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Rare earths metals and the corruption footprint index for countries worldwide

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Abstract

This article presents, for the first time, a convergence of two datasets: the first dataset, consists of the results, of the Corruption Footprint Index (CFI), an index that measures the impact of various forms of corruption· the second dataset, pertains to the countries, with the highest production of critical raw materials (REE) worldwide. The outcome of this convergence is an analysis of the impact that, the leading producers of critical raw materials, exert on the Corruption Footprint Index, particularly in the context of global energy demands and transitions. This assessment spans a period of nearly fifteen years, covering the timeframe from 2010 to 2024.

Keywords: Corruption Phenomenon; Corruption form; Corruption Footprint index; Critical raw materials

1. Introduction

Corruption is defined, as a human phenomenon encompassing a set of forms that vary from country to country in terms of their origins, dimensions and consequences. [1] The concept of a form of corruption, is understood as a human act that, reflecting the pursuit of an individual-the homo corruptus, creates an impact within the framework of a coexistence structure. [2]

Regarding the question of whether a human phenomenon, such as corruption, can be transformed into a measurable quantity, the answer is provided through the so-called measurement indices. [3] However, two critical epistemological clarifications must be made.

The first clarification concerns the fact that when we refer to corruption measurement indices, we are actually referring to indices that assess the impact of specific or overall forms of the phenomenon, according to the methodology of each index. The second clarification is that transforming a phenomenon into a measurable quantity does not necessarily make it comparable. It is not scientifically accurate to use a measurement index to compare populations with different homo corruptus profiles or to compare countries with distinct corruption ideal types in terms of forms and effects of corruption. [4] In this article, the Corruption Footprint Index-CFI will be utilized.

The Corruption Footprint Index-CFI, was developed by the author and was first introduced in 2014. [5] According to the index model, the impact of different forms of corruption in a country is expressed through its Corruption Footprint as a function of three factors: the population's perception of corruption (Corruption Perceptions Index - CPI), the level of good governance (World Governance Indicators - WGI) and the level of human development (Human Development Index - HDI). Each of these factors is analyzed into specific components, and for a country to be included in the index, annual data must be available for all the individual indicators that constitute it. The scale of the index ranges from zero to one: the closer a country's scores are to one, the smaller its corruption footprint, meaning that the impacts of corruption's forms, are minimal. Conversely, as a country's scores approach zero, the effects of corruption's forms become more significant and stronger, increasing its corruption footprint. [6] As highlighted, this article presents the

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impact on the Corruption Footprint Index of those countries that are the largest producers of critical raw materials, essential for the global economy's energy pursuits and transitions. This analysis spans a nearly fifteen-year period, from 2010 to 2024.

The classification of a raw material as 'critical' is primarily based on its economic significance and supply risks. However, there are raw materials that, despite not being labeled as critical, are still essential to the global economy, as they form the initial stages of the so-called value chains in the manufacturing sector. A distinct category of critical raw materials includes the so-called rare earth elements (REE), which are classified into heavy and light rare earths. These elements possess unique magnetic and electrochemical properties. Their rarity is primarily due to the challenges associated with their extraction and processing. Given their industrial value, global demand for rare earth elements is continuously rising. Various countries, international and private organizations, as well as multinational corporations, adopt different methodologies to assess these factors. For example, supply risk calculations consider dependencies on imports and export restrictions. Additionally, substitution and recycling are examined as corrective factors for both economic significance and supply risk. Finally, the distribution of raw material end-uses is analyzed based on industrial applications to determine their final economic importance. The availability of these critical raw materials is influenced not only by the complexities of their extraction and their concentration in other elements (uranium) but also by trade flows and developments in international trade policies. Their importance is further elevated when considered in the context of the transition toward a circular economy—one characterized by low carbon emissions, efficient resource use, enhanced recycling activities and the facilitation of new extraction projects.

The following table includes the most significant countries in terms of the production (not reserves) of critical raw materials, based on the average output over the last fifteen years (2010–2024). The data for this period reveal a high dependency on China for critical raw materials across the global economy. For instance, European Union member states secure 98% of their critical raw material needs from the Chinese market. Beyond China's dominant role in supplying most critical raw materials worldwide, other countries also hold notable positions in their production. Such countries include Brazil (niobium), the United States (beryllium and helium), Russia (palladium), South Africa (iridium, platinum, rhodium, and ruthenium), Australia (lithium), Argentina (lithium) and Chile.

Table 1 Critical Raw Materials and Leading Producing Countries

Critical Raw Materials	**Leading Producing Countries (Average Global Share, 2010–2024)**				
Antimony (Sb)	China (87%)	Vietnam (11%)			
Barite ($BaSO_4$)	China (44%)	India (18%)	Morocco (10%)		
Beryllium (Be)	USA (90%)	China (8 %)			
Bismuth (Bi)	China (82%)	Mexico (11 %)	Japan(7%)		
Borates	Turkey (38%)	USA (23%)	Argentina (12%)		
Cobalt (Co)	D. R. Congo (64%)	China (5 %)	Canada (5%)		
Coking Coal	China (54%)	Australia (15%)	USA (7%)	Russia (7%)	
Fluorspar (CaF_2)	China (64%)	Mexico (16%)	Mongolia (5%)		
Gallium (Ga)	China (85%)	Germany (7%)	Kazakhstan (5%)		
Germanium (Ge)	China (67%)	Finland (11%)	Canada (9%)	USA (9%)	
Hafnium (Hf)	France (43%)	USA (41%)	Ukraine (8%)	Russia (8%)	
Helium (He)	USA (73%)	Katar (12%)	Algeria (10%)		
Indium (In)	China (57%)	S. Korea (15%)	Japan (10%)		
Magnesium (Mg)	China (87%)	USA (5%)			
Natural Graphite	China (69%)	India (12%)	Brazil (8%)		
Natural Rubber	Thailand (32%)	Indonesia (26%)	Vietnam (8%)	India (8%)	
Niobium (Nb)	Brazil (90%)	Canada (10%)			

Phosphate Rock (P_2O_5)	China (44%)	Morocco (13%)	USA (13%)		
Phosphorus (P)	China (58%)	Vietnam (19%)	Kazakhstan (13%)	USA (11%)	
Scandium (Sc)	China (66%)	Russia (26%)	Ukraine (7%)		
Metallurgical Silicon	China (61%)	Brazil (9%)	Norway (7%)	USA (6%)	France (6%)
Tantalum (Ta)	Rwanda (31%)	D. R. Congo (19%)	Brazil (14%)		
Tungsten (W)	China (84%)	Russia (4%)			
Vanadium (V)	China (53%)	S. Africa (25%)	Russia (20%)		
Platinum Group Metals (PGMs)	S. Africa (83%)	Russia (46%)			
Heavy Rare Earth Elements (HREEs)	China (95%)				
Light Rare Earth Elements (LREEs)	China (95%)				
Lithium (Li)	Australia (44%)	Chile (34%)	Argentina (13%)	China (6%)	Bolivia (4%)

Source: Data Processing https://documents.worldbank.org/curated/The-Growing-Role-of-Minerals-and-Metals-for-a-Low-Carbon-Future· https://www.sciencedirect.com/· https://www.oecd.org/environment/.

If, for the same period 2010–2024, the Corruption Footprint Index (CFI) is applied to these major countries producing critical raw materials, the results obtained are reflected in the table below.

Table 2 The Corruption Footprint of the Major Producing Countries of Critical Raw Materials

A/A	Producing Country of Critical Raw Materials	Corruption Footprint Index- CFI (avg.) 2010-2024
1	USA	0.501
2	China	0.082
3	India	0.071
4	Vietnam	0.062
5	Rwanda	0.071
6	Indonesia	0.068
7	S. Korea	-
8	Chile	0.410
9	Australia	0.610
10	Morocco	0.087
11	Germany	0.521
12	S. Africa	0.161
13	Mexico	0.117
14	Japan	0.432
15	Turkey	0.127
16	Argentina	0.104
17	Democratic Republic of Congo (DRC)	0.031
18	Russia	0.064
19	Mongolia	0.102

20	Kazakhstan	0.072
21	Finland	0.708
22	France	0.448
23	Ukraine	0.061
24	Algeria	0.045
25	Katar	0.334
26	Thailand	0.111
27	Brazil	0.131
28	Norway	0.684
29	Argentina	0.108
30	Bolivia	0.070

Source: Data Processing https://www.corruption-map.org

2. Conclusion

The available data demonstrate that, concerning sources of critical raw materials, the global economy is entirely dependent on countries with a particularly high Corruption Footprint. Nations such as China, India, Vietnam, Rwanda, Indonesia, Chile, Brazil, and South Africa, which are among the world's most significant suppliers of critical raw materials, according to the CFI index, exhibit medium to high levels of corruption-related impacts within their territories. The only exceptions to this trend are the United States, Germany, Finland, Norway, and Australia, which display low levels of corruption-related effects.

The results of the Corruption Footprint Index (CFI), raise critical analytical questions, regarding the frameworks governing the formation of resource exploitation agreements, as well as interpretations concerning the structuring of geopolitical rivalries at both regional and global levels. Additionally, they provide insights into the economies of dominant nations in the current era of transitions, highlighting their dependencies, not only on the aforementioned exploitation agreements but also, on the evolving dynamics of contemporary geopolitical competition. They demonstrate the critical importance of studying the theory of corruption phenomenon, in order to understand and manage its various forms within each country individually, especially during the current period of major transitions. This study will facilitate the collection of data on the origins and impacts of various forms of corruption, including political corruption, lobbying-related corruption, corruption in interstate relations, corruption form of bribery and corruption within the private sector. [7] These forms of corruption, undoubtedly manifest differently in each nation-state. However, in the modern world—particularly in matters concerning the exploitation of natural resources—they often intersect, amplifying their consequences for populations on a global scale.

Lastly, the results, serve as a reminder that, when studying the forms, consequences and management of corruption phenomenon, a researcher must always be prepared to confront realities, that they may either be unwilling or unable to fully comprehend. [8]

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