## Research questions

The main research question follows from the problem statement, knowledge gaps and project objective.

***What is the supply chain resilience of Cobalt?***

**What is resilience?**

“The adaptive capability of a supply chain to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover and respond by immediate and effective reactive plans to transcend the disturbance and restore the supply chain to a robust state of operations” (Kamalahmadi & Parast, 2016).

**Data**

PANORAMA

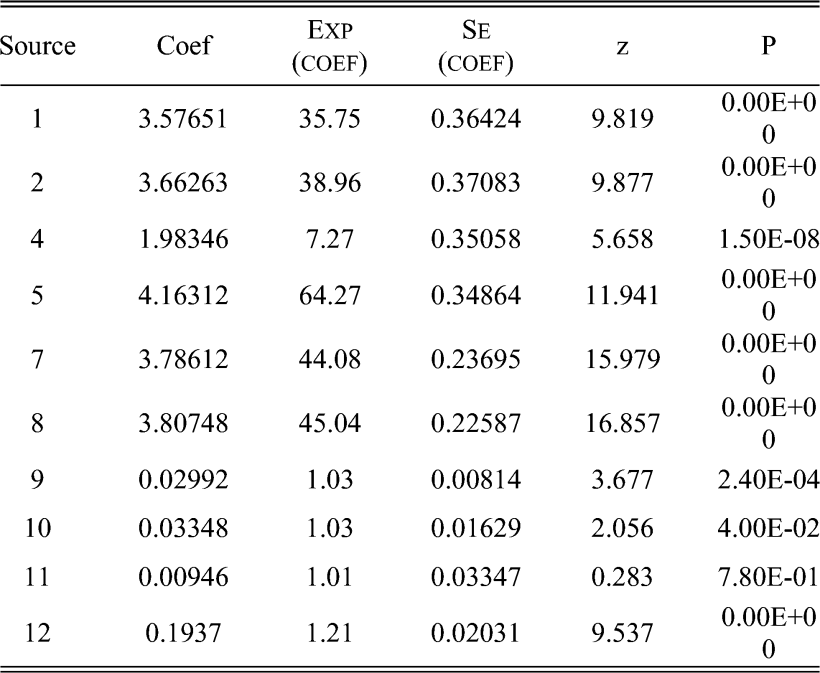
Cobalt paper excel sheet (compilation of many different sources)

# Cobalt ores and concentrates exports by country**(in 2019)**

**How do we measure resilience?**

Resilience will be measured based on the network configurations of efficiency and redundancy

1. ENA – examine redundancy and independence
   1. Calculating the alpha value – efficiency and redundancy of SC by primary + semi-refined material
   2. Calculating independence - of SC by primary + semi-refined material
   3. *Creating a cobalt network diagram – examining the links*
2. Cox PH model – survival of the system
   1. Disruption types – Based on their frequency of occurrence, SC risks that occur regularly are: supply risks, process risks, demand risks, intellectual property risks, behavioral risks, and political/social risks (Tang and Tomlin [2008](https://link-springer-com.tudelft.idm.oclc.org/article/10.1007/s10479-020-03912-1#ref-CR128));
   2. Coding using R: <http://www.sthda.com/english/wiki/cox-proportional-hazards-model>



1. Geopolitical risk calculation
   1. Cobalt mentioned in discussion section of paper: <https://onlinelibrary.wiley.com/doi/full/10.1111/jiec.12279?casa_token=S_y7J35sWVIAAAAA%3AijySj49Yk_ki6MIE3ED8-fPLl__aFSGOVXYWkBafOTuqKAP25d05FyF1SD-gg0ixigfDli6FpOqFkkQ>

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| **Research Questions** | **Method** | **Tools** |
| What has the resilience of cobalt products been over the past 10 years? | Calculating alpha for cobalt products over a time series (i.e., 2009 – 2019) | Python |
| Which cobalt products are the most vulnerable to supply chain disruptions? | Which products have high alpha values (overly efficient)   * Also find which EU countries are affected (which EU countries import these products) | Python |
| Which level of the supply chain is most vulnerable to supply chain disruptions? | Separate products by the stage of production and explore the alpha values per stage in the supply chain (raw materials, (refined?), semi-finished products, finished products) | Python |
| What is the global supply chain network of vulnerable products? | Seeing which products have high alpha values and are most relevant for the green transition from these high alpha values (i.e., lithium-ion batteries, magnets (for wind turbines), smart technology, etc.)  Mapping the supply chain network of these products (5-ish products)  Conducting a centrality analysis on the network to see the vulnerabilities of the supply chain (geographical locations)   * Degree centrality – important nodes have many connections * Betweenness centrality - important nodes connect other nodes   Compare the countries with the highest centrality to a geopolitical risk index (International country risk guide – July 2016 table) | Python  Package: pyvis, networkx |

**Data:**

* BACI Database

Amount of cobalt needed will need to increase by 14x by 2050