UNIVERSITÀ CATTOLICA del Sacro Cuore

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Working Paper n. 45 - February 2025

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Lorenzo Esposito, Department of Economic Policy, Università Cattolica del Sacro Cuore, Milano, Italy − Banca d'Italia, Milano, Italy

✉ lorenzo.esposito@unicatt.it

Marta Cocco, Università Cattolica del Sacro Cuore, Milano, Italy

✉ martacocco05@gmail.com

Dipartimento di Politica Economica
Università Cattolica del Sacro Cuore – Largo A. Gemelli 1 – 20123 Milano
Tel. 02-7234.2921

✉ dip.politicaeconomica@unicatt.it

https://dipartimenti.unicatt.it/politica_economica

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Abstract

The aim of this work is to assess how geopolitical tensions and risks can affect sustainable investment strategies and the approach to the transition that is dependent on a growing supply of critical raw materials. In particular, we analyze the effect that tensions in the US-China relation have on the US investment in renewables. Using the Electricity Installed Capacity Index, we show that an increase in tensions in the bilateral trade relations and, more generally, an increase in the uncertainty of the geopolitical context, can act as a stimulus for the renewable energy sector. Given the prudent strategy of the US financial institutions in funding green energy, this correlation is not much connected to better green investment yields but to the US governments attempts to decouple from China. It also shows that US trade policy will be used to help the development of US green technologies.

JEL Classification: F50, G2, Q56
Keywords: critical raw materials; sustainable investment; geopolitical risks

1. Introduction*

The naïve stage of development of sustainable finance, with no connection to the wider geopolitical context, has definitely ended with the pandemic and the new cold war[1]. Even the evidence of a continuous increase in global emissions is now part of political clashes inside the countries and between the Western and Eastern blocs. Key aspects of the climate change risk, in particular the transition risk, cannot be understood outside this new geo-political set-up. As several climate reports highlight, the major global economic powers, in particular the United States and China, maintain a leading position as the main financiers of fossil fuels and, in general, as supporters of industrial activities that generate and release large quantities of carbon dioxide, making the objectives of the Paris Agreement increasingly distant.

Analyzing the motivations that lead the largest financial institutions to persist in financing highly polluting projects, one in particular emerges in the new era: the role of geopolitical risk. The contribution that geopolitical tensions and risks generate in influencing sustainable investment strategies and decisions is increasingly evident. The aim of this paper is to assess how the riskiness inherent in geopolitical relations can influence the approach to the transition.

We focus, in particular, in one of the way the geopolitical risk can materialize. While much of the literature focuses on the analysis of geopolitical tensions in terms of economic policy uncertainty, political unrest or extreme events such as wars or terrorist acts, and diplomatic events, here we investigate the ambiguous and precarious trade relations among countries in the field of critical raw materials (CRM) that are needed for the development of renewable technologies. This critical issue, given by a peculiar structure that characterizes the CRM supply chain, has contributed in recent years to redefine international and political relations. In particular, the commanding position assumed by China in the transition and renewable energy technologies has pushed several countries to reconsider their relationships with the Asian economic giant. In the context of the new cold war, the US-China trade relationship has changed, with the intensification of the use of export restriction measures, such as duties. In this paper we analyze the effect that uncertainty and tensions in this relation have on the approach that the US adopts towards investment in renewables.

In particular, the work is structured as follows. The first section deals with the analysis of the risks and opportunities arising from climate change in the new era and the role that the financial sector is taking, between investment opportunities and the political clashes on the transition. The second section analyzes the economics of the CRM following the outbreak of war in Ukraine and the gradual decoupling between the Eastern and Western blocs, that has put geopolitical issues at the center of the transition. In the fourth section the new geopolitical era is discussed in its outcome in terms of trade restrictions that are particularly relevant for the CRM that will also force a wider direct role of the State for example through subsidies, export restrictions or the reduction of foreign ownership. Then, in the fifth section an empirical analysis of the impact of geopolitical tensions on the transition is conducted. In particular, the research question we investigate is the link between the leading country in the renewable energy sector, China, and the other major global economic power, the US, characterized by significant mutual trade dependencies. We found that an increase in tensions in the bilateral trade relations and, in general, an increase in uncertainty in the geopolitical context, can act as a stimulus for the US renewable energy sector. This stimulus will fall more on government than on the markets. In other words, it will be part of the new cold war.

2. Climate change risks in the new era and the role of the banks in the transition

Climate change is one of the most important threats for the future of humankind as it can potentially compromise the health and well-being on the whole planet. Moreover, climate change risk represents a significant macroeconomic risk for the economy and the financial system. After the foundation of the Intergovernmental Panel on Climate Change (IPCC) in 1988, policy-makers and the public opinion have gradually and increasingly recognized the existence, extent and causes of climate change. The development of specific financial products, such as cat bonds, the trading of carbon dioxide emission permits, the EU

* The views expressed by Lorenzo Esposito do not involve the responsibility of the Bank of Italy.
[1] For a thorough analysis of the situation coming out from the new geopolitical era see Esposito et al., 2024.

Greenhouse Gas Emissions Trading System, has shown that public authorities were using financial markets as a key leverage to help the transition. Investment banks and asset managers caught this opportunity. These developments have been helped by the growth of Sustainable and Responsible Investments frameworks dealing with the main risks associated to the climate change. The financial system is already in a transition stage in order to help the building of a sustainable economy (UNEP, 2015). In 2016, the G20 launched the Green Finance Study Group to encourage private investors to fund sustainable investments. From their side, central banks are expanding their role in this issue, as highlighted by the creation, in 2017, of the Network for Greening the Financial System (NGFS), a globally interconnected system of central banks and supervisory authorities that promotes cooperation to develop the best practices on the management of climate change risks. For this purpose, the NGFS has developed a series of climate mitigation scenarios (NGFS, 2022) using process-based Integrated Assessment Models that allow to analyse different possible paths to the transition. Central banks have also developed climate stress tests revealing that climate-related risks are significant, and relevant capital buffers may be required to contain exposure to these risks. Some central banks are integrating climate scenarios and risks into existing stress test models (ECB, 2022 and Bank of England, 2022). In this context it is paramount to consider the role played by the *stranded assets* that can become a significant fraction of the firms' assets in many sectors (McGlade and Ekins, 2015). Several central banks are developing strategies to help the transition in both monetary policy and financial supervision. For example, the People's Bank of China, already before COP26, announced a Carbon Reduction Facility and began rapidly deploying funds to "promote carbon reduction and support the development of clean energy, energy conservation, environmental protection, carbon reduction technology and other key sectors" (PBoC, 2021). The Bank of Japan is also moving in the same direction, having introduced a green lending facility: through Climate Response Financing Operations, Japanese banks provide zero-interest financing for investments that can contribute to achieve climate goals (Bank of Japan, 2021). Moreover, several central banks are planning to change the eligibility criteria for collateral and applying haircuts that reflect climate risks (Banque de France, 2022).

Overall, there is significant growth in sustainable assets. According to the Climate Policy Initiative's 2023 report, global climate finance reached $1.3 trillion in 2022, up sharply from $653 billion in 2020 (CPI, 2023). Much of this growth is driven by increased mitigation projects, with the largest increases in renewable energy and transportation. However, this growth is not sufficient, nor is it evenly distributed across sectors and regions. Increases in global climate finance are largely driven by a significant increase in clean energy investments in some countries. The US, China, Europe, Japan, Brazil and India account for 90% of the increase in financing. As for industries, energy and transport sectors attract most of the investment, 44 and 29% respectively. The agriculture and industry sectors, which represent the second largest emitter, benefit from a low share, less than 4% of the total. In this context, the role of banks and other financial operators is paramount. However, despite the growth of green finance, a certain inconsistency in the banks' strategies is apparent (Moore, 2024). A case in point are the US that, despite having formally joined the Clean Energy Transition Partnership, have continued to allocate billions of dollars to fund oil and gas projects, raising doubts and criticisms about its real intention to meet their international commitments (Millard and Pickard, 2024).

From their part, banks have published ambitious plans to reduce the emissions they finance and increase funding for sustainable activities. For example, 145 major banks globally have made explicit commitments through the Net Zero Banking Alliance (NZBA)[2]. However, while many commentators see the NZBA initiative as a proof that banks are starting to incorporate climate concerns into their strategies, others argue that these commitments are voluntary and border with greenwashing. The annual Banking on Climate Chaos Report (RAN, 2024) has provided an updated analysis of the world major banks' fossil fuel financing. Interestingly, while 33 banks have actually committed to reducing their financing to companies with high fossil fuel exposure between 2022 and 2023, another 27 banks, in a reversal of the trend, have increased their commitments to these sectors. Furthermore, other non-bank lenders, such as private equity, are stepping in to fill the void left by the banks and these financial operators are not exposed to the same pressures on the climate issue, and are regular buyers of carbon-related assets, managing them in less regulated private markets, exempt from most financial disclosure requirements.

[2] At the end of 2024, this number was 141, from 44 countries, with combined assets of $61 trillion, representing around a third of total banking assets (https://www.unepfi.org/net-zero-banking/members/).

Banks do have ways to decarbonize their assets. The point is if their commitments make a real difference in their strategy (Sastry et al, 2024). Political uncertainties explain the uncertainties of the financial operators. JPMorgan Asset Management and State Street Global Advisors have reportedly confirmed their decision to abandon participation in Climate Action 100+, a global initiative designed to push polluting companies to reduce their carbon emissions (Temple-West and Masters, 2024). Also BlackRock, the world's leading asset managers, underlined the importance of maintaining neutrality in the face of political influences, asserting that investment decisions should primarily reflect the choice of investors themselves, regardless of any undue external pressure. In particular, the strategy implemented by Blackrock to allow its investors to maintain their discretion, is embodied in a new management option that allows its clients to include the goal of decarbonization but also to exclude it. The new stance of these financial giants underscores the growing political pressure to which they are subject, especially in the US, where climate issues have become deeply polarized and the subject of intense political debate. At the same time, ESG investment funds are also going through a phase of crisis and revision: according to research by Barclays, clients of asset managers withdrew a net $40 billion from ESG equity funds in the first quarter of 2024. This phenomenon is attributable not only to their recent underperformance, but also to political controversies that have led to a reconsideration of their effectiveness and relevance. Recent analyses confirm that US banks are abandoning their climate alliances *en masse* (Buller, 2025).

The contradictory attitude of US operators towards the transition is clear from the market data. For example, using the ESG criteria of the London Stock Exchange for mutual funds, in the third quarter of 2024, 80% of the funds belonging to the worst classes were of US origin[3], although US public institutions make a great use of ESG Bonds, Sustainability Bonds, CBI Aligned Green Bonds, Self-Labeled Green Bonds, and Social Bonds. The effort of the public sector and the inertia of the private sector are further underlined by the data showing massive public investments for climate change (BloombergNEF, 2024).

In order to channel their capital effectively towards sustainable environmental projects, investors and stakeholders must be able to understand which banks are actually implementing pro-transition credit policies. In the light of growing institutional pressures, banks have significantly increased the disclosure of information on environmental objectives and their initiatives to improve the sustainability of their financing policies. Nonetheless, there are concerns regarding whether environmental disclosures actually include real action strategies and not just mere reputational and advertising tools. A recent study (Giannetti et al., 2024) confirm that banks are less inclined to provide new loans to companies operating in eco-sustainable sectors and allocate a significant share of new credit to polluting industries because they are no longer inclined to cut ties with existing polluting borrowers, while banks with more extensive environmental disclosures underwrite a greater amount of green bonds. Although a more environmentally aware business model makes banks more stable and profitable in the long term (Ameli et al., 2021), a too rapid decarbonization of assets could generate losses for banks, even if the literature presents conflicting data. While some argue that the impact is positive (Henriques and Sadorsky, 2018), others believe that divestment does not lead to clear differences in financial performance (Trinks et al., 2018), or that it could even lead to a negative impact (Cornell, 2018). Downstream effects may also be mixed. For example, ESG funds can sell securities issued by highly polluting sectors to reduce their exposure to ESG risk (EBA 2021); this induces firms in these sectors to scale back environmental investments and spending. This suggests that the most effective strategy for reducing emissions is to directly reduce the cost of capital for sustainable projects (Bartocci et al., 2024). Portfolio rotation is still possible without harm. For example, Plantinga and Scholtens (2020) find that excluding securities exposed to the fossil fuel sector from a financial portfolio does not have a significant impact on either the risk or the return of an adequately diversified global portfolio of industrial indices. Therefore, divestment from fossil fuels does not affect the total financial risk of the investor. All in all, financial operators seem to be more cautious towards sustainable finance for political more than economic reasons.

[3] The London School methodology includes a scale of 12 ratings, from the worst (D-, indicating a poor relative ESG performance and an insufficient degree of transparency in publicly reporting the ESG data collected) to the best (A+, indicating an excellent relative ESG performance and a high degree of transparency in publicly reporting the data collected). The chosen score corresponds to the C- class. The methodology for assigning these scores is based on a series of principles available on: https://www.lseg.com/content/dam/data-analytics/en_us/documents/methodology/lseg-esg-scores-methodology.pdf.

3. Enter geopolitics: the economics of the critical raw materials

Following the outbreak of war in Ukraine, with the following gradual interruption of economic relations between the West and the Russian Federation and the gradual decoupling between the Eastern and Western blocs, geopolitical issues have become of vital interest also in sustainable finance. The choices of financial operators about their participation in sustainability objectives is now the final outcome of a complex balancing act among their business plans and the goals of the governments as far as the transition is concerned. These goals are now connected to international political relations and to the consequences in terms of availability of some critical resources and technologies, articulation of global supply chains, end markets. In the last years we are witnessing the remodeling of industrial and commercial alliances and, although it is still premature to see the results of this remodeling, what is certain is that, on the one hand, there will be a reduction in dependence on external fossil fuel sources, and on the other hand, there will be a rush to ensure a sufficient availability of CRM, that are essential to produce intermediate and final goods connected to the transition (Kowalski and Legendre, 2023). Empirical evidence shows that current global CRM reserves are insufficient to meet projected demand levels (Herrington, 2021). In addition, the processing yield (i.e. mineral) of the various inputs that are crucial for green technologies is decreasing, which means that growing production should be met by an even stronger increase in extraction with increasing unit extraction costs (Heijlen et al., 2021). Secondly, geopolitical tensions, such as the ongoing conflict in Ukraine or in some Central African countries, can further limit the number of supplier countries, moreover, restrictions on CRM exports are increasing for political reasons (Kowalski and Legendre, 2023), like trade restrictions in general. The last update has been made in 2023 and it contains both CRM and strategic raw materials. From 2012 to 2019, global production of CRM increased, on average by 30%. Lithium, rare earths, chromium, arsenic, cobalt, titanium and magnesium are the materials for which global production has increased more rapidly (Kowalski and Legendre, 2023) but this growth is still insufficient to meet the transition goals. Moreover, global production of other CRM has actually declined (EC, 2023).

Minerals and metals play a fundamental role in the emergence of today's widely used clean energy technologies. Elements such as silicon and base metals such as aluminum, copper, zinc and nickel are particularly important due to their applicability to multiple sectors, both green and non-green (Hund et al., 2020; IEA, 2021). The following figure shows the need for minerals in various energy sources.

	Copper	Cobalt	Nickel	Lithium	REEs	Chrominum	Zinc	PGMs	Aluminium*
Solar PV	High	Low	Low	Low	Low	Low	Low	Low	High
Wind	High	Low	Moderate	Low	High	Moderate	High	Low	Moderate
Hydro	Moderate	Low	Low	Low	Low	Moderate	Moderate	Low	Moderate
CSP	Moderate	Low	Moderate	Low	Low	High	Moderate	Low	High
Bioenergy	High	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Geothermal	Low	Low	High	Low	Low	High	Low	Low	Low
Nuclear	Moderate	Low	Moderate	Low	Low	Moderate	Low	Low	Low
Electricity networks	High	Low	Low	Low	Low	Low	Low	Low	High
EVs and battery storage	High	High	High	High	High	Low	Low	Low	High
Hydrogen	Low	Low	High	Low	Moderate	Low	Low	High	Moderate

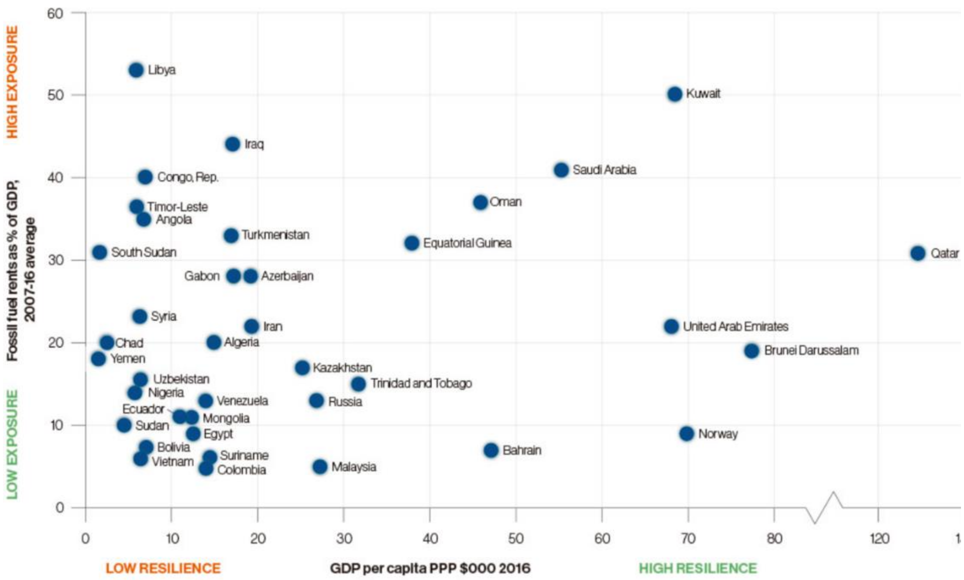
Importance: High ● Moderate ● Low ●

(Figure 1: Critical minerals for clean energies; source: IEA, 2021).

By 2040, total mineral demand from clean energy technologies will at least double (IEA, 2021). In particular, more companies and utilities are expected to invest in solar and wind farms (Bobba et al., 2020). Moreover, electric vehicles and battery storage will represent about half of mineral demand from clean energy technologies over the next 20 years, driven by the increased demand for battery materials.

Furthermore, the rapid development of hydrogen use is driving significant growth in spending on nickel and zirconium for electrolysis and copper and platinum group metals for fuel cell electric vehicles (IEA, 2021). Demand forecasts are subject to large variations, which leads to a wide range of possible future scenarios. For example, according to an analysis carried out by the IEA, in 2040, demand for lithium could be 13 to 51 times higher than current levels depending on its degree of market penetration. The large uncertainties regarding possible futures could be a factor that hinders investment decisions. These uncertainties help to understand, together with geopolitical problems, how, starting from the second half of 2020, the prices of some minerals have increased significantly, in some cases reaching their highest levels. The recovery of Chinese demand has also had an impact.

Factors like the geographic concentration, the length of the investment projects and availability of critical materials can delay the transition and must be carefully considered by authorities as they can affect strongly the economy of a country on many fronts. For instance, many fossil fuel-rich countries have considerable international power and have used fossil fuel revenues to fund their economic development and gain political clout. If fossil fuel revenues decline, these countries will need to reconsider their domestic priorities and rents. For countries that have not sufficiently prepared their economies for the transition, declining fossil fuel rents could have significant consequences. The following figure illustrates the situation of fossil fuel exporters by exposure and resilience.



(Figure 2: Exposure and resilience of fossil fuel exporting countries. Fossil fuel rents are calculated as a percentage of GDP over the period 2007–2016; source: IMF, 2018).

The graph highlights four groups of countries:

1. Highly exposed and low resilient countries. These countries are highly dependent on fossil fuel revenues, which typically represent more than 20% of their GDP. They also lack resilience capacity as their GDP per capita is low and their financial reserves are limited. Countries in this group are Libya, Angola, the Republic of Congo, East Timor and South Sudan.

2. Highly exposed and highly resilient countries. These are countries that are highly dependent on fossil fuel revenues, but have the income and capacity to reinvent themselves and adapt to the energy transition. These include the Gulf States, such as Saudi Arabia, Qatar, Kuwait, the United Arab Emirates and Brunei Darussalam.

3. Moderately exposed and moderately resilient countries. These are countries that are quite exposed, but their economies are moderately resilient. Consequently, they should be able to manage the transition,

provided they implement effective policies to diversify their economies. This group is composed of Russia, Iran, Algeria and Azerbaijan.

4. Countries with a generally low exposure. In these countries, fossil fuel revenues are less than 10% of GDP, which is why they should be less vulnerable to the energy transition. This group includes Malaysia, Bahrain, Colombia and Norway.

If oil revenues were to decline for a prolonged period, many of these countries would be subjected to violent political and social tensions, causing geopolitical consequences at a global level, as emerges from several studies (IRENA, 2019). The solution is to implement a diversification and decarbonization strategy (Lederman and Maloney, 2007).

By the same token, the growing role of clean energy has significant geopolitical ramifications. The race to CRM is remodeling international relationships, investment patterns, and trade alliances. While a decarbonized planet will require extensive supply networks for clean energy materials, components, and products, the globalization of energy trade itself is set to decline (Bordoff and O'Sullivan, 2021). We should remember that the geographic concentration of oil, natural gas, and coal reserves has shaped the international geopolitical landscape for two centuries and the control of oil production and trade has long been a key factor in 20th-century power strategy.

The transition from fossil fuels to renewables will transform global power relations as did the transitions from wood to coal and from coal to oil. Rapid development of the renewable energy sector may change the relative power and importance of nations. In this sense, innovation will be a key factor in determining the pace of change, and the pace of the energy transition depends largely on countries' exposure to changes in fossil fuel trade flows. Some countries are already net exporters of electricity from renewable sources. In particular, Brazil is a major exporter of renewable electricity from hydropower. Norway also exports electricity to neighboring countries and the Netherlands, and builds new transmission cables to Germany, the Netherlands, and the United Kingdom. Bhutan exports electricity to India that accounts for more than 27% of government revenue and 14% of its GDP (IRENA, 2019). Green energy will not only affect the balance of power between countries, it will also reshape alliances and trade flows. The more global demand for fossil fuels declines, the more alliances built on fossil fuels are likely to weaken. Given the high but still decreasing geographical concentration of renewable energy, geopolitical relationships and maps will take on new shapes. In 2009, Germany promoted the creation of IRENA and committed to developing bilateral energy partnerships with several countries where renewable energy plays a prominent role (Westphal, 2012). Numerous new alliances and initiatives are emerging to foster international cooperation and promote specific renewable technologies[4]. Numerous new alliances and initiatives are emerging to foster international cooperation and promote specific renewable technologies. Although many of these alliances are in their early stages, they are likely to gain greater geopolitical impact. At the launch of the first assembly of the International Solar Alliance (ISA), Indian Prime Minister Modi stated that "ISA will play the role of OPEC in the future" (Mohan, 2018).

Among the international initiatives for energy development, China's global strategic plan, the "Belt and Road Initiative" is of great importance, with projects in nearly 80 countries. Also very ambitious is the goal of China's largest state-owned company, State Grid, to create a global network "Global Energy Interconnection" with the aim of connecting all continents via submarine transmission cables for the passage of green energy[5]. With these projects, China aims to help reduce its dependence on energy and raw material imports. To counter the growth of Chinese influence, other major countries have promoted their own infrastructure plans in recent years, for example among ASEAN members[6], and the European Union has presented its global strategy for better connectivity between Europe and Asia (EC, 2018). These initiatives are also aimed at reducing possible disruptions in material supplies, an issue that has significant repercussions on the entire economy. IRENA (2023) identifies six most discussed geopolitical risks on the supply chain of materials, in the short and medium term, especially for countries that show a high dependence on imports:

[4] For instance: http://isolaralliance.org, www.globalgeothermalalliance.org, http://mission-innovation.net.
[5] https://m.geidco.org.cn/?lang=en.
[6] https://connectivity.asean.org/.

A. External shocks

Supply chains of globally critical materials could in fact be interrupted as a result of natural events, but also human acts such as trade disputes even accidental (such as, for example, power cuts). The most serious external event of 2020, namely the COVID-19 pandemic, led to the blocking of entire economies and the interruption of supplies from mines, smelters and refineries, causing a collapse in global demand for metals.

B. “Resource nationalism”

In recent years, many governments have decided to intensify state control over their mineral resources in order to enjoy the maximization of the benefits deriving from extraction and, where possible, to mitigate the negative effects. Australia, Canada, Chile, and several other countries have been the protagonists of policies to strengthen the tax regime, renegotiate royalties, increase the birth of state-owned mining companies as well as the increase in nationalized critical materials industries and, again, the provision of restrictions on investments from abroad. Proposals aimed at reviewing property rights and access and/or use of natural resources can impact global supply. White and Hook (2023) estimate a 15% interruption of global cobalt supply in the months following the second half of 2022 due to a dispute regarding royalties in the Democratic Republic of Congo, which caused a temporary blockage of copper and cobalt supplies. Again, in April 2023, the decision to nationalize the lithium industry came from China, generating concerns among analysts and industry groups (Dempsey and White, 2023).

B. Restrictions on exports of CRM

This third risk factor is a growing concern in international trade and manifests itself in terms of export quotas, export taxes, mandatory minimum export prices or licenses. The commodities most subject to export restrictions are critical materials, with several countries having implemented significant export bans. For example, Zimbabwe banned the export of raw lithium in December 2022 (Marawanyika and Ndlovu, 2022), and Indonesia did the same with bauxite in 2023 (Shofa, 2023).

D. The birth of OPEC-like mining cartels

In the past, producers and governments have attempted to influence mining markets through collusion (World Bank, 2022). In the early 20th century, there were cartels of producers of aluminum, copper, nickel, steel, zinc, and lead (Barbezat, 1989; Bray, 1997; Storli, 2014). Many of these cartels were created in the 1930s in response to the extremely low prices that characterized the Great Depression. Recently, several producing states have reconsidered the idea of cartelization.

E. Political instability

Political or social tensions in producing countries, including coups, strikes, and civil wars, can disrupt the supply of minerals. The majority of minerals are mined in countries classified as extremely unstable. For example, in 1978, civil war in Angola spread to the Zairian province of Shaba (now Katanga, in the Democratic Republic of Congo), causing the price of cobalt to increase sevenfold in two years, due to fears of a global cobalt shortage (Gulley, 2022). A second example concerns Myanmar, which saw protests and strikes in the mining sector following the coup in February 2021. These instabilities caused the country, which is a major producer of rare earths, to decrease its mineral export revenues by 80% (Frontier, 2022).

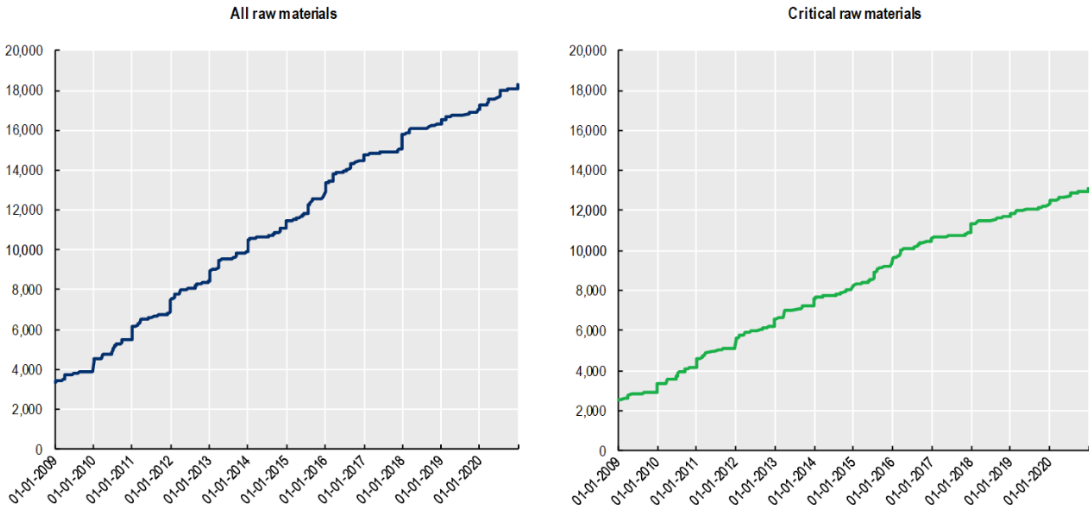
F. Market volatility and manipulation

Critical materials markets, similarly to other commodity markets, also have a cyclical nature, displaying the classic boom-bust pattern partly due to the long lead times required to establish new mines, causing a mismatch between supply and demand, especially during periods of rapid demand growth. This means that technological progress can trigger demand for resources much faster than producers can increase supplies, periodically causing prices to spike (IRENA, 2023). This dynamic is exacerbated by the fact that critical minerals are often by-products of other mined base metals. For example, cobalt is typically a by-product of nickel and copper mining, virtually all indium is a by-product of zinc mining, and many rare earths are by-products of iron ore mining. Therefore, the production of these minor metals is highly dependent on the production of base metals, which often generate higher revenues. Investment in new cobalt projects, for example, is often more dependent on the market dynamics of copper than on those of cobalt. The price of cobalt, in other words, is not necessarily a sufficient incentive for copper miners to produce more. (Nassar et al., 2015). As for manipulations, between 2000 and 2010, antitrust authorities discovered and sanctioned numerous attempts to form international private cartels in the mining and primary metals sector (Connor, 2012).

Faced with this situation, different countries will exploit their strengths to gain an advantage. The recent Draghi report (2024) shows the difficulty of European countries, given the absence of a real European political dimension, to transform the strength that European companies still have in many sectors, into an overall strength of Europe. In a phase of breakdown of trade relations, given its considerable commercial openness, Europe is particularly vulnerable to the acceleration of these trends.

4. Trade restrictions and their consequences

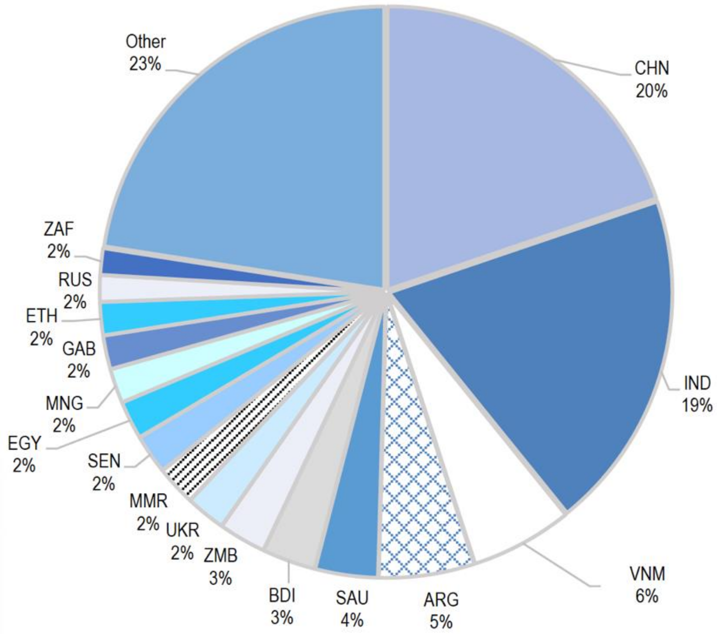
The potential of global trade is increasingly accompanied by difficulties. A growing number of trade disputes related to green technologies and geopolitical tensions could drive important shifts in trade and investment flows (Aguilar et al., 2024). Given the role of CRM in national and international supply chains, this is a key aspect that justifies State intervention, for example through subsidies, export restrictions or the reduction of foreign ownership, with the ultimate goal of supporting domestic downstream sectors and, in parallel, reducing the role of geopolitical rivalries on CRM supply. In fact, restrictions can increase prices and make it difficult for companies from other countries to have access to a regular supply, especially if the exporter holds a high market share (Kowalski and Legendre, 2023). These measures have also distributional effects, as trade restriction typically favor the profits of the domestic companies directly affected at the expense of a loss of welfare for companies in other sectors and consumers[7]. Considering the OECD list of raw materials, the number of these measures between 2009 and 2020 increased from 3,337 to 18,263 and from 2,518 to 13,102 for CRM (Kowalski and Legendre, 2023). The trend is clearly depicted in the following graphs:



(Figure 3: Increase in export restrictions between 2009 and 2020; Source: Kowalski and Legendre, 2023).

It is interesting to note that in 2022, among the countries with the highest incidence of restrictions, we find China, India and Vietnam, which together represented approximately 50% of the sample (see next graph).

[7] See USITC (2023) for the results of sanctions on steel and aluminum products.



(Figure 4: main countries contributing to export restrictions between 2009 and 2022; source: OECD, 2024).

This shows that, before the new geopolitical era, restrictions were concentrated in emerging countries, but things are changing. Today, more and more countries make significant use of such measures. In fact, about 10% of the total value of raw material exports are now subject to restriction measures (Kowalski and Legendre, 2023). The OECD analysis also shows that restrictions are not aimed at helping domestic companies to gain market shares but, above all, to ensure supply of CRM. Before the development of the new geopolitical era, the outcome of restrictions was a decrease in overall production and an increase in prices (Garcia-Lembergman et al., 2018, Akter, 2022). It remains to be seen whether these conclusions can be applied to the current clash between US and China.

As the *Financial Times* recalls, the beginning of the new American trade policy can be traced back to 2018 during the first Trump presidency with the approval of duties on approximately 300 billion dollars of goods from China (Williams, 2024). The protectionist policy was aimed at reducing the US' trade deficit and protecting national production, especially in key technology sectors, such as those related to telecommunications. Since 2022, the Biden administration has continued on the same path, maintaining most of the tariffs introduced by Trump, especially targeting electric vehicles, solar panels and batteries from China. Along the same lines, in order to protect the domestic automotive industry and support the labour market, on May 2024, an action was proposed and subsequently confirmed to quadruple tariffs on Chinese electric vehicles from 25% to 100% (Ibidem). Going beyond economic protectionism, Biden's approach has become an attack on Chinese technological development, considered a threat to the US. During the last presidential campaign, Trump promised even higher tariffs, up to the point of proposing to withdraw the Most Favored Nation clause, that would make an all-out trade war inevitable (Fasulo, 2024). Trump's high tariff proposals are not only aimed at China, but at all exporters including Mexico and the European Union. For example, Trump has threatened to impose tariffs of up to 200% on vehicles imported from Mexico, which would lead to the crisis of currently functioning global supply chains. The effects on the prices of these goods for American consumers are difficult to predict, but considering the market shares of Chinese companies, they will be significant. By reducing the openness of the US market, tariffs will force China to shift to other markets, which could lead to cascading effects of tariffs in many other countries, further increasing uncertainty about the prices path. Equally difficult to predict is the effect of decoupling on innovation: by trying to reduce dependence on Chinese imports, the US risks delays in innovation that may undermine US competitiveness in the long run. While the Biden administration has taken many initiatives to incentivize domestic production through subsidies and other fiscal incentives, this is not easy to achieve as China and other countries have secured most CRM supplies.

The EU's trade policy will have to take this new framework into account (Fasulo, 2024). The first signs of the new attitude were the clash over Chinese subsidies to its car manufacturers, with Chinese retaliation on dairy products imported from the EU (Torbidoni, 2024). However, passing such tariffs was not an easy path in the EU deliberation process: although countries such as Italy and France were in favour, other countries, such as Germany and Hungary, were skeptical due to the risk of deteriorating diplomatic relations with China. The way in which the decision was reached reflects the EU approach towards China and its trade relations in general. It is attempting to follow both the path of economic protectionism and of defending the free market (Bounds and Inagaki, 2024). The EU would prefer negotiated solutions, including through voluntary price controls, but this strategy is unlikely to work in the new phase. The Draghi report highlights in several steps the need for a significant change in EU trade policy towards US and China. Furthermore, the demands of the transition towards low emissions lead to the need to protect the Union from excessive dependencies on supplies of CRM. In a decoupling process between Chinese and American economies, this objective is very complex.

The impact of this new uncertain context on investments for the transition could be significant. It is clear that now these investments cannot be considered only taking into accounts their return, geopolitics will be more and more the driving force behind investment.

5. An empirical analysis of the impact of geopolitical tensions on the transition

5.1 Scientific literature

CRM are crucial for the transition and their limited availability and concentration in some countries gives rise to inevitable connections with geopolitical aspects especially as far as the supply chains are concerned. Our aim is therefore to evaluate the impact and influence that these risks can have on the ability of a country to develop a coherent transition path. In particular, we will focus on how geopolitical tensions can influence investment flows in green energies and productions. In recent years, scientific literature has explored the links between geopolitical risk, as measured and developed by Caldara and Iacoviello (2018), and renewable energy sources. More specifically, a number of studies analyzed the key variables for renewable energy from both an economic and political perspective (Bourcet, 2020). Focusing on the nexus between geopolitics and energy, assessed through geopolitical risk, most scholars have assessed this link with fossil fuels, with mixed results. Anser et al. (2021), for example, find a strong positive correlation between geopolitical risk and CO_2 emissions, especially if BRICS are considered. Similar results have been found if military power (Jorgenson et al., 2010) or terrorism are considered (Bildirici, 2021; Bildirici and Gokmenoglu, 2020). Abid (2016) also concludes that there is a positive relationship between political and economic instability and CO_2 emissions. Furthermore, Antonakakis et al. (2017), among the first to analyse the effects of geopolitical risk using the Caldara and Iacoviello index, have seen that a large part of the volatility of the oil market can be explained by the geopolitical risks. Therefore, an increase in economic uncertainty is followed by an increase in CO_2 emissions (Baker et al., 2016). Subsequent analyses have highlighted a negative correlation in the long term between renewable energy consumption and political uncertainty because greater uncertainty in economic policy causes a reduction in renewable energy consumption (Shafiullah et al., 2021). Thus, renewable energy markets are strongly connected to important political decisions, also because geopolitical risk heavily influences private investments (Bilgin et al., 2020). Pan (2019), underlining the strong dependence of renewable energy sources on R&D activity, also finds a negative relationship between geopolitical risk and investments. Sweidan (2021a, 2021 b) shows that geopolitical risk significantly influences the diffusion of renewable energy in the US via the volatility of yields and prices. On the contrary, Balcilar et al. (2019) highlight how uncertainties about future economic policies negatively affect the growth of renewable energy reducing the connected investment. All in all, geopolitical issues have significant impacts on financial and raw material markets, including CRM. This has been shown particularly relevant for Europe (Balcilar et al., 2019).

5.2 The data

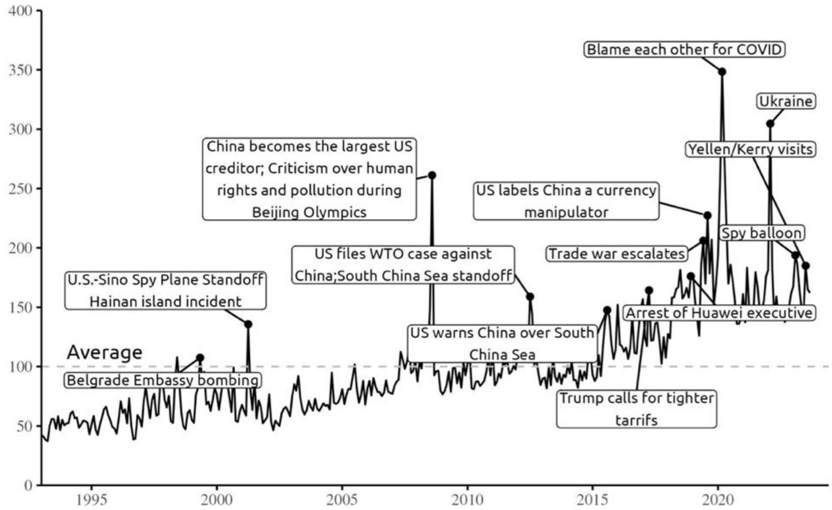
The research question we investigate is the link between the leading country in the renewable energy sector, China, and the other major global economic power, the United States, characterized by significant mutual trade dependencies. We use the data from 2000 to 2023 that is when China emerged as main industrial power and the economic interdependence with the US has become relevant. More in detail, we focus on the effect that export restrictions have on the US approach to renewable energy. Given the data available, we use the green Electricity Installed Capacity (EIC), which represents the maximum production capacity of electricity that can be generated at a given time by a particular plant, expressed in megawatts[8]. This choice is justified by the high correlation between renewable investments and EIC in the US. In fact, data show that investment choices in the US renewable energy sector are significantly reflected in the country's EIC (See the following table).

Multiple R	0,99					
R^2	0,98					
Adjusted R^2	0,85					
Standard deviation	42227,8					
Observations	9					
	Degrees of Freedom	*SQ (Sum of Squares)*	*MQ (Mean Squares)*	*F - Statistic*	*Significance F*	
Regression	1	651.652.962.258,15	651.652.962.258,15	365,44	0,00***	
Residual	8	4.265.493.102,54	1.783.186.637,82			
Total	9	665.918.455.360,69				
	Coefficients	*Standard Error*	*T- Statistic*	*P - value*	*Lower 95%*	*Upper 95%*
Intercept	0					
Renewable Investment	0,00	0,00	19,12	0,00***	0,00	0,00

(Table 1: Renewable Investment-EIC correlation; Source: IRENA 2024 and IEA 2024)[9]

On the geopolitical level, the first index taken into consideration is the Policy-related Economic Uncertainty index (EPU), that indicates the media coverage of uncertainty related to economic policies through the analysis of articles from the ten most important US newspapers. Among the component of the EPU we consider specifically the Trade Policy Uncertainty index (TPU), which represents the uncertainty related to US trade policy and whose construction is similar to that of the EPU. Finally, we consider the US–China Tension index (UCT) also built following the methodology used for the EPU[10]. The index's fluctuations appear to be aligned with the frequency of interventions about the US-China tension, for instance in corporate earnings updates and in presidential speeches. All these indices are normalized with monthly data in order to obtain an average of 100 within the sample (see next graph).

[8] EIC data have been taken from the IRENA dataset (https://www.irena.org/Publications/2024/Jul/Renewable-energy-statistics-2024). We considered only renewable energy production (in particular: biogas, geothermal energy, liquid biofuels, marine energy, mixed hydroelectric plants, multiple renewable energies, offshore wind energy, onshore wind energy, other renewable energies, renewable hydroelectric energy, renewables, solar energy, photovoltaic solar energy, solar thermal energy). The ensuing data set is not very long (24 observations). However, previous data are not reliable neither interesting in the present situation.
[9] Here, and hereafter, significance codes are: * p<0,5, ** $p < 0.05$, *** $p < 0.01$.
[10] https://www.policyuncertainty.com/US_China_Tension.html.



(Figure 5: US-China Tension index 1993 – 2024; source: Economic Policy Uncertainty, 2024).

To improve the robustness and reliability of the analysis results, three control variables were also considered to allow the isolation of the specific effects of political and trade tensions on the renewable electricity production capacity: WTI Crude–Oil price index (WTI); Industrial Production Index (IPI) and USD/CNY exchange rate (UCE). We summarize the variables used in the study in the following table:

Variable	Name	Definition	Source
EIC	Electricity Installed Capacity	The index shows the maximum capacity of a plant to produce electricity	IRENA: https://www.irena.org/Publications/2024/Jul/Renewable-energy-statistics-2024
UCT	U.S. - China Tension	The index quantifies the degree of tension between US and China over economic policies, including trade relations	Economic Policy Uncertainty: http://www.policyuncertainty.com/
EPU	Policy-related Economic Uncertainty	The index quantifies the degree of uncertainty about economic activity resulting from changes in US policies	Economic Policy Uncertainty: http://www.policyuncertainty.com/
TPU	Trade Policy Uncertainty	The index quantifies the degree of uncertainty about economic activity resulting from changes in US trade policies	Economic Policy Uncertainty: http://www.policyuncertainty.com/
UCE	Dollar-Renminbi rate of Exchange	Exchange rate between the US dollar and the Chinese renminbi	Federal Reserve Board: https://fred.stlouisfed.org/series/DEXCHUS
WTI	WTI Crude Oil	US crude oil price	Federal Reserve Board: https://fred.stlouisfed.org/series/DCOILWTICO
IPI	Industrial Production Index	The index highlights the level of production of manufacturing, mining, electricity, and gas industries	Federal Reserve Board: https://fred.stlouisfed.org/series/INDPRO

(Table 2: Variable definitions)

5.3 Methodology

We use a multivariate linear regression analysis using a backward approach, a method that involves the initial use of all the variables, dependent, independent and control, into the regression equation. This approach is suitable for a short-term evaluation such as the one related to our case and it involves a progressive elimination of non-effective variables. We model the relationship that highlights the effects of the independent variables on the dependent variable in the US in year t as follows:

(1) $\boldsymbol{EIC}_{USA,t} = b_0 + b_1 UCT_{USA,t} + b_2 EPU_{USA,t} + b_3 TPU_{USA,t} + b_4 UCE_{USA,t} + b_5 WTI_{USA,t} + b_6 IPI_{USA,t} + \varepsilon_{USA,t}$

The multivariate linear regression equation sees $\boldsymbol{EIC}_{USA,t}$ modeled on the basis of all the independent and control variables. The coefficient b_0 represents the intercept of the model, i.e. the value of the dependent variable when all the other independent variables are equal to zero. The other coefficients, from b_1 to b_6, represent the effect that each variable has on EIC, keeping all the other variables within the model constant. Variables $UCT_{USA,t}$, $EPU_{USA,t}$, $TPU_{USA,t}$, $UCE_{USA,t}$, $WTI_{USA,t}$, $IPI_{USA,t}$ have the meaning described in the table 2 and $\varepsilon_{USA,t}$ represents the error term. The descriptive statistics of our model are the following:

	EIC	UCT	EPU	TPU	UCE	WTI	IPI
Mean	175131,47	110,51	107,68	115,81	7,13	63,38	97,04
Standard error	17306,28	7,40	9,43	35,057	0,16	4,98	0,987
Median	155615,08	98,35	109,89	58,71	6,86	64,23	98,32
Standard Deviation	84782,90	36,26	46,18	171,74	0,78	24,39	4,83
Sample Variance	7188140626	1315,04	2132,28	29495,35	0,61	595,036	23,34
Kurtosis	0,49	-0,069	7,67	11,48	-1,32	-1,23	-0,83
Asymmetry	1,07	0,75	2,15	3,30	0,53	-0,02	-0,51
Interval	294567,13	140,35	222,81	768,38	2,14	73,34	16,36
Minimum	90637,86	59,19	56,06	28,74	6,14	25,24	86,80
Maximum	385204,99	199,54	278,87	797,12	8,28	98,59	103,16
Sum	4203155,24	2652,24	2584,43	2779,36	171,05	1521,13	2328,99
Observations	24	24	24	24	24	24	24
Confidence at 95% Level	35800,68	15,31	19,50	72,52	0,34	10,30	2,040

(Table 3: descriptive statistics)

6. The role of geopolitical set-up

We start from the correlation matrix:

	EIC	UCT	EPU	TPU	UCE	WTI	IPI
EIC	1						
UCT	0,85**	1					
EPU	0,38*	0,54	1				
TPU	0,37*	0,54	0,096	1			
UCE	-0,54	-0,55	-0,21	-0,14	1		
WTI	0,25*	0,20	0,01	-0,14	-0,66	1	
IPI	0,62**	0,58	-0,23	0,32	-0,50	0,47	1

(Table 4: Correlation matrix)

Correlation analysis highlights a strong positive relationship between EIC and UCT. This result shows that when the tension index increases, renewable energy production also undergoes a significant increase. As for the correlation with EPU, we note that there is a more moderate correlation (less than 40%), showing that, although to a lesser extent, the uncertainty associated with economic policies is also correlated to an EIC increase. As far as the other indices are concerned, they also highlight a positive relationship, although even less remarkable. The correlation between the Dollar-Renminbi exchange rate is negative, showing that an appreciation of the US dollar is associated with a reduction in the EIC while the other control variables show positive correlations. On the basis of these results, we proceed with the backward multivariate linear regression. The first regression will include all the variables considered so far.

Multiple R	0,98					
R^2	0,95					
Adjusted R^2	0,89					
Standard deviation	47715,59					
Observations	24					
	Degrees of Freedom	*SQ (Sum of Squares)*	*MQ (Mean Squares)*	*F - Statistic*		*Significance F*
Regression	6	860.449.982.339,5	143.408.330.389,9	63,0		0,0***
Residual	18	40.982.001.214,9	2.276.777.845,3			
Total	24	901.431.983.554,4				
	Coefficients	*Standard Error*	*T - Statistic*	*P - value*	*Lower 95%*	*Upper 95%*
Intercept	0	-	-	-	-	-
UCT	2205,92	686,35	3,21	0,00**	763,96	3647,89
EPU	-235,08	329,33	-0,71	0,48	-926,98	456,82
TPU	-75,81	77,90	-0,97	0,34	-239,47	87,85
UCE	-9095,64	20746,46	-0,44	0,67	-52682,34	34491,06
WTI	-98,80	662,92	-0,15	0,88	-1491,54	1293,95
IPI	378,49	2230,90	0,17	0,87	-4308,47	5065,45

(Table 5: correlation with all the variables)

The analysis highlights that there is a strong correlation between the dependent variable, the independent and the control ones, supported by a very high multiple R; moreover, it shows that the regression model is adequate and robust with high correlation. As for the intercept, this was not included in the model as it was found to be non-significant in the previous regression. Secondly, the significant independent variable is UCT, showing that an increase in US-China tension has a positive impact on EIC. The other variables do not show a significant role. Overall, the particularly low value of F underlines that at least one of the independent variables has an effect on UCT. In order to bring out more clearly this connection, we continue with the backward analysis excluding the most non-significant variables (IPI, WTI, and UCE).

Multiple R	0,97					
R^2	0,95					
R^2 adjusted	0,90					
Standard deviation	46756,98					
Observations	24					
	Degrees of Freedom	*SQ (Sum of Squares)*	*MQ (Mean Squares)*	*F - Statistic*	*Significance F*	
Regression	3	855.521.457.725,90	285.173.819.241,97	130,44	0,00***	
Residual	21	45.910.525.828,54	2.186.215.515,64			
Total	24	901.431.983.554,44				
	Coefficients	*Standard Error*	*T - Statistic*	*P - value*	*Lower 95%*	*Upper 95%*
Intercept	0	-	-	-	-	-
UCT	2010,23	293,93	6,84	0,00***	1398,97	2621,49
EPU	-339,48	258,13	-1,32	0,20	-876,28	197,32
TPU	-55,33	67,54	-0,82	0,42	-195,79	85,13

(Table 6: correlation with the significant variables)

In this analysis correlations remain particularly strong. The positive impact that the UCT variable has on the EIC variable emerges even stronger. The p-value for the remaining variables also decreased. The regression that follows has the aim of concentrating the analysis on US–China tensions more relevant aspect, highlighting how significantly they influence renewable investment. The other indices of uncertainty (EPU and TPU) are eliminated.

Multiple R	0,97					
R^2	0,94					
R^2 adjusted	0,90					
Standard deviation	46641,92					
Observations	24					
	Degrees of Freedom	*SQ (Sum of Squares)*	*MQ (Mean Squares)*	*F - Statistic*	*Significance F*	
Regression	1	851.396.193.687,32	851.396.193.687,32	391,36	0,00***	
Residual	23	50.035.789.867,12	2.175.469.124,66			
Total	24	901.431.983.554,44				
	Coefficients	*Standard Error*	*T - Statistic*	*P - value*	*Lower 95%*	*Upper 95%*
Intercept	0	-	-	-	-	-
UCT	1622,68	82,02	19,78	0,00***	1.453,00	1.792,36

(Table 7: EIC-UCT correlation)

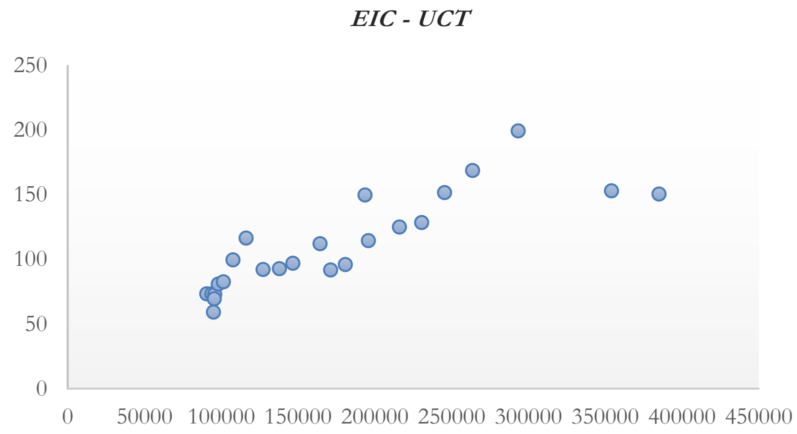
The model maintains its high level of robustness and explanatory capacity and, it is highly significant. The further reduction of the p–value in the transition from a multivariate linear regression to a simple linear regression shows that the UCT variable emerges as the only relevant and significant variable with a strong positive relationship between EIC and UCT.

In order to delve deeper into the impact of the geopolitical context on the approach of US to renewable energy, it is important to investigate the exchange rate dynamics. In this regard, the negative correlation between UCE and EIC that emerged in the analysis of the correlation matrix and in the multivariate linear regression requires further investigation. We therefore conducted a simple linear regressive analysis to investigate more clearly the link between US-China exchange rate and the EIC. The following table highlights the results of the analysis.

Multiple R	0,87					
R^2	0,76					
R^2 adjusted	0,72					
Standard deviation	96020,46					
Observations	24					
	Degrees of Freedom	*SQ (Sum of Squares)*	*MQ (Mean Squares)*	*F - Statistic*		*Significance F*
Regression	1	689.374.000.000	689.374.000.000	74,77		0,00
Residual	23	212.058.000.000	9.219.927.848			
Total	24	901.432.000.000				
	Coefficients	*Standard Error*	*T - Statistic*	*P - value*	*Lower 95%*	*Upper 95%*
Intercept	0	-	-	-	-	-
UCT	23.645,20	2.734,51	8,65	0,00	17.988,44	29.301,97

Table 8: EIC-UCE correlation.

Data show a robust positive relationship, in contrast with what emerged through the correlation matrix and the first regression. An explanation for this inconsistency may be the presence of multicollinearity within the model. To prove this, we performed a test calculating the Variance Inflation Factor (VIF) that highlighted the presence of multicollinearity for approximately 50% of the variables in the model. Another explanation could lie in the presence of one or more variables that mediate the relationship between EIC and UCE. We leave these discrepancies for future research. The continuous reduction of the p–value in the transition from a multivariate linear regression to a simple linear regression shows that the UCT variable emerges as the only relevant and significant variable with a strong positive relationship between EIC and UCT (se the following graph).



(Figure 6: EIC – UCT Dispersion).

7. Conclusions

This study aimed at appraising the effect of both the US-China tension index (UCT) and the USD/CNY exchange rate on the approach to production and investment in renewables in the US using the US Electricity Installed Capacity (EIC) in the period 2000–2023. We used these variables to highlight how geopolitical uncertainties and, in particular, tensions in bilateral trade relations, affect investment in energy transition. In a situation characterized by a race to control CRM, to reduce dependence on other blocs' countries, also using export restriction measures, we analyse the influence of geopolitical factors on US investment in clean energy. We found that an increase in tensions in the bilateral trade relations and, in general, an increase in uncertainty in the geopolitical context, can act as a stimulus for the renewable energy sector. In other words, the transition becomes a weapon in the new cold war. Provided that a too quick transition is unfeasible, US investment decisions in the field of renewable energy are a significant indicator of the attempts to decouple from China. Therefore, the positive relationship between UCT and EIC that we found may reflect a prudent strategy in the implementation of renewable energy that materializes in the willingness of US financial institutions to persist in brown investments and financing as long as the transition seems a long and complex path. This means that funding the transition will fall more on government than on the markets. This could explain trade tariffs and the US trade policy more broadly. However, the strength of the dollar and the efficiency and liquidity of US financial markets can help to channel private investment towards the transition. On the other side, a stronger dollar makes Chinese product more competitive thus pointing to an extension of the trade war.

All in all, our results confirm that the investment decisions concerning the transition are more and more connected to the international situation in terms of the reshaping of the global supply chains due to the new cold war. What will make green economic sense in the next years is not much the result of the comparison of different investment returns but the molding of the pieces on the chessboard game between the Eastern and Western blocs.

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