CENTS: A Research Network for the Sustainable Transport Community

Circular Economy Network+ in Transportation Systems

British Geological Survey

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CENTS Feasibility Funding Case Study:
Learning from history - The impact of extreme shocks on raw material supply chains for the transport manufacturing sector

Executive summary

The project investigated the impact of extreme shocks or crises on mineral supply and demand dynamics. The objective was to evaluate the impact of the event, including the duration of its effects on mineral supply, and the time taken for mineral production to recover. The research focussed on aluminium, nickel and cobalt, three metals essential to the transport sector, and each having different supply-demand characteristics.

The research shows that historical shocks (e.g. pandemics and financial crises) have had a significant impact on the production of these metals. However, it is difficult to draw direct comparisons between historical events and Covid-19, as the current pandemic is unprecedented in terms of its magnitude, uneven global impact and rates of recovery, varied international policy responses, and the scale of the shock to the world economy. Government stimulus packages and vaccine-driven reopening of the global economy should result in gradual strengthening of raw material demand. However, Covid-19 has clearly exposed the vulnerabilities associated with complex, global supply chains that are supporting the UK economy. The long-lasting effects of the Covid-19 pandemic on primary raw materials production, as a result of reduced investment in the exploration and mining sectors is unclear. Coupled with the impact of Covid-19 on waste systems and a recession that may keep products and materials in use longer, it may setback efforts to develop a circular economy.

The study involved compiling datasets of annual production of mined mineral ores and their refined products for three commodities (aluminium, cobalt, nickel), by country for more than a century (1913–2018). The mineral commodity data was compared with other time-series data (e.g. energy consumption, crude oil, gold price and the FTSE index), to explore the relationship between mineral production and the global economy.

Indices (e.g. market share, production concentration ratio, Hirschman-Herfindahl Index) that measure market diversity, were calculated for each commodity to understand how their global production has evolved during the last hundred years.

The mineral commodity production data and calculated indices were studied in the context of major historical events (i.e. world wars, pandemics, financial crises) to understand their effect on mineral production, rates of recovery and the time lags involved.

Project Team

Pierre Josso (PI – early career researcher): Minerals Geoscientist, BGS

Paul Lusty: Principal Economic Geologist and BGS Critical Raw Materials Lead, BGS

Teresa Brown: Mineral Commodity Geologist, BGS

Eimear Deady (early career researcher): Minerals Geoscientist, BGS

Naomi Idoine: Administrator Economic Minerals, BGS

Carolin Kresse (co-I – early career researcher): Mineral Commodity Geologist, BGS

Project Rationale

This is the first project to assess the impact of major global crises, spanning more than a century, on the production of mineral commodities that are essential for transportation, using the BGS world mineral database.

Key Findings

1) Historical events that have led to health or economic crises are indicative of how contemporary mineral markets may respond. However, they do not provide a good proxy for the longer-term effects of the Covid-19 pandemic on mineral supply and demand and the circular economy. This is because the current pandemic represents an unprecedented shock to the economy and may result in fundamental changes to consumer and societal behaviours.

2) The transportation sector is dependent on some mineral raw materials that have highly concentrated production and associated security of supply risks. This risk could be reduced through diversification of primary production, improved understanding of global supply chains and greater domestic recycling of metals.

Background

Decarbonising the UK economy to tackle climate change requires fundamental changes to our transport and energy production systems, which will require vast quantities of mineral raw materials. Covid-19 had a significant impact on the production of some minerals and metals, disrupted international trade, exposed the fragility of global supply chains, and has led to an unprecedented recession. Understanding the potential rates of recovery of global mineral production and supply chains is of critical importance for the UK transportation sector, which is under growing pressure as a result of recently announced plans to accelerate a greener transport future. The project aimed to assess the potential magnitude and duration of the effects of the Covid-19 pandemic on mineral raw material supply, by studying how past crises have affected the supply and demand dynamics of three mineral commodities.

Results

Global mineral production trends

Aluminium production has increased annually, by on average 10, 2 and 5 per cent during the periods of 1945–1974, 1975–2000, and 2001–2018, respectively. The period when annual production increased the least correlates with highly fluctuating energy prices associated with the two oil shocks of 1974 and 1979. Global production has become dominated by China, where production increased from 24 to 57 per cent of total world production between 2005–2018.

Nickel production increased exponentially, by an annual average rate about 7 per cent between 1913–2018. Indonesia is the world's largest producer of mined nickel ores, but has caused significant uncertainty in the global market since 2014, as a result of a ban on the export of unprocessed ores, partial relaxation on export policies in 2017 and reimplementation of the ban in 2020.

Cobalt production levels since 1913 have been highly variable, owing to a range of factors including, substantial market volatility, evolving end-uses, government stockpiling, and production concentration in the Democratic Republic of Congo (DRC), which accounts for 65 per cent of global cobalt mine production. Since 1995, world cobalt mine production has increased annually by more than 9 per cent, with total production increasing from 35 000 tonnes in 2000 to 168 000 tonnes in 2018, principally driven by increased demand from the lithium-ion battery market.

Market evolution

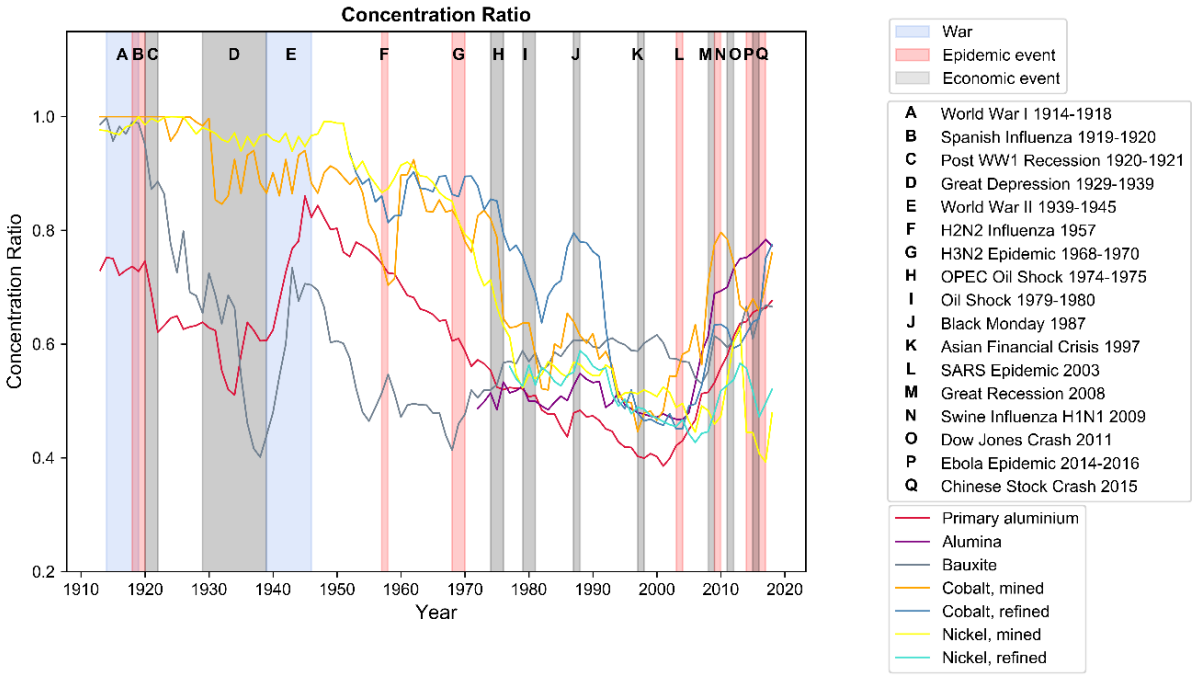

Figure 1: Concentration ratio represented by the summed share of the top three producers for each of the commodities considered.

Concentration ratio data for **nickel** and **cobalt** production have similar trends with diversification of the market and steadily decreasing dominance of the largest three (CR3) producers until 1997 for cobalt (CR3 = 0.45) and 2006 for nickel (CR3 = 0.45) (Figure 1). Cobalt is currently characterised by a monopolistic market (CR = 0.76), owing to 65 per cent of mine production being from the DRC. The concentration ratio of the nickel market fluctuates between 0.45–0.7 as a result of changes to Indonesia's export policies on nickel ore.

Primary **aluminium** production became increasingly concentrated during WWII due to growth in production in the United States, Canada, and Germany. After WWII the CR3 (lowest value in 2001 = 0.39) for **aluminium** decreased as the number of producing countries grew year-on-year until 1974, and subsequently their market share expanded. It reached its lowest value in 2001 (CR3 = 0.39). However, since then the market has changed to become oligopolistic with a CR of 0.68, as China accounted for 57 per cent of world production in 2018.

The impact of selected crisis on mineral production

The impact and duration of effects on mineral production arising from the events considered are summarised in Table 1. Figure 2 illustrates how each event was analysed to populate Table 1.

Event	Period	Comments/Caveats	Primary Al	Bauxite	Alumina	Nickel, mined	Nickel, refined	Cobalt, mined	Cobalt, refined
WWI	1914-1918	War economies drove higher production of most metals							
Spanish Flu	1919-1920	Normalisation to WWI years. Transition from war to peace time economies	-50% in 1921	-60% in 1921		-75% in 1921		-75% in 1919-1921	
WWI recession	1920-1921								
Great depression	1929-1939		-20%/-50% for all commodities over a 3-5 year period. Recovery to pre-crisis levels in 1933 for Co, 1934 for Ni, 1935 for Al						
WWII	1939-1945								
H2N2 influenza	1957		No discernable effects			-18% in 1957		-3% in 1957	
H3N2 influenza	1968-1970		No discernable effects						
OPEC oil shock 1	1974-1975		-7% in 1975 compared to 1974			No discernable effects		-45% in 1975	-17% in 1975
Iran oil shock	1979-1980	transient event of increasing oil price by 250% over 2 year period, delayed reaction from the mining sector	successive -2% and -11% in 1980-81	successive -3% and -18% in 1980-81	successive -8%, -7% and -3% in 1980-81-82	successive -5% and -12% in 1980-81	successive -5% and -10% in 1980-81	successive -15%, -25% and -8% in 1980-81-82	successive -14%, -26% and -7% in 1980-81-82
Black Monday	1987		No discernable effects						
Asian financial crisis	1997		No discernable effects						
SARS	2003		No discernable effects						
Great recession	2008	Rapid recovery in the following year. Impact on cobalt potentially hidden by surge in production in DRC	-7%	-7%	-7.3%	-13%	-5%	Drop in Canada's production	
Swine Flu	2009		No discernable effects						
Dow Jones Crash	2011		No discernable effects					-6%	-5%
Chinese Stock Crash	2015-2016	Major reduction in Ni global production from Indonesia ore export ban		-2.5%				-6%	

Table 1: Summary of the effects of global-scale shocks during the 20th and 21st centuries on mineral production.

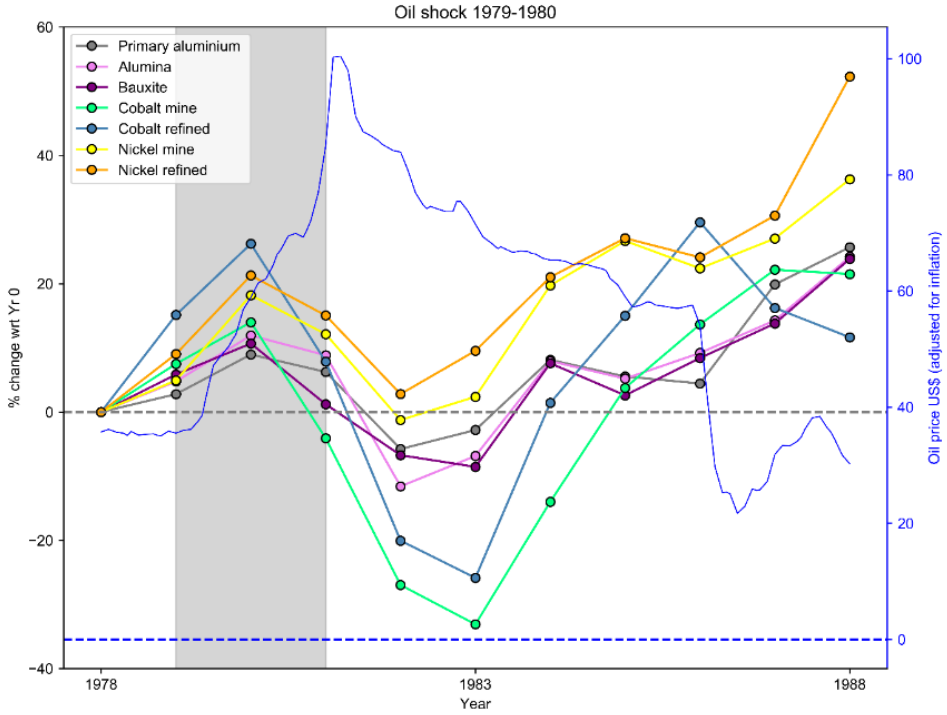

Figure 2: Mineral production normalised to 1978 to illustrate the effect of the Iranian oil shock of 1979–1980.

Comparison of the impact of Covid-19 with previous shocks

Previous pandemics and health emergencies are incomparable with the Covid-19 pandemic, because they either only had relatively restricted, regional impacts (e.g. Ebola, SARS, Swine Influenza), or the socio-economic conditions at the time (e.g. Spanish Influenza) contrast strongly with the contemporary globalised economy.

Historical economic recessions and energy crises demonstrate the variable duration of impacts on mineral production. The oil shocks of 1974 and 1979 caused world production of the commodities studied to decline for up to three years. The more severe economic effects of the Great Depression of 1929 resulted in decline in the production of these commodities for up to six years.

When major economic crises over the last 40 years and their impact on commodity prices, and supply and demand dynamics are examined, four distinct phases can be recognised (Figure 3).

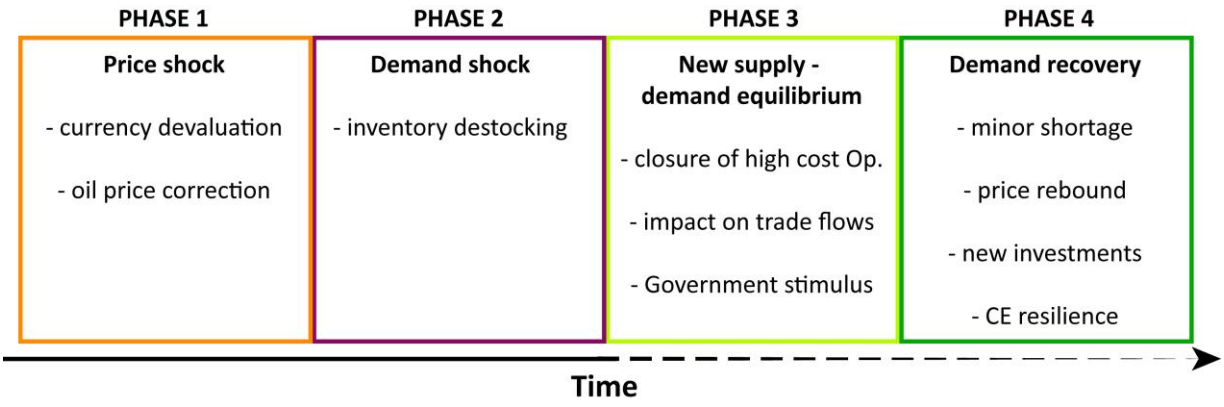

Figure 3: The four phases of a major economic crisis as defined by [1].

Phases 1 and 2 of the Covid-19 economic crisis extended from March 2020 to present. The length of phases 3 and 4 will be dependent on the speed of the global vaccine roll-out, the willingness of governments to open up the economy, including for international travel, economic stimulus packages, and any sustained or long-term changes in consumer and societal behaviour.

[1] McKinsey and Company (July 2020). Lessons from the past: Informing the mining industry's trajectory to the next normal. https://www.mckinsey.com/industries/metals-and-mining/our-insights/lessons-from-the-past-informing-the-mining-industrys-trajectory-to-the-next-normal

Impact

Understanding the magnitude and potential duration of the impacts of the Covid-19 pandemic on the supply and demand dynamics of mineral commodities is vital for assessing supply chain risk, and ensuring secure and sustainable supply of mineral raw materials for the UK. This research highlights that three mineral commodities on which the green transport revolution is dependent have had volatile supply-demand histories, that during the last 100 years their production has been affected and evolved in response to global crises, and security of supply risks remain, principally owing to the concentration of primary production. This research highlights to those that are less familiar with the relationships between mineral production, security of supply and global economic cycles related to crises that some of the technologies and ambitions identified for delivering our Industrial Strategy (e.g. "…put the UK at the forefront of the design and manufacturing of zero emission vehicles.") are dependent on supplies of mineral raw materials, which are subject to potential supply disruption because of various factors such as pandemic restrictions, geopolitical actions or ethical concerns. It will hopefully strengthen interdisciplinary cooperation to address this issue, by pursuing a range of options, including: improving understanding of UK import dependence on mineral raw materials and global supply chains; strengthening trade relationships with countries that dominate the production of minerals or have significant undeveloped resources of minerals essential to the transportation sector; and assessing the potential for domestic primary production, alongside greater recovery and recycling.

Next Steps

This project has led to many new potential research ideas, including: ongoing, long-term (2, 5 and 10 years) assessment of how the Covid-19 pandemic has affected world mineral production. This will be useful to map the long-term impacts and the optimum points to intervene in supply chains to improve resilience and sustainability, particularly during periods of global crisis.

The results provided here are a brief summary of a much more detailed analysis and description of how historic crises have affected world mineral production. The project team, led by Dr Josso, plan a peer-review publication based on the project outlined above. The project team is currently developing a new proposal to submit to the CENTS 2nd Call for Feasibility Studies. This is based on assessing the contribution that secondary resources can make to the supply of battery raw materials to the UK transport sector, based upon the products currently in use and how this will change with time.

Testimonials

From the Early Career Researcher(s)

"The knowledge and skills of the ECRs have been greatly enhanced by participation in this CENTS project. Detailed investigation of the supply-demand dynamics of mineral commodities is a relatively new research area for one of the ECRs, meaning they have developed knowledge and recognise the research potential associated with an almost entirely new discipline. Furthermore, although they have worked in the general field of economic geology for some time this has provided them with additional context to the strategic importance of their role. The research has required the ECRs to familiarise themselves with BGS and other relevant time-series datasets, and develop new statistical analysis skills, including those for coding (using R and Python). These were necessary to manipulate the large datasets and effectively display them in a graphical form. As the feasibility study was led by an ECR, it has provided an excellent opportunity to develop research proposal writing skills, and undertake project and team management.

The overall support from the CENTS network has been excellent, with prompt responses and clear guidance throughout the project. The CENTS network has provided an opportunity to engage with researchers from outside our existing range of collaborators. The invitation to attend and actively participate in the road-mapping exercise was greatly appreciated and inclusive. Discussions in the break out groups provided exposure to the broad range of socio-economic factors and design considerations that will influence the role of the circular economy in transport systems, and have provided some stimulation for future research ideas." Pierre Josso