“The Raw Material Risk of the Energy Transition”

Outline:

1. Introduction

The rapid development of Solar PV, Windmills, and Energy Storage requires a substantial amount of raw materials and production (mining) capacity to be able to meet the demand for clean electricity set by policies. An important factor in overcoming the challenges lying ahead, like the high face value of green technologies – (C. King, 2018), is designing policies and regulations that are based on informed decisions. Three factors need to be taken into consideration when designing policies for the short and long-term future: the price of metals and minerals, the production of metals & minerals, and the economic activity during the energy transition process.

In this paper, I measure and forecast the relationship between metals & minerals prices, metals & minerals production, and economic activity and their impact on one another. I built a structural Vector Auto Regression model where I make forecasts via impulse response functions on the metal & minerals production and prices and estimate supply elasticities.

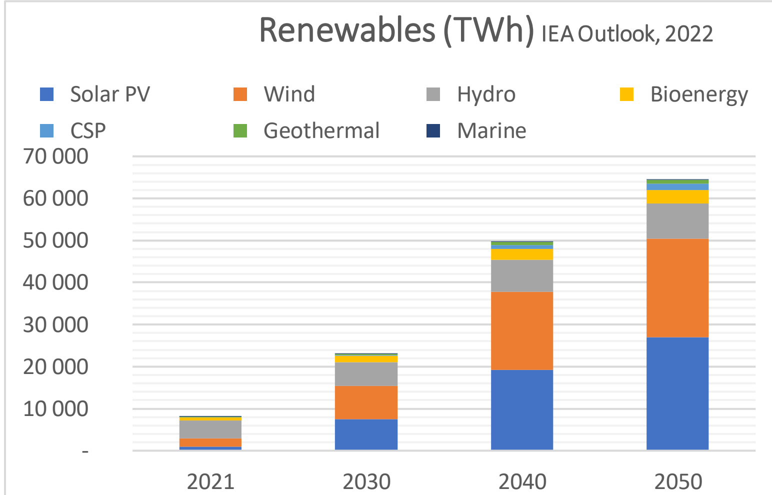
2. The Net-Zero-by-2050 Roadmap

On August 16th, 2022, the Biden administration of the United States of America, passed the "Inflation Reduction Act" which allocated $300 billion for deficit reduction and $369 billion for modernizing the American energy system and security. (DOE,2022) The aim of modernizing the energy system is to cut emissions by 40% compared to the 2005 levels by the year 2030 and come to a net-zero-CO2 by 2050. The department of energy (DOE) has estimated that the act will reduce emissions to about 1,000 million metric tons by 2030 which constitutes the average annual emissions amount of every US household. – DOE, In addition, such act aims to increase energy security, mitigate climate change, and improve human health prosperities. Economic dynamics are expected to change. Imposed carbon taxes and higher initial capital needed for renewables are expected to drop the US GDP by 2% by 2030 (IMF, 2022) , and in another estimation from 3% - 10% by the end of this century. (Federal Budget, 2022)

In 2018 a special report from Intergovernmental Panel on Climate Change (IPCC) stressed the importance of a net-zero target to avoid the catastrophic nature of climate change. (IPCC, 2018) Recently driven by the war in Ukraine governments have now as their main agenda energy security and independence, to secure a stable economy and healthy future. Net-zero pledges have been announced by governments and private corporations. As of 2021, 44 countries and the European Union have pledged to a net-zero policy, altogether accounting for 70% of the total global CO2 emissions. (IEA, 2021) Out of these governments, 10 of them have made it a legal obligation and another 8 are considering doing so as well.

3. Quantifying the net-zero-Co2 roadmap

The International Energy Agency (IEA) in a recent report, the World Energy Outlook 2022 (IEA Outlook, 2022), has forecasted what the global energy landscape could look like. The net-zero scenario has been forecasted for the global electricity sector. By 2050, renewable energy will hike to 88%, with nuclear at 8% and fossil fuels at 0%. Solar PV and Wind will meet the global electricity demand by 37% and 32% respectively, and together they will account for 78% of renewable energy generation. (IEA Dataset)

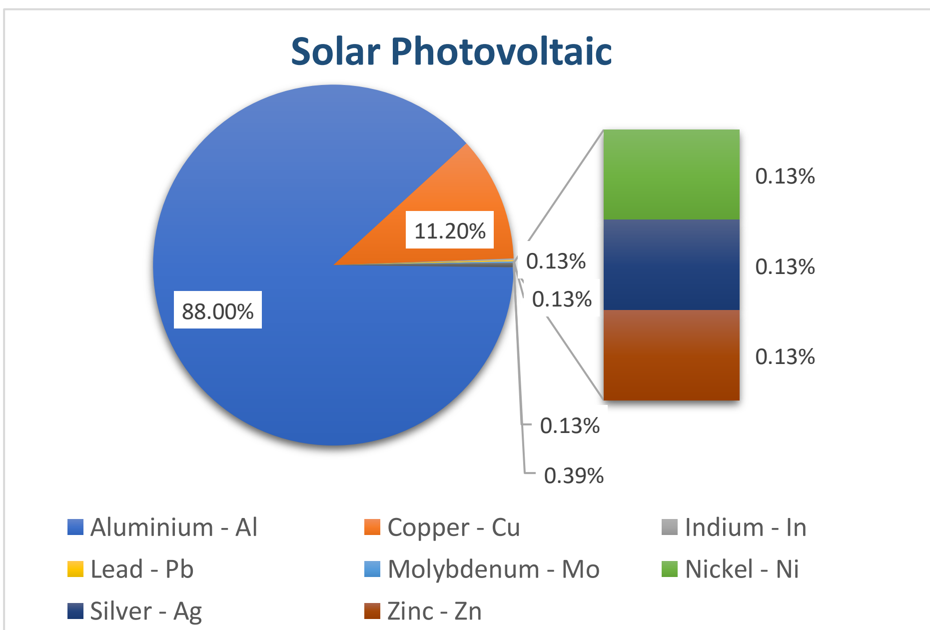


DATASET, IEA Energy Outlook, 2022

3.1 The mineral requirements of Solar PV and Windmills

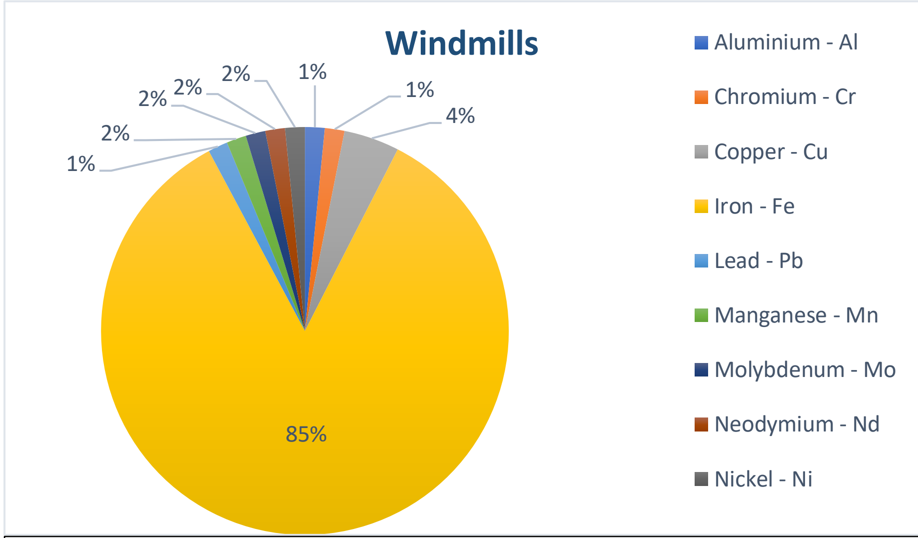
According to the IEA forecast, we notice the large share that Solar PV and Wind will have in meeting the global electricity demand. Also, we will consider Energy Storage as a complement to these technologies. The economic implications of these rapid developments lie in the raw materials needed to build Solar and Wind, moreover in the raw material prices and production. I will be referring to Solar PV, Windmills, & Energy Storage (Batteries) as SWB.

For Solar Photovoltaic systems, the main materials used are Aluminum at 88% and second comes copper at 11.2%. At a smaller amount but at high costs come Silver, Zinc, Lead, Indium, Nickel, and Molybdenum. (World Bank, 2020)



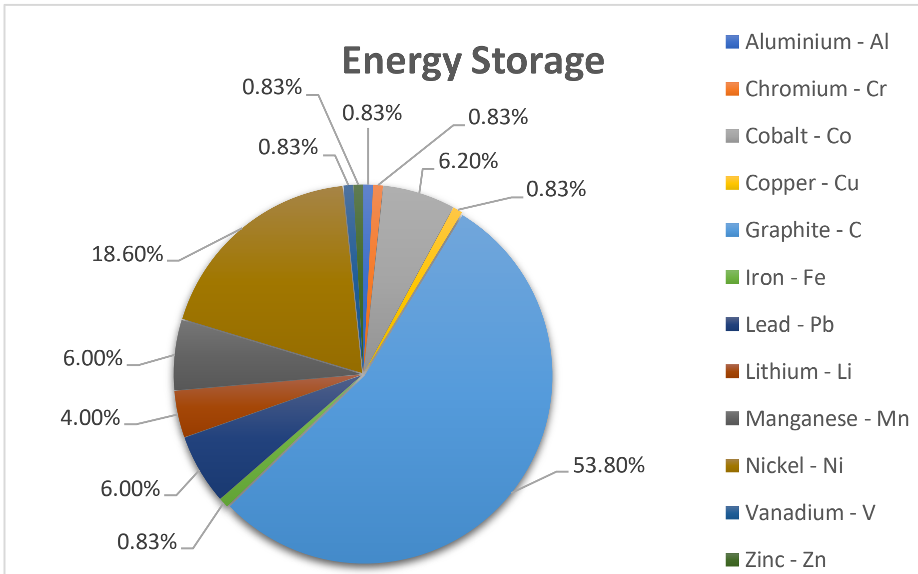
WORLD BANK, "The Mineral Intensity of Energy Transition," 2020

The major share of metals needed for windmills is Iron at 85%, Copper at 4.4%, and the rest follows with Aluminum, Chromium, Lead, and Nickel, mainly. ([World Bank, 2020](#))



WORLD BANK, "The Mineral Intensity of Energy Transition," 2020

The share of metals and minerals demand energy storage starts with Graphite at 53.8%, Nickel 18.6%, Cobalt 6.2%, Lithium 4%, Lead 6%, and Manganese 6.0%. ([World Bank, 2020](#))



WORLD BANK, "The Mineral Intensity of Energy Transition," 2020

3.2 High-Impact metal identification for Solar PV, Windmills & Energy Storage.

A High-Impact metal is a metal with wide usage across the three different technologies we are considering and a metal with high net usage. I call it the "cross-usage index". The values of weight and cross-usage are between 0% - 100%. A high percentage weight refers to a large share of raw metal needed for production. A high cross-usage percentage refers to a large adoption of raw metal across Solar, Wind, and Energy Storage technologies. I have identified four metals that have the strongest impact on Solar, Wind, and energy storage, those are *Aluminum*, *Copper*, *Nickel*, and *Lithium*.

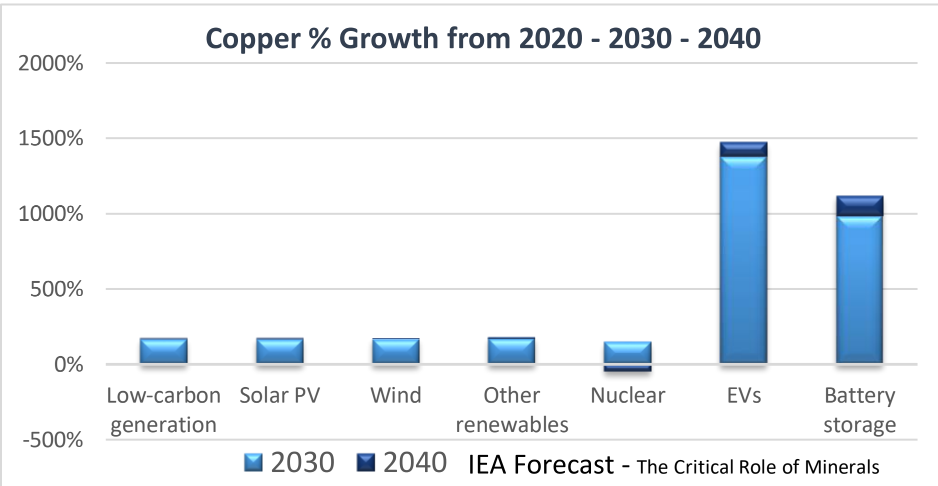
Metals	*Weight*	*Cross Usage*
** Aluminium - Al*	88.80%	100.00%
Chromium - Cr	0.80%	66.67%
** Copper - Cu*	12.94%	100.00%
Iron - Fe	29.03%	66.67%
Lead - Pb	2.56%	100.00%
Manganese - Mn	2.52%	66.67%
Molybdenum - Mo	0.56%	66.67%
Neodymium - Nd	0.52%	33.33%
** Nickel - Ni*	6.76%	100.00%
Cobalt - Co	2.07%	33.33%
Graphite - C	17.93%	33.33%
** Lithium - Li*	4.00%	33.33%
Vanadium - V	0.28%	33.33%
Zinc - Zn	0.32%	66.67%
Indium - In	0.04%	33.33%
Silver - Ag	0.04%	33.33%

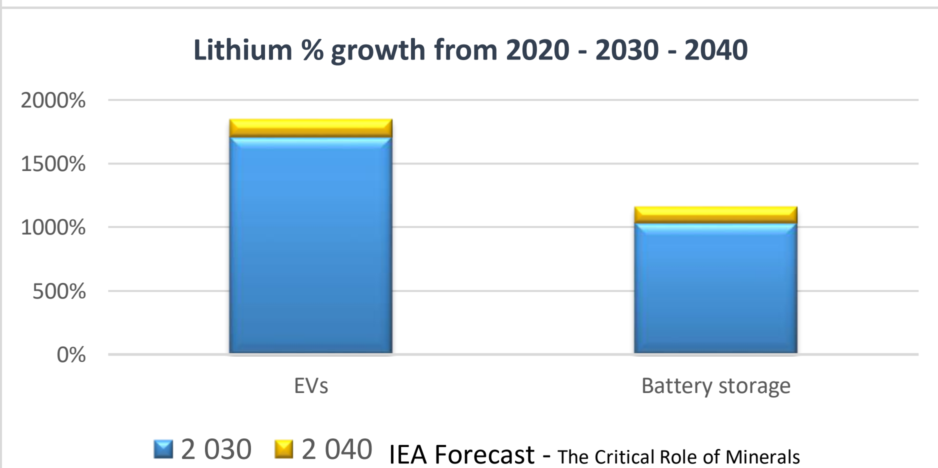
Kapaj, 2022

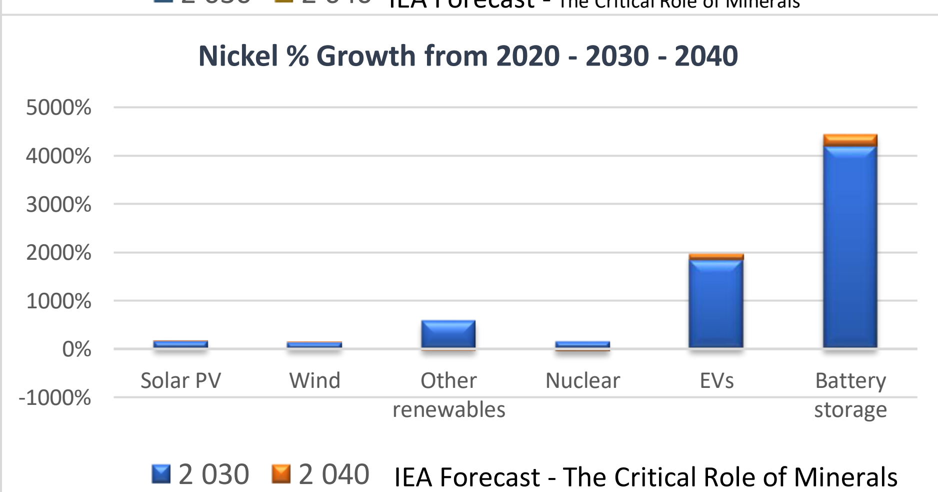
Aluminum is a metal that will be required highly to build the structural parts of every green technology. Copper is a crucial part of the energy system infrastructure and is being adopted by every technology. Nickel serves as a critical ingredient for the manufacturing of batteries, solar panels, and windmills. Lastly, Lithium is a mineral that is used in smaller net-weight amounts for energy storage batteries and is a critical ingredient for lithium-ion batteries. (IEA, 2022)

3.3 The SWB rapid developments' implications on raw metal demand requirements.

In another report from IEA – "The Role of Critical Minerals on Clean Energy Transitions" (IEA, 2022), IEA forecasts raw metal requirements of each technology for the years 2030, and 2040. The relationship between the growth of SWB technologies and their raw metal requirements is non-linear. While the SWB technologies will have to be developed 3-4 folds (meeting the net-zero targets), the results from the IEA study indicate that the raw material requirements will climb 3-20 folds by the year 2040. The graphs below give a visual representation of 3 of the metals we have considered as high impact. (Aluminum not visualized due to the lack of data.)







The major requirements will come from EVs, and Battery storage. This growth for all three metals climbs to thousands of percentages of current production. In effect, the risks of encountering supply shortages are high.

4. Econometric Model

After having identified the high-impact metals & minerals I will model a Structural Vector Autoregression for *Aluminum*, *Lithium*, *Copper*, and *Nickel*. The three factors that I consider as crucial in understanding the landscape of the energy transition are; the price of metals & minerals, the production of metals & minerals, and economic activity. Therefore, testing for shocks on each factor will help in shaping policies.

In my VAR model I am including 4 endogenous variables; the log of economic activity industrial production index REA, the percentage change of global production of each metal, the log of the price of each metal, and an anchor variable the log of cotton price representing the aggregate demand serving as a frontiers of global trade while being dissociated from the metals impact. To understand the relationship between the three factors; prices, production of each metal, and economic activity I want to shock test each factor. Namely, I am referring to these shocks as Metal-Specific Demand Shock, Metal-Specific supply Shock, and Aggregate Demand Shock, respectively.

4.1 Historical Data

The time-series data for each metal's global production and price has been sourced from the (U.S. Geological Survey, 2019). The global economic activity industrial production has been sourced from (FRED, 2022) economic data. The global cotton price has been sourced from the commodity market prices of the (World Bank, 2022) I have tried to go back in time as much as possible to capture the full effect of the VAR model, namely 1970 – 2018.

4.2 Shock Identification

- A positive aggregate demand shock effect indicates that the economy is in an expanding business cycle and every variable's demand increases.
- Metal-specific supply shock refers to a new opening of a supply chain, namely a new mine, or reserves release. This positive shock will increase industrial production activity and reduce metal-specific prices. Regarding the price of cotton, there should be negligible change.
- Metal-specific demand shock refers to a steep rise in prices due to a shortage of supply only for the metals we are considering in this paper. This shock has no effect on industrial production but in the long term, it should increase production.

Table 1. Expected responses

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Positive Aggregate Demand Shock	+	+	+	+
Positive Metal-Specific supply shock	+	+	-	0
Positive Metal-Specific demand shock	0	+	+	0

4.3 Shock Responses for Each Metal

4.3.1 Copper VAR model

In the appendix section fig, we can see the impulse response functions of each variable. On the second row is displayed the endogenous variable response functions to a positive shock on Industrial production. In the third row, we will see the variable response functions to a positive shock on the price of copper. First row the cotton price shock and forth by the copper production shock. The time-series data I am using is annual and the forecasting period I am doing extends to 22 periods, therefore my forecast is 22 years (the year 2040) from period 0 (the year 2018). Note: ***varbasic, Production, Industrial_Pro***; refer to the response of the industrial production to a positive shock on copper production.

- A positive **aggregate demand shock** (row 2) in itself stabilizes after 5-10 periods with minor fluctuations. But its effect on the price of copper is substantial. Initially, the price of copper experiences a slight rise for the first two periods then shifts to a drop for 5 periods before it can start to rise again. It takes the price of copper about 15 periods to return to the initial level. The effect of the positive shock of industrial production is positive on production is , similar to the price of copper but with smaller in size.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Aggregate Demand Shock – Responses.	+	+	+	+

- A positive shock on **metal-specific supply shock** (row 4), which refers to an opening of a new copper mine, shows little to no effect on industrial production. Its effect on the price of copper shows a sight initial increase for 5 periods. The effect of a supply shock on cotton prices is a slight fluctuation around the mean. Lastly, a supply shock increases production in the first period to then stabilize in the following period.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Metal-Specific supply shock - Response	0	+	+	0

- A positive **metal-specific demand shock** is a price increase due to a shortage of supply, hence a positive shock in the copper price for an impulse (row 3). Metal-specific demand shock on industrial production and cotton price has no effect, but in itself, we see an increase for the first 5 periods before returning to the initial level. The most important thing to point out is the small production response to a supply shortage.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Metal-Specific demand shock - Response	0	+	+	0

Based on the results of each shock I have tested; it is noticeable the highly limited elasticity of supply for copper. The opening of a new copper mine is the only way to increase the supply of copper. Both the aggregate demand and metal-specific demand shock affect production, but by small amounts compared to the demand.

4.3.2 Lithium VAR model

In the appending section in fig 2. , we can see the impulse response functions of each variable. On the first row are displayed the response functions of each variable to a shock on the price of cotton, followed second by aggregate demand shock represented by a positive shock on industrial production. The third row displays the variable responses to a shock in the price of lithium and lastly the lithium production shock.

- A **positive shock on aggregate demand** (row 2) shows an initial drop in cotton prices followed by an increase in period 5. In itself, the shock on industrial production takes 10 periods to return to initial levels. Its effect on the lithium price shows an initial drop followed by a slight rise from period 5 to period 10, ending period 22 at a slightly higher level. Lastly, an aggregate demand shock on production follows a similar pattern to its price.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Aggregate Demand Shock – Responses.	+	+	+	+

- **Metal-specific supply shock** (row 4) shows no signs of cotton prices (fluctuations around the mean) and industrial production as expected. Moreover, it shows a rise on lithium prices and production. Although we have an increase in supply, the price of lithium stays relatively the same indicating a high demand for the metal, hence a large adoption across many industries.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Metal-Specific Supply shock – Responses	0	+	+	0

- **Metal-specific demand shock** (row 3) shows little signs of cotton prices and industrial production as expected. Its effect on itself shows an increase in period 1 and stabilizes after period 10. The most important effect to point out is the demand shock on production which shows little signs of adjustment on meeting the increased demand.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Metal-Specific demand shock – Responses	0	+	+	0

Based on the results of the VAR model for Lithium we noticed two main qualities. Lithium is a mineral with a high cross-usage among different sectors and the supply elasticity of lithium is also very low in meeting a rapidly growing demand. The rise in production for lithium during the industrial production positive shock can be explained by recycling the metal. These results indicate that demand-imposed price increases of lithium will ripple across many sectors. The chances of that happening are very high considering the low supply of elasticity lithium has.

4.3.3 Nickel VAR model

In the appendix section fig 3., we can see the response functions for each variable for a nickel. In the second row, we can see the response functions of each variable from a shock on industrial production. The first row displayed the cotton price shocks, the third comes the variable responses from a shock in nickel price. Fourth row the effect a shock on nickel production has on our selected variables.

- A **positive aggregate demand shock** (row 1) can be described as a shock on industrial production. Its effect on cotton is positive, indicating an expanding business cycle, as expected. The same positive effects can be seen in the nickel price, although with high fluctuations. In the case of production, we see a slight increase for the first 15 periods.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Aggregate Demand Shock – Responses.	+	+	+	+

- **Metal-specific supply shock** (row 4) can be described as a positive shock on production. As expected, the opening of a nickel mine does not affect industrial production and cotton prices. However, we notice a slight drop in the prices of nickel. The production rate increases for the first period and then it stabilizes in period 4 to initial levels.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Metal-Specific Supply shock – Responses	0	+	-	0

- **Metal-specific demand shocks** its displayed-on row 3. Its effect on industrial production and cotton price is 0. However, after a price shock, it takes about 10 periods for prices to return to initial levels. Another important response is the production response to a shortage in supply, almost non-existent.

	Industrial Production	Metal-Specific Production	Metal-Specific Price	Cotton Price
Metal-Specific demand shock – Responses	0	~0	+	0

Based on the results of the model I have built the only issue that we can point out is the low elasticity of supply for a nickel.

4.3.4 Aluminum VAR model

Based on the impulse response functions results for aluminum fig 4. we notice a positive response of aluminum production under the industrial production shock. The industrial production shock has a strong effect on the price of Aluminum but less so on the production of Aluminum. This indicates that aluminum is a widely used metal that has matured on the market, and it can meet its market demand through recycling. Similar to what we saw with other metals a rapid increase in demand for aluminum will increase prices as the supply faces a shortage.

5 Elasticity Computation

The supply elasticity of each metal and mineral is given by the production response for a given positive shock to price. We compute the elasticity by regressing the table data of price responses and production responses to a positive price shock. In this section, we introduce the results, and in the appendix, we attach the STATA results under the name of "Elasticity Table". The coefficient represents the percentage rise in production for a 1%-demand shock-price increase.

Metal or Mineral	**Coefficient**
Copper	.20
Lithium	.69
Nickel	.045
Aluminum	-.02

6 Conclusion

On this paper I pointed out some high impact metals and minerals needed for the energy transition. The data on this paper was collected from a single source. The authors of the time-series data mention that some of the metal productions time series were withheld from the private mining companies due to proprietary rights. Nonetheless, the results of the paper do point out the supply shortage risk we are facing towards reaching net-zero aspirations. Rapid investment in renewables would induce elevated raw material prices due to the supply shortage given by the low supply elasticities. This in effect would increase inflation due to higher energy prices and in part due to the role these raw materials play in other sectors. Governments should start investing first in raw material supply chain security and domestic mining. The second investment should go towards green technologies development to reach higher efficiency and reduce raw material requirements.

7 Appendix

Figure 1. Copper VAR model – Impulse Response Functions Graphs

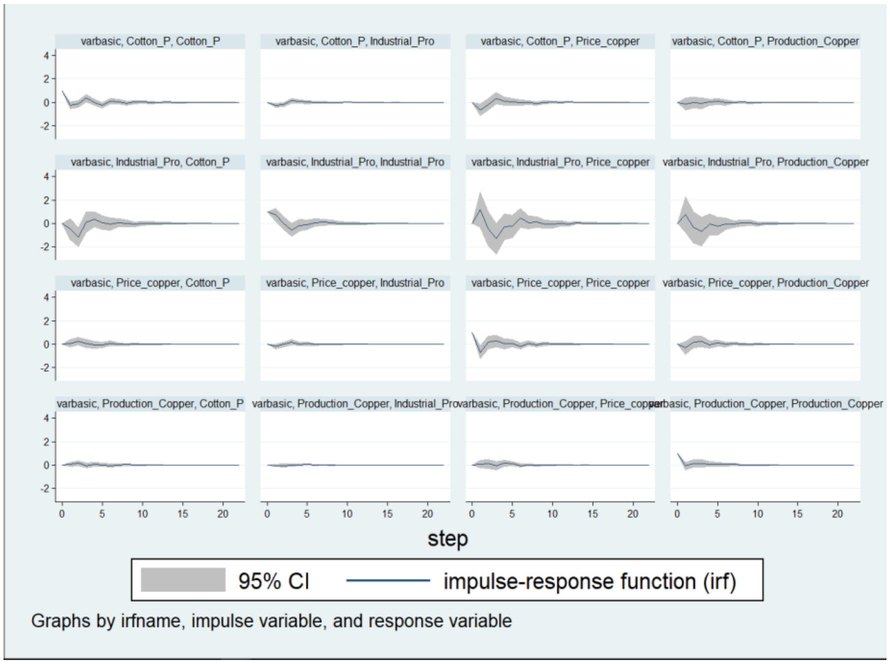


Table 1.1 Copper IRF Table

step	(1) irf	(2) irf	(3) irf	(4) irf	(5) irf	(6) irf	(7) irf	(8) irf	(9) irf	(10) irf	(11) irf	(12) irf
0	1	0	0	0	0	0	0	1	0	0	0	1
1	.723577	1.17666	.766571	-.231084	-.633402	-.132776	-.210702	-.694658	-.323402	-.031925	.075516	-.082011
2	.008815	-.467098	-.354797	-.207802	-.185649	-.024181	-.029645	.155996	.196906	-.039739	.088869	.122143
3	-.574271	-1.30718	-.70596	.129026	.346513	-.051555	.168921	.262185	.204914	-.016065	-.07237	.128821
4	-.161043	-.308422	-.095561	.072806	.089232	.018447	.002432	.041905	-.04529	.025499	.146303	.084042
5	-.13547	-.269545	-.264597	.012086	.059858	.089221	.026534	.075651	.095405	.056041	.10874	.075407
6	.070402	.462283	-.057049	.011119	-.021584	-.031748	-.03057	-.154545	-.029219	-.012919	-.04213	.027985
7	.091887	.067589	-.068874	.009451	-.008136	.010643	.002082	.061777	.042792	.002616	.026493	.044001
8	.062244	.119084	.042104	-.03411	-.084607	.012715	-.017508	-.064273	-.012809	-.004201	-.029933	.000115
9	.014614	-.058858	.038457	-.016643	.004771	-.02583	-.003951	.035911	-.008668	-.004097	.011565	.0158
10	-.037144	-.087473	-.052525	.013485	.024468	-.006862	.013273	.012427	.014306	-.003379	-.007211	.004654
11	-.015683	-.028912	-.006111	-.000164	-.004272	.007462	-.001793	-.00244	-.001383	.002514	.01413	-.000108
12	-.024049	-.052763	-.030268	.002379	.015358	.005827	.005807	.017156	.011123	.004828	.006622	.009436
13	.004756	.043558	-.002629	.005237	.002908	-.005255	-.002206	-.015155	-.005821	-.001586	-.003459	.001639
14	.009458	.007612	-.006043	-.000201	-.004132	.004737	-.000486	.005025	.004948	.001458	.005399	.002788
15	.005564	.015589	.004246	-.004107	-.008213	.000918	-.001915	-.007834	-.001372	-.000468	-.004591	-.000234
16	.003077	-.00196	.004351	-.000432	.001993	-.003973	-.00026	.004022	-.001346	-.000909	.000503	.001703
17	-.002292	-.007525	-.004125	.000911	.000497	.000455	.001092	.000695	.001546	-.000185	-.000511	-.000192
18	-.001395	-.002944	.001293	-.00095	-.001225	.000666	-.000485	-.00054	-.000607	.000257	.00118	-.000256
19	-.003026	-.006677	-.003418	.000732	.002855	-.000211	.000895	.002435	.00112	.000285	.000372	.001037
20	.000346	.004281	-.000485	.000752	.000111	-.000233	-.000187	-.001761	-.000535	-.000148	-.000205	-.00012
21	.000691	.000023	-.000447	-.000292	-.000662	.000823	-.000093	.000632	.000569	.000294	.00075	.000249
22	.000427	.001878	.000406	-.000287	-.000422	-.000193	-.000152	-.000823	-.000246	-.000099	-.000656	.000041

(1) irfname = varbasic, impulse = Industrial_Pro, and response = Industrial_Pro
(2) irfname = varbasic, impulse = Industrial_Pro, and response = Price_copper
(3) irfname = varbasic, impulse = Industrial_Pro, and response = Production_Copper
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Figure 2. Lithium VAR model – Impulse Response Functions Graphs

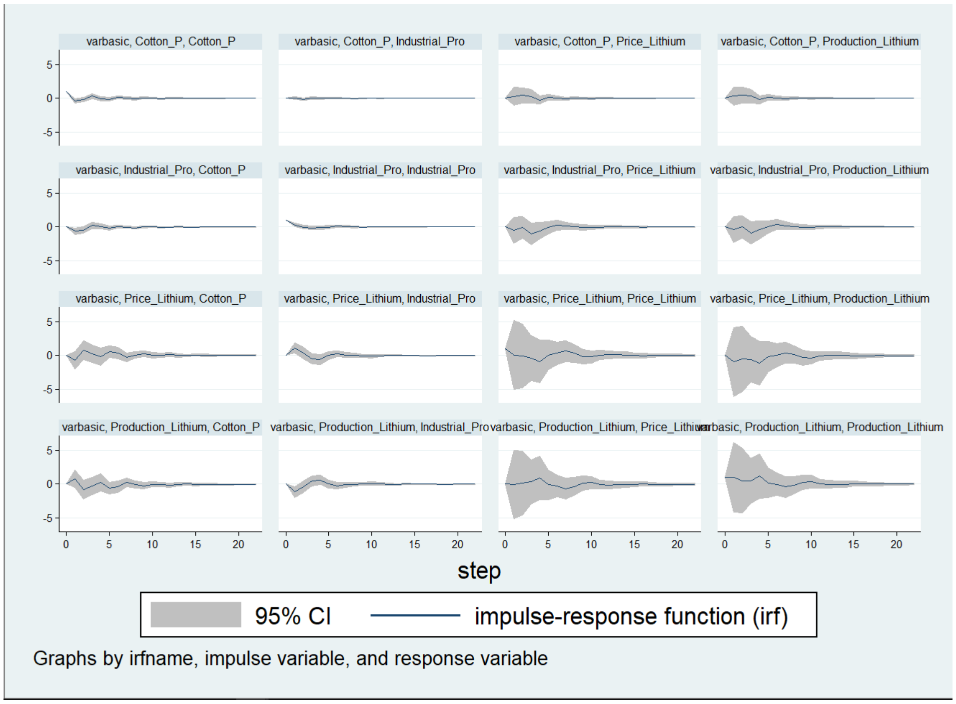

Table 2.1 Lithium IRF Table

step	(1) irf	(2) irf	(3) irf	(4) irf	(5) irf	(6) irf	(7) irf	(8) irf	(9) irf	(10) irf	(11) irf	(12) irf
0	1	0	0	0	1	0	0	0	1	0	0	0
1	.293704	-.433464	-.509666	-1.1562	.997979	-.03109	1.11529	-.945278	.083093	.048198	.317138	.283116
2	-.027526	.008316	-.089976	-.371146	.527434	.147869	.344848	-.467163	-.074823	-.1399	.472882	.399301
3	-.136988	-.888961	-1.04331	.467826	.492622	.326493	-.486551	-.581249	-.397956	.027453	.324566	.271558
4	-.120267	-.433518	-.560248	.617813	1.18285	.932194	-.606962	-1.14678	-.879972	-.011846	-.235964	-.251074
5	-.03547	-.017606	-.090375	.002647	.210665	-.085993	.004473	-.213048	.096391	.001178	.147914	.150217
6	.104815	.352713	.295327	-.237505	-.027177	-.297925	.237308	.049632	.331779	.043757	.039269	.02069
7	.080481	.171531	.110194	-.092528	-.412607	-.652444	.090539	.403554	.652083	-.001521	-.038332	-.059336
8	-.010796	.068887	.01249	-.00436	-.150845	-.327132	.002034	.13576	.319311	-.034159	-.010971	-.020864
9	-.027219	-.032144	-.086493	.047688	.304452	.176638	-.050987	-.316248	-.181285	.006378	.02227	.011899
10	-.011183	-.073742	-.12253	.099127	.344338	.218352	-.098833	-.343148	-.210685	.01215	-.021845	-.03265
11	-.006654	-.012862	-.04851	.02901	.06871	-.054791	-.027354	-.069309	.059517	-.0056	.016178	.010851
12	.01119	.066313	.038186	-.041943	-.011627	-.115662	.041719	.010683	.11941	.002887	.029153	.023387
13	.018289	.048028	.020566	-.015869	-.008789	-.099394	.015096	.007335	.101975	.005702	-.006934	-.014636
14	.001785	.013638	-.011121	.011179	-.006399	-.08493	-.011443	.003092	.08494	-.005443	-.009805	-.014905
15	-.005913	.005699	-.015532	.006463	.053083	-.009694	-.007017	-.056433	.009314	-.002146	.008886	.005218
16	-.000333	-.00152	-.020675	.012974	.084619	.030058	-.013326	-.085524	-.028252	.004137	.00169	-.002634
17	.000757	-.000888	-.017004	.012471	.035209	-.016023	-.012264	-.035709	.017814	.000052	-.001369	-.004715
18	.000813	.013128	.000136	-.003244	.005421	-.038867	.003249	-.006492	.039754	-.001171	.006387	.003999
19	.003301	.014489	.002813	-.004202	.014244	-.023158	.00392	-.015098	.024037	.001551	.002531	-.000188
20	.001851	.005398	-.005218	.004191	.013545	-.019509	-.004316	-.01437	.020161	.000108	-.002627	-.005046
21	-.000844	.003135	-.005884	.003355	.01325	-.014998	-.003433	-.014279	.015239	-.001063	.001355	-.000326
22	-.000073	.003615	-.004227	.001586	.021186	-.002695	-.001727	-.021835	.003181	.000613	.002332	.000712

(1) irfname = varbasic, impulse = Industrial_Pro, and response = Industrial_Pro
(2) irfname = varbasic, impulse = Industrial_Pro, and response = Production_Lithium
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(7) irfname = varbasic, impulse = Price_Lithium, and response = Industrial_Pro
(8) irfname = varbasic, impulse = Price_Lithium, and response = Production_Lithium
(9) irfname = varbasic, impulse = Price_Lithium, and response = Price_Lithium
(10) irfname = varbasic, impulse = Cotton_P, and response = Industrial_Pro
(11) irfname = varbasic, impulse = Cotton_P, and response = Production_Lithium
(12) irfname = varbasic, impulse = Cotton_P, and response = Price_Lithium

Figure 3. Nickel VAR model – Impulse Response Functions Graphs

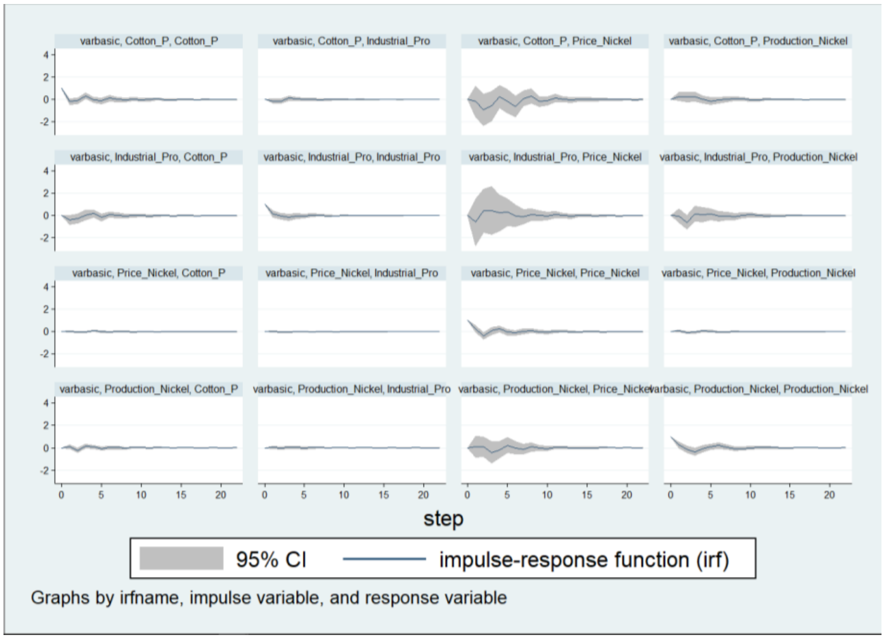

Table 3.1 Nickel IRF Table

step	(1) irf	(2) irf	(3) irf	(4) irf	(5) irf	(6) irf	(7) irf	(8) irf	(9) irf	(10) irf	(11) irf	(12) irf
0	1	0	0	0	1	0	0	0	1	0	0	0
1	.15616	-.032817	-.597602	.028229	.24075	.077135	.011972	.074189	.25362	-.141227	.27803	-.187189
2	-.052075	-.602619	.427586	-.032364	-.155185	.102495	-.024287	-.065872	-.408713	-.133523	.230655	-.919169
3	-.179646	.151413	.453159	.020835	-.357503	-.429517	-.031921	-.057452	.073281	.109011	.237685	-.601465
4	-.038619	.076514	.236925	.011255	-.092047	-.179857	.016502	.061525	.249025	.050213	-.000129	.246557
5	-.047925	.123303	.301376	-.031552	.097864	.220448	.010448	.048263	-.054698	.0049	-.13651	-.147789
6	.043869	-.067344	-.012622	.007193	.191509	-.004706	-.015076	-.033426	-.115519	.016431	-.066832	-.618957
7	.036919	-.052142	-.080939	.012551	.039183	-.117093	.004011	-.015759	.015519	-.015084	.002123	.078271
8	-.018866	-.082308	.084536	-.003508	-.090081	.067806	.008878	.011614	.057183	-.012318	.094259	.311417
9	-.009385	.041488	.001218	.006812	-.064248	-.006607	-.00689	-.000101	-.006458	.019309	.059067	-.180656
10	.001993	.055144	-.044093	.001558	-.007011	-.074817	-.002444	-.000965	-.051903	-.003054	-.056271	-.126708
11	-.007545	.011641	.078181	-.012464	.025528	.033824	.004083	.004399	.008789	-.005125	-.051773	.126829
12	.004202	-.013038	.004474	.001696	.040715	.035769	-.000602	.000714	.042705	.011858	.016384	.002891
13	.007695	-.020212	-.063712	.006672	.008903	-.01662	-.00047	-.001921	-.019856	-.005233	.010414	-.06107
14	-.005906	-.016651	.017432	-.002422	-.027998	-.002231	.000663	-.003226	-.028222	-.00897	.003289	.023865
15	-.001416	.01267	.021672	.000075	-.017009	-.005813	-.000952	-.000707	.022495	.007861	.013911	.019143
16	.002944	.01776	-.018894	.001576	.004455	-.00755	.00037	.004248	.011562	.002313	-.005228	-.003227
17	-.002251	-.00199	.006511	-.002884	.009204	.013997	.000602	.001065	-.01733	-.004906	-.015894	-.006185
18	.000249	-.006103	.007141	-.000266	.00752	.002168	-.00091	-.003203	-.00085	.001824	.000561	-.013757
19	.002504	-.003005	-.012244	.002088	-.000236	-.008908	.000236	-.000097	.009399	.00092	.006781	.010687
20	-.001656	-.002727	.002053	-.000462	-.007127	.004858	.000692	.00143	-.002496	-.002241	.002828	.014367
21	-.00093	.002714	.004824	-.000308	-.003097	.000783	-.000651	-.000756	-.003564	.001065	.000762	-.014759
22	.00125	.004501	-.004233	.000426	.002033	-.006465	-.000183	-.000164	.001592	.000805	-.003105	-.004685

(1) irfname = varbasic, impulse = Industrial_Pro, and response = Industrial_Pro
(2) irfname = varbasic, impulse = Industrial_Pro, and response = Production_Nickel
(3) irfname = varbasic, impulse = Industrial_Pro, and response = Price_Nickel
(4) irfname = varbasic, impulse = Production_Nickel, and response = Industrial_Pro
(5) irfname = varbasic, impulse = Production_Nickel, and response = Production_Nickel
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(8) irfname = varbasic, impulse = Price_Nickel, and response = Production_Nickel
(9) irfname = varbasic, impulse = Price_Nickel, and response = Price_Nickel
(10) irfname = varbasic, impulse = Cotton_P, and response = Industrial_Pro
(11) irfname = varbasic, impulse = Cotton_P, and response = Production_Nickel
(12) irfname = varbasic, impulse = Cotton_P, and response = Price_Nickel

Figure 4. Aluminum VAR model – Impulse Response Functions

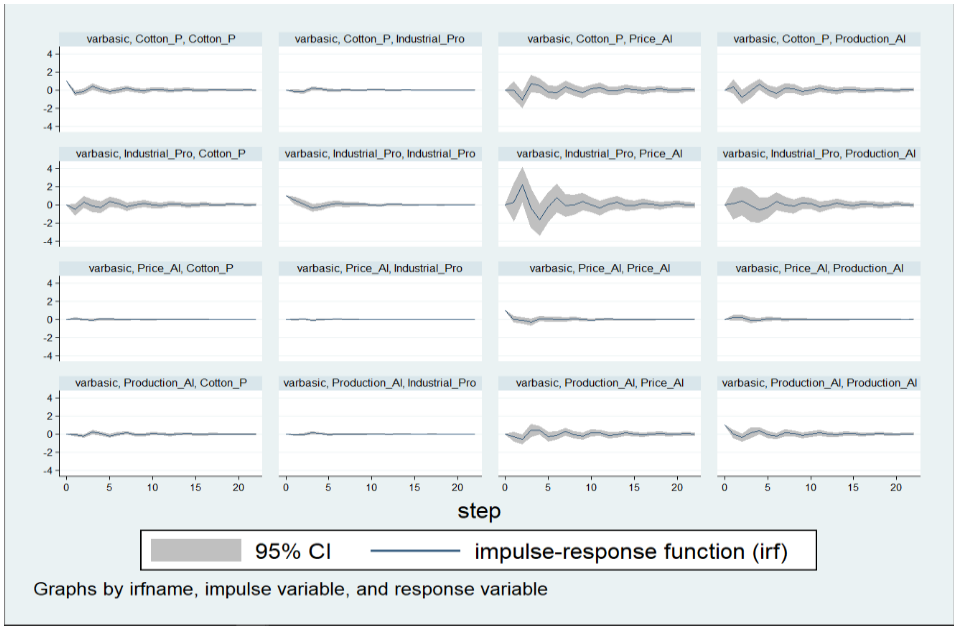

Table 4.1 Aluminum IRF Table

step	(1) irf	(2) irf	(3) irf	(4) irf	(5) irf	(6) irf	(7) irf	(8) irf	(9) irf	(10) irf	(11) irf	(12) irf
0	1	0	0	0	0	0	0	1	0	0	0	1
1	.457446	.240455	.107688	-.152108	-.030137	.35646	-.006453	.001661	.185826	-.074987	-.318544	-.018008
2	.053596	2.20774	.378875	-.187539	-1.11816	-.77651	.022728	-.108443	.209099	-.055282	-.555266	-.395421
3	-.344035	-.363067	-.114924	.154468	.690154	-.122077	-.067232	-.314359	-.097267	.112457	.394383	.148483
4	-.245064	-1.64114	-.598559	.091438	.484752	.623233	-.010188	.095335	-.061151	.070542	.432129	.351401
5	-.003425	-.263603	-.32756	-.02354	-.2133	-.042733	.015606	.034273	.054628	-.042797	-.304319	-.068544
6	.101557	.730278	.350758	-.050483	-.2866	-.35517	.026302	.018306	.048204	-.020455	-.14606	-.209323
7	.033828	-.102048	.010158	.025437	.3474	.186898	.002152	-.015761	-.02355	.016852	.253019	.138442
8	.046794	-.027348	-.193948	-.019176	-.037842	.13952	.000367	.066312	.01701	-.016349	-.066049	.085755
9	.023106	.348067	.185701	-.025629	-.301035	-.195219	-.009439	-.021658	.013328	-.01434	-.212049	-.160616
10	-.049431	-.028858	.124477	.024233	.086099	-.055317	-.0057	-.049275	-.022124	.023425	.119001	-.006351
11	-.059477	-.398504	-.230157	.028087	.256163	.180124	.001052	-.005418	-.012726	.014115	.150662	.13209
12	.018224	.034058	-.070073	-.020412	-.131327	-.006426	.005401	.036269	.019125	-.016925	-.117699	-.03275
13	.033685	.22965	.16513	-.01099	-.123667	-.125439	.000164	-.005532	.003378	-.005629	-.068708	-.083505
14	-.004458	-.066208	.006712	.013159	.126044	.046475	-.000224	-.010018	-.010841	.010526	.102705	.050262
15	-.005326	-.093551	-.105532	-.000716	.03777	.074144	.000538	.010783	.003615	-.002658	.005193	.041161
16	.011202	.121218	.047062	-.011819	-.120334	-.066751	-.000909	.003683	.007483	-.007469	-.08442	-.054745
17	-.006356	.020237	.064173	.006616	.016942	-.032083	-.001885	-.015147	-.007345	.006231	.02862	-.01166
18	-.01449	-.122235	-.066055	.008698	.089903	.063677	.00077	.000235	-.004383	.004999	.05864	.047443
19	.005655	.008449	-.033569	-.006799	-.038261	.004208	.001385	.010621	.006712	-.005979	-.039377	-.006503
20	.010417	.088578	.059974	-.004694	-.054952	-.049263	-.000335	-.001855	.001613	-.002173	-.031058	-.033662
21	-.004491	-.029158	.006961	.005968	.046468	.013444	-.000579	-.00608	-.005083	.004613	.038789	.016101
22	-.003949	-.047923	-.044234	.000799	.022695	.031617	.000459	.004146	.000844	-.000301	.008468	.019225

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(4) irfname = varbasic, impulse = Cotton_P, and response = Industrial_Pro
(5) irfname = varbasic, impulse = Cotton_P, and response = Price_Al
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(11) irfname = varbasic, impulse = Production_Al, and response = Price_Al
(12) irfname = varbasic, impulse = Production_Al, and response = Production_Al

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