producer of lithium or rare earth is positively correlated with the FDI and the lGDPpc for developed countries, whereas it is only correlated with the lGDPpc for developing countries.

From these first observations, we could "predict" that lithium and REE production has no important impact on the lGDPpc for developing countries while it may have a positive and significant impact for developed countries. This first observation is quite consistent with our literature review. However, we must be very careful about a correlation link between variables and a cause-and-effect link. Indeed, these two are quite different and do not imply the same thing.

In addition to the correlogram, it is interesting to compute a scatter plot to show the correlation between the dependent variable and the two explanatory variables (respectively lithium and rare earth production).

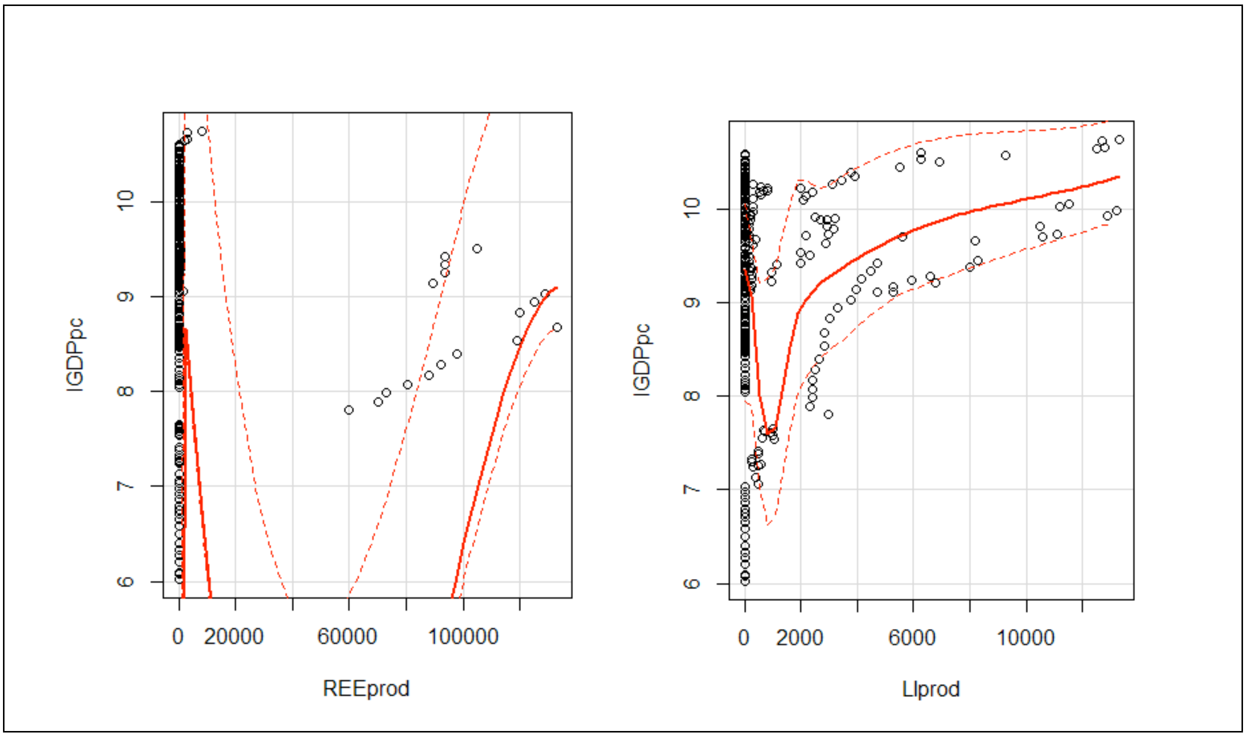

Figure V.2 – Scatter plots between the logarithm of the GDP and the explanatory variables

As we can observe, lGDPpc and LIprod seems to have linear relation. This plot seems to indicate a positive relation between these two variables. Once again, however, this does not mean that a cause-and-effect relationship exists. On the contrary, rare earth production seems to be less linear. An large number of observations are equal to zero due to the fact half of the data relate to countries that do not produce any REE. Nonetheless, the graphics appears to show, with the second line on the right, a positive relation with the production and lGDPpc.

V.3 Heterogeneity Across Year and Country

From our data and the GDP plot (cf. Figures, appendices), we can observe that we are dealing with heterogeneous panel data. The variables vary across individuals but also across years. This mainly explains why we do not use a regular OLS regression, as it does not consider heterogeneity across time or country. The two following graphics will show the heterogeneity that exists in the panel data.

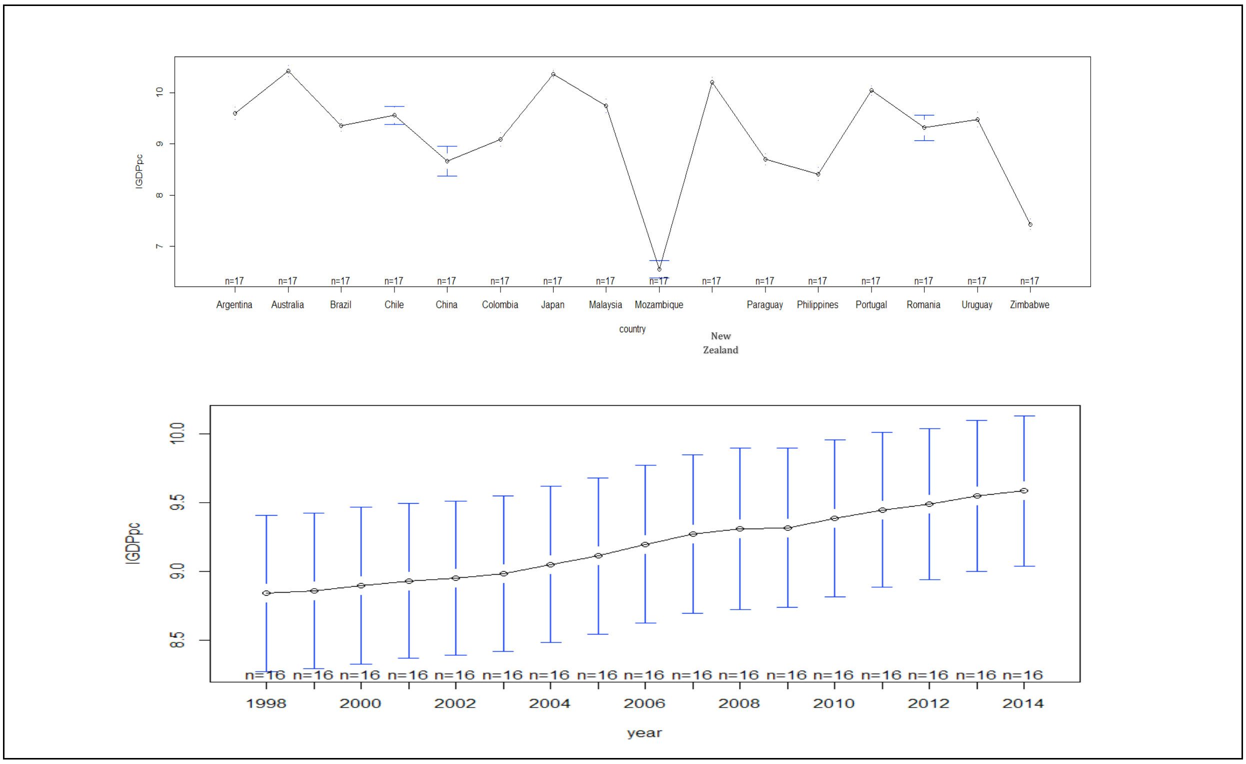

Figure V.3 – Heterogeneity across countries and years

We can detect important heterogeneity between countries as well as for years; this is a main reason why we will deal with time-fixed effects.

V.4 Panel Data Regressions Model

V.4.1 Economic growth

The results of panel data regression models of the influence of lithium and rare earth production on economic growth are revealed in the following table. The table is separated in three by country types: the whole sample (1), the underdeveloped countries (2) and the developed countries (3). Hence, it will allow us to observe if lithium and REE production affect economic growth in different ways according to the country's development. The data from lireeDATA includes 16 countries whereas only eight produces lithium or rare earth. Since we could expect a major problem of heteroskedasticity across countries, the standard errors for the coefficients are controlled with a heteroskedasticity-consistent covariance matrix (sandwich estimator).

Variables	Dependent variable is the Log GDP per capita		
	Country type		
	(1) All	(2) UD	(3) D
LIprod	2.8475e-06	3.0803e-05**	-4.8734e-05***
REEprod	5.3400e-06***	6.3873e-06***	2.0774e-05***
LIANDREE	-1.1754e-01*	-1.0829e-02	1.4585e-01**
price98LI	-5.4646e-04***	-5.3847e-04***	-5.7266e-04***
price98REE	-3.9630e-06***	-1.4466e-05***	-1.0287e-05***
EXP	-1.1020e-05**	-3.0855e-01	-6.3705e-01***
FDI	3.1410e-01**	3.0690e-01**	4.3893e-01***
CONS	-2.3044e+00***	-1.9651e+00***	-4.6579e+00***
GOV	9.8211e-01**	7.8811e-01*	9.1292e-01**
F statistic	74.60***	55.30***	54.92***
Adj. R-sqrd.	0.86	0.86	0.93
Obs.	272	187	85
Countries	16	11	5

Notes: coefficient controlled for heteroscedasticity with the sandwich estimator. ***p<0.01, ** p<0.05, * p<0.1. The panel is balanced and covers the period 1998–2014. All regression has years and countries fixed-effects.

Table V.4 – Panel Data growth regression estimates with the fixed-effect models

First, we notice the significantly positive influence of rare earth production on gross domestic product per capita on each case (no matter if developing or developed countries). We observe, with the binary variable, LIANDREE, that if a country becomes a producer of lithium and rare earth elements, it will affect negatively and significantly the logarithm of the gross domestic product for developed countries. For underdeveloped countries, we observe that both lithium and REE production have a statistically significant coefficient and both affect positively the logarithm of the GDP. On the contrary we observed that lithium production has a negative effect on economic growth for developed countries. Considering the other variables, we note that consumption expenditure negatively affects economic growth (which is quite surprising). Exports of goods and services have a significant negative coefficient on the logarithm of GDP for developing countries. From this, we could assume that the more a country is dependent on exports, the more it is likely that it negatively affects economic growth. Finally, the annual price of lithium and REE (with 1998 as the base year) has a negative and statistically significant coefficient at the 1% level in each case (developed or developing countries). It seems that the lithium price may affect economic growth and not production in itself.

From our first regression, we can conclude that a statistical relationship appears to exist between rare earth production and economic growth. In contradiction with the resource curse literature, the relationship seems to be positive. However, we must emphasize the slight extent of the impact. On the other hand, the coefficient for the price of lithium is negative and from this, we could presume that the volatility in commodity price may affect economic growth as mentioned and demonstrated in several studies. However, we observe that developing countries are not any less or more likely to be affected by natural resources prices than developed countries.

V.4.2 Foreign Direct Investment

The goal of this section and the two following ones it to explore if the results are different by switching the dependent variables with the foreign direct investment (FDI), the consumption expenditure or the exports of goods and services. At the same time, we will explore if these three variables are affected in a particular way by lithium and rare earth production and how. From the literature review, we have observed that a natural resource endowment may affect foreign direct investment (through sovereign wealth fund, and the Dutch disease seems to have a greater effect on economic growth when the country is more open to foreign direct investment).

We have seen in the descriptive statistics that the FDI median is quite different between lithium and REE producer countries and the others. Once again, we run a Hausman test (cf. Tables) to see if we have to run a random-effect or a fixed-effect. Contrary to the lGDPpc model, here the p-value is superior to 0.05, thus we should use the random-effect model, as the variations across entities are, here, assumed random.

Variables	Dependent variable is the Foreign Direct Investment		
	Country type		
	(1) All	(2) UD	(3) D
LIprod	2.0307e-06*	4.1758e-06***	3.8440e-06***
REEprod	3.4807e-07	2.7110e-07	-3.0322e-06
LIANDREE	-7.8348e-03	-1.8570e-03	-3.1887e-03
LIORREE	-7.5987e-03	-2.4998e-02	7.2797e-03*
price98LI	2.6507e-06	3.7766e-06*	-1.8999e-06
price98REE	4.8588e-07	6.6933e-07	-3.5015e-08
EXP	8.7328e-02	7.5179e-02	4.4537e-02
CONS	8.7975e-02	6.7101e-02	2.7463e-01***
GOV	3.5402e-01	4.3903e-01	-3.3599e-01
intercept	-1.2956e-01	-1.1387e-01	-1.4340e-01***
F statistic	4.29***	4.15***	2.59**
Adj. R-sqrd.	0.09	0.13	0.14
Obs.	272	187	85
Countries	16	11	5

Notes: coefficient controlled for heteroscedasticity with the sandwich estimator. ***p<0.01, ** p<0.05, * p<0.1. The panel is balanced and covers the period 1998-2014. All regression is based on a random-effect model.

Table V.5 – Panel Data FDI regression estimates with the random-effect models

Thanks to these results, we observed that lithium production has a statistically significant and positive coefficient on the foreign direct investment (in % of GDP), unlike rare earth production, whose coefficient is not statistically significant. For developing countries, the coefficient of the price of lithium is statistically significant at a 10% level. It seems that the lithium price affects positively foreign direct investment, which is to say that an annual increase in lithium price will encourage foreign direct investment for lithium producer countries. In respect of the adjusted R squared, we observed that it is quite low, and thus our model and our explanatory variable do not explain all the amount of variance of Y. It seems that the two models are quite similar even if one contains only developed countries and the other only developed countries.

V.4.3 Exports of Goods and Services

Even though this section is obvious: an increase in the lithium and REE output will lead to an increase of exports, we may wonder what the model shows and how the price could affect exports. As in the last section, we use a random-effect model to determine the exports of goods and services.

Variables	Dependent variable is the Exports of goods and services		
	Country type		
	(1) All	(2) UD	(3) D
LIprod	4.5835e-06	9.3490e-06***	-3.7231e-06
REEprod	3.3977e-07	1.2951e-07	4.3343e-06
LIANDREE	-2.0363e-02	-8.2180e-04	7.2855e-03
LIORREE	1.3464e-02	-2.3619e-03	4.0292e-03
price98LI	-1.1699e-05***	-1.5286e-05***	-6.1361e-06
price98REE	-2.4295e-07	-9.5615e-07	1.2744e-06*
CONS	-4.7616e-01*	-4.9245e-01	4.8773e-01
FDI	4.1248e-01***	4.9003e-01***	2.7648e-01
GOV	-3.6498e-01**	-3.5220e-01	-1.1297e+00
intercept	7.6127e-01***	8.1332e-01***	7.1842e-02
F statistic	8.55***	7.62***	2.24**
Adj. R-sqrd.	0.20	0.24	0.11
Obs.	272	187	85
Countries	16	11	5

Notes: coefficient controlled for heteroscedasticity with the sandwich estimator. ***p<0.01, ** p<0.05, * p<0.1. The panel is balanced and covers the period 1998-2014. All regression is based on a random-effect model.

Table V.6 – Panel Data Export of goods and services regression estimates with the random-effects model

The coefficient for lithium and REE production are not statistically significant except for developed country lithium production where we notice that an increase in production leads to an increase in the exports. As expected, we observe that an annual increase in lithium affects negatively exports of goods and services. Indeed, if the price increases, importers will decide to choose substitutes.

According to USGS (2017), several substitutes do exist for lithium compounds such as calcium, magnesium and zinc. On the contrary, if the annual rare earth price increases for developed countries, it will raise total exports as the substitutes for REE are less effective according to the USGS.

V.4.4 Consumption Expenditure

As with the last two sections, we run our model and switch our dependent variable to consumption expenditure. The correlation shows that rare earth production was highly and negatively correlated with consumption expenditure. We could run our model to see if these two variables are still linked and if they are statistically significant.

Variables	Dependent variable is the consumption expenditure		
	Country type		
	(1) All	(2) UD	(3) D
LIprod	-3.7031e-06**	-5.7763e-06	-9.0421e-06***
REEprod	-1.6112e-06***	-1.6055e-06***	4.1823e-06
LIANDREE	-7.7172e-03	-2.3254e-02	2.2821e-02
LIORREE	-1.5210e-02	-2.9202e-02	2.0511e-02
price98LI	-2.1158e-06	-2.6409e-06	2.7521e-06
price98REE	3.3202e-07	3.6460e-07	-6.8803e-08
EXP	-2.3263e-01***	-2.5291e-01***	1.3956e-01
FDI	1.3102e-01**	1.2614e-01***	4.8786e-01
GOV	1.0842e-01	3.3670e-02	9.3816e-01
intercept	8.6679e-01***	9.1365e-01***	5.6328e-01***
F statistic	8.19***	6.45***	6.59***
Adj. R-sqrd.	0.19	0.20	0.37
Obs.	272	187	85
Countries	16	11	5

Notes: coefficient controlled for heteroscedasticity with the sandwich estimator. ***p<0.01, ** p<0.05, * p<0.1. The panel is balanced and covers the period 1998-2014. All regression is based on a random-effect model.

Table V.7 – Panel Data consumption expenditure estimates with the random-effect models

As can be observed, lithium and rare earth production have a statistically significant coefficient where both affect negatively consumption expenditure. We do not have any explanation of this phenomenon except perhaps that an increase in REE and lithium production leads the country to a more extractive economy, and thus the consumption rate is expected to decrease. It would be possible to deepen this subject and try to find a rational explanation.

These three sections have helped us to truly understand how an increase in lithium and rare earth demand can have an effect on growth. We see that lithium has a particular and positive effect on foreign direct investment, while an increase in rare earth price does not decrease the amount exported and thus leads to a larger income for the extraction company. Finally, lithium and rare earth production have a negative effect on consumption expenditures in each case. Below, you will find a summary of the main findings from our model.

Variables	Developing countries (UD)		Developed countries (D)	
	Lithium	REE	Lithium	REE
lGDPpc	+	+	-	+
FDI	+	?	+	?
EXP	+	?	?	?
CONS	?	-	-	?
Notes: +: it has a positive and statistically significant impact -: it has a negative and statistically significant impact ?: it has a positive or negative impact but it is not statistically significant				

Table V.8 – Summary of Our Main Findings From Our Model

As we can discern, lithium production seems to have a positive effect in general for developing countries while it has a controversial impact for developed countries. The case of rare earth is much more ambiguous for developing and developed countries. As fewer countries actually hold large deposits of a natural resource, it becomes harder to assess its impact.

Chapter VI Limitations and Further Discussions

In this thesis, we have adopted a panel data approach. As previously explained, this method demonstrates several advantages. The main one with the fixed-effects is that the correlations between explanatory variables and the fixed-effects do not create bias. We must remain careful as some caveats subsist in our model. Normally with cross-country panel growth regression, most authors use data spaced in time in order to diminish the consequences of measurement errors and cyclicality in the series (Durlauf et al., 2005). Due to our limited observations, there exists a vulnerability in results from cyclicality. However, we diminished the cyclicality of the year and country fixed-effects model.

One other concern in our analysis is the small number of observations for rare earth country-producers, which makes it harder to evaluate the real impact on economic growth. An additional concern from our dataset is that production is estimated and not actually calculated. In addition to this, REE production is even harder to measure as illegal extraction plays an important role. The problem of omitted variables bias is not completely resolved with the fixed-effects model: the logarithm of GDP and the production of lithium and rare earth could be correlated to common variables that are not included in the model.

Another problem to grasp is that the choice to produce lithium and rare earth elements is endogenous. Indeed, some countries that are endowed with deposits may decide not to extract them (such as Bolivia); therefore, the estimation can be biased. The fact of not producing can be linked to GDP growth, the degree of institutional development and rudimentary infrastructure… In other terms, countries like Bolivia are not able to produce lithium as it has a major cost, they are closed to foreign direct investment, and the government does not have enough money and stability to directly invest in this sector. A potential solution to overcome this difficulty is by finding a proxy that does not suffer from the same problem. A potential proxy could be the quantity of annual discovery of lithium reserve each year. With this proxy, we could build a model that more reliably shows how an increase in demand for lithium may affect economic growth in endowed countries and in what ways. However, this kind of data is probably quite difficult to obtain. Other solutions may exist to overcome this endogeneity bias for further research into this increasingly important natural resource.

The point of our model was to cover important dimensions that affect economic growth and resource growth but we did not, in any case, present the entire set of variables that affect economic activity. The main findings are still important due to the scarcity of scholarly research that seeks to explain economic growth in terms of “new” (such as lithium and rare earth elements) natural resources for developing countries. We believe there is room for further research, for “new” natural resources and their different impact on growth. Nowadays, we are facing new challenges to respond to increases in aggregate demand with new methods, and therefore these new natural resources will alter in one way or another the world economy.

Conclusion

The aim of this thesis was to evaluate and investigate the impact of these "new" natural resources on economic growth. Given recent increases and the prospect of future development, we can expect that they will affect the economy of countries which are endowed with these resources, especially if these countries are not "developed". Even if fossil fuels are still the main source of energy, we can expect other natural resources to be used[20]. To assess the effects, we analyzed the annual production of rare earth and lithium on the logarithm of gross domestic product per capita for each country. More precisely, we used panel data fixed-effects regression models for 16 countries (eight of which are are lithium or rare earth producers and eight are similar countries) over the period of 1998 to 2014.

The first part of the literature review indicated that developing economies are often subject to "curse" when they are endowed with large amounts of a natural resource. As their institutions tend not to be well developed, they are more subject to the Dutch Disease, to the rent-seeking model and other factors. These phenomena will directly lead the country to an economic crisis, especially if these natural resources are mismanaged by the government. The second part of the literature review focused on the potential benefits of natural resources. There is evidence that natural resource exports can provide positive spillovers to domestic sectors and spillovers to its productivity. Even with poor institutions and corruption, the increase of production can result in an audit to monitor the flow of investment and to deter corruption. Finally, the sovereign wealth fund is seen as a new response to the resource curse as it provides better tools to face natural resource booms. In the last section of the literature review, we observe how these "new" natural resources have been evolving over the years. We can observe that shifts in consumer preference affect the way an economy will extract its natural resource, as there is a shift in demand.

[20] As reserves of fossils fuels are decreasing drastically.

In the empirical study, we first study the main differences between lithium and rare earth producer countries and similar countries and we observe that only the foreign direct investment seems to be different. In addition, we notice that our entire set of variables are not highly correlated to our explanatory variables, and thus we cannot expect our model to explain the growth in an economy. This is why we rely on a fixed-effect model that will remove the effect of time-invariant characteristics of each entity. From our model, we provide evidence for a positive influence of lithium production over the logarithm of gross domestic per capita, the exports of goods and services, and foreign direct investment for developing countries. However, we notice that several substitutes exist for lithium (such as calcium, magnesium and zinc) and when the price rises, it has a negative impact on exports and the gross domestic product. Likewise, we provide evidence for a positive influence of rare earth production on gross domestic product for developed and developing countries. The huge question mark is the negative effect of rare earth production on consumption expenditure for developing countries to which we are not able to find any plausible explanation.

These results must be taken with a pinch of salt, as our model could be endogenous and lead to false results. Moreover, we must remain careful with the data production as illegal extraction plays an important role. From what we learn, we could assume that lithium and rare earth are not doomed to be "cursed resources" and they seem rather to have a positive impact for developing countries except on their consumption expenditure. However, one must take into account that the lithium price affects negatively exports and gross domestic product, and thus a major boom in the price of lithium could affect negatively a developing economy especially if this economy is dependent on this resource.

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