The Role of Critical Raw Material Imports in Shaping Economic Competitiveness within the European Union

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Abstract
Critical raw materials (CRMs) represent essential resources for several strategic sectors in the European Union and strategies are necessary to reduce dependence on imports and improve the efficiency of their use. The European Union is facing significant challenges in diversifying supply chains, implementing effective sustainability standards, and reducing strategic dependencies on imports. Our study investigates the impact of critical raw material (CRM) imports on the competitiveness of the European market, addressing significant gaps in the existing literature regarding this relationship. Utilizing quarterly import values of CRMs for the EU during the period 2023-2024, the research employs a linear regression model to explore the correlation between CRM imports and economic competitiveness. The findings underscore the complexities of the relationship between CRM imports and EU competitiveness, highlighting the need for strategic policy frameworks that enhance recycling rates, promote research into alternative materials, and ensure sustainable practices in raw material extraction. This research contributes to a deeper understanding of the dynamics between resource dependency and market competitiveness, providing insights for policymakers aiming to secure a sustainable and competitive European economy.

Keywords: Critical Raw Materials, Competitiveness, Imports, Supply Chain Diversification, Sustainability

JEL Classifications: Q32, O13, Q34

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1. Introduction

Critical raw materials (CRMs) are essential resources that play a strategic role in the economic development. These materials are characterized by their high economic importance and significant supply risks, which arise from their uneven geographical distribution and the concentration of production in a limited number of countries, particularly in China (Ferro & Bonollo, 2019; Ujaczki et al., 2017).

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The latest CRM list, from 2023, includes raw materials such as rare earth elements (REEs), graphite, tungsten, lithium, cobalt and antimony, reflecting the dynamic nature of the market and strategic priorities. Updates to the list are based on analysis of the economic importance of CRM for strategic EU industries such as energy, automotive, electronics and defence. This list is a point of reference for policy makers, trade negotiators and researchers concerned with the EU's industrial strength.

The EU's faces significant challenges due to the dependence on CRM's imports and effective strategies are needed to diversify supply chains and increased resource efficiency (Kosai et al., 2018). The importance of CRMs has been underscored by their critical applications in technologies such as electric vehicles, solar panels, and wind turbines, which are vital for achieving the EU's sustainability and climate goals (Schmid, 2020). As the demand for these materials continues to rise, understanding their criticality becomes increasingly important for policymakers and industry stakeholders alike. This understanding is crucial not only for securing a stable supply but also for fostering competitiveness and sustainability in the European economy (Graedel & Reck, 2015; Diemer et al., 2018). This paper aims to explore the dynamics of CRM imports and their implications for the competitiveness of the European market, highlighting the necessity for strategic approach regarding the supply.

2. Critical raw materials and supply risk

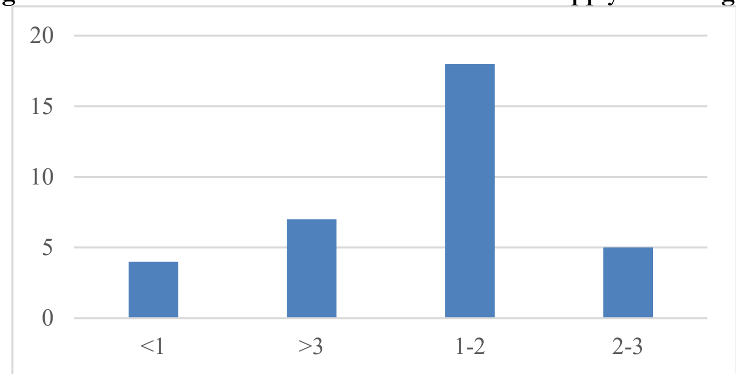
The EU has a comprehensive approach regarding policies aimed to promote supply chain resilience combining diversification, strategic stockpiling, regulatory measures and international collaboration. These strategies are designed to mitigate risks, ensure the continuous flow of critical goods and improve the overall resilience of supply chains in the face of global challenges, such as geopolitical tensions, as well as market fluctuations.

Critical raw materials (CRM) are vital in industries such as automotive, aerospace and renewable energy, essential for the development of advanced technologies and sustainable solutions (Domaracká et al., 2022).

The list of critical raw materials at EU level is updated every three years (Sullivan & Cromwell, 2024) and highlights materials of high economic importance, as well as a high risk in terms of security of supply. Within this list, there is a differentiation between the raw materials considered truly critical, and those categorized as strategic (with economic importance, but without current supply risk). The 31 materials included in the list and the 3 groups of materials are also assigned a supply risk (Carrara et al, 2023), which in the present case takes values from 0.1 (Copper) to 5.1 (HREE) (Figure 1).

Regarding the calculation of supply risk, research shows that the Geopolitical Supply Risk method, initially developed by Gemechu et al. (2016) and later extended by Helbig (2016), as well as Cimprich et al. (2017), aims to integrate the assessment of supply risk for critical raw materials, thereby complementing life cycle assessment from an environmental perspective and contributing to a more comprehensive analysis of life cycle sustainability (Santillán-Saldivar, 2021).

Figure 1. Number of raw materials related to each supply risk category



Source: Author's processing based on data provided by Müller, Ghiotto and Bárcena, 2024

Critical raw materials (CRMs) represent essential resources for several strategic sectors in the European Union (see Table 1). Dependence on CRMs imports creates vulnerabilities that affect the long-term competitiveness of European industrial sectors. Increased costs of CRMs and price variations due to market uncertainties have a direct impact on final product prices.

Table 1. The use of CRM in strategic sectors at EU level

Strategic sectors	The role of critical raw materials
Energy	The transition to a green economy is an EU priority in the context of the European Green Deal. Green technologies such as solar panels, wind turbines and electric batteries are dependent on CRMs. For example, wind turbines require neodymium and praseodymium for permanent magnets, which ensure high efficiency and durability.
Automotive	Electric vehicle (EV) production depends on lithium-ion batteries, which require metals such as lithium and cobalt. The EU competes globally with other large markets, making stable access to CRMs vital for competitiveness.
Electronics& Telecomunications	Electronic devices such as smartphones, tablets and computers require CRMs such as tantalum, used in miniaturized capacitors. Europeans buy a considerable amount of electronic equipment annualy, which increases the demand for these materials and the relevance of CRMs recycling from e-waste.
Defence	The defence sector uses CRMs in various applications, including communication systems, surveillance technologies, and advanced

Strategic sectors	The role of critical raw materials
	weaponry. Lightweight yet extremely strong materials such as niobium and titanium are essential in the production of defence equipment.
Aerospace	The aerospace sector also depends on these materials for manufacturing components that require high strength-to-weight ratios and resistance to extreme conditions

Source: by the authors, based on Guzik et al., 2021; Hool, 2023; Lewicka et al., 2021; Domaracká et al., 2022.

Supply delays due to disruptions in global supply chains can lead to reduced production capacity and financial losses. The European Union is aware of these risks and aims to strengthen its resilience. Policies such as the Critical Raw Materials Action Plan (2020) aim to reduce external dependence and create a more sustainable internal market for CRMs (European Commission, 2021). By encouraging recycling and supporting research into new sources of raw materials, the EU aims to increase its strategic autonomy and reduce vulnerabilities.

3 Circular economy and CRM recycling

The evolution of the EU's ability to meet its demand for raw materials using scrap is shown in Table 2. Entry rates for lead have been above those of other materials, while copper, yttrium, nickel, palladium, aluminium and zinc have all seen high rates. The percentage change from the earliest reporting period to the latest in waste input rates (values smoothed by a smoothing term of 0.5) shows that yttrium, praseodymium and natural rubber are the materials with the largest positive change (mainly due to the absence of any inflows in 2013), but also copper (1.70), molybdenum (0.74), tantalum (2) and zinc (3.05) saw improved rates. On the other hand, scrap use for nickel (-0.49), palladium (-0.70), platinum (-0.67) and beryllium (down to 0) decreased by a large margin.

Table 2. End-of-life recycling input rates in Europe (in %)

	2013	2016	2019	2022		2013	2016	2019	2022
Aggregates*	-	8	8	9	Magnesium	14	9.5	13.4	13
Aluminium	35	12.4	12.3	32	Molybdenum	17	30	30	30
Beryllium	19	0	0	0	Natural rubber	0	0.9	1	5
Bismuth	-	1	0	0	Neodymium	0	1.3	1.3	1
Cobalt	16	0	22.1	22	Nickel	32	33.9	17	16
Copper	20	55	16.9	55	Palladium	35	9.7	27.8	10
Dysprosium	0	0	0	0	Platinum	35	11.5	25.3	11
Gallium	0	0	0	0	Praseodymium	0	10	10	10
Germanium	0	1.7	1.7	2	Sapele wood	-	15	0	7
Gypsum	1	1.1	1.1	1	Tantalum	4	1	5	13

	2013	2016	2019	2022		2013	2016	2019	2022
Indium	0	0.1	0.1	1	Tellurium	0	1	1	1
Iron	22	24	31.5	31	Titanium	6	19.1	19.1	1
Lead	-	75	75	83	Vanadium	0	44	1.7	1
Limestone	0	58	19	1	Yttrium	0	31.4	31.4	31
Lithium	0	0	0.1	0	Zinc	8	30.8	31	34

* Includes crushed rock, other sands (not silica), pebbles, gravel, bitumen additives

Source: Eurostat, 2024, *https://ec.europa.eu/eurostat/databrowser/view/cei_srm010$defaultview/default/table*

4. Analysis of the impact of CRM imports on the competitiveness of the European market

A study (Černý et al, 2021) undertaken during the period 1994-2012, analyses the way in which the economic indicators recorded at the EU level influence the domestic demand for critical raw materials. The results obtained from the study reveal the fact that for some raw materials, such as silicon, magnesium (magnesite), chromium or cobalt, there is a close correlation between internal demand and the economic factors studied. However, the GDP of the Union as well as its population prove to be significant indicators in order to predict the evolution of the demand for critical raw materials, unlike the price of the materials. However, the study does not conclude that there is a direct link between imports of critical raw materials and the EU's economic competitiveness. The results of this study can be important regarding the recycling activities, as well as identifying investment needs in order to reduce Europe's dependence on raw material imports.

However, there are also studies that mark the existence of a positive correlation between the two variables. Thus, according to the research carried out by Hennebel et al (2015), the EU faces increasing risks regarding the supply of critical raw materials, a fact that can be countered by innovations brought to the primary mining sector. At the same time, since most of the critical raw materials are used in order to implement renewable energy sources, batteries represent an important element for storing this energy, a fact that makes them extremely important for the Union's economy. At the same time, imports of critical raw materials also have a significant impact on the EU solar, as well as on the wind industries, as demonstrated by Rabe et al (2017) in their research. Thus, for these two industries the EU is dependent on the raw materials indium, tellurium, gallium, and the rare earths, such as dysprosium and neodymium, imported from China. According to the results obtained from this study, European competitiveness - quantified not from the perspective of economic development, but rather from the perspective of increased dependence on this third country for the previously mentioned raw materials - can be negatively affected in the long term. However, even this study, even if it points to the existence of a negative impact between imports of critical raw materials and the economic competitiveness of the EU, does not deny the correlation between the two variables.

In this sense, the main objective of this study is the analysis of the impact that the amount of critical raw materials imported at the EU level has on the competitiveness of the European market. The originality of the study is based on the gaps identified in the specialized literature regarding the quantification of the impact of imports of critical raw materials on the competitiveness of the European market.

5. Research methodology

Thus, in order to quantify the amount of critical raw materials, the value of the quarterly imports made by the Union in the period 2023-2024 (IRM) will be used, while to quantify the competitiveness of the economic market, the GDP per inhabitant at the European level was chosen as an indicator (GDP). Thus, the study will be based on the undertaking of a linear regression model that will test the existence of a correlation between the two variables, in which IRM will be the independent variable, and GDP will represent the dependent variable. The research hypotheses are based on previously mentioned studies (Table 3). Thus, the null hypothesis, which predicts the absence of a significant impact between the level of imports of critical raw materials and the economic competitiveness of the European market, based on the study undertaken by Černý et al (2021). At the opposite pole, the alternative hypothesis is based on the fact that there is a significant impact between the imports of critical raw materials and the competitiveness of the economic market, based on the studies undertaken by Hennebel et al (2015) and Rabe et al (2017).

Table 3. Assumptions of the regression model

H0: The level of imports of critical raw materials at the EU level does not have a significant impact on the competitiveness of the European market
H1: The level of competitiveness of the EU is significantly influenced by imports of critical raw materials from third countries.

Source: Author's projection

Data from the Eurostat platform was collected to illustrate the current situation of the CRM imports in the European Union. Thus, the data related to the two variables were collected on a quarterly basis for the last two quarters of 2023 and respectively the first two quarters of 2024. The minimum value recorded for imports of critical raw materials in the analysed period was 14839.8 million euros (related to the quarter 3 of the year 2023), while the maximum value of 31400.8 million euros corresponds to the 2nd quarter of the year 2024, this indicating that this variable had an upward trend throughout the analysed period. The value of GDP per inhabitant does not increase, but constantly in the four analysed periods, but also in the case of this variable, the minimum value of 4263792.3 8 million euros is recorded in the third quarter of 2023 and the maximum value of 4416037.5 8 million euros is related to the 2nd quarter of the year 2024. The average value of imports of critical raw materials at the EU level during the analysed period is 23,008,825 million euros, while in the case of GDP per inhabitant it is 4,361,372.8 million euros.

6. Results and discussion

In the analysis, the Pearson correlation coefficient was first calculated, which recorded a value of 0.57, which illustrates an average correlation between the two variables. Therefore, an increasing trend in the value of imports of critical raw materials at the EU level will also lead to an increase in the value of GDP per inhabitant as a measure of economic competitiveness.

Since the built regression model is based on a linear regression, its foundation assumes a direct causality between the two variables, but also a linear one throughout the analysed period. Analysing the results obtained (Table 5), the first important statistic is represented by the value of the coefficient of determination (R2). A value of 0.32 for this coefficient indicates that 32% of the variation of the dependent variable represented by the GDP per inhabitant as a measure to quantify the economic competitiveness of the EU, is explained by the fluctuation of imports of critical raw materials at the level of the Union. At the same time, the value of the β coefficient is a representative indicator for the relationship between the dependent and the independent variable. In this sense, a value of 9.08 (Table 5) indicates that there is a positive relationship between the two variables (a fact also supported by the value of the Pearson coefficient calculated previously). Also, the coefficient indicates how for an increase of one unit (1 million euros) in the value of imports of critical raw materials at the EU level, the value of the economic competitiveness of the union (represented by the value of GDP per inhabitant) increases by 9.08 units (millions of euros).

Table 4. Regression model statistics

Regression statistics	Value
Multiple R	0.571
R Square	0.326

Source: Author's processing using SPSS

Table 5. Regression model coefficients

Coeficient	Corresponding variable	Value
α	-	4152392.11
Β	IRM	9.08

Source: Author's processing using SPSS

The testing of the built regression model was done by means of the F-test. This involved the calculation of the F-statistic for a probability of 5%, 1 and 2 degrees of freedom respectively, and comparing this calculated value with the value of the

F-statistic obtained from the implementation of the regression. As a result of the calculations, the calculated value of the F statistic was 18.51, which is significantly higher than the statistical value of F of only 0.97. Based on this inequality, it is considered necessary to accept the null hypothesis H0 and reject the alternative hypothesis that implies the existence of a significant impact of imports of critical raw materials on the economic competitiveness of the EU. As a result, the built regression model is not representative from a statistical point of view, which prompts us not to consider the coefficients and statistics obtained as representative from an economic perspective. This lack of statistical representativeness is also supported by the value obtained for the significance threshold (significance F), whose value (0.42) exceeds the imposed threshold of 0.05 (5%) in order to validate the model.

The results of this analysis are thus in line with the study of Černý et al. (2021), Rabe et al. (2017) who support the lack of a concrete causal relationship between the level of imports of critical raw materials and the economic development or competitiveness of the Union. However, the limitation of the present study may be based on the use of a variable that does not represent economic competitiveness as a whole (GDP per inhabitant), which is why further research directions may consider the use of an alternative variable (for example, the expenses made in field of research and development).

Conclusions

EU is carefully evaluating the risks associated with CRM import dependency and is trying to find solutions for diversifying supply sources and increasing the resilience of supply chains. Policy initiatives such as the Critical Raw Materials Action Plan aim to reduce external dependence and create a more competitive internal market. By encouraging recycling and supporting research into new sources of raw materials, the EU aims to increase its strategic autonomy, promote sustainability and reduce vulnerabilities. Considering the risks posed by pressure on CRM supply chains and geopolitical tensions, the EU has created an enabling environment that offers significant opportunities in the development of new raw material supply chains and the recycling of existing ones.

The results of our econometric analysis do not show a direct correlation between the imports of critical raw materials and the competitiveness of the EU market, but we identified some limits of our research. One future direction is to include more variables to represent the competitiveness of a region.

Our study emphasizes the importance of preparing for various scenarios in EU-China relations, as well as the necessity for ongoing dialogue and strategic engagement with Chinese policymakers to bolster supply chain resilience. Also, more investments are necessary to promote innovation in the area of alternative materials and recycling of the existing ones.

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