THE ECONOMIC COSTS OF OLIGOPOLY IN THE MARKETS OF RARE EARTH ELEMENTS (REEs)

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Abstract

This research estimates the costs related to rare earth elements (REEs) due to the oligopolistic market structure, where China dominates, controlling over 60 percent of deposits and more than 80 percent of traded REEs. Other countries play a minor role in this market, which is critical for future economic growth and technological development. Using the fringe oligopoly model, we analyze the economic costs for countries with fewer REE deposits. We calculated the Herfindahl-Hirschman Index and developed a dependence index to assess economic vulnerability. Our database includes fifty years of data from sixty-two countries, primarily sourced from the World Bank. Through quantile econometric models, we evaluate the economic losses incurred by countries with limited REEs due to the market power of the leading nations. Lastly, technological advancements can help reduce reliance on REEs through policies that minimize their use, promote recycling, and encourage the discovery of alternative materials.

Introduction

Energy markets for non-renewable resources are often characterized by oligopoly with fringe structures, where a few dominant firms set prices and output while smaller firms adapt (Gilbert, 1978; Lewis and Schmalensee, 1980; Benchelkroun et al., 2023). We analyze this framework in the international Rare Earth Elements (REEs) market to estimate the social costs of oligopolistic market power. REEs are a group of 17 non-renewable but partly recyclable metals (Binnemans et al., 2013; Lai et al., 2024), essential for defense technologies (Zhou et al., 2017) and for the green energy transition, including wind turbines, solar panels, batteries, and microprocessors (Voncken, 2016; Schulze et al., 2018; Baskaran, 2024; Ghorbani et al., 2024; Alfaro et al., 2025). Their demand is expected to increase sharply, with a projected global deficit of 47,000 tons by 2023 (Lai et al., 2024). As exhaustible resources, scarce REEs generate rising rents for countries holding large deposits (Stiglitz, 1974; Jowitt, 2022). The unequal distribution of REEs creates macroeconomic inefficiencies and geopolitical dependence, as only the flow of extracted REEs is tradable. This inequality allows resource-rich countries to extract substantial rents (Liski and Montero, 2014). Today, China produces 60% of global REEs and processes nearly 90%, leading to a quasi-monopoly (Fan et al., 2023; Baskaran, 2024). Despite existing work on oligopoly in exhaustible resources (Gilbert, 1978; Lewis and Schmalensee, 1980; Newbery, 1981; Benchekroun et al., 2023), no study has assessed the macroeconomic impact of REE market power exercised by a single country. This study fills that gap by developing a new index of inequality in REE endowments, weighted by population, which improves upon the Gini and HHI used in geopolitical risk assessments (Goe and Gaustad, 2014; Zhang et al., 2015; Althaf and Babbitt, 2021; Santillan-Saldivar et al., 2021). Using a balanced panel (1973–2022) of 62 countries (WDI, 2024) and quantile regressions to analyze how REE inequality affects GDP and GDP per capita across low (.10–.25), medium (.50), and high (.75–.90) quantiles. Unequal REE distribution reduces economic performance in low- and middle-quantile countries but benefits high-quantile countries with strong REE endowments.

Methods and Materials

First, we develop a new index of inequality in the endowment of REEs deposits among countries as an alternative measure to the Gini Index or the Herfindahl-Hirschman Index (HHI). Second, we employ an original balanced panel dataset that covers fifty years, from 1973 to 2022, considering 62 countries (3,100 observations). Most of the data used was drawn from the World Development Indicators (WDI) held by the World Bank (WDI, 2024). Additionally, we adopt quantile regression analysis to evaluate the heterogeneous effects of the unequal distribution of REEs on the gross domestic product (GDP) and per capita GDP (GDPPC) of countries worldwide—located in low (.10 and .25), middle (.50), and high (.75 and .90) quantiles—mainly focusing on developing and developed countries

Results

The results of our research are twofold. First, there is a negative relationship between the unequal distribution of REEs and economic performance across countries located in the low (.10 and .25) and medium (.50) quantiles only. In contrast, a positive relationship exists between the unequal distribution of the REEs and the economic performance of countries located in the high quantiles (0.75 and 0.90). Thus, the effects of the unequal distribution of REEs are heterogeneous across countries and are disproportionately experienced by developing countries (in lower quantiles).

Table 1. Quantile regression with bootstrapped standard errors

	(1)	(2)	(3)	(4)	(5)
Quantiles	.10	.25	.50	.75	.90
Dependent Variable	gdpgrowr	gdpgrowr	gdpgrowr	gdpgrowr	gdpgrowr
Inequality_REEs	**-1.366**	**-0.5845**	**-1.555***	**1.858***	**2.375***
	(1.237)	**(0.941)**	**(0.821)**	**(0.691)**	**(0.766)**
Constant	8.026*	10.98***	12.69***	12.43***	12.14***
	(4.481)	(2.134)	(1.226)	(1.847)	(1.110)
Other controls	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	2,578	2,578	2,578	2,578	2,578

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; Results are presented as b/se

Second, we calculate the costs of oligopoly in the REEs market, assuming China and several other countries (e.g., Australia, Brazil, India, Russia, the US, and Vietnam) are oligopolists. We find evidence that the cost of oligopoly and economic performance vary in magnitude across countries placed in the low (.10 and .25), medium (.50), and high (.75) quantiles. Given the income level of each country, developing countries—especially those in the lowest quantiles—are more adversely affected than the most developed ones—located in the highest quantile—by the oligopolistic behavior of China and a few other nations with REEs.

Table 2. Quantile regression with oligopoly cost and interaction term

	(1)	(2)	(3)	(4)	(5)
Quantiles	.10	.25	.50	.75	.90
Dependent Variable	gdpgrowr	gdpgrowr	gdpgrowr	gdpgrowr	gdpgrowr
Inequality_REEs	**-15.771***	**-9.769***	**-5.919***	**-1.220**	**0.0300**
	(0.791)	**(1.644)**	**(0.704)**	**(2.964)**	**(1.759)**
Oligopoly_cost	-16.481***	-11.571**	-8.195	-11.281*	-7.696
	(4.444)	(4.866)	(5.440)	(6.162)	(5.530)
lngdppc	4.230***	1.677***	0.387	0.431***	0.153
	(0.551)	(0.425)	(0.287)	(0.150)	(0.290)
Oligopoly_cost*lngdppc	-2.794***	-1.037**	-0.311	0.0607	-0.947**
	(0.394)	(0.414)	(0.511)	(0.217)	(0.379)
Constant	-15.15***	0.937	10.15***	15.13***	13.24***
	(3.724)	(3.223)	(1.855)	(1.911)	(2.011)
Other controls	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	2,578	2,578	2,578	2,578	2,578

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; Results are presented as b/se

Discussion

REEs have become essential for high-tech, green energy, and military applications (Wang et al., 2020; Proelss et al., 2018), with permanent magnets driving a significant portion of global demand (Salim et al., 2022). Their inelastic demand and uneven supply give producing countries strong market power (Mancheri et al., 2019). China remains the dominant actor, controlling the most significant reserves and processing capacity, which has triggered global policy reactions (Bonaime et al., 2018). While prior research has focused mainly on China's REE policies (Hayes-Labruto et al., 2013; Zhang et al., 2015), few studies have examined the global economic effects. Our quantile regressions show that REE inequality harms countries in low and medium-income quantiles, while high-quantile economies may benefit. This is due to limited extraction capacity, dependence on raw material exports, weak adoption of the circular economy, and institutional constraints (Watari et al., 2019; Salim et al., 2022).

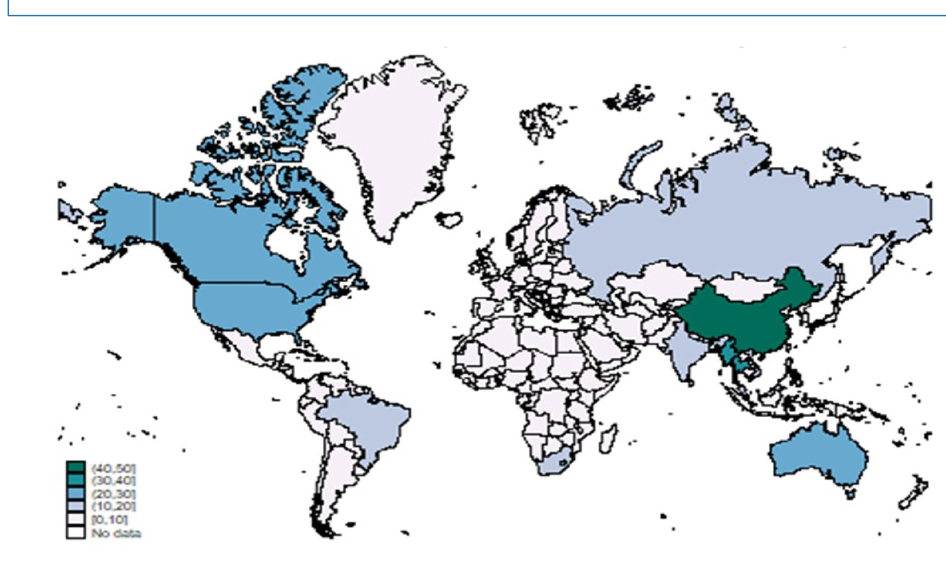

Figure 1. Distribution of Rare Earth Elements (REEs%) worldwide by country (2023)

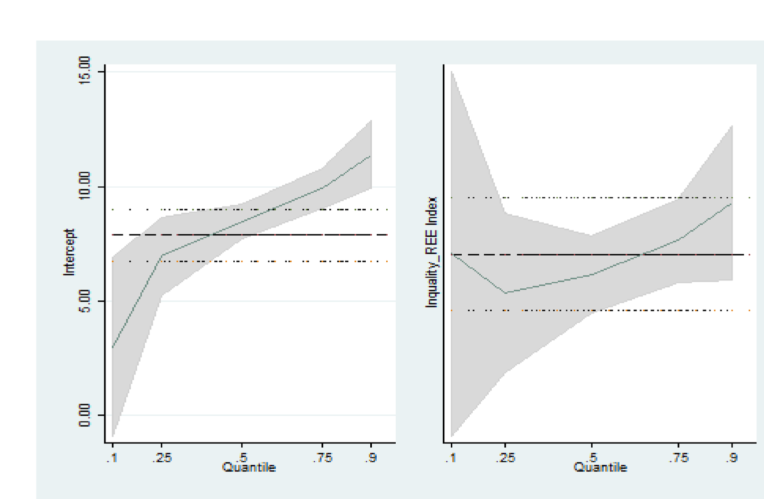

Figure 2. Inequality Index – Univariate Quantile Regression

Conclusions

Rare Earth Elements (REEs) are vital, non-renewable resources used in technologies like information and communication technology (ICT), renewable energy, aerospace, and military applications. Their limited availability, high extraction costs, and concentration in a few countries, especially China, lead to supply instability and geopolitical dependence. This study highlights that unequal access to REEs contributes to global economic disparities. It shows that REE inequality hinders growth in low- and mid-growth economies, while high-growth economies benefit from concentrated access. Furthermore, REE inequality harms long-term GDP growth, particularly in countries that lack domestic supply. To reduce vulnerability, governments should adopt REE-efficient technologies, improve recycling efforts, and explore alternative materials. Given the environmental issues associated with REE extraction, emerging options such as deep-sea and asteroid mining present uncertain but potentially viable future sources of supply. Ultimately, advancing REE recycling technologies is crucial for enhancing supply security and supporting transitions to clean energy systems. Future research should assess the effects of recycling policies on global REE availability.

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