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Security of mineral resources: A new framework for quantitative assessment of criticality

Georges Daw

Université Paris 8 Vincennes Saint-Denis (Laboratoire d'économie dionysien-LED) et Université Paris 1 Panthéon-Sorbonne (Centre d'économie de la Sorbonne-CES), Paris, France

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A B S T R A C T

This article discusses the limits of economic growth through the issue of criticality of mineral raw materials. It proposes to use and expand the existing work-but not in France or for France- and then apply them to the French economy between 2009 and 2014 via the example of lithium to provide available indicators and the methodology for identifying pressure signals in the supply of raw materials not so far undetectable in existing criticality studies. After building a database on 15 years of production and world trade of lithium, a literature contextualizing the issue of criticality and articulating the criticality factors with the functioning of commodity markets is performed. The reference model of the European Commission is then explained. In addition to these introductory contributions, the main are threefold: the reconfiguration of existing indicators criticality to the French case; the proposal of a new complementary criticality indicator to the Commission's two and which takes into account not only the upstream market of the material but also its downstream processing by the economy; finally the definition of high and low criticality allows to generate twelve indicators and variants (four strong(s) and eight low) from the two previous points and subjected to robustness checks.

1. Introduction

The dual need for physical access to raw materials at affordable prices affects the normal functioning of global economies and their development. This dual requirement is also a concern expressed since Malthus (1798) that the demographic and economic developments cannot ignore the occurrence of a natural exhaustible resource shortage or voluntarily limited by economic policy. Highlighting since the Paley reports Commission (not reports) (1952) and Meadows et al. (1972), this problem becomes current without prejudice to external strategic interests of States to secure supplies of natural resources (Niger's uranium and the recent French intervention in Mali, China's increasing penetration or Indian on the African continent for two decades, Russia and its investigative project in 2011 within the framework of the Antarctic Treaty are non-limiting examples...). Recently, in fact, the subject regains interest worldwide and in France: The Critical Material Stockpiling Act (U.S. National Research Council, 2008) who made a list of 42 critical raw materials for the US defense industry, 'Raw materials Initiative of the European Commission CE (2008), the publications of the European Commission on critical materials for the European Economy (2010a, 2010b, 2014), the report of the German geological resource Office (Hilpert and Mildner, 2013) centered the necessary issue of coordination of national commodity policies; In France, the strategic metals Committee (COMES) created in 2011 around the supply security objective in strategic resources for French industry; In 2012, the Minister of Productive Recovery had declared: "France must become a mining country"; We should also mention the proposed creation of the National Mining Company of France (CMF) in 2014 in charge with identifying and exploiting, in the lap of the French state, mineral resources in France and abroad -which however has still not emerged 2015- and also the first exploration licenses and operating for thirty years granted in 2013 and 2014, the redesign of the French mining Code in 2015. The all reflects concerns about the future security of raw material supplies. Given these concerns, national policies of raw materials of the G20 countries are also diverging, and currently insufficiently cooperative, lifting-and beyond G20- the issue of global governance of raw materials (Hilpert and Mildner, 2013). The European economies-already alerted by historical precedents in the energy sector as the two oil shocks of 1973 and 1979 or the price peak of the barrel during the first quarter of 2008-which do not have local access to certain natural resources are dependence on significant parts of their wealth creation are particularly concerned.

This article discusses the limitations of economic growth through the issue of criticality of mineral raw materials intended

E-mail address: Georgdaw@gmail.com.

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to allow the identification of raw materials whose supply shortage would present an economic risk. It proposes to use and expand existing work and apply them to the French economy in order to make available indicators to identify tensions signals in the supply of raw materials of nature and degree hitherto undetectable in existing criticality studies. The illustration is on lithium but modeling is applicable as to all natural elements of Mendeleev's table. The literature on criticality is virtually emerging and focused on the last 15 years. We find this literature mainly in the United States and Germany or the UK with treatment by authors in geosciences, physics or environmental science even when the central problem of the subject is economic and financial. For the European economy, the Commission produced since about eight years reports presenting interesting forays into this field. In France, economists have not yet addressed this issue. A contribution in economics articulating with the existing and presenting arguments in favor of its enrichment is the project of this work.

The article is based on four observations. On the one hand the fifteen existing studies apply the issue of criticality on the single market of the raw material concerned. The approach is almost exclusively physical: the prices are almost absent and when present they concern only that market of raw material which obscures the question of international raw material processing. The consideration of this international transformation influences the criticality outcome. It is therefore necessary to model and quantify it. On the other, in the specific case of the EC study (2010a, 2010b, 2014), the observation of one criticality indicators, the risk of supply, shows that each European country is exposed to the same supply risk in a given substance. We show why the supply risk indicator is differentiated by country. Third, the criticality analysis and quantitative assessments by country have, for the time being, concerned only three countries (USA, Germany, UK) but not in France. Finally, incidentally, in literature, critical thresholds used in some indicators are not justified when they are not intuitive.

The text is organized in two main parts. The first begins with a summary on lithium which presents the substance and the construction of a production and lithium international trade database on 15 years. Literature review accompanied by reflections on the issue of criticality related to the functioning of commodity markets is then presented. The model for evaluating the criticality of the European Commission (EC) (See Appendix A), which is the benchmark modeling, is first positioned relative to other references and the presentation of its criticality risk indicators concludes the first part. A second part begins with an amendment in the supply risk indicator and its impact is quantified and compared to that of the EC. A second indicator (economic importance) is taken identically, but a discussion of his pairing with the French situation serves as second section. A third section focuses on the construction of a new additional indicator of criticality (international raw material transformation). After we justified it and synthesized the nature of trade links that it may reveal, an improved version of this indicator, in the spirit of the current work of the EC, is proposed. The quantification of this new indicator and its improved version remains dependent on the availability of statistical information but the choice has nevertheless been to calibrate it with the existing data in a spirit of methodological continuity (two first subsections). In total, with 5 indicators of criticality (the two of the EC, the amended supply risk indicator, the new indicator and its improved version) we asses in a before last subsection, the global lithium criticality for French economy from 2009 to 2014 with the associated variants. The overall criticality testing is criticality matrices-and in this case, it shows that lithium has never been critical -or criticality index- and then, in this case, lithium appears permanently critical. This work concludes with a final sub-section on comparing the two indicators aggregation methods, revealing their theoretical and empirical robustness (compared robustness and internal).

2. Summary on lithium, criticality sights and model of European Commission (EC)

2.1. Lithium: General outlook, production and international trade

2.1.1. General outlook

Lithium is the third element of the Mendeleev table. It is an alkali metal such as sodium and potassium. It is the lightest of all metals and is almost two times lighter than water (density 0.54). It is a silvery white metal that is very abundant in the earth's crust (20 ppm [ppm] as niobium, three times less than copper but twice as lead). The oceans contain about 0.18 mg/l. According to sectors, the lithium is used in the form of minerals (spodumene, petalite, lepidolite…), carbonate (Li2CO3), hydroxide (LiOH), lithium metal (Li), lithium chloride (LiCl), lithium niobate (LiNbO3), lithium nitrate (LiNO 3), butyllithium (C4H9Li)… According to USGS (2011, 2012, 2013, 2014 and 2015) and our calculations concerning the specific production of the United States, lithium world production for the period [2010–2014] is on average 33,500 t. In 2014 it was 37,000 t. Andersen [2012] announced in 2011 and 2012 a production of lithium around 68,000 t by 2020. According to Kevin Ray Evans cited by MIT Technology Review magazine in 2011 "if all planned or ongoing projects around the world arrive in production, total production will approach 80,000 t by 2020. Yaksic and Tilton (2009) show that there will be enough lithium for the future but does not plan production figure projection while stressing uncertainties related to the future supply of lithium. The USGS has no global supply projection. These forecasts based on announcements of production companies or states announce remain so fragile. Furthermore, these projections determine production regardless of consumption. Yet, the history of previous 15 years shows that global production and consumption are much less divergent.

According to Roskill (2009, 2013), world consumption was at 21,300 t in 2008 and 26,600 t in 2011. According to the USGS (2013), it was 28,300 t in 2012 and 30,000 t in 2013. For Clarke (2012), it should be around 35,000 t in 2015. In a projection of future demand from Roskill (2009), Labbé and Daw (2012) estimate for 2015–2016 consumption of 32500 t and 37,000 t in medium and high assumptions respectively.

The uses of lithium are divided roughly by year and country, in the glass industry, ceramics and ceramic (30%), storage batteries and lithium batteries (23% and growing: see about this use Gruber et al. (2011) showing supply-demand scenarios according to the penetration of electric, hybrid or plug-in on the automotive market), lubricating greases (11%), air treatment (4%), continuous casting (3%), rubber and thermoplastics (3%), pharmaceuticals and fine chemicals (2%), aluminum (2% and falling) aluminum-lithium alloys (0.4% and in growth) but for a little over 20% in electronics, construction, the water treatment, dyeing, pyrotechnics, or thermonuclear fusion.

The lithium compounds consumed by the market may be segmented into three compartments:

- The various minerals containing lithium (Spodumene, lepidolite, petalite, amblygonite…) are purchased by the glass and ceramics industry and in the continuous casting without prior conversion toward a lithium compound. This compartment weighs about a fifth of the market.
- Lithium-based compounds under which we have lithium carbonate (Li2CO3, and can be produced from rocks or brines as well as two elements that follow), lithium hydroxide (LiOH, can be produced from rocks or lithium carbonate), lithium chloride (LiCl can be directly produced from brines or is lithium carbonate or lithium hydroxide), lithium metal (Li is being obtained by electrolytic mixture at high temperature between lithium and potassium chlorides).
- The other chemicals of high purity are produced from two of the