

ECONOMY-WIDE ASSESSMENT OF 'KEY RESOURCE SECTORS' OF INDIA AND
PROSPECT OF VALUE CHAIN INTEGRATION WITH
SELECTED ASIAN ECONOMIES

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DECLARATION

I Priyam Sengupta hereby declare that this thesis on the topic entitled, "*Economy-Wide Assessment of 'Key Resource Sectors' of India and Prospect of Value Chain Integration with Selected Asian Economies*" is submitted for the award of Degree of Doctor of Philosophy in Economics to the Gokhale Institute of Politics and Economics, Pune 411004.

It is an original contribution and has been completed during my tenure as a research scholar at Gokhale Institute of Politics and Economics, Pune.

This thesis has not been submitted by me elsewhere for the award of any degree or diploma-part or full. The information gathered by me elsewhere for the thesis is original, true, and factual. Such material as has been obtained from other sources has been duly acknowledged in the thesis. I hereby request, to consider the thesis for the award of the degree of 'Doctor of Philosophy.'



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ABSTRACT

The thesis hovers around the concept of ‘key resources’ of an economy. The study describes a group of ‘non-fuel minerals’ as ‘key-resources.’ The study underscores the crucial role of these key resources (non-fuel minerals) in determining the growth dynamics of the countries in 21st Century. The study has outlined some systematic processes for identification of key resources of a country, depending on its production structure and endowment of natural resources. The perspective of this work is built on some emerging global scenarios in 21st Century, more specifically in the post-Covid timeline.

The study's objectives include an in-depth analysis of India's mineral sector, identification of key resources, and examination of the economy in the context of value chain integration for selected Asian economies. Analytical tools such as multipliers, backward and forward linkages, and Principal Component Analysis (PCA) are employed for a structured analytical framework.

The document outlines the impact analysis of national policies like 'Make in India' and 'Atmanirbhar Bharat Abhiyan,' using modified Input Output analysis. The implications for the construction sector, including insights into feasibility, sustainability factors, and potential resource drain, are discussed.

Concerns regarding meeting projected market size targets, predicting pollution rates, and assessing international environmental impact are identified. Thorough studies on various sectors, including Capital Goods, Chemicals, ESDM, Power, and Energy, are conducted, emphasizing the understanding of value chain integration in a Computable General Equilibrium (CGE) framework.

The document aims to provide a holistic view of Indian economic dynamics, considering intricate economic factors and the interplay of endogenous and exogenous elements. It also delves into the feasibility of self-reliance policies concerning depleting mineral reserves. The comprehensive discussion on the availability, reserves, and importance of mineral resources in India, along with the systematic incorporation of an extended list of minerals in Input Output Tables, contributes to the study's depth and thoroughness

The thesis also explores various government initiatives, such as 'Make in India' and 'Atmanirbhar Bharat Abhiyaan,' aimed at attracting investments, strengthening the manufacturing sector, and achieving self-reliance. The focus on export promotion and import

substitution is highlighted as part of the government's strategy to reduce the import burden and minimize the environmental impact. The economic growth outlook for India is optimistic, with projections placing it among the world's top economies by 2050. However, this growth heavily relies on a consistent supply of key resources. The thesis has highlighted that the need for prudent resource utilization is the key to ensure sustainable development and minimal environmental impact. The National Infrastructure Pipeline is introduced as a government initiative to streamline investment for this purpose. Expansionary macroeconomic policies in India, particularly their feasibility and sustainability in light of depleting mineral reserves, have been assessed in the thesis.

Government policies initiated since 2020-21 have specifically articulated with a focus towards achieving self-reliance and sustainability through export promotion and import substitution. The thesis introspected on the challenges associated with the expansion of the manufacturing base, including concerns about over-exploitation and the need for careful analysis of trade policies. Economic integration, especially with Global Value Chains (GVCs) and Regional Value Chains (RVCs), is deemed essential in the current geopolitical scenario, with a focus on manufacturing value chains.

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I take full responsibility for any errors that may have occurred along the way.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION	1
1.1 Overview and Perspective	1
1.2 Concept of ‘Key Resources’ and the Importance of Key Resources in Determining the Growth Trajectory of a Country	2
1.3 Focusing on Non-fuel Minerals as the ‘Key Resources’ of the Economy	4
1.4 Current Global Perspective: An Era Marked by Pandemic, War, and Humanitarian Crises	5
1.4.1 <i>The Great Lockdown: Outbreak of Coronavirus</i>	6
1.4.2 <i>Recovery from ‘Great Lockdown’</i>	9
1.4.3 <i>Cost-of-living Crisis: Lingering Impact of Pandemic and Global Unrest</i>	10
1.4.4 <i>Climate Change Crisis: Imminent Threat in Front to the Mankind</i>	10
1.5 Objectives of the Study	16
1.6 Objectives of the Study	18
1.7 Key Objectives of the Study	19
1.8 Key Resources V/s Critical Minerals	20
CHAPTER 2: LITERATURE REVIEW	22
2.1 Introduction	22
2.2 Literature Review	22
CHAPTER 3: METHODOLOGY AND DATA CONSTRUCTION	32
3.1 Methodology	32
3.1.1 <i>Input-Output Framework</i>	34
3.1.2 <i>Construction of Input-Output Table</i>	36
3.2 Expanding Input-Output Table (IOT) by Incorporating a Comprehensive List Of Non-Fuel Minerals	37
3.2.1 <i>Allocation along Commodity-line (Row-wise)</i>	38
3.2.2 <i>Allocation along Industry-line (Column-wise)</i>	39
3.3 Calculating Multipliers and Linkages	40
3.4 Principal Component Analysis (PCA)	42
3.4.1 <i>Mathematical Construct</i>	43
3.5 Construction of Modified Input-Output Table	47
3.6 Value Chain Models	49
CHAPTER 4: SYSTEMATIC INCORPORATION OF THE EXTENDED LIST OF MINERALS IN IO TABLE (2018-19), ISSUE OF DATA ANOMALY AND IDENTIFICATION OF “KEY RESOURCES” IN INDIAN CONTEXT	52
4.1 Discrepancies in India’s Mineral Statistics	52
4.1.1 <i>Organizational Structure for Dissemination of Mineral Statistics in India</i>	52
4.1.2 <i>Comparison of Data Published by the Indian Bureau of Mines (IBM) and Ministry of Mines (MoM)</i>	54
4.1.3 <i>Comparison of the data published by the Indian Bureau of Mines (IBM), Ministry of Mines (MoM) and Central Statistical Organisation (CSO)</i>	57
4.1.4 <i>Introspecting Reasons behind Data Anomaly</i>	58
4.1.4.1 <i>Sources of Data</i>	58
4.1.4.2 <i>Delay in Updating Data</i>	59

4.1.4.3	<i>Human Error</i>	59
4.1.5	<i>Discussion</i>	60
4.2	Expansion of Input-Output Table	60
4.2.1	<i>Construction of Input-Output Table (IOT) from Supply-Use Table (SUT)</i>	60
4.2.2	<i>Expansion of Input-Output Table by Incorporating More Minerals</i>	61
4.3	Identification of ‘Key Resources’ of Indian Economy	63
4.3.1	<i>Analysis of Forward and Backward Linkages</i>	63
4.4	Principal Component Analysis (PCA)	65
4.5	Identification of Key Resources: Compiling Results Obtained from Computation of Linkages and PCA	66
4.6	Conclusion	68
CHAPTER 5: IMPACT ANALYSIS IN THE FRAMEWORK OF A ‘MODIFIED INPUT-OUTPUT (IO) MODEL’		69
5.1	Growth Story of India since Independence: Government Policies in Retrospect	69
5.2	Government policies in India immediately after Independence	72
5.3	Government Policies during 1990s	74
5.4	Percentage Changes in GDP and Per Capita GDP of India	74
5.5	New Growth Policies: Make in India and Atmanirbhar Bharat Abhiyaan	74
5.5.1	<i>Make in India</i>	76
5.5.2	<i>Atmanirbhar Bharat Abhiyaan</i>	77
5.6	Impact Analysis Using a Modified Input-Output Model	79
5.7	Summary of Result	82
5.8	Observations	82
5.9	Copper Ore and Manganese Ore: Two Key Enablers of India’s Growth Story	86
5.9.1	<i>Copper Ore</i>	88
5.9.1.1	<i>Uses of Copper Ore in Industry</i>	88
5.9.1.2	<i>Copper’s Role in Energy Transition</i>	89
5.9.1.3	<i>Copper Sector in India: Issues and Concerns</i>	89
5.9.1.4	<i>Opportunities in Copper Sector of India</i>	90
5.9.2	<i>Manganese Ore</i>	90
5.9.2.1	<i>Manganese Sector in India: An overview</i>	90
5.9.2.2	<i>Challenges and Concerns</i>	90
5.9.2.3	<i>Opportunities</i>	91
5.9.2.4	<i>Future Trends</i>	91
CHAPTER 6: INDIA’S PARTICIPATION WITH GLOBAL VALUE CHAINS (GVC)		92
6.1	Introduction to the topic	92
6.2	Global Value Chains (GVCs) & Value Chain Integration	95
6.2.1	<i>Measurement of Participation in GVCs</i>	95
6.3	Logical background of our Study: Relation between Value Chain Integration and Key Sector	96
6.4	Details of the Study	97
6.5	Calculation of Indices	99
6.5.1	<i>Forward Linkages</i>	99
6.5.2	<i>Backward linkage: Import Content of Export for i-th Commodity ((X_M^i)</i>	100
6.6	Database	100
6.7	Results	101

	6.7.1 <i>Forward Linkage: VAS Exp and VASFD</i>	101
	6.7.2 <i>Calculation of Backward Linkage</i>	102
6.8	Checking Robustness	102
6.9	Conclusion	104
	CHAPTER 7: DISCUSSION OF RESULTS AND CONCLUSION	106
7.1	Theoretical Background: Relationship between Mineral Resources and GDP Growth	106
7.2	Global Perspective: Current Trends	107
7.3	Case Study of India: Ensuring Self-Reliance with Sustainability	108
7.4	Major Findings of our Research	110
	7.4.1 <i>Backward and Forward Linkages</i>	111
	7.4.2 <i>Impact Analysis</i>	112
	7.4.3 <i>Economic Integration with GVCs</i>	113
	7.4.4 <i>Consolidated Results</i>	114
	7.4.5 <i>Other Findings</i>	115
7.5	Conclusion	116

LIST OF TABLES

Table 1.1: Summary of World Output	6
Table 1.2: Rare Earth Elements (REE): Availability and Use in India	14
Table 3.1: Sectoral Classification in Terms of Backward and Forward Linkages.....	41
Table 4.1: Deviations in Production Value of Eight Minerals in India from 2017-18 to 2019-20, as Provided by the Ministry Of Mines (Mom) and Indian Bureau of Mines (IBM).....	56
Table 4.2: Production Value of Five (5) Principal Minerals as Provided by Three Government Bodies: CSO, Ministry of Mines and IBM (Value In ‘000)	57
Table 4.3: Number of Minerals in Aggregated IO Table (38x38) and Expanded IO Table (61x61)	61
Table 4.4: Comprehensive List of Minerals.....	62
Table 4.5: Classification of Backward and Forward Linkage Results.....	65
Table 4.6: Key Resources from Results of Linkages and PCA Calculations.....	67
Table 5.1: Comparative Macroeconomic Performance of India and Britain, 1600 -1947...	70
Table 5.2: Brief Description about Five Tranches of <i>Atmanirbhar Bharat Abhiyaan</i>	78
Table 5.3: Growth Forecast In Different Sectors Of The Economy Targeted Demand / Supply Figures Across Sectors.....	80
Table 5.4: The Maximum Production of ‘Key Minerals’, Simple Growth Rate Required per Annum (%) and CAGR (%) Figures.....	82
Table 6.1: Export of India to East Asian Countries (\$ Million)	97
Table 6.2: Import of India from East Asian Countries (\$ Million)	98
Table 7.1: Score Table	113
Table 7.2: Identification of Key Resources.....	114

LIST OF FIGURES

Figure 1.1:	Annual Percentage Growths in Output of India from 2005 to 2028 (P)	7
Figure 1.2:	Annual Percentage Growths in Output of Some Selected Countries from 2005 to 2028 (P)	7
Figure 1.3:	Annual Percentage Change in Output in Countries having Export Income from Fuel & Non-fuel	8
Figure 1.4:	Potential of Demand-Side Mitigation Options by 2050	12
Figure 3.1:	Graphical overview of Supply and Use Table for construction of IOT.....	37
Figure 3.2:	Sectoral Classification in Terms of Backward and Forward Linkages	41
Figure 4.1:	Ideal Information Sharing Process among Government Bodies	54
Figure 4.2:	Average Deviations in Production Value of Metallic and Non-Metallic Minerals from 2017-18 to 2019-20, as provided by the Ministry of Mines (MoM) and Indian Bureau of Mines (IBM).....	55
Figure 4.3:	Average Deviation (%) between IBM and MoM Data for Production Value Eight Minerals	56
Figure 4.4:	Production Figures for Five Principal Minerals in 2018-19 as provided by CSO, IBM and MoM	57
Figure 5.1:	Comparison of GDP Figures of India and Britain, 1600 – 1947 (million 1990 int. dollars)	70
Figure 5.2:	GDP of Indian economy from 1950-51 to 2020 -22	73
Figure 5.3:	Growth Rate (%) of GDP in India from 2011-12 to 2021-22	75
Figure 5.4:	Percentage Share of Fund Allotted in Five Tranches and Other Measures	78
Figure 5.5:	Required Productions of Key Minerals to Satisfy Demand from All the Sectors	83
Figure 5.6:	Simple Growth Rate Required per Annum of Key Minerals to Satisfy Demand from All the Sectors	84
Figure 5.7:	Compound Growth Rate Required per Annum of Key Minerals to Satisfy Demand from All the Sectors	84
Figure 5.8:	Total Resources, Remaining Resources and Reserves (all in thousand tonnes) of the 'Key Minerals' in Indian Context	85
Figure 5.9:	Quantity of Import (tonnes) of MCDR Minerals^ during 2018-19 to 2022-23.	86
Figure 5.10:	Value of Import (Rs. Crore) of MCDR Minerals during 2018-19 to 2022-23..	87
Figure 6.1:	Annual Imports of Coking Coal in India	93

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
COP	Conference of the Parties
EIA	Economic Impact Assessment
FDI	Foreign Direct Investment
GVC	Global Value Chain
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Co-operation and Development
UNEP	United Nations Environment Programme
WTO	World Trade Organization

CHAPTER 1: INTRODUCTION

Non-fuel minerals are the indispensable raw materials required for the production of capital goods. It is well established that the adequate supply of capital goods is extremely important for developing the productive capacities of an economy. Without steady supply of machineries, engineering equipment and machine tools, production of all sectors across the economy is highly impaired. An economy can never unleash the full potential of its production system, unless advanced machineries with cutting-edge technologies are used. So, indirectly, the adequate supply of vital minerals plays the most crucial role in bolstering the production capacity of a country. The production capacities in turn, contribute heavily to the development of 'structural strength' of the economy and determine its 'growth dynamics' in terms of GDP growth.

1.1 Overview and Perspective:

Since the advent of the new decade in 2020, the world has been jolted by several consecutive and unprecedented humanitarian disasters. First, the outbreak of COVID-19, the most virulent epidemic after the “Spanish Flu” (1918-19), which took 6,987,222 lives so far (WHO 2023)¹. Second, the prevalence of a global recession in the aftermath of the pandemic, which resulted in worldwide economic distress in the form of unemployment and income loss. Third, the outbreak of war between Russia and Ukraine, causing a total casualty of more than 500,000 lives². Lastly a global “Climate change crisis,” which can make our planet inhabitable very soon. Chronologically, the ‘climate crises’ should come in the first place as it was looming large during the rest three predicaments. At the end of the pandemic, it emerged as the most serious threat to humankind.

We have described all of these incidents as “humanitarian crises” because the pandemic and war directly caused massive loss of human lives, recession resulted in financial distress and climatic disasters have posed a serious threat to the existence of human beings on Earth. War, recession, and climate crisis collectively resulted in an upsurge in food prices and a subsequent food crisis. The world has reached a critical juncture at this stage of human history when the ordeal of these crises is still going on at full steam. At present, food and

¹ <https://extranet.who.int/publicemergency>

² <https://www.reuters.com/world/europe/troop-deaths-injures-ukraine-war-nearing-500000-nyt-citing-us-officials-2023-08-18/>

energy happen to be the Achilles heels of the global economy in its pursuit of growth and development. The countries all across the globe have already gone into a “crisis mode” and are desperately trying to devise “defence mechanisms” to safeguard themselves from any other disaster in future. Frequent adjustments in the geopolitical alignments of the countries to minimise supply chain disruptions, and adoption of green technologies in almost every field of human activities - are some of the extreme measures that countries are taking to sail through this difficult time.

Successful implementation of all these countermeasures requires a concerted and well-coordinated effort from all the countries across the globe. Sadly, the world has now gone into a conflicting mode without paying any heed to the imminent danger of obliteration. However, from an economic point of view, it is possible to figure out probable structural dynamics of the market reeling under multiple adversities, emergence of new technologies based on revised objectives and focus, assessment of demand and supply of newly emerged items of importance, vulnerabilities in existing supply chains etc. Based on this introspection, appropriate macroeconomic policies can be formulated to derive a sustainable development plan for the country.

A preliminary examination in this regard reveals that to ensure the resilience of the economic system, the adoption of completely new kinds of technologies will be required. New technologies (often referred to as ‘clean/green technologies’) will be fundamentally different from conventional technologies in terms of dependence on fossil fuels and emission of greenhouse gases (GHG) in production processes across different sectors. Further introspection reveals that the adoption of “clean technologies” entails the substitution of “fuel minerals” for “non-fuel minerals.” It is estimated that this technological shift will require a huge amount of “non-fuel minerals” in future.

1.2 Concept of ‘Key Resources’ and the Importance of Key Resources in Determining the Growth Trajectory of a Country

The central idea of this thesis revolves around the concept of the "key resource" and its significance within the framework of the Indian economy. To begin with, we need to bring sufficient clarity to the concept of ‘key resources’ and its underpinning meaning in the context of this thesis. Key resources can be described as a specified set of non-fuel minerals, relying on which the juggernaut of an economy moves. In other words, to identify the ‘key resources’, a systematic introspection of country’s non-fuel minerals is pre-requisite.

For example, iron ore is an indispensable ingredient for the manufacturing of steel and allied products. Steel, on the other hand, is the most important input to set up a solid manufacturing base for an economy. There is no doubt that to develop the overall productive capacity of an economy, adequate supply of iron and steel is a prerequisite. So, there is no doubt that “iron ore” is an important ‘key resource’ on which one of the ‘prime movers’ of the economy – the ‘steel industry’ relies heavily. In case a country is not endowed with a sufficient amount of iron ore and is not capable of producing enough steel, it is bound to be dependent on imports from other countries to build its basic infrastructure.

Dependence on other countries for the supply of a ‘key resource’ can make a country seriously vulnerable to supply chain disruptions due to external factors. This can instil a hidden weakness in the production system of the country and eventually leave the producers at the mercy of foreign suppliers. In case of any disturbance like economic turmoil, natural cataclysm, geopolitical realignment, or deterioration in bilateral relations can suddenly pose a serious threat to the steady production flow of the indigenous industry. Historically, all four large Asian countries: China, Japan, India and South Korea have always been heavily reliant on imported Petroleum and Natural Gas (PNG). Imports of mineral fuels in India averaged USD 72817 million from 1996 until 2023, reaching an all-time high of USD 260921 million in 2022 and a record low of USD 8043 million in 1998.³ During October 2023, crude oil imports rose by 2.2%, and from April to October 2023, there was a 0.6% increase compared to the corresponding period in the previous year. Notably, imports from OPEC countries declined to 47.8% of the total from April to October 2023-24, down from 63.6% recorded in the same period of 2022-23.⁴ This huge import burden for acquiring oil has always thwarted other big-ticket development projects in India to a large extent. Worldwide, for the growth of an economy, some basic minerals like iron ore, coal, aluminium etc are indispensable. But apart from these well-known “key minerals,” some more non-fuel minerals are playing an equally important role in shaping the country’s growth dynamics. The challenge is to identify all of them with some appropriate indicators. Currently, India produces as many as 95

³ Export-Import Data Bank, Ministry of Commerce & Industry, India

⁴ Monthly report on indigenous crude oil production, import & processing and production, import & export of petroleum products in the country, November 2023; Petroleum Planning & Analysis Cell, Ministry of Petroleum & Natural Gas

minerals, which include fuel, metallic, non-metallic, atomic, and minor minerals⁵. However, only a handful of these minerals can be considered as “key resources.”

The story around ‘key resources’ becomes more complicated and extremely intriguing when we introspect the role of “key resources” from a much broader perspective. The exact mechanism by which the ‘key resources’ participate in the complex interplay of macroeconomic variables, in a highly globalised and inter-twinning production system, is a matter of intensive and thoughtful study.

1.3 Focusing on Non-fuel Minerals as the ‘Key Resources’ of the Economy

Minerals are inorganic substances found naturally in the rocks of the Earth's lithosphere and mantle. Definition of ‘Mineral’ is many, but the most comprehensive definition has been provided by Encyclopædia Britannica⁶:

“Mineral, naturally occurring homogeneous solid with a definite chemical composition and a highly ordered atomic arrangement; it is usually formed by inorganic processes. There are several thousand known mineral species, about 100 of which constitute the major mineral components of rocks; these are the so-called rock-forming minerals..... By its definition as a homogeneous solid, a mineral is composed of a single solid substance of uniform composition that cannot be physically separated into simpler chemical compounds.”

(Encyclopædia Britannica, 2023)

Minerals have always been one of the most important drivers in the industrialisation process of a country, owing to their characteristic physical and chemical properties. Minerals are used as indispensable inputs for production in sectors like ‘metallurgy,’ ‘chemicals’, ‘pharmaceuticals’, ‘fertilizers’ and ‘pesticides. Some sectors like ‘construction’ indirectly consume a lot of minerals by using Cement as the basic construction material. Similarly, the entire metal industry (i.e. Steel, Copper, Aluminium etc) directly uses metallic ores for the production of metals. Metals, in turn, are used as primary inputs for the production of all important capital goods like machines, equipment and machine tools. Thus, in totality, the entire manufacturing sector relies heavily on the availability of adequate amounts of minerals. The primary sector is also highly dependent on minerals because the production of fertilizers and pesticides requires huge amounts of minerals.

⁵ As per latest update by Ministry of Mines, Government of India

⁶ <https://www.britannica.com/science/mineral-chemical-compound/Carbonates>

Minerals can be broadly classified into two classes: Fuel Minerals and Non-fuel Minerals. Three minerals: ‘Coal and Lignite,’ ‘Natural Gas’ and ‘Crude Petroleum’ fall under the category of ‘fuel minerals,’ whereas the rest are of ‘non-fuel’ type. Although ‘fuel minerals’ have tremendous economic, and geopolitical significance, non-fuel minerals also wield crucial roles encompassing a wide variety of substances and play essential roles in various industries, including construction, manufacturing, electronics, and more. These minerals include metals (e.g., copper, iron, aluminium), gemstones (e.g., diamonds, emeralds), industrial minerals (e.g., gypsum, talc, quartz), and many others.

Around 5990 kinds of minerals are available on Earth as per the latest “Mineral List (2023)”, released by International Mineralogical Association (IMA, 2023). In this huge list, some minerals are specifically identified as having a maximum influence on the growth dynamics of a country. According to the terminologies defined in this thesis, these minerals have been referred to as ‘key resources’ of the economy. Key resources refer to a specific set of minerals upon which economic growth relies.

The COVID-19 pandemic and its delayed effects have severely afflicted the global economy. Especially, the production systems relying on hydrocarbons and fossil fuels suffered the brunt of the shock due to disruption in fuel supply chains. However, it was observed that energy systems based on ‘Clean Energy Technologies’ (like renewables and Electric vehicles) remained almost untouched by the perils of pandemic-related shock on the global economy. For this reason - and also for some other equally compelling factors –countries across the globe are taking extreme measures to fast-track the process of transformation from a fuel-intensive to a material-intensive energy system.

Primarily for this reason, this thesis has zeroed in on “non-fuel minerals” and kept “fuel minerals” out of the purview of discussion. We have taken into consideration, ONLY ‘non-fuel’ and ‘non-radioactive’ minerals while searching for the ‘key resources’ in the context of the Indian economy.

1.4 Current Global Perspective: An Era Marked by Pandemic, War, and Humanitarian Crises

The decade starting with 2020 has already faced a series of unprecedented crises that have grappled the global economy in all respects. The production functions of the economy have gone through a sea change as a result of the combined impact of these disasters in a very short spell of time. Drastic changes have been observed in production technologies, inputs and outputs of the production processes based on emerging market scenarios after three

consecutive shock waves. To understand the reasons behind these significant changes, a detailed study of the nature and impact of crises and their underpinning implications needs to be explored in greater detail.

1.4.1 The Great Lockdown: Outbreak of Coronavirus

The world has witnessed two unprecedented humanitarian crises during the cusp of the decadal changeover in 2020. Undoubtedly, the most remarkable crisis was Covid 19, the virulent outbreak of Coronavirus that suddenly put the entire world into a standstill mode. The duration of this global pandemic was more than three years (from 11th March 2020 to 5th May 2023, as per the WHO declarations⁷). The pandemic had a profound impact on the global economy due to intermittent lockdowns and ‘supply chain disruptions.’ The World Economic Outlook of April 2020, published by the International Monetary Fund (IMF) described this downturn as the “*Worst Economic Downturn since the Great Depression*” and designated the crisis as “Great Lockdown”.⁸ **Table 1.1** gives a summary of World Output in this context.

**Table 1.1: Summary of World Output[^]
(Annual Per cent Change) ^ Real GDP**

	2018	2019	2020	2021	2022
World	3.6	2.8	-2.8	6.3	3.5
Advanced Economies	2.3	1.7	-4.2	5.6	2.6
Emerging and Developing Asia	6.4	5.2	-0.5	7.5	4.5
Countries with Export Earning from Fuel	0.8	-0.2	-4.0	4	5.4
Countries with Export Earning from Non-Fuel	5.1	4.1	-1.5	7.2	3.9
Euro Area	1.8	1.6	-6.1	5.6	3.3
United States	2.9	2.3	-2.8	5.9	2.1
United Kingdom	1.7	1.6	-11.0	7.6	4.1
China	6.8	6	2.2	8.4	3
India	6.5	3.9	-5.8	9.1	7.2

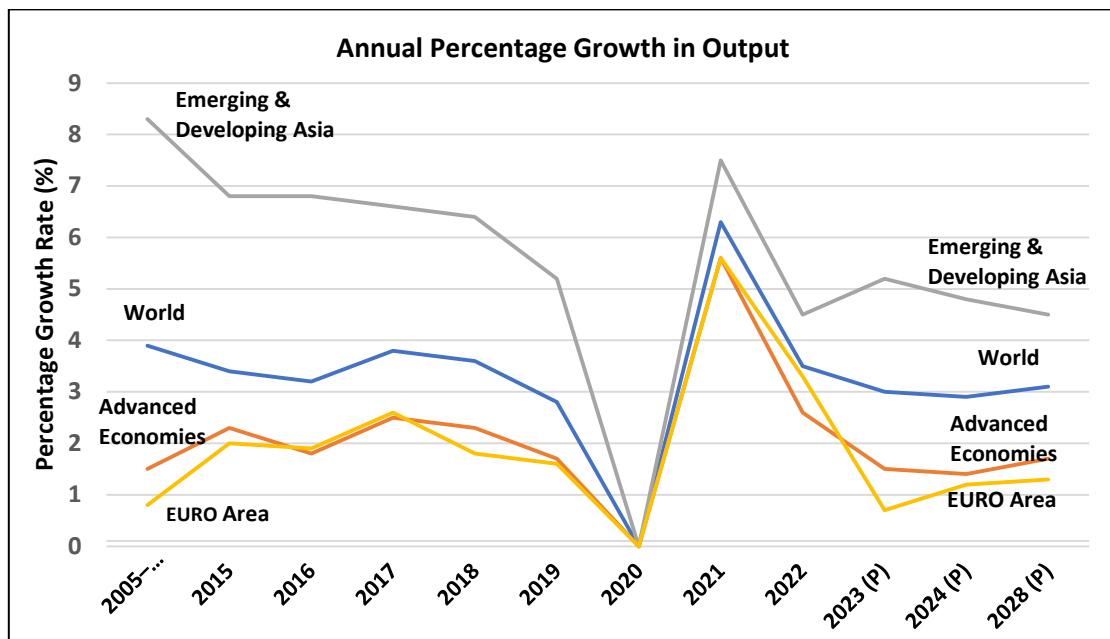
Source: World Economic Outlook: Navigating Global Divergences, International Monetary Fund, October 2023

⁷ [https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-\(2005\)-emergency-committee-regarding-the-coronavirus-disease-\(covid-19\)-pandemic](https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-coronavirus-disease-(covid-19)-pandemic)

⁸ <https://www.imf.org/en/Blogs/Articles/2020/04/14/blog-weo-the-great-lockdown-worst-economic-downturn-since-the-great-depression>

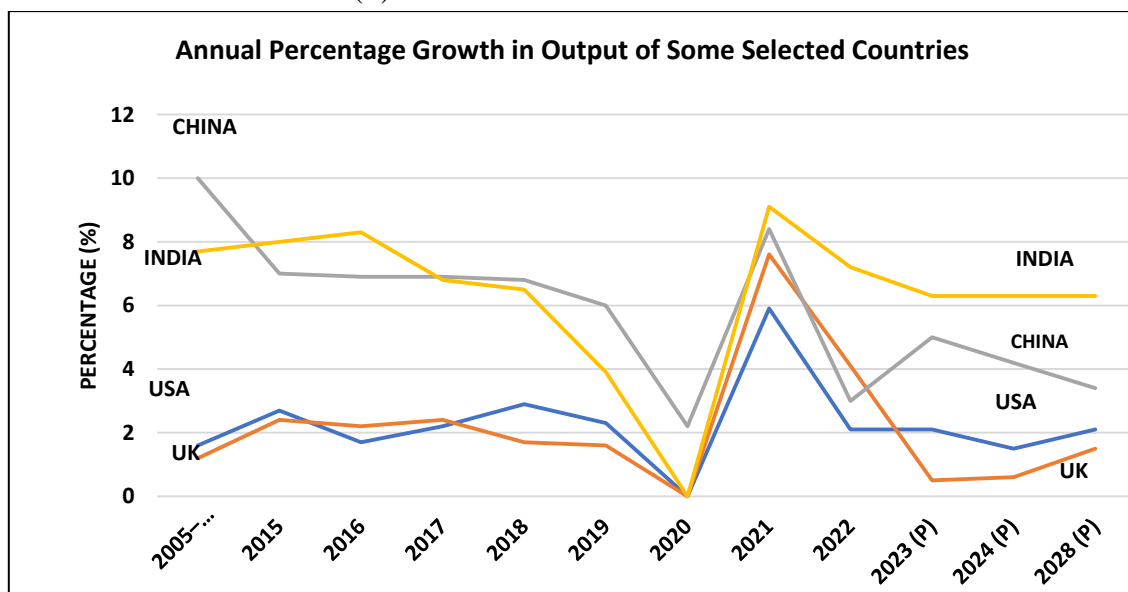
The annual percentage change in the output of the global economy reduced from 3.6% in 2018 to 2.8% in 2019 and finally plummeted further to -2.8% (i.e. de-growth) in 2020. All the countries across the globe faced headwinds of the Covid19 and eventually plunged into a recessionary phase. However, the depression and later on the revival both have been of varied extent across the countries, depending on their respective structural strengths and intrinsic economic resilience.

Figure 1.1 Annual Percentage Growths in Output of India from 2005 to 2028 (P)



Source: Author's creation using data available with Statista

Figure 1.2 Annual Percentage Growths in Output of Some Selected Countries from 2005 to 2028 (P)

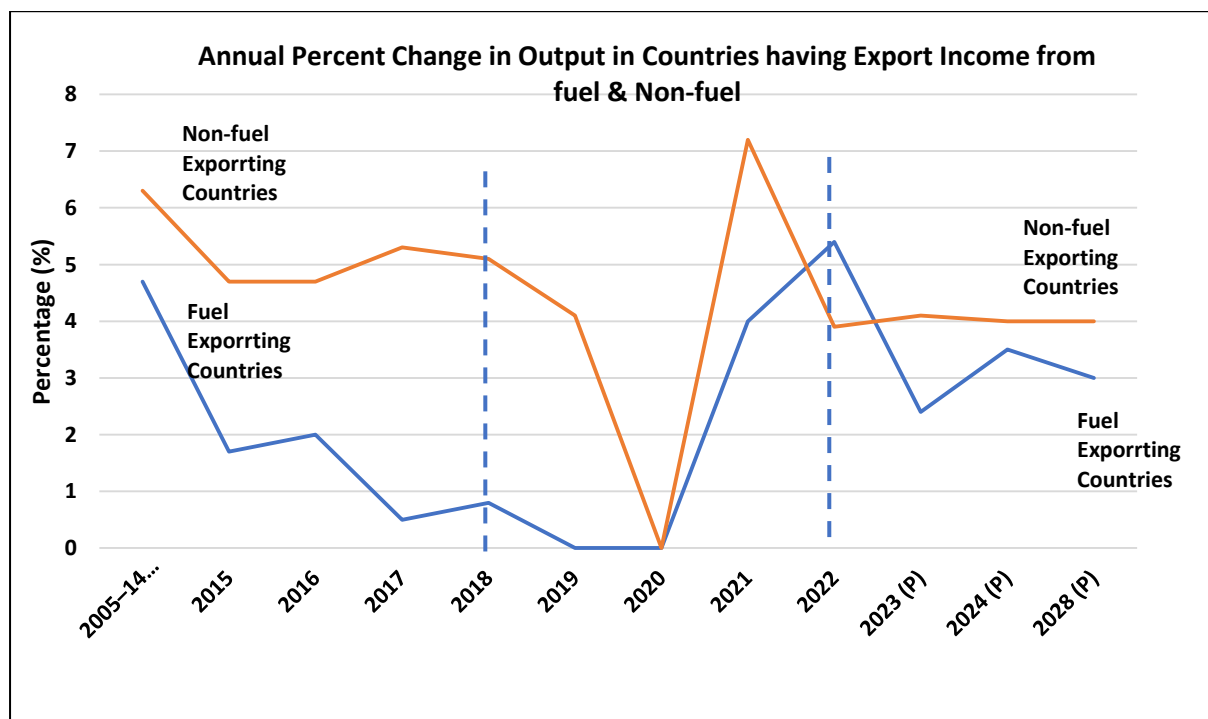


Source: Author's creation using data available with Statista

In the case of India, the revival and subsequent stabilisation process, both have been very fast due to her strong resilience, emanating mainly from the huge demographic dividend and prudent policy management by the Government. Many countries of the world (including advanced countries like the UK), however, failed miserably in this respect and eventually succumbed to the quicksand of stagnating growth rate. These countries are still finding it hard to fully recover from the adversities inflicted by the “Great Lockdown.”

Revealing Cases of Countries having Export Income from “Fuel Minerals” and Non-Fuel Minerals”. Another interesting observation in this respect is the comparison of growth rates recorded by countries having export income from ‘Fuel’ and ‘Non-fuel’ respectively. It has been found that in the year preceding the pandemic (2018), the growth rate of “fuel exporting countries’ has been way below the growth rate of “non-fuel exporting countries”. Considering 2023 as the ending year of the pandemic (WHO Declaration), in the post-pandemic year the gap between the growth rates registered by “non-fuel exporting countries” and “fuel exporting countries” has been drastically narrowed down.

Figure 1.3 Annual Percentage Change in Output in Countries having Export Income from Fuel & Non-fuel



Source: Author’s creation using data available with Statista

It can be conjectured that the economic position of countries that export “fuel minerals” has improved significantly in comparison to countries that export “non-fuel minerals” during the “pandemic period.” This observation hints at the fact that the countries that export “non-fuel minerals” are more vulnerable to “supply chain disruptions.” Hence, supply chain disruptions are a matter of grave concern for these countries and the respective governments should keep backup arrangements to counter situations that can disrupt the export. A few possible strategies to this end could be as follows:

- i) Focusing on nearby export markets: This can be a prudent policy decision to avoid long-distance transshipment of export commodities. This also implies that economic integration with Regional Value Chains (RVCs) should get a preference over integration with Global Value Chains (GVCs). To be more specific, India should engage more with countries under regional trade blocs like ASEAN and BIMSTEC, than a distant trading partner in the EU.
- ii) Developing alternative export destinations for the same product: It is always advisable to develop alternative export markets so that if commodity flow is somehow hindered in the case of one export destination, some other will come to the rescue and help in clearing the unsold product.
- iii) Looking inward: It is always advisable to promote indigenous industries that require non-fuel minerals as inputs. This kind of inward-looking policy can give rise to two serious problems. First, WTO may object to restrictive trade practices, which are against the international trading norms. Any retaliatory action by WTO can have serious implications. Second, supply to the indigenous industries can fetch significantly lower earnings than export income. This can have a direct impact on the country’s exchequer.

1.4.2 Recovery from ‘Great Lockdown’

The brunt of the Covid-shock was extreme during 2019-20. The situation started improving immediately after the successful development of vaccines and the gradual lifting of COVID-related restrictions. The first dose of the vaccine was administered in December 2020, followed by a worldwide vaccination drive by the countries. The world economy picked up very quickly and the annual growth rate leapfrogged to notch a fantastic growth rate of 6.3% (2021). However, in the following year (2022), the growth rate of the world again saw a

downturn and nosedived to touch the 3.5% mark. The growth rate of almost all the countries of the world moved in tandem with the global trend with some country-specific variations.

1.4.3 Cost-of-living Crisis: Lingering Impact of Pandemic and Global Unrest

The war between Russia and Ukraine has been continuing for almost two years (started in February 2022). War for such a prolonged period has made an adverse impact on the world economy by escalating the costs of food, energy, and finance. All of these factors have collectively contributed to a global ‘cost-of-living’ crisis. The recent conflicts in West Asia can further intensify the perils of ‘cost-of-living crises.’

1.4.4 Climate Change Crisis: Imminent Threat in Front of the Mankind

The third humanitarian crisis that emerged as a global threat was the ‘Climate Crisis’ primarily caused by large-scale deforestation across the globe to facilitate the industrialisation process and indiscriminate use of highly polluting ‘fossil fuels.’

The Paris Agreement, established at the UN Climate Change Conference (COP21) in Paris on December 12, 2015, is a legally binding international treaty addressing climate change. Ratified by 196 Parties, it became effective on November 4, 2016. The primary objective is to restrict the rise in the global average temperature under 2° C from pre-industrial levels, with additional endeavours to cap the increase at 1.5° C above pre-industrial levels. However, the initial pledges of 2015 are insufficient to meet the target. Hence, Paris Agreement commitments were reviewed at the climate change conference known as COP 26 in Glasgow, UK in November 2021.

In the last decade or so, the development paradigm of the globe has dramatically shifted its focus towards “sustainability” factors. International organisations like the United Nations (UN) emphatically urged the global community to curb carbon emissions from industrial activities on a war footing basis. Since the usage of fossil fuels has been found to be the main culprit for environmental damage, ‘Conference of the Parties (COP)’ – the highest decision-making body of the “United Nations Framework Convention on Climate Change (UNFCCC),” consistently urged countries to resort to green energy to skyrocketing industrial activities. But “Green Energy” requires “Green Technology.” And to implement “Green Technology,” the ‘key resources’ are also different. Minerals like Lithium and Selenium are indispensable to generate “Green Energy.” Apart from ‘energy,’ some minor minerals have also gained prominence.

To track climate change caused by human activities, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. This UN body tracks various indicators measuring Climate Change on real-time basis and comes out with an Assessment Report (AR) for each year. The Sixth Assessment Report (AR6) for the year 2023, has made some serious observations:

“Observed Warming and its Causes: Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1° C above 1850–1900 in 2011–2020.

“Observed Changes and Impacts: Widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses.

“Current Progress in Adaptation and Gaps and Challenges: Adaptation planning and implementation has progressed across all sectors and regions, with documented benefits and varying effectiveness. Despite progress, adaptation gaps exist, and will continue to grow at current rates of implementation

“Future Climate Change: Continued greenhouse gas emissions will lead to increasing global warming, with the best estimate of reaching 1.5° C in the near term in considered scenarios and modelled pathways. Every increment of global warming will intensify multiple and concurrent hazards.

“Carbon Budgets and Net Zero Emissions: Cumulative carbon emissions until the time of reaching net-zero CO2 emissions and the level of greenhouse gas emission reductions this decade largely determine whether warming can be limited to 1.5° C or 2° C. Projected CO2 emissions from existing fossil fuel infrastructure without additional abatement would exceed the remaining carbon budget for 1.5° C (50%)

“Urgency of Near-Term Integrated Climate Action: Climate resilient development integrates adaptation and mitigation to advance sustainable development for all, and is enabled by increased international cooperation including improved access to adequate financial resources, particularly for vulnerable regions.

“Synergies and Trade-Offs with Sustainable Development: Accelerated and equitable action in mitigating and adapting to climate change impacts is critical to sustainable development. Mitigation and adaptation actions have more synergies than trade-offs with Sustainable Development Goals.

“Finance, Technology and International Cooperation: Finance, technology and international cooperation are critical enablers for accelerated climate action. Enhancing technology

innovation systems is key to accelerate the widespread adoption of technologies and practices. Enhancing international cooperation is possible through multiple channels.”

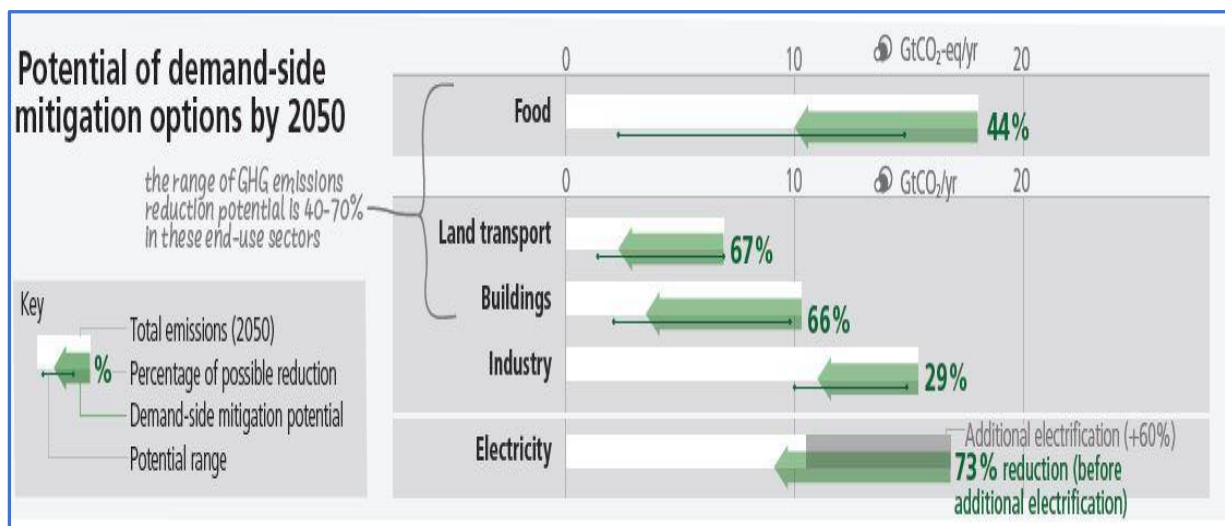
(The Sixth Assessment Report, IPCC, 2023)

Based on these observations, IPCC has held the carbon emission from the existing ‘fossil fuel infrastructures’ as the main culprit behind the “Climate Change Crisis.” The report has described this as ‘unsustainable energy use’ and strongly advocated for the adoption of a ‘Climate Resilient Development Plan’ to bring back the climatic conditions to normalcy. In this regard, ICCP has made two interesting mitigation strategies to fast-track the decarbonisation process:

- 1) Calibrating national development plans in sync with seventeen (17) “Sustainable Development Goals (SDGs)”, put forward by United Nations (UN)
- 2) Enhancing the “Technology Innovation System” in the economy to restrict carbon emissions. Global tendency to adopt “Clean Energy Technology” in the post-Covid era has emerged as an unavoidable strategy move in this regard.

The potential of demand-side mitigation options to reduce Green House Gases (GHG) by 2050 is described in the following figure:

Figure 1.4 Potential of Demand-Side Mitigation Options by 2050



Source: ICCP, 2023

Hence, as per this current estimation, the maximum mitigation is possible in following sectors:

- i) Electricity Generation (73%)
- ii) Land Transport (67%) and

iii) Construction Sector (66%)

There is a clear indication that to get out of the quicksand of ‘climate change crisis’, countries across the globe need to devise ways to reduce carbon emission in above three sectors. At this point, adoption of “Clean Energy Technology” seems to be the most effective strategic move on the part of the government to reduce carbon emission substantially. This explains the reason behind the sudden upsurge in full-fledged policy drives initiated by different countries to transform the energy system from being “fuel minerals based” to “non-fuel mineral based”, as an integral part of the “Sustainable Development Plan”.

As one of the founder members of United Nations (UN), India has made significant progress in terms of fulfilling SDG target to mitigate climate change (Goal No: 13). During COP-21 in 2015, India took a pledge to reduce country’s emissions intensity by 33% by 2030; but the same has been achieved by 2019 – that is 11 years ahead of schedule. India has also successfully accomplished the target of having 40% of electric installed capacity through non-fossil fuel sources. During 2017-2023, India added 100 GW of installed electric capacity in the country. Around 80% of this added capacity has been done using non-fossil-fuel-based resources (PIB Press Release, 14 Nov 2023)⁹

However, transforming the behemoth energy infrastructure of the country from a ‘fuel-based’ to a ‘material-based’ system is not an easy task and it entails huge requirement of some specific “non-fuel minerals.” For example, production of one unit of Electric Vehicle (EV) usually takes six times more of non-fuel mineral resources in comparison to the mineral requirement to manufacture one conventional car. Similarly, an onshore wind plant requires nine times more mineral resources than a gas-fired plant. Since 2010 the average amount of minerals needed for a new unit of power generation capacity has increased by 50% as the share of renewables in new investment has risen (IEA, May 2021)¹⁰

Adoption of “Clean Energy Technology” in the case of Electricity Generation, application of ‘Low-Carbon Technology’ and use of ‘Green Materials’ for ‘Road Transport’ and ‘Construction’ sectors respectively, can significantly reduce carbon emissions. However, few specific instruments, devices and materials must be made available to successfully implement the new technologies.

⁹ COP-21 in 2015, that we will reduce our emissions intensity by 33% by 2030; we did this by 2019

¹⁰ The Role of Critical Minerals in Clean Energy Transitions; World Energy Outlook, Special Report; International Energy Agency (IEA); May 2021

This study has performed two exercises:

- i) Mapping between devices and materials needed for implementation of ‘Clean Energy Technology’ (**Table A1: Appendix**)
- ii) Mapping between minerals required to manufacture devices with materials (i.e non-fuel minerals) to implement ‘clean energy technology’
(**Table A2: Appendix**)

However, ‘Clean energy transition’ is basically the ‘technology transition’, of which we have discussed in detail at the beginning of this thesis.

Table A2 and Table A3 collectively imply that the ‘energy transition’ process entails huge amounts of non-fuel minerals for the generation of electricity. A cursory look at these tables reveals that most of these minerals fall under the category of Rare Earth Elements (REE). The Rare Earth (RE) resources in India are reported to be the fifth largest in the world. However, the availability of these mineral resources is highly limited due to the absence of an intermediate sector in the extraction process and the lack of advanced mining technologies.

Table 1.2 Rare Earth Elements (REE): Availability and Use in India

Rare Earth Elements	Availability & Use
1. Monazite (Contains ~55-60% total Rare Earth Elements oxide)	Coastal beach placer sands in parts of Kerala, Tamil Nadu, Odisha, Andhra Pradesh, Maharashtra and Gujarat and in the inland placers in parts of Jharkhand, West Bengal and Tamil Nadu
2. Magnetic REE (Neodymium, Praseodymium, Dysprosium and Terbium)	Used in energy transition initiatives

Source: PIB, 06 April 2023

Table 1.2 gives a glimpse of the availability and use of Rare Earth Elements (REE) in India
Absence of an intermediate sector in the extraction process in India:

- **The Missing Middle in India’s Extraction Industry**

In India, the extraction industry faces a significant gap between small-scale and large-scale operations. The mining industry in India is clearly divided into two distinct segments: large multinational companies and small-scale local operations. Large companies benefit from substantial capital, advanced technology, and skilled labor, allowing for efficient large-scale

extraction. Small-scale operations rely on manual labor with minimal technological input, resulting in inefficiency and environmental harm. Unfortunately, the intermediate sector, which should bridge the gap with moderately advanced technology for medium-scale operations, remains underdeveloped or absent. The absence of an intermediate sector hinders the growth of small-scale operations. Small businesses miss out on a bridge that could facilitate their scaling up. Medium-sized enterprises play a vital role in innovation and balance between flexibility and efficiency. Moreover, medium-sized enterprises provide significant employment opportunities. These jobs require higher skill levels than small-scale operations but are more numerous and locally rooted than those in large-scale enterprises. The lack of this sector results in missed job creation opportunities, especially for semi-skilled and skilled workers.

Another structural constraint that has been seriously limiting potential of mining sector in India is lack of advanced mining technologies.

- **Lack of advanced mining technologies in India**

India has progressed in integrating and developing mining technologies, yet various obstacles continue to limit the industry's capacity to reach its utmost potential. These obstacles affect productivity, environmental sustainability, safety, and overall operational efficiency. Although there have been strides forward, the integration of advanced technology within the Indian mining sector varies widely across different areas and sectors. Particularly, small to medium-sized mining enterprises often do not have the necessary funds or knowledge to invest in sophisticated technologies, relying instead on outdated and less efficient practices. The substantial upfront costs needed to adopt state-of-the-art mining technologies pose a major hurdle, particularly for smaller entities. A lack of sufficient financial support and incentives for technological enhancement hampers the broad adoption of contemporary mining techniques and tools. Employing advanced mining technologies necessitates a workforce proficient in current methods and equipment.

The industry faces a skills shortage, with a lack of workers adept in operating, maintaining, and managing modern mining technologies, which can stall the adoption of new technologies and diminish operational efficacy. Although emerging technologies promise lower environmental footprints, their implementation is not yet widespread. Persistent use of conventional mining practices leads to significant ecological harm, such as deforestation, water contamination, and soil erosion. Furthermore, insufficient regulatory oversight can lead to a neglect of technologies aimed at minimizing these impacts. In India, the regulatory

environment can sometimes obstruct the adoption of sophisticated mining technologies. Challenges such as regulatory obstacles, administrative delays, and the absence of definitive policies for the deployment of innovative technologies can hinder progress.

Additionally, there is a need for policies that specifically promote innovation and ecological sustainability in mining operations. Obstacles related to infrastructure, including subpar transportation and logistics capabilities, can restrict the smooth functioning of mining operations. The absence of essential infrastructure for modern technologies, such as adequate power and water supply, communication systems, and access roads, additionally complicates the adoption of new technologies and efficient mining practices. Even with technological advancements, mining remains a perilous profession in India, with a higher incidence of accidents and fatalities compared to many other countries. The scant adoption of safety-oriented technologies, including real-time monitoring systems, automated machinery, and enhanced protective equipment, continues to be a concern for worker safety.

Tackling these limitations demands a unified effort from the government, industry players, and the academic sector. Investments in research and development, specific policy measures, training programs, and improvements in infrastructure are essential to surmount these obstacles and fully leverage the capabilities of mining technologies in India.

1.5 Objectives of the Study

The principal objective of this thesis is to investigate the intricate inter-relationship between the economic progress of a country with the endowments of 'natural resources' that the country possesses. By natural resources we mean a set of 'non-fuel minerals', which the thesis has defined as 'key resources'. The thesis seeks to understand the unique mechanism through which 'key resources' influence the growth trajectory of a country. It was made clear at the beginning, that by "key resources" we intend to refer a specified set of non-fuel minerals. This set of minerals is subject to continuous change and modulation as per the requirement of time and perspective. In this background, we can delineate the following objectives as the key points of enquiry in our study:

The key resources are in fact the juggernauts on which the global economy moves. The economic history of the fifth largest economy of the world also conforms to the same fact. After Independence; the infrastructural backbone of Indian economy started to take shape with huge emphasis on heavy industries by the policy makers. Several large steel plants were

established in the years following independence. Most important among them were Bhilai Steel Plant (1955), Rourkela Steel Plant (1955), Durgapur Steel Plant (1959) and Bokaro Steel Plant (1964). Major power plants established during the formative stage of India's industrial base included: Damodar Valley Corporation (1948), Bhakra Nangal Dam Project (1960), Neyveli Power Plants (1960) and Tarapur Atomic Power Station (1960). These plants along with other heavy industries were part of India's first major wave of industrialization and played a crucial role in the development of the country's infrastructure and economy.

The set of minerals extensively used in this period included iron ore, aluminium ore, bauxite and fuel minerals like coal. Some of these minerals have become an integral part of India's growth story and are still playing key roles in determining the growth. But the list continuously kept on changing depending on evolving situation: both external and internal. In 21st Century, the deciding factors have mostly been external, starting with impact of Global Climate Change; insurgence of Covid 19 pandemic to onset of Russia-Ukraine war and myriad regional skirmishes over territorial dominance. All of these factors have significantly contributed to a complete overhaul of production processes along different industry lines.

- 1) The first and foremost objective of this thesis is to identify “key resources” in the case of the Indian economy in the post-Covid era. Globally, there have been drastic changes in the production systems in terms of industrial output produced, types of technologies applied and changes in market motive and purpose. All of these changes have happened in the emerging global perspectives. At this point, we need to identify newly evolved “key resources” in the case of the Indian economy. The most important objective of this study is to identify the “key resources” in the case of the Indian economy. After enumeration of the extended IO Table of India, this identification process needs to be initiated
- 2) Looking at the highly interdependent industrial structure of the Indian economy, Input-Output analysis provides the most robust and Computable General Equilibrium (CGE) framework. To incorporate all the “knock-on” effects of economic/geopolitical turbulence, this analytical framework is ideal for our research. This thesis has made extensive use of the Input-Output framework to perform our analysis. Construction of the Input-Output Table is the first step for carrying out any analysis in this theoretical framework. So, we need to extend the IO Table to get a comprehensive result for introspection. The primary focus of this thesis is on the

“non-fuel mineral” sector, we need to incorporate more of such minerals in the existing IO Table of India. The second most important objective is to extend the latest available IO Table of India (2018-19) based on data available from the Indian Bureau of Mines (IBM) and the Ministry of Mines (MoM), Government of India.

- 3) Enumeration of the extended IO Table of India (2018-19) opens a plethora of research opportunities using the analytical framework of IO model. One such intriguing research area will be to examine the feasibility of ambitious growth targets, as envisaged by the Government of India for different sectors of the economy in recent times. Our objective in this part of our study is to examine the feasibility and implications of different schemes and missions initiated by the Government of India. This thesis has however been concentrated on the path-breaking policy initiative: ‘*Atmanirbhar Bharat Abhiyaan*’(2020)
- 4) Introspecting the mineral sector of India with greater details. Explore all the minerals referred to as “major minerals” by Ministry of Mines, Government of India and incorporate them in a structured analytical framework (i.e., Input-Output Table of the country) for subsequent sensitivity analysis.
- 5) Another key objective of this thesis is to examine the extent of the connectedness of the Indian economy with other countries. The measurement of ‘value chain integration’ can be a revealing exercise to understand the vulnerability factor of the existing supply chains.
- 6) Lastly, based on the results obtained from our analysis, the final objective of this thesis will be to make suitable policy prescriptions for deriving a “Sustainable Development Plan” for the country.

1.6 Novelty of the Study

1. **Focus on Non-fuel Minerals:** There has been more than enough research works and studies conducted on “Fuel Minerals,” both globally and in India. There are innumerable research works conducted by reputed academic institutions, professional research bodies, experts and independent researchers. Considering the gravity of “hydrocarbon fuels” for running almost all industrial activities and associated production processes, regular research work was conducted to enable the Government of any country to make informed decisions, in the right direction on a real-time basis.

Every nook and corner of the conventional energy sector has been studied, introspected, and analysed multiple times by multiple agencies. However, research on “non-fuel minerals” is still at a very nascent stage. It was mainly an area restricted to metallurgical engineers, technical experts, academic institutions etc. There is much good research work conducted by reputed research institutions, but most of these studies were done with some technical quest. There is a dearth of pure economic research on “non-fuel minerals” at present. However, the current global situations and geopolitical perspectives have already brought a dramatic change in the “non-fuel mineral” sector in the last few years. The newly evolved economic situation demands more economic research to be conducted at the earliest. This thesis is an attempt to meet this requirement.

2. **Comprehensive Analysis on Non-fuel Minerals:** At the outset, this thesis has aggregated the (140x140) Input-Output (IO) matrix to (38x38) Aggregated IO Matrix following an Aggregation Scheme (**Table A5: Appendix**). The Input-Output Tables (2018-19) constructed from Supply and Use tables (SUT) published by Central Statistical Organisation (CSO) incorporated only 9 mineral resources in a structured framework. The list includes 3 fuel minerals (*Coal & Lignite, Natural Gas and Crude Petroleum*) and 6 non-fuel minerals (*Iron ore, Manganese Ore, Bauxite, Copper Ore, Limestone and Mica.*). Rest of the minerals have been categorised into two broad sectors: Other Metallic Minerals and Other Non-metallic Minerals.

However, according to Ministry of Mining, Government of India, a list of 30 non-fuel minerals (metallic and non-metallic) have been cited as “Major Minerals”, which are used extensively as raw materials by the manufacturing sector of the country.

The list includes the following minerals as cited below:

Fuel Minerals (3): *Coal and Lignite, Natural Gas, Crude Petroleum*

Non-fuel Minerals (30): *Iron Ore, Manganese Ore, Bauxite, Copper Ore, Chromite, Gold Ore & Gold, Lead conc., Zinc conc, Silver, Tin conc., Limestone, Mica, Phosphorite, Diamond, Fluorite (graded), Garnet (abrasive), Graphite (r.o.m.), Iolite, Kyanite, Sillimanite, Limeshell, Magnesite, Marl, Moulding sand, Salt (rock), Selenite, Siliceous earth, Vermiculite, Wollastonite, Minor Minerals*

We have incorporated all these non-fuel minerals into the structured framework of IO table and conducted our subsequent research. This has broadened scope of more extensive study to get a holistic view of our research area.

3. **Introspecting Feasibility of Envisaged Growth Targets:** Checking feasibility and sustainability of new Schemes and Projects initiated by the Government of India is an upheaval task. One of the most convenient and robust ways to do that is probably by applying a suitable IO Model. Hence, important government policies like “*Atmanirbhar Bharat*,” “*Make in India*” etc need to be testified to measure status of the progress made. Since the current perspective insists to redirect funds from “fuel” to “mineral” based energy system, requirement of existing Schemes should be reviewed by the Government. This thesis has attempted to accomplish this task for a few selective Government projects.
4. **Incorporating Non-fuel Minerals in the Purview of Value Chain Integration:** The study showed an alternative route through which ‘Key Resources’ of an economy can be identified and promoted to foster future growth and development. The route is through advancing policy directive with focus on few sectors of the economy, which are highly integrated with Global Value Chains (GVCs). Sectors, which have strong linkages with cross-border supply chains, induce growth and development of the domestic economy through multiplier effect on income and employment. In case of India, we have found that few minerals - already identified as the ‘Key Resources’ in terms of linkage effects - are also proved to be crucial in terms of Value Chain integration.

1.7 Key Resources V/s Critical Minerals

At the outset, it is necessary to clarify that ambit of thesis is ‘Key Resources’, not ‘Critical Minerals’. Very recently a document¹¹ published by Ministry of Mines, Government of India has identified 30 minerals as “**Critical Minerals**”. These are: *Antimony, Beryllium, Bismuth, Cobalt, Copper, Gallium, Germanium, Graphite, Hafnium, Indium, Lithium, Molybdenum, Niobium, Nickel, PGE, Phosphorous, Potash, REE, Rhenium, Silicon, Strontium, Tantalum, Tellurium, Tin, Titanium, Tungsten, Vanadium, Zirconium, Selenium and Cadmium.*

¹¹ Critical Minerals for India; Report of the Committee on Identification of Critical Minerals, Ministry of Mines, June 2023

The report has defined ‘Critical Minerals’ as those minerals which are essential for economic development and national security, the lack of availability of these minerals or even concentration of existence, extraction or processing of these minerals in few geographical locations may lead to supply chain vulnerability and disruption.

It is noteworthy that ‘Critical Minerals’ are scarcely found minerals primarily used for generation of renewable energy. As a result, barring a few, most of these minerals are imported from outside in India. Secondly, Critical Minerals are required in smaller proportion compared to any other fuel or non-fuel minerals in the production process.

On the other hand, this thesis focuses on particular set of non-fuel minerals, which drives the economy as a whole. These minerals have higher multiplier values, strong backward and forward linkages or highly integrated in the supply chain of some GVCs. These minerals are required in higher proportion to build the basic infrastructure of an economy. The availability of these minerals are often not constrained but always subject to fast depletion. To be concise, the ‘Key Resources’ are primarily a group of non-fuel minerals, which are exhaustively required for developing the manufacturing base of a country. However, due to world-wide energy transition in process, some of the ‘Critical Minerals’ have emerged as ‘Key Resources’ for the growth and development.

Hence, this thesis delves into these 30 major non-fuel minerals of India to identify the ‘Key Resources’ of the country. These ‘Key Resources’ may or may be ‘Critical Mineral’ in nature. One of the primary objective of this thesis is to understand, how many of these 30 major non-fuel minerals can be categorised as ‘Key Resources’ for India

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This thesis can be visualized as a tapestry of interlinked ideas. These ideas can be summarized as:

- A set of non-fuel minerals can be identified as key resources of the economy
- The set of key resources changes over time, depending on myriad structural and non-structural factors
- Since, the world has gone through a sea change after the outbreak of Covid pandemic, it is imperative to revise policy decisions based on the updated list of key resources
- To make the policy framework more effective, the new age developments like – heightened importance of Clean or Green technology, cutting edge technology products like Semiconductors, Photovoltaic Cells, Electric Vehicles (EVs) etc should be brought under the purview of policy formulation process.

2.2 Literature Review

The thesis has been sequentially organized and presented in the form of seven Chapters:

Chapter 1 started with a brief introduction of the topic and the stated objective to introspect on the “key resources” of the Indian economy. To bring more clarity to the objective of this study, the thesis has started with a discussion on the concept of ‘key resources and their importance in specifying the growth trajectory of a country’ in Chapter 1. In this thesis, ‘key resources’ have been described as a specified set of non-fuel minerals, relying on which the juggernaut of an economy moves. To put it in other words, ‘key resources’ represent a group of non-fuel minerals that have the maximum impact on the GDP of the economy.

To investigate the mineral sector more intensively, the thesis covered various related issues. Hassani and Tannant (2016) explored the safety aspects of mining operations not involved in extracting energy-providing minerals, such as metals and non-metals. They pointed out various hazards present in these mining activities, including but not limited to, air and water pollution, as well as risks of accidents and injuries to workers. The study also provided recommendations for mitigating these risks, emphasizing the importance of measures like effective ventilation, efficient waste management, and comprehensive safety training for mining personnel. In a similar vein, Wang Q. and Li Z. (2017) investigated the global patterns in the production and consumption of non-fuel minerals in their study "Global

Trends in non-fuel mineral Production and Consumption". This research is particularly relevant given the widespread use of such minerals across diverse sectors such as technology and transportation. The findings indicate a notable increase in worldwide production and consumption of these minerals, underscoring their environmental repercussions. The authors stress the imperative for sustainable management practices among policymakers, industries, and the general populace to mitigate environmental harm.

Gupta and Chen (2018) examined the economic consequences of scarcity in non-fuel minerals, which are critical for a wide array of sectors such as electronics, construction, and transportation. Employing a quantitative methodology, they modelled the global economic repercussions of limited non-fuel mineral resources. Their research indicates that the sustained availability of these minerals is pivotal for future economic development. This study offers significant insights into the discourse surrounding the sustainability of the global mining sector, underscoring the urgency of adopting more sustainable practices in resource management.

In their article "The geopolitical implications of non-fuel mineral resources," Baker E. and Jones M. (2018) delved into the role of non-fuel mineral resources, like metals and minerals, within the context of global geopolitics. They contended that the diminishing availability and escalating costs of oil have elevated the strategic importance of these resources. The paper examines how this trend affects different nations and regions, highlighting the geopolitical ramifications of the shift.

Ying L. and Wang H. (2019) conducted a thorough investigation into the technological progress in processing non-fuel minerals, focusing on iron ore. Their study emphasized the utilization of artificial intelligence and machine learning to enhance the efficiency and reduce the costs associated with iron ore processing. Concurrently, Smith J. K. (2019) contributed an article to "Mineral Economics," examining the critical role non-fuel minerals play in modern society. This article covered the functions, impacts, and applications of non-fuel minerals in current economic and industrial activities.

In the article titled 'Sustainable extraction and utilization of non-fuel minerals,' authored by Mary L. Johnson M.L and Anderson R.S. (2020) explored the opportunities and obstacles associated with the sustainable extraction and utilization of non-fuel minerals. These minerals are crucial for various sectors such as electronics, construction, and transportation, yet their extraction poses environmental risks. The authors examined existing methods and suggested

alternative approaches to lessen these adverse effects, including the adoption of circular economy principles, implementation of decision-making frameworks, and enhancement of stakeholder involvement.

Roberts P.A (2021) conducted a comprehensive review in the journal *Environmental Science & Technology* on the environmental repercussions of mining and extracting non-fuel minerals like metals, non-metals, and construction materials. The review addressed significant issues like habitat disruption, water contamination, and greenhouse gas emissions, among others. Roberts concluded by emphasizing the urgent need for stricter regulations and better management practices in the non-fuel mineral extraction industry to reduce its environmental footprint.

Subsequently, Foley and Jancsurak (2022) highlighted the importance of non-fuel minerals in sustainable development. These minerals, which include metals, non-metals, and organic compounds, play crucial roles in various industries, including energy, agriculture, construction, and electronics. However, the extraction and use of these minerals can have significant environmental and social impacts, such as habitat destruction, pollution, and labour exploitation. Therefore, the authors propose a sustainable approach to mineral extraction and use, which involves reducing demand, improving efficiency, and promoting the recycling and reuse of minerals. The article provides valuable insights into the pressing challenges and opportunities associated with mineral resources and offers practical solutions to address them.

The Chapter 2 of this thesis provided a comprehensive literature review on the economy-wide assessment of 'key resource sectors' of India and the prospect of value chain integration with selected Asian economies. Works of literature about "key sectors", mining and minerals, value chain integration, critical minerals etc. and all the background documents like reports, books, journals, academic papers and newspaper articles have been discussed briefly in this Chapter.

The methodologies for the derivation of the Input-Output Table (IOT) from the Supply Use Table (SUT), Leontief and Ghosh multipliers, backward and forward linkages, Principal Component Analysis (PCA), and Value Chain Analysis were explained in Chapter 3 of this thesis. Adhering to the methodologies, corresponding data was also constructed. The methodological background of this thesis is based on the analytical framework of Input-Output Analysis. Rasmussen P.N. (1956) wrote extensively on intersectoral relations in his

book, "Studies in Intersectoral Relations". The book explored the importance of the interactions between different sectors of society. Rasmussen was particularly interested in investigating the social, economic, and political factors, and the way they intersect and influence each other. In the book, he examined numerous case studies from history and contemporary society to illustrate his insights on intersectoral relations. Rasmussen's work continues to be relevant today, as researchers continue to study the complex ways in which different sectors of society interact and shape each other. Walter I. (1960) wrote a book on economics that introduced the input-output analysis method, which is a computational model used to understand the relationships between different parts of the economy. The author presented the concept of an interregional input-output model and its applications to regional economies. This work has been influential in regional research and economic development planning.

"The Elements of Input-Output Analysis" authored by Miernyk W.H (1965) serves as an extensive exploration of input-output systems, applying mathematical methods to understand the dynamics of complex systems like economies or ecosystems. Esteemed as a foundational work in operations research, this text remains a vital resource today for its thorough examination of the subject.

Arrow K.J, Frank H. and Hahn F.H. (1971) authored a book titled "General Competitive Analysis" which stands as a cornerstone text in game theory and competitive economics. This work lays down theoretical frameworks for scrutinizing market structures and competitive scenarios, encompassing discussions on market equilibrium, product differentiation, and the strategic behaviors of monopolies and oligopolies. It is extensively utilized by economists and business professionals to grasp market behaviors and inform strategic decisions.

"Input-Output Analysis: Foundations and Extensions" by Miller R.E and Blair P.D. (1985, 2009) is a pivotal reference on input-output analysis, offering insights into the economic flows between industries. The book elucidates the methodology for evaluating economic changes' effects on supply and demand, and for predicting economic expansion, presenting both fundamental and advanced applications of input-output analysis.

"Economics of the Environment: Selected Readings," edited by Armand Schor A. and Shughart W.D II (2003), compiles essential writings on environmental economics, touching on environmental regulation, sustainability, and the economics of natural resources.

Erik Dietzenbacher E. and Lahr M.L (2006) authored an article titled “Regional Science Matters: Studies Dedicated to Walter Isard” (2006) pays tribute to Walter Isard's significant contributions to regional science, offering a collection of studies that reflect his impact on the field. The book delves into the spatial dynamics and interrelationships of socio-economic systems, embodying the interdisciplinary essence of regional science.

Lastly, "Inter-industry Analysis and Input-Output Models" by Eric C. Wang and Regemorter D.V (2018) provides an accessible guide to input-output models and their applications in understanding industry interconnections within economies. Through practical examples, case studies, and exercises, this book demonstrates the utility of input-output models in regional development, environmental analysis, and policy assessment.

The thesis observed a serious anomaly in the mineral statistics of India. Database published by the Indian Bureau of Mines (IBM), Ministry of Mines (MoM) and Central Statistical Organisation (CSO) have been found to vary widely.

The first part of Chapter 4 explained the process of systematic incorporation of the extended list of minerals in IO Table (2018-19) and the identification of “Key Resources” in the Indian context. It is noteworthy that the importance of ‘key resources’ has become more pervasive due to its crucial role in achieving the global target of having ‘net-zero carbon emission’ by 2070. Many new minerals are being added to the list of ‘key resources’ due to their crucial role in the transformation process towards a ‘green economy’. Accordingly, the list of ‘key resources’ needs to be more broad-based to understand the overall impact on the economy.

The Input-Output Table published by the Central Statistical Organisation (CSO), Ministry of Statistics and Programme Implementation (MoSPI), Government of India provides information about only (8) minerals in the structured format of Input-Output Table. Whereas, the Indian Bureau of Mines (IBM), Ministry of Mines, and Government of India regularly publish all relevant data regarding (26) minerals. This Chapter has attempted to make the analytical framework of Input-Output analysis more inclusive in the case of the Indian economy, by systematically incorporating 25 new non-fuel minerals into the existing Input-Output Table (IOT 2018-19).

The second part, Chapter 4 deals with the identification of “key resources” in the case of the Indian economy by applying a few specific mathematical techniques. The identification has

been done using two mathematical processes. We have used multipliers and backward and forward linkages as the indicators for the identification process.

Second, we have applied a mathematical technique called “Principal Component Analysis (PCA)” to identify the most important sectors of the economy. PCA is a “systematic factor reduction process”, often used to filter out the most important factors (here sectors) from others in terms of their respective influences on final output (here GDP). The beauty of this method is that, while filtering out the most important sectors, it retains the essence of the collective impact of less influential sectors through a rigorous mathematical process.

The thesis has enumerated the multiplier values of various sectors as classified in the Input-Output Table of India (2018-19) and calculated the ‘linkage effects’ to understand the relative strengths of different sectors in influencing the GDP of the country. Some similar approaches to identifying the ‘key sectors’ in this way include the studies made by Polenske (2002), which focused on unraveling the role of links and linkages in economic development, with a particular emphasis on the development of inter-industry and inter-firm linkages. The author discussed various aspects of linkages, including the types of linkages that are typically found in different types of regions, the role of linkages in reaching economic growth, and the challenges facing linkages in different regions of the world. Polenske's work has been influential in the field of economic development and has contributed to research on linkages. Much before to this seminal work, Hazari (1970), presented an empirical study of key sectors in the Indian economy. The paper provided a detailed analysis of the expansion and growth of different sectors in India, including manufacturing, agriculture, and trade, based on annual data from 1961 to 1968. The author identified various factors affecting the growth of these sectors, such as capital inflows, government policies, and external trade. The study provided important insights into the Indian economy and its structural changes during this period.

Principal Component Analysis (PCA) is a statistical technique used to project high-dimensional data into a lower-dimensional space while retaining most of the variation in the data. It is commonly used for data compression, dimensionality reduction, and data visualization. This thesis has tried to identify the ‘key resources’ of the Indian economy through the application of PCA. For this, we have used the reference book written by Jolliffe, Ian T. (2002) entitled "Principal Component Analysis". The book provides a comprehensive overview of principal component analysis, which is a widely used statistical technique for dimensionality reduction and data analysis. It includes mathematical derivations, practical applications, and real-world examples of PCA. Overall, the book is a valuable resource for

researchers, statisticians, and data scientists looking to understand and apply PCA in their work. Yoshida, Yukihiro and Terasaki T. (2009) jointly authored the paper "Principal Component Analysis with Non-Gaussian Data: Application to Metabolomics," published in the *Journal of Bioscience and Bioengineering*. In the paper, the authors introduced a new method for performing principal component analysis (PCA) on non-Gaussian data, specifically metabolomics data. The method they propose is based on the Johnson–Shannon divergence and can handle the presence of outliers and non-linear relationships within the data. The application of this method to metabolomics data is demonstrated through the analysis of experimental results, providing valuable insights. The article written by Abdi, Hervé, and Williams L.J (2010), provided a thorough review of the theory, implementation, and applications of PCA.

The input-output model is an econometric tool used to analyze the relationships between the production and consumption of goods and services in an economy. In the paper "Extending the input-output model with assets," authors Chen, Guo, and Yang (2005) proposed an extension to this model that takes into account the role of assets in economic activity. They argued that assets, such as buildings and equipment, play a crucial role in productivity and must be included in the model to provide a more accurate representation of the real economy. The paper presented a new method for incorporating assets into the input-output model and used it to analyze the impact of asset investment on economic growth in China.

Mehmet K.U.L.A. and Expert T. (2008) authored a study focusing on the supply-use and input-output tables, as well as the backward and forward linkages within the Turkish economy. This work sheds light on the intricate economic interconnections present in Turkey. The article "From Input-output Tables to Supply-and-Use Tables" by Kazemier B., Driesen C.H. and Hoogbruin E. (2012) published in *Economic Systems Research*, explores the transition between input-output and supply-and-use tables. These tools are essential for gauging economic activities and analyzing goods and services flows. The authors address the conversion challenges between these tables, providing insights crucial for economists, policymakers, and analysts.

Lenzen and Rueda-Cantuche (2012) delved into the application of supply-use tables in evaluating environmental impacts across various sectors. Their discussion highlights the tables' potential to inform policies aimed at mitigating environmental damages while acknowledging the methodological hurdles. This paper serves as an informative guide for those interested in environmental policy and sectoral interdependencies.

Nazri M.M. (2012) published an article in *Anusandhanika*, "Mineral Resources and Economic Growth of India," examines the nexus between India's mineral wealth and its economic expansion from 1950 to 2010. Through statistical analysis, Nazri underscores the pivotal role of mineral resources in India's development, despite accompanying challenges.

The paper authored by Bhattacharya and Rajeev (2013) applies the Input-Output (I-O) model to dissect the Indian economy's sectoral interrelations, identifying key sectors such as manufacturing, services, and agriculture. Their findings, based on the 2008-2009 National Accounts Statistics of India, highlight the significant inter-sectoral linkages essential for understanding the economy's structure.

J. Dubiński (2013) contributed an article to the *Journal of Sustainable Mining*, which discussed the mining industry's sustainable development. The paper argues for the sustainable and responsible exploitation of mineral resources to ensure their longevity and to garner socio-economic and environmental benefits, emphasizing the industry's role in sustainable practices.

One of the studies titled "Mining export, industrial production and economic growth: A co-integration and causality analysis for India" authored by Sahoo A.K.; Sahoo D. and Sahu N.C. (2014) was published in the journal *Resources Policy* (pages 27-34). In the paper, the authors examine the relationship between mining exports, industrial production, and economic growth in India using co-integration and causality analysis. They found that mining exports have a significant positive relationship with economic growth, while industrial production has a positive relationship with both mining exports and economic growth. The study's results have important implications for

India's Critical Mineral Resources by Gupta and Ganesan (2014) is a policy brief released by the Center for Energy and Environment (CEEW). The document provides a comprehensive analysis of India's critical mineral resources and their trade and economic implications. Critical minerals are minerals that are essential for the development of various industries, such as defense, energy, technology, and transportation. In this report, the authors identify India's critical mineral resources, discuss their current status, and assess their future demand. Additionally, they provide recommendations for India to improve its position in the global mineral market by enhancing its capability to produce, process, and export these minerals.

Another research paper authored by Chattopadhyay M. and Lahiri A. (2017) was published in the *Statistical Journal of the IAOS*. In the paper, the authors discuss data anomalies found in

mining statistics related to India. They identify various inconsistencies and errors in the data, and propose potential solutions to address these issues.

The article "National Mineral Policy and its Impact on Indian Mineral Sector" by Randive R. K., Jawadand S. A., and Raut T. S. (2017), published in the Journal of Geoscience Research examines the impact of India's National Mineral Policy on its mineral sector. The policy was aimed at increasing the country's mineral production, promoting the development of the sector, and ensuring sustainable mining practices. The study finds that the policy has had a positive impact on the sector, leading to increased production and investment. However, the authors also note that challenges remain, including the need for better infrastructure and management practices, as well as addressing concerns around

The paper written by Rueda-Cantuche, Amores, and Remond-Tiedrez (2020) focuses on the possibility of converting supply, use, and input-output tables into a different classification, which involves the use of aggregate information. They argue that this approach can provide more efficient and accurate analyses of economic systems. The paper is published in the Economic Systems Research and contributes to the field of economic systems analysis.

The article by Marimuthu et al. (2021) discusses the socio-economic and environmental challenges faced by the mining industry in emerging economies. The authors assess the implications of these challenges on resource policies and sustainability in the mining sector. They find that mineral extraction has significant impacts on local populations, ecosystems, and economies, and that there is a need for more sustainable resource policies to mitigate these impacts. The article is published in the journal Sustainable Production and Consumption, which focuses on sustainable development and resource management.

A research paper by Chadha and Sivamani (2022) discusses the critical minerals for India and their importance in the development of green technologies. The paper evaluates the criticality of minerals such as lithium, cobalt, copper, nickel, and rare earth elements, and projects their future needs based on the increasing demand for clean energy technologies like electric vehicles, wind turbines, and solar panels. The authors also explore alternative sources and recycling methods to reduce India's dependence on imports and mitigate environmental impacts.

Padhan D. and Das A. (2022) presented a study on Physical and monetary asset accounting of mineral resources in India. The paper focuses on the importance of better resource accounting to improve efficiency and transparency. The authors used a quantitative approach to estimate the physical and monetary value of mineral resources in India. They reported that the total

value of mineral assets in India is estimated to be around trillion of dollars. The study highlights the country's mineral resource sector as an important contributor to the economy, and the need for better resource management practices to promote sustainable development.

The article "Building Resilient Mineral Supply Chains for Energy Security" is a report from the Council on Energy, Environment and Water (CEEW) that was published by Dutt A. and Tyagi A. (2022). The document explores the importance of mineral resources, particularly those found within the Asia-Pacific region, for the development of a sustainable energy industry. It offers recommendations for enhancing the supply chain resilience and flexibility of these materials, including policies that promote diversification, energy efficiency, and recycling. The report emphasizes the need for a collaborative, multi-faceted approach to ensure a secure, reliable, and sustainable supply of critical minerals

Raju et al. (2022) present a study on the critical minerals that can be recovered from radioactive materials for economic benefits. They specifically focus on examples from India and publish their findings in the International Journal of Research and Technology (UIJRT). The paper discusses various minerals that can be recovered through this process such as uranium, copper, and zinc, and their potential applications. The authors highlight the importance of using these minerals sustainably and safely to minimize environmental hazards.

The article by Boraiaha and Chandan examines the potential impact of clean energy minerals in India's energy landscape by 2050. Clean energy minerals, such as lithium, cobalt, and nickel, are essential for the production of batteries for electric vehicles and renewable energy systems. The authors discuss the current state of clean energy minerals in India, including production, consumption, and trade. They also identify challenges and issues, such as resource scarcity and environmental concerns that need to be addressed to ensure a sustainable future for these minerals. Overall, the article provides valuable insights into the role of clean energy minerals in India's energy transition and the associated challenges.

In Chapter 5, the sustainability and feasibility of ambitious growth targets attached to some recently introduced Government Schemes have been testified. A modified Input-Output model has been used to accomplish this task. This exercise has been performed to understand the long-term sustainability of these schemes on the background of the current global perspective. There is a genuine need to relook at these Schemes because the new growth paradigm is more focused on sustainability, and equitability factors. The adoption of "Clean

Energy Technologies” is now insisting on a complete transformation of the “energy infrastructure” from being a “fuel-based” to a “material-based” system. The time is ripe now to understand whether the existing Government Schemes are following this new paradigm or not.

"Trade, Networks and Hierarchies" is a book written by Hewings G.J.D, Sonis M., and Boyce D.(1998). It was published in Springer in Berlin, Germany. The book focuses on regional and interregional economies, specifically on how trade, networks, and hierarchies interact to influence regional development. The book provides a comprehensive framework for analyzing the dynamics of regional economies, drawing on insights from economics, psychology, sociology, and geography. The authors incorporate a range of quantitative and qualitative methods to explore the complex relationships between economic regions and the factors that shape them.

Dietzenbacher, Erik, and Los B. (2004) published a paper on "Structural Decomposition Techniques: Sense and Sensitivity" in the journal Economic Systems Research. The paper focused on analyzing the performance and properties of structural methods for Decomposing structural VAR models. The authors also examined the impact of different sensor types and factors on the methods used. The paper's findings contributed to the tools and techniques available for use in macro econometrics, economic modeling, and forecasting.

Analyzing the scope of “Value Chain Integration” with some Asian countries has been dealt in Chapter 6. The pandemic has made it evident that supply chain disruption can easily translate into a full-fledged economic crisis within a very short duration. To make the economy resilient, the economy must get rid of all vulnerabilities in the supply chain. The Indo-Pacific region is now going through an adjustment process to reinstate “supply-chain security” after the pandemic. Measuring India’s participation with Global Value Chains (GVCs) with special emphasis on “key resource materials” could be a source of security in this situation. In addition to this, the prospect of sustainable development policies for the non-fuel mineral sector needs to be ascertained in the Indian context. The purview of our study has been to examine the scope of value chain integration for selected emerging Asian economies and India. This Chapter has explored the opportunities and scope of ‘value-chain integration’ in the “non-fuel mineral sector,” with the help of the “Computable General Equilibrium (CGE)” model using the GTAP database. The GVC participation index provides an estimation of how much an economy is connected to global value chains for its production and foreign trade. In this regard, the article written by Beverelli, Cosimo, Stolzenburg V.,

Koopman R.B, and Neumueller S. (2019), titled "Domestic Value Chains as Stepping Stones to Global Value Chain Integration" and published in *The World Economy* 42, no. 5 (2019): 1467-1494 is very important. This paper delves into the factors influencing the integration into global value chains (GVCs), crucial for understanding their historical expansion and recent slowdown. It specifically examines the impact of domestic value chains (DVCs) on GVC integration. Given the industry-specific costs associated with fragmenting production and changing input suppliers, DVCs may serve either as facilitators or barriers to entering GVCs. Concentrating on backward linkages—the procurement of intermediate goods—the study robustly supports the idea that DVCs act as precursors to GVC integration. Another study by Banga, K.(2022) titled "Impact of Global Value Chains on Total Factor Productivity: The Case of Indian Manufacturing" published in *Review of Development Economics* gives an wonderful account of the impact of global value chains (GVCs) on the productivity of developing countries, specifically through an analysis of Indian manufacturing firms from 2000/2001 to 2014/2015 using the Prowess dataset. The findings reveal that integration into GVCs significantly enhances total factor productivity (TFP) for these firms, even when considering the tendency of more productive firms to engage in GVCs. Furthermore, a deeper involvement in GVCs, measured by vertical specialization at the firm level, also positively influences productivity. The research underscores the potential of policies aimed at encouraging GVC participation and boosting firms' technological capacities to stimulate productivity improvements in developing countries.

CHAPTER 3: METHODOLOGY AND DATA CONSTRUCTION

3.1 Methodology

The capabilities of these minerals to influence the growth momentum of an economy, however varies from mineral to mineral. These differential capabilities of minerals are extremely important to identify the – ‘key drivers’ of an economy. This thesis has used different methods to identify the set of strongest influencers or most powerful non-fuel minerals as the – ‘Key Resources’. Chapter 3 elaborated these methodologies and the theoretical backgrounds for constructing the database for subsequent Chapters.

3.1.1 Input-Output Framework

The Input-Output framework (henceforth IO framework) is a powerful mathematical construct that is able to execute general equilibrium analysis in an economy, characterized by *inter-dependent* industrial structure. This unique macroeconomic framework was first conceptualized and developed by *Wassily Wassilyevich Leontief* - a Soviet-American economist known for his path-breaking research on how changes in one economic sector may affect other sectors. The mathematical rigor of the framework enables the researcher to capture the economy-wide impacts of any macroeconomic change (both internal and external) by taking all knock-on effects into consideration. Leontief won the Nobel Memorial Prize in Economic Sciences in 1973.

The Input-Output Table (henceforth IOT) is an integral part of the IO framework. It gives a comprehensive measure of the *inter-industry transactions* in value terms at factor cost. The table is represented in matrix form, where the columns represent industries and the rows represent commodities (principal products of the corresponding industries). Each row of the matrix shows the *allocation* of the total output of the commodities to the different industries for intermediate consumption and final use. On the other hand, the industry columns present the commodity inputs of raw materials and services, which are required to produce outputs of particular industries.

The entries at the bottom of the table provide the measurement of Net Indirect Taxes (NIT) on the inputs and the primary inputs (income from the use of labour and capital), i.e., Gross Value Added (GVA). The row totals of an IO Table do not tally with the column totals due to the inclusion of the secondary products, which appear particularly in the case of manufacturing industries. For preparing the industry by industry and commodity by

commodity matrices, the secondary products are transferred to the industries where they are principally produced following the procedures recommended in the UN System of National Accounts (SNA).

Let, there are ‘n’ commodities ($i = 1, 2, 3, \dots, n$) produced by ‘n’ industries ($j = 1, 2, 3, \dots, n$)

x_i : Total Output (Production) of sector i

f_i : Total final demand for sector i 's product

z_{ij} : Interindustry sales by sector i to all sectors j (including itself, when $j = i$)

The flow of commodities produced in the economy can be summarised in terms of the following set of linear equations:

$$\begin{aligned}
 x_1 &= z_{11} + \dots + z_{1j} + \dots + z_{1n} + f_1 \\
 &\cdot \\
 &\cdot \\
 &\cdot \\
 x_i &= z_{i1} + \dots + z_{ij} + \dots + z_{in} + f_i \\
 &\cdot \\
 &\cdot \\
 x_n &= z_{n1} + \dots + z_{nj} + \dots + z_{nn} + f_n
 \end{aligned}
 \tag{3.1}$$

This system of equations can be written in matrix format as follows:

$$\begin{vmatrix} x_1 \\ \vdots \\ x_n \end{vmatrix} = \begin{bmatrix} z_{11} & \dots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \dots & z_{nn} \end{bmatrix} + \begin{vmatrix} f_1 \\ \vdots \\ f_n \end{vmatrix}
 \tag{3.2}$$

Throughout this thesis, lower-case bold letters have been used for (column) vectors, as in f and x (and x' as the corresponding row vector), and upper-case bold letters have been used to denote matrices, as in Z .

Following these notations, equation (3.2) can be summarised as:

$$\mathbf{x} = \mathbf{Zi} + \mathbf{f} \tag{3.3}$$

Where ‘ i ’ is a column vector of 1’s of appropriate dimension (in this case ‘ n ’). This column vector is also termed as “summation vector.”

3.1.2 Construction of Input-Output Table

In IO framework, there is an underlying assumption about the type of production function, all industries are supposed to exhibit **Constant Returns to Scale (CRS)** production function during the course of the production process. This fundamental assumption states that the inter-industry flows from i to j depend entirely on the total output of sector j for that same time period. Leontief viewed the entire perspective from ‘**supply side**’ and assumed that the ratio of the amount of some input required for the production of a certain quantity of a particular commodity always remains fixed throughout the production period. This ratio (a_{ij}) is termed as ‘technical coefficient’ or ‘direct input coefficient’ in IO framework developed by Leontief.

$$a_{ij} = \frac{z_{ij}}{x_j}$$

Using this, the system of equation (3.3) can be re-written as:

$$\begin{vmatrix} x_1 \\ \vdots \\ x_n \end{vmatrix} = \begin{bmatrix} a_{11}x_1 & \cdots & a_{1n}x_n \\ \vdots & \ddots & \vdots \\ a_{n1}x_1 & \cdots & a_{nn}x_n \end{bmatrix} + \begin{vmatrix} f_1 \\ \vdots \\ f_n \end{vmatrix}$$

$$\text{Or, } \begin{vmatrix} x_1 \\ \vdots \\ x_n \end{vmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \cdot \begin{vmatrix} x_1 \\ \vdots \\ x_n \end{vmatrix} + \begin{vmatrix} f_1 \\ \vdots \\ f_n \end{vmatrix}$$

$$\text{Or, } x = A \cdot x + f$$

$$\text{Or, } (I - A) \cdot x = f$$

$$\text{Or, } x = (I - A)^{-1} \cdot f \dots\dots\dots (3.4)$$

Matrix ‘A’ is known as “technical” or “direct input coefficient” matrix. And $(I - A)^{-1}$ matrix is called ‘Leontief Inverse’ or ‘Output multiplier’ matrix.

The Input-Output Table for 2018-19 has been constructed from the Supply Use Table (SUT) for 2018-19, published by CSO. We have followed the procedure mentioned in the ‘Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications; Chapter 12; (United Nations, 2018)’

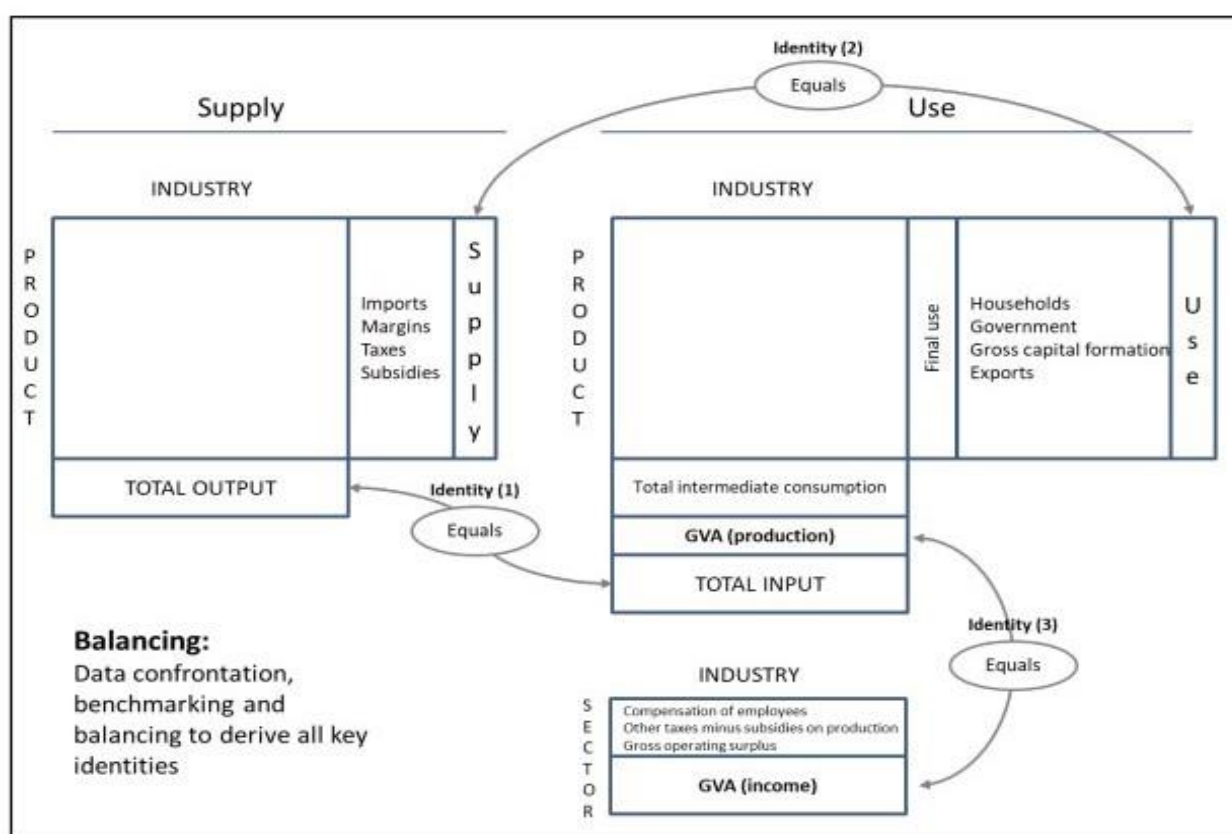
The detailed procedure can be described in the following step-wise manner:

Step 1: Construction of an ‘integrated matrix’ placing both the Supply and Use table together in a particular format

- Step 2:** Construction of Leontief Inverse, based on ‘industry technology assumption’. According to this assumption: “Each industry has its specific way of production, irrespective of its product mix.”
- Step 3:** Construction of Transformation Matrix
- Step 4:** Construction of IOT by matrix multiplication of “Integrated Matrix” and “Transformation Matrix”)
- Step 5:** Balancing the IOT

All these steps were followed one by one to arrive at (140x140), commodity by commodity IOT. The logical ground of this conversion method can be demonstrated by the figure illustrated below (**Figure 3.1**)

Figure 3.1: Graphical overview of Supply and Use Table for construction of IOT



Source: Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications; Chapter 12; (United Nations, 2018)

3.2 Expanding Input-Output Table (IOT) by Incorporating a Comprehensive List of Non-Fuel Minerals

The Input-Output Table published by Central Statistical Organization (CSO), Ministry of Statistics and Programme Implementation (MoSPI), Government of India incorporates only

eight (8) **Non-fuel Minerals** in its structured form. Whereas, Indian Bureau of Mines (IBM), Ministry of Mines, Government of India comes out with output figures of **23 Non-fuel Minerals** under the category of '**Major Minerals**' (**6 Metallic**, **17 Non-metallic** and **Minor Minerals**). (**Table A4: Appendix**). This is exclusive of the eight (8) non-fuel minerals covered by CSO.

To get a more holistic picture into the mineral sector of the country, this thesis has systematically incorporated all the mineral statistics into the IO table of India to facilitate a deeper analysis of Indian mineral sector. The thesis has devised a process to accomplish this task and illustrated the step-wise procedure as given below. Following this procedure, we have expanded the IO Table (38x38) to a more exhaustive IO Table of dimension: (61x61) after duly incorporating all minerals as specified by IBM and Ministry of Mines (MoM). The task has been accomplished by collating the IBM and MoM data.

Since, the newly incorporated minerals have been valued at 'Purchasing Price,' we have made tax adjustment to get production values at 'Basic Price'. We have distributed "Production Tax Less subsidy" of Metallic and Non-metallic Minerals proportionately to the production values in respective categories. 'Minor Minerals' and 'Other Minerals' have been allocated tax burden within the bracket of "Non-metallic Minerals". Now, before replacing the existing list of minerals in IO table (2018-19) by this new list of minerals, some re-allocation of input and output figures (row-wise & column-wise) will be required.

The thesis has replaced the existing list of minerals in the IO table (2018-19) with this new list of minerals. Hence, re-allocation of output figures along product -line (row-wise) will be required

3.2.1 Allocation along Commodity-line (Row-wise)

i) **For Metallic Minerals**: Production of each newly introduced Metallic Mineral is allocated in the same proportion in which 'Other Metallic Minerals' are allocated along industries.

- 1) We have incorporated 6 new metallic minerals in the existing list of IO Table consisting only 4 minerals
- 2) These newly specified metallic minerals have been taken as a part of the "Other Metallic Minerals" as specified by IO-2018-19

3) We have carved out these newly specified 6 metallic minerals from the "Other Metallic Minerals" as per IO figure available

ii) **For Non-metallic Minerals:** Production of each newly introduced Non-metallic Mineral will be allocated in the same proportion in which 'Other Non-metallic Minerals' are allocated along industries.

1) We have incorporated new 23 non-metallic minerals (inclusive of 'Minor Minerals') in the existing list of IO Table of 2 Non-metallic minerals

2) These newly specified Non-metallic minerals have been a part of the Other Non-metallic Minerals as specified by IOT 2018-19

3) We have carved out these newly specified 23 Non-metallic minerals from the "Other Non-metallic Minerals" as per IO figure available

3.2.2 Allocation along Industry-line (Column-wise)

For this, re-allocation of input figures along industry -line (column-wise) will be required.

Hence, we make 2 simple assumptions:

i) **For metallic minerals:** Each industry will use newly introduced Metallic Minerals in the same proportion in which 'Other Metallic Minerals' are used in the production process

ii) **For non-metallic minerals:** each industry will use newly introduced Non-metallic Minerals in the same proportion in which 'Other Non-metallic Minerals' are used in the production process.

After some minimal balancing, the (38x38) aggregated matrix is expanded to the (61x61) matrix, containing an exhaustive list of 34 minerals in total. This matrix has been used throughout this thesis for analytical purposes.

For easy understanding of the entire procedure, we have cited a '**Demonstrative Example**' in the **Appendix: B** This procedure has been followed for final compilation of the 'aggregated IO table (61x61)' (**Table A5: Appendix**). The newly constructed table contains total 31 Non-fuel minerals as listed below:

- Metallic Minerals = 10
- Non-metallic Minerals = 19
- Minor Minerals = 1
- Other Minerals = 1

3.3 Calculating Multipliers and Linkages

The production of each industry generates two types of rippling effects in the economy. First, it demands more inputs to produce more output. This causes “demand pull” for the “downstream industries”, which in turn set the multiplier process in action. The impact is called “backward linkage” effects. Backward linkage happens in the demand side.

Second, the industry in concern, supplies inputs to the “upstream industries”, which enables them to produce more and meet excess demand in the market. This impact is known as “forward linkage” effect. Quite understandably, “forward linkage” effects appear in the “supply side” of the economic system.

Both forward and backward linkages induce positive impulses within the economy.

Now, we consider a simple Input-Output framework, characterised by CRS production function with ‘n’ number of commodities ($i = 1, 2, 3, \dots, n$) and ‘n’ number of industries /sectors ($j = 1, 2, 3, \dots, n$).

From “supply side” (Leontief model), technical coefficient’ or ‘direct input coefficient’ is calculated as: $a_{ij} = x_{ij}/x_j$

In matrix notation, A is “input coefficient matrix” and L is Leontief inverse / multiplier matrix.

Where, $A = [a_{ij}]$, and $L = [l_{ij}]$

L is calculated as: $L = (I - A)^{-1}$

From “**Supply Side**”,

- 1) **Total backward linkage (Rasmussen, 1957)** of sector j is measured by calculating the column sum of the Leontief inverse or the total requirements matrix ($L = [l_{ij}]$)

Hence, Rasmussen’s Total Backward Linkage Measure: $BL_j = \sum_{i=1}^n l_{ij}$

- 2) **Backward dependence** on or linkage to the *rest* of the economy is calculated by omitting ‘on-diagonal’ elements in L matrix during summation

- 3) **Normalized direct backward linkage measure.**

It is calculated as: $\overline{BL}_j = BL_j / (\frac{1}{n} \sum_{j=1}^n BL_j)$

(Here, the overbar suggests a normalized measure)

From “Demand Side” (Ghosh model), ‘allocation coefficient’ is defined as:

$$b_{ij} = z_{ij}/x_i$$

In matrix notation, B is “allocation coefficient matrix” and G is ‘Ghosh inverse’ matrix.

Where, $B = [b_{ij}]$, and $G = [g_{ij}]$

From “**Demand Side**”,

- 1) **Total forward linkage** of sector **i** is measured by calculating the **row-sum** of the Ghosh inverse matrix ($G = [g_{ij}]$)

Hence, Total Forward Linkage Measure: $FL_i = \sum_{j=1}^n g_{ij}$

- 2) **Forward dependence** on or linkage to the *rest* of the economy is calculated by omitting ‘on-diagonal’ elements in G matrix during summation

- 3) **Normalized direct forward linkage measure.**

It is calculated as: $\overline{FL}_i = FL_i / (\frac{1}{n} \sum_{i=1}^n FL_i)$

(Here, the overbar suggests a normalized measure)

On the basis of our results, sectors can be classified into 4 groups:

- 1) Generally independent of (not strongly connected to) other sectors (both linkage measures less than 1)
- 2) Generally dependent on (connected to) other sectors (both linkage measures greater than 1)
- 3) Dependent on inter-industry supply (only backward linkage greater than 1)
- 4) Dependent on inter-industry demand (only forward linkage greater than 1).

In tabular format, the sectoral classifications in terms of backward and forward linkages have been presented in **Table 3.2**.

Table 3.2 Sectoral Classification in Terms of Backward and Forward Linkages

		<i>Total Forward Linkage</i>	
		Low (<1)	High (>1)
<i>Total Backward Linkage</i>	Low (<1)	(I) Generally independent	(II) Dependent on Inter-industry demand
	High (>1)	(IV) Dependent on Inter-industry supply	(III) Generally dependent

Source: Author’s Calculations

Calculation of multipliers and economic linkages occupy a very crucial position in Input-Output theory. Some standard measures of economic connectedness in an interdependent

industrial scenario have been used in this thesis to identify “key resources” in Indian context. The relative strengths of backward and forward linkages for the sectors in a single economy provide a suitable mechanism for identifying “key” or “leading” sectors in that economy. The most connected sectors are thought to be most important for the economy in this context.

3.4 Principal Component Analysis (PCA)

Since the focus of this thesis zeroes in on the prime movers of Indian economy, identification of ‘key resources’ needs to be done from various angles. One important way by which we can identify the key resource sectors is by systematic elimination of least important minerals in terms of their productivity or influence in determining the GDP of the country. In this way, the minerals having maximum influence on GDP can be identified as ‘key resources’. However, for a highly complicated economy like India - having innumerable inter-linkages between sectors - completely doing away with some minerals (however insignificant they may be) can seriously blur the insights obtainable from our analysis. To capture both direct and indirect impact of a mineral resource in an economy, a specialised mathematical technique called ‘Principal Component Analysis (PCA)’ has been used in this thesis.

PCA is a dimensionality reduction technique for reducing the number of variables while preserving as much information as possible. The main idea is to transform the original variables into a lower number of ‘principal components’ that serve as summaries of the features, potentially revealing hidden patterns in the data. By analyzing the principal components, one can gain insights into the relationships between the variables and the underlying structure of the data.

The PCA procedure involves the following steps:

1. Standardization: The original variables are standardized (mean of 0 and variance of 1), especially if they have different units of measurement.
2. Covariance Matrix Computation: Calculation of the covariance matrix to understand how the variables of the input data are varying from the mean with respect to each other.
3. Eigenvalue and Eigenvector Computation: Computing the eigenvalues and eigenvectors of the covariance matrix to identify the principal components. Eigenvectors (principal directions) determine the directions of the new feature space, and eigenvalues determine their magnitude.

4. Sort and Select Principal Components: The eigenvalues are sorted in descending order, and only the top ‘n’ eigenvectors are kept, where ‘n’ is the number of dimensions to reduce to.
5. Projection: The original data is projected onto the principal components to transform the data into the new feature space.

This technique is widely used in exploratory data analysis and in making predictive models. In our aggregated IO Table (61x61), total number of non-fuel minerals is 31. Now, we want to figure out which of these 31 non-fuel minerals are most important in terms of GDP contributions, so that we can easily do away with the rest, however retaining most of the information contained in them. The goal is to reduce the number of variables and attain simplicity in analysis, without causing much of a deviation from accuracy. Thus, PCA ensures brevity in our analysis

3.4.1 Mathematical Construct

At the beginning it is mention-worthy that PCA works only when the set of independent variables are interdependent. Hence an IO framework is ideal for application of PCA. In IO platform, PCA can systematically filter out the least important variables (factors of production) by consolidating a large set of variables into a smaller one that still contains most of the information in the large set. In other words, PCA reduces the number of independent variables from a system when they are highly interdependent among themselves. In mathematical language, PCA extracts low dimensional set of features by taking a projection of irrelevant dimensions from a high dimensional data set with a motive to capture as much information as possible.

Now, PCA is a method that brings together:

1. A measure of how each variable is associated with one another. (Covariance matrix.)
2. The directions in which our data are dispersed. (Eigenvectors.)
3. The relative importance of these different directions. (Eigenvalues.)

A standard PCA model starts with a system of equations as written below:

$$y = f(x_1, x_2, x_3, \dots, x_k) \dots \dots \dots (3.5)$$

Here, **k** is number of independent variables (which are interdependent with each other). These variables are also referred as “features”/“dimensions” etc. Y is the dependent variable in this case.

For 'n' observations, we get the following equations:

$$\begin{aligned}
 y_1 &= f_1(x_1, x_2, x_3, \dots, x_k) \\
 y_2 &= f_1(x_1, x_2, x_3, \dots, x_k) \\
 y_3 &= f_1(x_1, x_2, x_3, \dots, x_k) \\
 &\vdots \\
 y_n &= f_1(x_1, x_2, x_3, \dots, x_k)
 \end{aligned}
 \dots\dots\dots (3.6)$$

Here, 'n' is number of observations. In case of time-series data n refers to number of years (or months etc.)

The entire process of PCA is executed in following 5 steps:

Step 1: Standardizing the range of continuous initial variables

The aim of this step is to standardize the range of the continuous initial variables so that each one of them contributes equally to the analysis

Using matrix notation this system of equation can be represented as:

$$\begin{matrix} y_1 \\ \vdots \\ y_n \end{matrix} = \begin{bmatrix} x_{11} & \cdots & x_{1k} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nk} \end{bmatrix}$$

Or, $Y = X \dots\dots\dots (3.7)$

X = Matrix of independent variables

Y = Vector of dependent variables

For each column in X, row-elements are standardised using following formula:

$$\begin{aligned}
 z_{ij} &= (x_{ij} - \text{column mean}) / \text{standard deviation} \\
 \text{Or, } z_{ij} &= (x_{ij} - \mu_i) / \sigma_i
 \end{aligned}$$

Here,

Mean: $\mu_i = \sum_1^n x_{ij}$

Standard deviation: $\sigma_i = \sqrt{\frac{1}{n} \sum_1^n (x_{ij} - \mu_i)^2}$

i = 1, 2, 3, , n (in case of time series, this refers years) and j = 1, 2, 3, , k (number of independent variables)

Let us call the Centred and Standardized matrix as: **Z**.

$$Z = \begin{bmatrix} z_{11} & \cdots & z_{1k} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nk} \end{bmatrix}
 \dots\dots\dots (3.8)$$

Step 2: Covariance Matrix Computation

The aim of this step is to understand how the variables are varying from the mean with respect to each other, or in other words, to see if there is any relationship between them.

In order to identify correlations, Covariance matrix: $Cov(Z)$ has been computed. This covariance matrix is a $(k \times k)$ symmetric matrix (where k is the number of dimensions) that has as entries the covariances associated with all possible pairs of the initial variables.

$$Cov Z = \begin{bmatrix} Cov(z_{11}, z_{11}) & \cdots & Cov(z_{1k}, z_{1k}) \\ \vdots & \ddots & \vdots \\ Cov(z_{n1}, z_{n2}) & \cdots & Cov(z_{nk}, z_{nk}) \end{bmatrix}$$

The simplest way in which $Cov Z$ is calculated is as follows:

$$Cov Z = Z^T \cdot Z \dots\dots\dots (3.9)$$

It's actually the sign of the covariance that matters.

- a) If positive: the two variables increase or decrease together (correlated)
- b) If negative: One increases when the other decreases (Inversely correlated)

Step 3: Computation of the eigenvectors and eigenvalues of the covariance matrix to identify the Principal Components

The calculation of eigenvectors and eigenvalues from the covariance matrix is essential in identifying the principal components of the data within linear algebra. Principal components are new variables formed through linear combinations of the original variables. These combinations are devised to ensure that the resulting variables, referred to as principal components, are uncorrelated. Moreover, the majority of information from the initial variables is condensed into the first components. Consequently, in a k -dimensional dataset, k principal components are derived, with PCA striving to allocate the maximum information to the first component, followed by the successive distribution of the remaining information to subsequent components.

The eigenvectors and their corresponding eigenvalues (L_i) of $Z^T Z$ are calculated by a method called **Eigen decomposition**. The method is described below:

$Z^T Z$ is decomposed into PDP^{-1} , where P represents the matrix of eigenvectors and D is the diagonal matrix featuring eigenvalues on the diagonal and zeros elsewhere. The eigenvalues on the diagonal of D are associated with the corresponding column in P — meaning that the first element of $D(L_1)$ and the corresponding eigenvector is the first column of P . This holds

for all elements in D and their corresponding eigenvectors in \mathbf{P} . It is always possible to calculate \mathbf{PDP}^{-1} in this manner because $\mathbf{Z}^T\mathbf{Z}$ is a symmetric, positive semi-definite matrix.

Since, the number of variables is large; we have used a **statistical package (R)**, to calculate Eigen Values and Eigen Vectors.

The details of **R-Code** have been provided in **Annexure: C**

Step 4: Creation of a feature vector to decide which principal components to keep

By computing the eigenvectors and arranging them based on their eigenvalues in descending order, the Principal Components have been identified in terms of their significance. During this stage, the decision arises to either retain all these components or discard those with lower significance (characterized by low eigenvalues). The ensuing matrix of vectors, known as the **Feature vector**, is formed by retaining the chosen components. Essentially, the feature vector is a matrix with columns representing the eigenvectors of the selected components. This makes it the first step towards dimensionality reduction, because if we choose to keep only \mathbf{m} eigenvectors (components) out of \mathbf{k} , the final data set will have only \mathbf{m} dimensions.

Following this method, **eigenvalues** ($L_1; L_2 \dots \dots \dots ; L_k$) have been sorted in descending order. The eigenvectors in \mathbf{P} have also been arranged in the same order. The sorted matrix of eigenvectors is \mathbf{P}^* consists of all the columns of \mathbf{P} , but arranged in a different order. Eigenvectors always remain independent of one another.

Step 5: Recasting the data along the Principal Component axes

Finally, we need to determine how many features to keep versus how many to drop. For this, we have calculated the proportion of variance explained for each feature. We have started with the largest explained proportion of variance variables and kept on adding variables until the 100% variation in the value of the dependent variable could be explained.

Since, each eigenvalue is roughly the importance of its corresponding eigenvector, the proportion of variance explained is the sum of the eigenvalues of the features considered divided by the sum of the eigenvalues of all features.

$$L_i = Imp (X_j)$$

$$\text{Or, } \sum_{i=1}^n L_{ij} = L_j$$

$$\text{Proportion of Variance Explained } (PEV_K) = L_j / \sum_{j=1}^k L_{ij} \dots\dots\dots (3.10)$$

3.5 Construction of Modified Input-Output Table

We consider a simple Leontief Model, characterized by *Constant Returns to Scale (CRS)* production functions, with fixed input coefficients: $a_{ij} = x_{ij}/x_j$. It is also assumed that there are 'n' commodities in the economy produced by 'n' number of industries.

Outputs are: $x_1, x_2, x_3, \dots, x_n$ (*Endogenous Variables*)

Final demands are: $f_1, f_2, f_3, \dots, f_n$ (*Exogenous Variables*)

In 'Modified Leontief Model', one of the outputs (say, x_j) is considered as exogenous (i.e., a fixed 'production target' is set by factors outside the *inter-dependent industry framework*).

As a result, an economy wide impact happens. To maintain balance in the system, the 'final demand (f_j)' of the corresponding sector is determined endogenously.

Let, $x_j = \bar{x}_j$: Exogenously fixed output (Target) ('Overbar' on a variable denotes that it is *exogenously fixed*). Hence, the Leontief Modified Model can be summarized in the form of following system of linear equation:

$$x_1 = a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \dots + a_{1j}\bar{x}_j + \dots + a_{1n}x_n + \bar{f}_1$$

$$x_2 = a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \dots + a_{2j}\bar{x}_j + \dots + a_{2n}x_n + \bar{f}_2$$

$$x_3 = a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \dots + a_{3j}\bar{x}_j + \dots + a_{3n}x_n + \bar{f}_3$$

.....

$$\bar{x}_j = a_{j1}x_1 + a_{j2}x_2 + a_{j3}x_3 + \dots + a_{jj}\bar{x}_j + \dots + a_{jn}x_n + f_j$$

.....

$$x_n = a_{n1}x_1 + a_{n2}x_2 + a_{n3}x_3 + \dots + a_{nj}\bar{x}_j + \dots + a_{nn}x_n + \bar{f}_n$$

Changing sides,

$$\begin{aligned}
 (1 - a_{11})x_1 - a_{12}x_2 - a_{13}x_3 - \dots - 0 \cdot f_j - \dots - a_{1n}x_n &= (\bar{f}_1 + a_{1j}\bar{x}_j) \\
 -a_{21}x_1 + (1 - a_{22})x_2 - a_{23}x_3 - \dots - 0 \cdot f_j - \dots - a_{2n}x_n &= (\bar{f}_2 + a_{2j}\bar{x}_j) \\
 -a_{31}x_1 - a_{32}x_2 + (1 - a_{33})x_3 - \dots - 0 \cdot f_j - \dots - a_{3n}x_n &= (\bar{f}_3 + a_{3j}\bar{x}_j) \\
 \dots & \\
 -a_{j1}x_1 - a_{j2}x_2 - a_{j3}x_3 - \dots - 1 \cdot f_j - \dots - a_{jn}x_n &= (a_{jj} - 1)\bar{x}_j \\
 \dots & \\
 -a_{n1}x_1 - a_{n2}x_2 - a_{n3}x_3 - \dots - 0 \cdot f_j - \dots + (1 - a_{nn})x_n &= (\bar{f}_n + a_{nj}\bar{x}_j)
 \end{aligned}$$

..... (3.11)

Expressing in ‘matrix’ notation:

$$\mathbf{Modified(I - A).V1 = Modified(I).V2} \dots\dots\dots (3.12)$$

$$\mathbf{Modified} \quad \mathbf{(I - A)} = \begin{vmatrix} (1 - a_{11}) & -a_{12} & 0 & \dots & -a_{1n} \\ -a_{21} & (1 - a_{22}) & 0 & \dots & -a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ -a_{j1} & -a_{j2} & -1 & \dots & -a_{jn} \\ \dots & \dots & 0 & \dots & \dots \\ \dots & \dots & 0 & \dots & \dots \\ -a_{n1} & -a_{n2} & 0 & \dots & (1 - a_{nn}) \end{vmatrix} \quad \text{and} \quad \mathbf{V1} = \begin{vmatrix} x_1 \\ x_2 \\ \dots \\ f_j \\ \dots \\ x_n \end{vmatrix}$$

$$\mathbf{Modified I} = \begin{vmatrix} 1 & 0 & 0 & a_{1j} & 0 & 0 & 0 \\ 0 & 1 & 0 & a_{2j} & 0 & 0 & 0 \\ 0 & 0 & 1 & a_{3j} & 0 & 0 & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & (a_{jj} - 1) & 0 & 0 & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & a_{nj} & 0 & 0 & 1 \end{vmatrix} \quad \text{and} \quad \mathbf{V2} = \begin{vmatrix} \bar{f}_1 \\ \bar{f}_1 \\ \dots \\ \bar{x}_j \\ \dots \\ \bar{f}_n \end{vmatrix}$$

..... (3.13)

Solution of equation (3.13) is:

$$V1 = \text{Inverse Modified } (I - A) \cdot \text{Modified } (I) \cdot V2 \dots \dots \dots (3.14)$$

Following these concepts and associated formulae, the economy-wide impact of some specific target-oriented growth strategies (schemes) initiated by Government of India, has been measured. The feasibility and long-run sustainability of these schemes has also been analyzed in this context.

3.6 Value Chain Models

Let, A and B are two countries /regions, where A is in ‘downstream production’ and B is in ‘upstream production’.

i = One of the important inputs for downstream production

j = One of the important inputs for upstream production

It is assumed that **i** is produced by A and **j** by B

X_A: Total export of A

and X_Aⁱ: Portion of total export of A, going to B as an input

for downstream production

i. e. Portion of total export of A, imported by B for it's export production

Or, X_Aⁱ = M_Bⁱ

..... (3.15)

Also,

X_B: Total export of B

and X_B^j: Portion of total export of B, going to A as an

input for upstream production

i. e. Portion of total export of B, imported by A for it's export production

Or, X_B^j = M_A^j

..... (3.16)

Hence, we can define the production function of export commodity in A is:

X_A = f(i, I_d) where **i** is imported input and **j** is domestic input

..... (3.17)

Similarly, we can define the production function of export commodity in B is:

$$X_B = g(j, J_d) \dots \dots \dots \text{where } \mathbf{j} \text{ is imported input and } \mathbf{I}_d \text{ is domestic input} \dots \dots \dots (3.18)$$

Participation of an economy in **Global Value Chain (GVC)** can be assessed in terms of following three parameters:

- i) **Forward Linkage:** Value-Added Share in Exports (VAS_{Exp})
- ii) **Backward Linkage:** Value-Added Share in Final demand (VAS_{FD})
- iii) **Import Content of Exports**

To measure impact of various trade policies on the equilibrium condition in the economy, we need to calculate the parameters using following formulae.

(In all cases, the trade (export/import) of a country captures exports to all trading partners as well as bilateral export of the country with some selected partners)

1) **Value Added Share in Export (VAS_{Exp}):**

$$VAS_{Exp} = \mathbf{a}_j^v * (\mathbf{I} - \mathbf{A}_d)^{-1} * \mathbf{ES} \dots \dots \dots (3.19)$$

Where:

A_d : Domestic Input Coefficient Matrix

The Export Share:

$$ES = \frac{E_i}{E}$$

E_i : Exports from sector i

E : Total exports.

Again, \mathbf{a}_j^v is the ‘**Ratio of Value Added (RVA)**’ which depicts the relative size of remuneration or income in the total size of the economy. And it is calculated from the following formula:

$$a_j^v = \frac{V_j}{X_j}$$

2) **Value Added Share in Final Demand (VAS_{FD}):**

$$VAS_{FD} = \mathbf{a}_j^v * (\mathbf{I} - \mathbf{A}_d)^{-1} * \mathbf{FD} \dots \dots \dots (3.20)$$

FD : Total Final Demand

3) **Import Content in Exports (VS_k):**

$$VS_k = U * \text{Import Coefficient} * (I - A_d)^{-1} * ES \dots\dots\dots (3.21)$$

It shows the volume of imported intermediate input embodied in the exports of the country. It can either be found for exports to all regions taken together or for bilateral exports depicting the impacts of trade on the trading partners. **Import Coefficients** calculated similar to the Technology Coefficient Matrix for the imports of intermediate inputs to the country in consideration.

CHAPTER 4: SYSTEMATIC INCORPORATION OF THE EXTENDED LIST OF MINERALS IN IO TABLE (2018-19), ISSUE OF DATA ANOMALY AND IDENTIFICATION OF “KEY RESOURCES” IN INDIAN CONTEXT

Integrating a comprehensive list of minerals into the Input-Output Table for 2018-19, addressing data discrepancies, and pinpointing crucial resources specific to India – these are the key areas covered in this Chapter.

To embark on any academic research under the Input-Output framework, access to reliable database is a prerequisite. Since the IO framework involves rigorous mathematical computation, even the slightest anomaly in data can lead to serious errors. Unfortunately, the mineral sector of India has been found to suffer from data anomalies. This Chapter has delved into the possible reasons of this data anomaly and emphasized on the importance of a synchronized database in Indian context.

The second part of the Chapter attempted to incorporate a larger set of minerals in the structured framework of the IO Table. This has been done to make the IO Table more inclusive in terms of its coverage of minerals. In the current global scenario, some non-fuel minerals have suddenly become extremely important. An extension of the IO Table incorporating these minerals can unravel new insights about the role of the mineral sector in achieving sustainable development goals.

The last part of this Chapter measures ‘backward’ and ‘forward linkages’ of the non-fuel minerals on the basis of the calculation of ‘multiplier values’ under IO framework. Theory suggests that inputs with high values of multipliers also possess stronger ‘backward’ and ‘forward linkages’. On the other hand, inputs having high ‘backward and forward linkages’ hold stronger capabilities in determining the GDP values. This Chapter identifies minerals having high ‘backward and forward linkages’ as ‘key resources’.

4.1 Discrepancies in India’s Mineral Statistics

4.1.1 Organizational Structure for Dissemination of Mineral Statistics in India

One of the main challenges in doing research work in the field of the mining and mineral sector of India is the availability and access to authentic databases. As per the administrative setup, the Indian Bureau of Mines, Nagpur, and the Ministry of Mines, Government of India has the shared responsibility to collect and publish data pertaining to the mining sector in India.

As per as Ministry website, the Ministry of Mines is responsible for “survey, exploration and mining of all minerals, other than natural gas, petroleum, atomic minerals and coal. In the case of atomic minerals and coal, activities of the Ministry are limited to regional exploration. The Ministry is responsible for the administration of the Mines and Minerals (Development and Regulation) Act, 1957 (67 of 1957) and rules made there concerning all mines and minerals other than coal, natural gas and petroleum. The Ministry also administers the Offshore Areas Mineral (Development and Regulation) Act, 2002 and rules made there under”¹².

Indian Bureau of Mines (IBM), Nagpur has been mentioned as a “Subordinate Office” under the Ministry. According to the National Mineral Policy, 2019 (NMP), the Indian Bureau of Mines is supposed to “perform as a National Technical Regulator and to discharge the developmental functions for the sustainable development of the mineral industry and to work as a repository of the database on mines and minerals”.

The present ‘Charter of Function,’ has clearly outlined the roles and responsibilities of IBM as follows. Some of these responsibilities can be summarised as follows:

“In the wake of liberalization of the policy regime governing the mineral sector and increasing need for adequate environment management as part of systematic and scientific mining, the mandated functions for IBM, as given for notification in Official Gazette vide Resolution No. 31/49/2014 – M. III, dated 3rd November 2014 are given below: -

*Collect, collate, and organize into a database, all information on exploration, prospecting, mines, and minerals in the country in the shape of a National Mineral Information Repository and take steps to publish and disseminate the same; establish institutional mechanisms of coordination between the centre, the States, the mineral industry, research, and academic institutions, and all stakeholders, to proactively develop solutions to the demands and problems faced by the industry; promote research on all aspects of practical relevance to the industry and act as a bridge between research institutions on the one hand and user industry on the other; advise Government on all matters relating to the mineral industry; and to undertake any such other activity that has become necessary in the light of developments in the field of geology, mining, mineral beneficiation, and the environment.”*¹³

(National Mineral Policy, 2019)

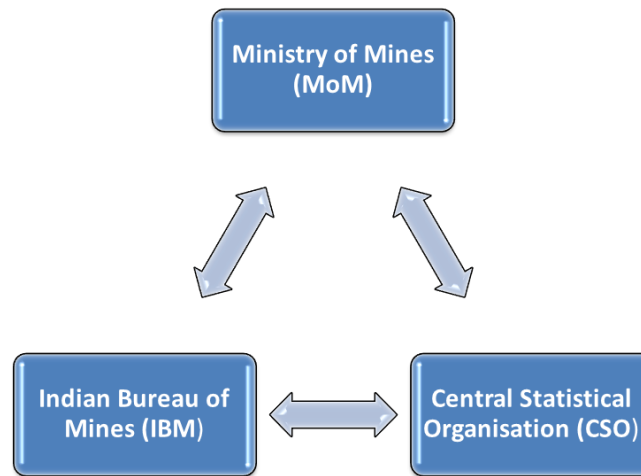
Quite clearly, the Ministry of Mines acts as the apex body in the mining and mineral ecosystem of India. It has the supreme authority to oversee and regulate the mining activities

¹² Ministry Website: <https://mines.gov.in/webportal/content/functions>

¹³ Documents available with the website of IBM: <https://ibm.gov.in/IBMPortal/pages/Functions>

of the country. Ministry is responsible for policy formulation, strategy planning and implementing various “Rules and Regulations” from time to time. On the other hand, the Indian Bureau of Mines is a subsidiary body of the Ministry of Mines, responsible for “collecting, collating, and organising” the database and publishing the latest statistics about the Mining and Mineral sector regularly. IBM is supposed to act as a “National Mineral Information Repository”. So, it is expected that the statistical information about mineral sector should flow freely among the three government bodies and the official data from each end must sync with each other.

Figure: 4.1 Ideal Information Sharing Process among Government Bodies



And this information flow should happen in real-time. So, logically there should not be any discrepancy or mismatch between data published by IBM and the Ministry of Mines (MoM).

4.1.2 Comparison of Data Published by the Indian Bureau of Mines (IBM) and Ministry of Mines (MoM)

A careful observation of data published by IBM and MoM shows that the production statistics provided by these two government bodies are often dissimilar. To introspect on this data anomaly, this thesis has computed ‘Average Deviation in Percentage’ as follows:

Year-wise percentage deviation between IBM and MoM data for mineral production:

$$Dev_{2017-18} = \frac{[PV_{2017-18}^{MoM} - PV_{2017-18}^{IBM}]}{PV_{2017-18}^{IBM}} \times 100 \%$$

Average Deviation in Percentage (2017-18 to 2019-20):

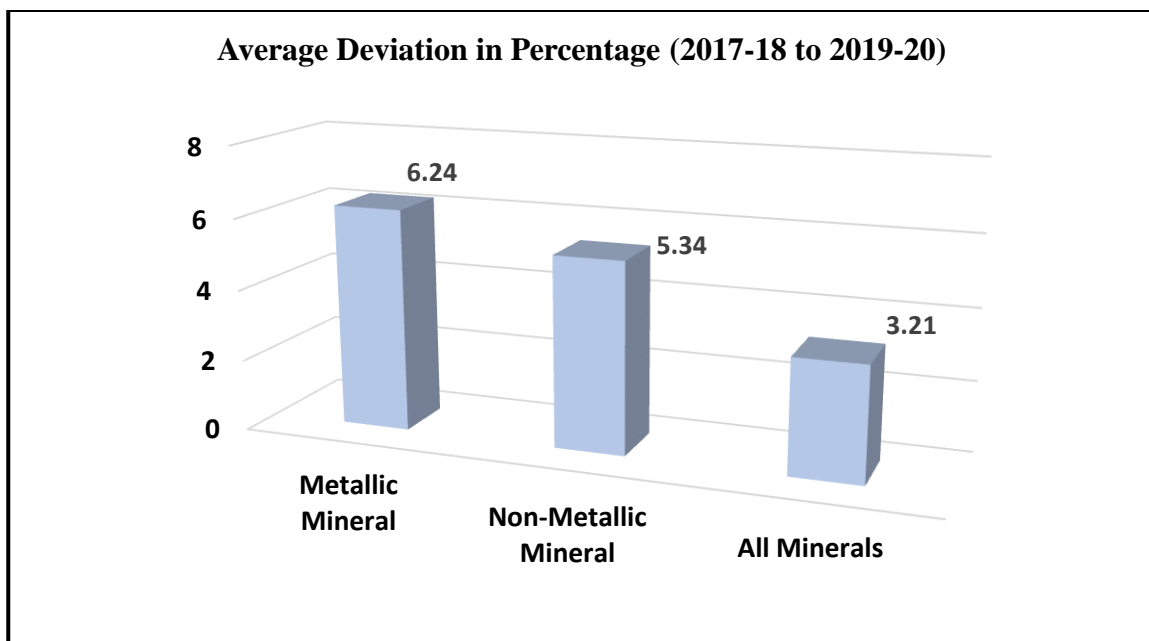
$$ADev_{2017-18 \text{ to } 2019-20} = \text{Average} (Dev_{2017-18}; Dev_{2018-19}; Dev_{2019-20})$$

As per our calculations, we have found a significant deviation between IBM and MoM data for the production value of minerals. The gap is more for metallic minerals (6.25%)

compared to that of non-metallic minerals (5.34%). The deviation for all minerals taken together stands at 3.21% (**Figure 4.2**)

If datasets published by two government bodies differ to such an extent, then that could lead to completely dissimilar results depending on which data set has been used. Hence, the choice of the appropriate dataset becomes a deciding factor to arrive at error-free and uniform results. For any researcher working in the field of mineral sector of India, obtaining authentic official statistics is a great challenge. However, access to authentic and consistent data is a prerequisite for any quality research.

Figure 4.2 Average Deviations in Production Value of Metallic and Non-Metallic Minerals from 2017-18 to 2019-20, as provided by the Ministry of Mines (MoM) and Indian Bureau of Mines (IBM)



Source: Author's calculations using -

1) *Indian Mineral Year Book (2021), India Bureau of Mines, December 2022*

2) *Ministry of Mines, Annual Report 2022-23, Annexure: 2.1*

Ministry of Mines (MoM) and Indian Bureau of Mines (IBM) provide data on production value of eight minerals in India. This study has further calculated the deviation in production values of these eight minerals in India from 2017-18 to 2019-20. The resulting deviation figures (in percentage) are presented in **Table 4.1**. This table clearly manifest the problem of data anomaly in case of these eight minerals. **Figure 4.3** gives a pictorial representation of Table 4.1.

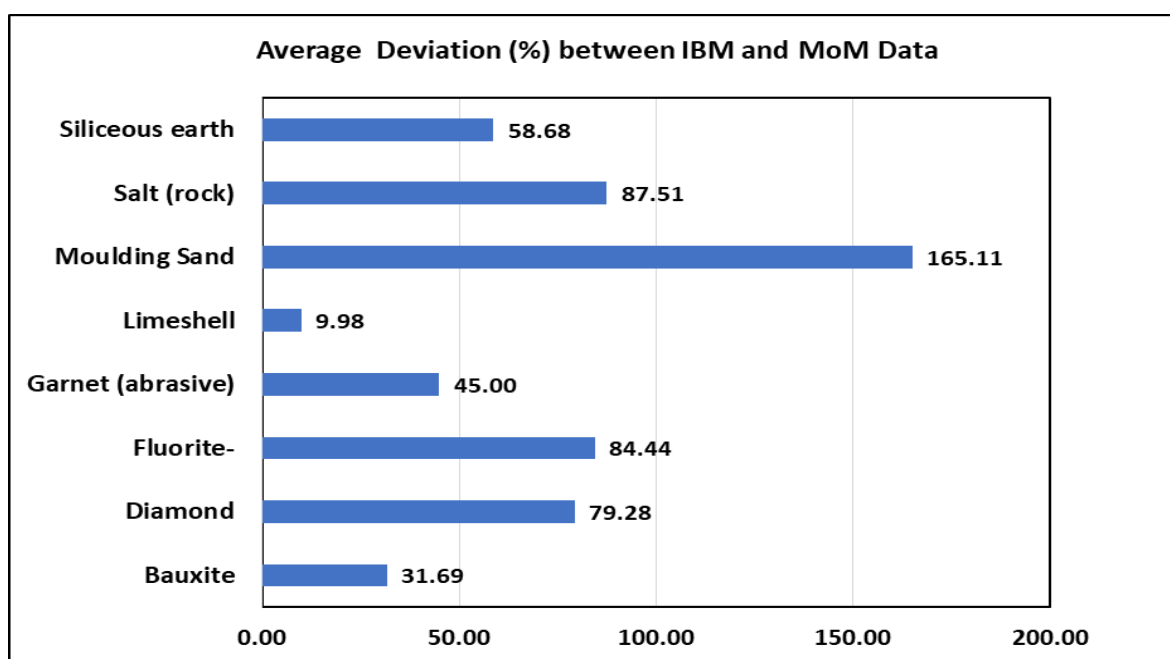
Table 4.1 Deviations in Production Value of Eight Minerals in India from 2017-18 to 2019-20, as Provided by the Ministry Of Mines (Mom) and Indian Bureau of Mines (IBM)

Sr. No	Minerals	Average Deviation (%) between IBM & MoM Data (2017-18 to 2019-20)
1	Bauxite	31.69
2	Diamond	79.28
3	Fluorite	84.44
4	Garnet (Abrasive)	45.00
5	Lime Shell	9.98
6	Moulding Sand	165.11
7	Salt (Rock)	87.51
8	Siliceous Earth	58.68

Source: Author’s calculations using-

- 1) Indian Mineral Year Book (2021), India Bureau of Mines, December 2022
- 2) Ministry of Mines, Annual Report 2022-23, Annexure: 2.1

Figure 4.3 Average Deviation (%) between IBM and MoM Data for Production Value Eight Minerals



Source: Ministry of Mines and Indian Bureau of Mines, Government of India

In the case of the above eight minerals, the variation of two datasets (i.e. IBM and MoM) ranges from 9.98% (Lime shell) to 165.11% (Moulding Sand). Variations for the remaining six minerals are also quite significant. In this situation, it becomes extremely difficult to choose one dataset over the other.

4.1.3 Comparison of the data published by the Indian Bureau of Mines (IBM), Ministry of Mines (MoM) and Central Statistical Organisation (CSO)

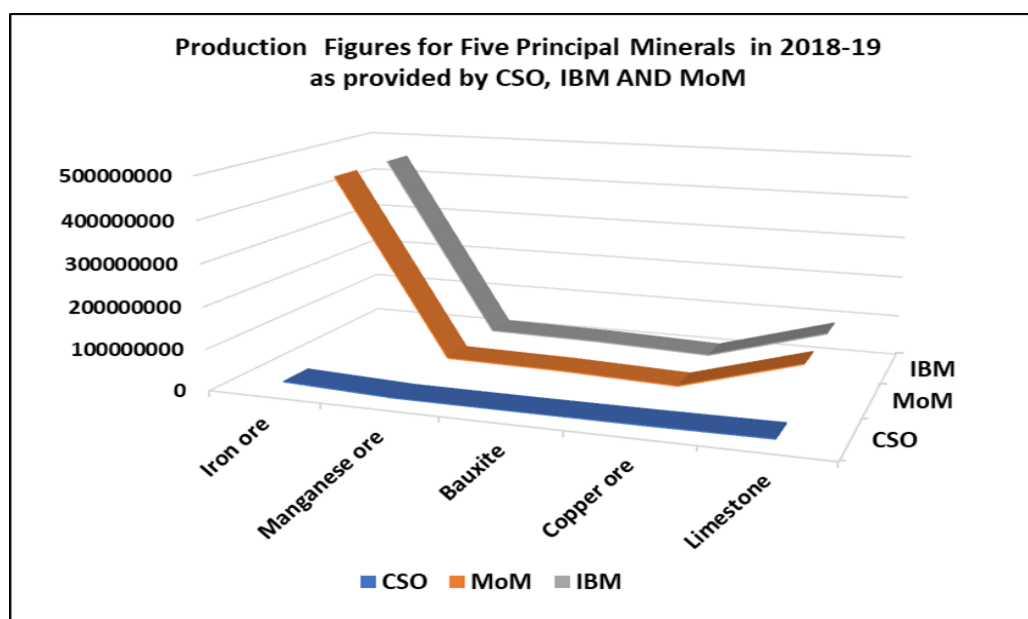
The data anomaly in the Mining sector deepens if we bring the Central Statistical Organisation (CSO) into the picture. CSO publishes a ‘Supply Table’ of commodities on a regular basis. This table include production figures of five (5) ‘Principal Minerals’ of the country (**Table 4.2**). When we plot datasets provided by CSO, IBM and MoM for the year 2018-19 (the latest available Supply Table with CSO is for 2018-19), the figures show wide divergence (**Figure: 4.4**) from each other.

Table 4.2: Production Value of Five (5) Principal Minerals as Provided by Three Government Bodies: CSO, Ministry of Mines and IBM (Value In ‘000)

Sr. No	Minerals	CSO	MoM	IBM
1	Iron ore	12115590.32	453465828	453465829
2	Manganese ore	1459261.92	21640166	21640165
3	Bauxite	908472.93	17836033	17836033
4	Copper ore	1692338.86	8846151	8846151
5	Limestone	3783228.12	89584489	89584491

Source: 1) Supply Table 2018-19, CSO 2) Ministry of Mines, GoI (MoM)
3) Indian Bureau of Mines (IBM)

Figure 4.4 Production Figures for Five Principal Minerals in 2018-19 as provided by CSO, IBM and MoM



Sources: 1) Indian Mineral Year Book (2021), India Bureau of Mines, December 2022
2) Ministry of Mines, Annual Report 2022-23, Annexure: 2.1
3) Supply Table 2018-19, CSO, MoSPI, GoI

The reasons behind the data anomaly in the mineral statistics of India can be manifold, but it seems to have persisted for a long time. A similar study published in 2017 (Chattopadhyay and Lahiri, 2017) pointed out data anomalies in the mineral statistics of India quite elaborately. After comparing official statistics on mining data (number of mines, workforce etc) provided by NSSO, DGMS and IBM for the year 2011–12, the paper observed that:

“Total number of mining sector workers varies from 2.2 million (NSSO, 2011–12) to 0.5 million (DGMS & IBM, 2011), a difference of 125%. The difference in the number of workers between NSSO, DGMS and IBM is related to the methods adopted for collecting data. NSSO data is based on a household survey whereas DGMS and IBM data is based on annual returns from the registered mine owners. Differences also are evident in the number of operating mines and miners between DGMS (2610) and IBM (3236), a difference of 21% and 5% respectively” (Chattopadhyay and Lahiri, 2017).

The differences in methods of collecting data have been tentatively held responsible for this discrepancy in datasets. Although this could be a reason for data related to ‘Number of Mines’, ‘Number of Workers’ etc., the same reason does not have any merit in the case of ‘mineral production’ figures. IBM and MoM use the same source (MDMC return) for preparing mineral production data. As the sole authority for data dissemination, IBM shares the same data with all government agencies.

4.1.4 Introspecting Reasons behind Data Anomaly

4.1.4.1 Sources of Data

As mentioned in the Annual Report 2022-23 of the Ministry of Mines, the source of the production statistics was ‘MCDR Returns’. But, as per the organisational set-up, the only data source for the Ministry should be IBM. In addition to that, the primary source of information for IBM is also the same; i.e., MCDR Returns. According to Rule 45 of ‘Mineral Conservation and Development Rules (MCDR), 2017 (Amended up to 3rd November 2021)’, all the mining lessees, traders, exporters, end users, etc. (who are engaged in mineral business) must register them with the Indian Bureau of Mines. The rule was officially issued by the Controller General, Indian Bureau of Mines (IBM) in January 2022. The rule further elaborates:

“The holder of a mining lease shall submit online returns in respect of each mine to the “Regional Controller or any other authorised official” of the Indian Bureau of Mines in the following manner, namely: -

A monthly return which shall be submitted before the tenth day of every month in respect of the preceding month in electronic form along with a signed print copy of the same. An annual return which shall be submitted before the 1st day of July each year for the preceding financial year in electronic form, along with a signed print copy of the same”¹⁴ (IBM, 2022)

So, MCDR returns are statutorily filed with IBM only via electronic mode. Hence, IBM is the first recipient of all information contained in the return form, definitely, Ministry also gets a copy of this return for reference and use. The MIAS unit of IBM is primarily responsible for providing updated statistics on mineral resources. After several rounds of scrutiny, validation and sanitisation, the finalised data are published by IBM. The publication department of IBM is responsible for the dissemination of updated data in print and electronic format. Thus, IBM comes out with statistics on mineral production, industry-wise consumption, domestic and international prices of mineral/metals, trade figures related to minerals/metals, details of exploration activities etc. IBM is also bound to share the updated data with all relevant government bodies. Hence, data published by IBM and the Ministry should necessarily be identical.

4.1.4.2 Delay in Updating Data

Discrepancy may arise if; the Ministry decides to quickly come out with new data before validation by IBM. As already mentioned, raw data about mining and minerals are collected, scrutinised, validated and sanitised by IBM and then the organised, cleaned and finalised data is passed on to all concerned government bodies, including the Ministry.

As IBM takes some time to accomplish the due process of validation, the Ministry may go for an “Early Release”. However, this data (early release) must be finalized by IBM in due course, after completion of the validation process and making rounds of necessary revisions.

To avoid this possibility, we have intentionally avoided using data for recent years. The database for three years (2017-18; 2018-19; 2019-20) that we have considered must have long been finalised and duly passed through all rounds of scrutiny and revisions. Hence, there is absolutely no logical ground based on which the data discrepancy could be justified.

4.1.4.3 Human Error

Human error may be a valid reason behind the anomaly between IBM and Ministry data. The entire process of data collection to data dissemination is a difficult task for the mining and mineral sector and it requires expert handling of data. The stakeholders involved in the mining business are often reluctant to disclose accurate data. The practice of illegal mining,

¹⁴ Mineral Conservation and Development (Amendment) Rules, 2021, Page 13

tax evasion, corruption and several other malpractices are serious deterrents to the free flow of information in the mining sector. But above all, the process of data collation and compilation must be accomplished by professional hands. Especially at Ministry, utmost care should be taken to prevent data mishandling.

4.1.5 Discussion

The data mismatch across government bodies is quite disturbing. Before embarking on any economic analysis in the Input-Output framework, the mathematical rigour of the model demands data precision. As already pointed out, in the case of “Moulding Sand,” the average percentage divergence is as high as 165%. Anomaly of such extent can completely ruin any analysis using a structured mathematical framework, like the IO Model. Even a minute error in the database always tends to multiply by a snowball effect in the case of an IO model and ultimately spoil the futility of the entire exercise.

Since data precision seems to be a perennial concern in regard to the mineral statistics of India, the utmost care and prudent judgment need to be applied while choosing the database. The current anomaly in data released by two government bodies is quite perplexing. The Ministry of Mines should come forward and take the necessary steps to clear the confusion. There should be only one version of official data; otherwise, this kind of discrepancy is bound to crop up.

4.2 Expansion of Input-Output Table

4.2.1 Construction of Input-Output Table (IOT) from Supply-Use Table (SUT)

Following the stepwise procedure mention in Handbook on Supply and Use Tables and Input-Output Tables with Extensions and Applications; Chapter 12; (United Nations, 2018, we have first calculated Input-Output (IO) Table of 2018-19 from Supply and Use Tables (SUT) of India (2018-19), as published by Central Statistical Organization (CSO). This IO table consists of 140 industries ($j = 1, \dots, 140$) and 140 Commodities ($i = 1, 2, \dots, 140$) respectively. The (140x140) IO table contains:

- i) **Fuel minerals** (Coal and Lignite; Natural Gas and Crude Petroleum) – (3)
- ii) **Non-fuel minerals** (Iron Ore; Manganese Ore, Bauxite; Copper Ore; Lime Stone; Mica) – (6). (In this, Iron Ore; Manganese Ore, Bauxite; Copper Ore (4) are ‘**metallic minerals**’ and Lime Stone and Mica (2) are ‘**non-metallic minerals**’)
- iii) Two (2) more items: ‘**Other metallic minerals**’ and ‘**Other non-metallic minerals**’ have been added to make the list comprehensive.

4.2.2 Expansion of Input-Output Table by Incorporating More Minerals

To get a more holistic view of Indian mineral sector, this thesis has systematically expanded the IO Table (2018-19), by incorporating additional 23 non-fuel minerals into existing 8 non-fuel minerals. This entire task of incorporating new minerals in the old IO table has been done in two stages in this thesis:

First, the Input-Output Table (2018-19) of dimension (140x140) has been re-grouped following a suitable ‘Aggregation Scheme’ (**Table A3: Appendix**) to get a new ‘aggregated IO Table’ of dimension (38x38). The aggregation scheme has been developed, keeping in mind the requirement of next course of computations in subsequent Chapters. However, in this thesis, both of the ‘Aggregated Matrix’ (38x38) and ‘Expanded Matrix’ (61x61) (**Table A5: Appendix**) have been used depending on the requirement of the study.

Second, this thesis incorporated additional 23 minerals into the structured framework of IO model. In these new minerals, there are 6 metallic minerals and 17 non-metallic minerals. Two more categories: Minor Minerals and Other Minerals have also been added to the list **Table 4.3**. The comprehensive list of all minerals extends to: Metallic Minerals: 11 and Non-Metallic: 20.

Table 4.3 Number of Minerals in Aggregated IO Table (38x38) and Expanded IO Table (61x61)

	Fuel Minerals	Non-fuel Minerals				Total
		Metallic		Non-metallic		
Aggregated Table: (38x38)		<i>Metallic Minerals</i>	<i>Other Metallic</i>	<i>Non-metallic</i>	<i>Other Non-metallic</i>	
	3	4	1	2	1	11
Expanded Table: (61x61)		<i>Metallic Minerals</i>	<i>Other Minerals</i>	<i>Non-metallic Minerals</i>	<i>Minor Minerals</i>	
	3	10	1	19	1	34
Addition of Minerals:	0	6		17		23

The production data for these 23 minerals (2018-19) have been obtained from “Indian Mineral Yearbook 2021”, Part-I, General Review, 60th Edition, Production (Advance Release), published by the Indian Bureau of Mines. This document was published by IBM in December 2022. IO Table (38x38) is then expanded to get a new IO Table (61x61). The

entire process of expanding an IO table has been illustrated with the help of a hypothetical table (**Appendix: B**).

- i) In the case of ‘metallic minerals,’ six (6) new metallic minerals have been carved out of ‘Other metallic Minerals’ in IOTT Sector No: 37 (**Table A5: Appendix**).
- ii) In the case of ‘non-metallic minerals, seventeen (17) new non-metallic minerals have been carved out of ‘Other non-metallic Minerals’ in IOTT Sector No: 40; (**Table A5: Appendix**)
- iii) “Other metallic minerals” and “Other non-metallic minerals’ have been clubbed together. The production figure of “Minor Minerals” has been deducted from the sum to form only one miscellaneous category: “Other Minerals.”

Following this procedure, the expanded IO table (**Table A 5: Appendix**) is obtained.

The comprehensive list of minerals has been presented in **Table 4.4**

Table 4.4: Comprehensive List of Minerals

Fuel Minerals (3)		
1. <i>Coal And Lignite</i>		
2. <i>Natural Gas</i>		
3. <i>Crude Petroleum</i>		
Metallic Minerals (10)		
1. <i>Iron Ore</i>	6. <i>Gold Ore & Gold</i>	
2. <i>Manganese Ore</i>	7. <i>Lead conc.</i>	
3. <i>Bauxite</i>	8. <i>Zinc conc</i>	
4. <i>Copper Ore</i>	9. <i>Silver</i>	
5. <i>Chromite</i>	10. <i>Tin conc.</i>	
Non-metallic Minerals (19)		
1. <i>Limestone</i>	8. <i>Iolite</i>	15. <i>Salt (rock)</i>
2. <i>Mica</i>	9. <i>Kyanite</i>	16. <i>Selenite</i>
3. <i>Phosphorite</i>	10. <i>Sillimanite</i>	17. <i>Siliceous earth</i>
4. <i>Diamond</i>	11. <i>Lime shell</i>	18. <i>Vermiculite</i>
5. <i>Fluorite (graded)</i>	12. <i>Magnesite</i>	19. <i>Wollastonite</i>
6. <i>Garnet (abrasive)</i>	13. <i>Marl</i>	
7. <i>Graphite (r.o.m.)</i>	14. <i>Moulding sand</i>	
Other Minerals (2)		
1. <i>Minor Minerals</i>		
2. <i>Other Minerals</i>		

Source: Author’s Compilation

4.3 Identification of ‘Key Resources’ of Indian Economy

4.3.1 Analysis of Forward and Backward Linkages

The Input-Output framework is considered to be the most robust analytical construct, which is capable of capturing the “knock-on effects” in an interdependent industry structure, in the most comprehensive manner possible. The concept of “linkages” explains the mechanism through which direct and indirect impacts of an economic change are transmitted in the form of waves of repercussions throughout the economy.

Industries remain interconnected through two routes:

- 1) From the demand side: It purchases inputs required for its production from the “upstream” industries.
- 2) From the supply side: It sells output to the “downstream” industries, which in turn use its output as their inputs.

Interconnection of a particular sector with the “upstream” and “downstream” sectors are referred to as “backward” and “forward” linkages respectively. Collectively, linkage effects give a measure of the economic “connectedness” of a sector with the rest of the economy.

The more connected a sector remains with the rest of the economy, wields more power to influence the total output of the economy, through longer chains of repercussions. In IO framework, this concept is used as a basic principle to identify the “key sectors” of the economy.

“Measures have been proposed to quantify such backward and forward linkages, or economic “connectedness.” Comparisons of the strengths of backward and forward linkages for the sectors in a single economy provide one mechanism for identifying “key” or “leading” sectors in that economy (those sectors that are most connected and therefore, in some sense, most “important”) and for grouping sectors into spatial clusters. And if data are available for more than one time period, the evolution of these interconnections can be studied. Also, examination of these measures for similar sectors in different countries provides one method of making international comparisons of the structure of production.”

(Miller and Blair, 2009)

This thesis has attempted to identify the “key sectors” of the Indian economy, based on some quantitative measures of “connectedness” as explained before. We have used the extended Input-Output Table (61x61) of India for 2018-19 to accomplish this task. To identify “key sectors”, the “backward” and “forward” linkage measures have been calculated (both in normalized form). High-scoring sectors (values greater than 1) are most important for the

economy, either from the demand side or from the supply side. Sectors scoring high from both sides are normally the most important.

The results of our calculation reveal that the following non-fuel minerals possess the highest “**backward linkage**” effects when arranged in decreasing order of respective values of “Normalized Total Backward Linkage Index” (Index Value > 1):

Non-fuel Minerals with Highest Backward Linkage Effects are:

- | |
|--|
| <ol style="list-style-type: none"> 1. Salt (rock) 2. Iolite 3. Vermiculite 4. Moulding Sand 5. Selenite |
|--|

“If the backward linkage of sector i is larger than that of sector j , one might conclude that a dollar’s worth of expansion of sector i output would be more beneficial to the economy than would an equal expansion in sector j ’s output, in terms of the productive activity throughout the economy that would be generated by it. (Miller and Blair, 2009)

Hence, considering the demand side, it can be concluded that increased production of these non-fuel minerals will have a maximum beneficial impact on the Indian economy. These minerals can generate maximum productive activity throughout the economy.

On the other hand, the results of our calculation reveal that the following non-fuel minerals possess the highest “**forward linkage**” effects, when arranged in decreasing order of respective values of “Normalized Total Forward Linkage Index” (Index Value > 1):

Non-fuel Minerals with Highest Forward Linkage Effects are:

- | | |
|--------------------|---|
| 1) Copper Ore | 7) Silver |
| 2) Manganese Ore | 8) Tin conc. |
| 3) Bauxite | 9) Chromite |
| 4) Gold Ore & Gold | 10) Limestone |
| 5) Lead conc. | 11) Iron Ore |
| 6) Zinc conc | 12) Non-Ferrous Basic Metals (Incl. Alloys) |

“If the forward linkage of sector r is larger than that of sector s , it could be said that a dollar’s worth of expansion of the output of sector r is more essential to the economy than a similar expansion in the output of sector s , from the point of view of the overall productive activity that it could support.” (Miller and Blair, 2009)

Quite similarly, considering the supply side, it can be concluded that increased production of these non-fuel minerals will have a maximum beneficial impact on the Indian economy. These minerals can support maximum productive activity by supplying inputs (i.e. its own output) throughout the economy. The summary table of results obtained from this analysis are presented in **Table 4.5**

Table 4.5 Classification of Backward and Forward Linkage Results

Dependent on Inter-industry Demand (FL > 1, BL < 1) (Forward Linkage: High, Backward Linkage: Low)
<i>Copper Ore, Manganese Ore, Bauxite Gold Ore & Gold, Lead conc., Zinc conc, Silver, Tin conc., Chromite, Limestone, Iron Ore, Non-Ferrous Basic Metals (Incl. Alloys)</i>
Dependent on Inter-industry Supply (FL < 1, BL > 1) (Forward Linkage: Low, Backward Linkage: High)
<i>Salt (rock), Iolite, Vermiculite, Moulding sand, Selenite</i>
Generally Independent (FL < 1, BL < 1) (Forward Linkage: Low, Backward Linkage: Low)
<i>Kyanite, Marl, Diamond, Garnet (abrasive), Sillimanite, Lime shell, Magnesite, Fluorite (graded), Graphite (r.o.m.), Wollastonite, Minor Minerals, Other Minerals, Phosphorite, Siliceous earth, Fertilizers, Miscellaneous Metal Products, Plastic Products, Rubber Products, Non-Metallic Mineral Products, Cement, Batteries, Wood & Rubber Products, Electrical Cables, Wires & Appliances, Electricity, Capital Goods, Financial Services, Precision Tools & Equipment, Transport, Vehicles & Transport Equipment, Natural Gas, Iron & Steel, Mica, Miscellaneous Manufacturing, Chemicals (Exc.. Fertilizer), Leather & Leather Products, All Other Services, Agriculture, Livestock & Natural Resources, Pharmaceuticals, Textile and Apparel, Gems & Jewelry, Food, Food Products & Other Consumables, Public Infrastructure, Construction</i>
Generally Dependent (FL > 1, BL > 1) (Forward Linkage: High; Backward Linkage: High)
<i>None</i>

Source: Author's Calculation

4.4 Principal Component Analysis (PCA)

We have applied another mathematical technique called 'Principal Component Analysis' (PCA) to identify the "key sectors." PCA is a dimensionality-reduction method that systematically filtered out the least important sectors by transforming a large set of sectors into a smaller one that still contains most of the information in the large set. By "importance," the capacity of the sector in terms of influencing output of the economy has been implied.

One of the serious limitations of PCA is that, it is able to identify importance of a sector from “supply side” only. Hence, imported items remains out of purview of PCA.

The result of the PCA is presented in **Table A6: Appendix**

As per this table, the results can be summarized as below:

- 1) Eight (8) non-fuel minerals have been found to explain 100% variance in dependent variables (i.e. Output of Indian economy). These are "Key non-fuel minerals"

Key Non-fuel Minerals from PCA are:

1. <i>Chromite</i>	5. <i>Bauxite</i>
2. <i>Copper ore & concentrate</i>	6. <i>Lead cone.</i>
3. <i>Gold ore and conc.</i>	7. <i>Manganese ore</i>
4. <i>Iron ore</i>	8. <i>Silver</i>

- 2) Eleven (11) non-fuel minerals have minimal impact on economy. These are important, but not prime-movers

Important Non-fuel Minerals from PCA are:

1. <i>Tin conc</i>	5. <i>Garnet (abrasive)</i>	9. <i>Lime shell</i>
2. <i>Zinc cone.</i>	6. <i>Graphite (r.o.m.)</i>	10. <i>Limestone</i>
3. <i>Diamond</i>	7. <i>Iolite</i>	11. <i>Magnesite</i>
4. <i>Fluorite-</i>	8. <i>Kyamte</i>	

- 3) These (10) non-fuel minerals do not have positive impact on economy. The probable reason is, majority of them are imported

Insignificant Non-fuel Minerals from PCA are:

1. <i>Marl</i>	6. <i>Siliceous earth</i>
2. <i>Moulding Sand</i>	7. <i>Sillimanite</i>
3. <i>Phosphorite</i>	8. <i>Vermiculite</i>
4. <i>Salt (rock)</i>	9. <i>Wollastonite</i>
5. <i>Selenite</i>	10. <i>Minor Minerals</i>

4.5 Identification of Key Resources: Compiling Results Obtained from Computation of Linkages and PCA

By observing results obtained from calculation of both “linkage effects” and “PCA”, we can identify eight (8) non-fuel minerals as the “key resources” of Indian economy.

Key Non-fuel Minerals/ Resources

Common to both linkage calculation and PCA results are: (Alphabetically):

1. Bauxite	3. Copper Ore	5. Iron Ore	7. Manganese Ore
2. Chromite	4. Gold ore and conc.	6. Lead conc.	8. Silver

Apart from this, following (9) minerals are also immensely important for Indian economy:

Important Non-fuel Minerals in India are (Alphabetically):

1. Iolite	4. Non-Ferrous Basic Metals (Incl. Alloys)	7. Tin conc.
2. Limestone	5. Salt (rock)	8. Vermiculite
3. Moulding sand	6. Selenite	9. Zinc conc

The results have been presented in **Table 4.6**

Table 4.6: Key Resources from Results of Linkages and PCA Calculations

Sr. No		Dependent on Inter-industry Demand	Dependent on Inter-industry Supply	PCA	Combined Result
1.	Bauxite	✓	✗	✓	✓
2.	Chromite	✓	✗	✓	✓
3.	Copper Ore	✓	✗	✓	✓
4.	Gold Ore & Conc.	✓	✗	✓	✓
5.	Iolite	✗	✓	✗	
6.	Iron Ore	✓	✗	✓	✓
7.	Lead Conc.	✓	✗	✓	✓
8.	Limestone	✓	✗	✗	
9.	Manganese Ore	✓	✗	✓	✓
10.	Moulding Sand	✗	✓	✗	
11.	Non-Ferrous Basic Metals (Incl. Alloys)	✗	✓	✗	
12.	Salt (Rock)	✗	✓	✗	
13.	Selenite	✗	✓	✗	
14.	Silver	✓	✗	✓	✓
15.	Tin Conc.	✓	✗	✗	
16.	Vermiculite	✗	✓	✗	
17.	Zinc Conc.	✓	✗	✗	

Source: Author's Calculations

4.6 Conclusion

The most important part of this Chapter has been the identification of ‘key resources’ of Indian economy using two methods. The first method is the calculation of ‘Backward’ and ‘Forward Linkages’ and the second one is the determination of ‘most important’ resources by application of ‘Principal Component Analysis’ (PCA). Results obtained from both the methods ascertained following eight (8) non-fuel minerals as the ‘key resources’ for the Indian economy:

Bauxite, Chromite, Copper Ore, Gold Ore and Conc., Iron Ore, Lead Conc., Manganese Ore, Silver

These minerals have been found to have strong linkage effects (Backward / Forward) and also capture maximum influence in country’s growth momentum. The most import finding in this case is that all of these resources have strong ‘backward linkages’. This implies these resources have strong linkages with the economy from demand side. This indicates towards high domestic demand of ‘key resources’ due to:

- i) A huge and rapidly growing manufacturing base of Indian economy.
- ii) Accelerating industrialization process and a structural shift from ‘agricultural’ to ‘manufacturing’ activities.
- iii) Increase in export of commodities that requires sizable amount of these non-fuel minerals as inputs.

Stronger ‘backward linkages’ implies that these eight ‘key resources’ develop the productive capacity of the economy in both intensive (more production of the commodities) and extensive (production of more commodities) ways.

“If the backward linkage of sector i is larger than that of sector j , one might conclude that a dollar’s worth of expansion of sector i output would be more beneficial to the economy than would an equal expansion in sector j ’s output, in terms of the productive activity throughout the economy that would be generated by it. (Miller and Blair, 2009)

CHAPTER 5: IMPACT ANALYSIS IN THE FRAMEWORK OF A ‘MODIFIED INPUT-OUTPUT (IO) MODEL’

This Chapter outlines the deep rooted implication of some path breaking macroeconomic policies adopted by Government of India since 2020-21. The focus has been on the most significant policy-move of the Government since Economic Reform in 1991; i.e Atmanirbhar Bharat Abhiyaan’ or ‘Self-reliant India’.

The term ‘impact analysis’ in the language of Input-Output theory implies assessment of the effects of changes in one sector of the economy on other sectors, and on the economy as a whole. In this Chapter ‘impact analysis’ has been done using a modified Input Output model to estimate the requirement of eight ‘key resources’- as already identified in the previous Chapter - for successful implementation of Atmanirbhar Bharat Abhiyaan’ under the ‘Make in India’ campaign. The comparison of the requirement of ‘key resources’ vis-à-vis their availability has been used to unravel few important insights about the ‘feasibility’ and ‘continuity’ of these policies and schemes.

5.1 Growth Story of India since Independence: Government Policies in Retrospect

The journey of the Indian economy in pursuit of economic excellence has been fascinating in many ways. At the time of Independence, the country's economy was completely in a dilapidated state as a consequence of the systematic plunder conducted by the British rulers during their 200-year-long occupation. During this long time period, the East India Company and the British Raj established a deep-rooted network of railways and roadways to siphon out the last drop of valuable resources from every nook and corner of the country and utilised these resources to fuel the industrialisation process in Britain. A comprehensive study made by renowned economist Utsa Patnaik estimated that between 1765 and 1938, the economic drain amounted to £9.2 trillion (equal to \$45 trillion), taking India’s export surplus earnings as the measure, and compounding it at a 5% rate of interest. This staggering figure is fifteen times the annual GDP of the UK today. As a consequence of this massive loot, India’s share of world income reduced from 22.6% in 1700 to 3.8% in 1952¹⁵. The comparative macroeconomic performance of India and Britain (1600 – 1947) is presented in **Table 5.1**

¹⁵ Byttebier, K. (2024). Unsustainability of the Capitalist Socio-Economic Order. In: Ethics of Socioeconomics. Economic and Financial Law & Policy – Shifting Insights & Values, vol 8. Springer, Cham. https://doi.org/10.1007/978-3-031-38837-8_3

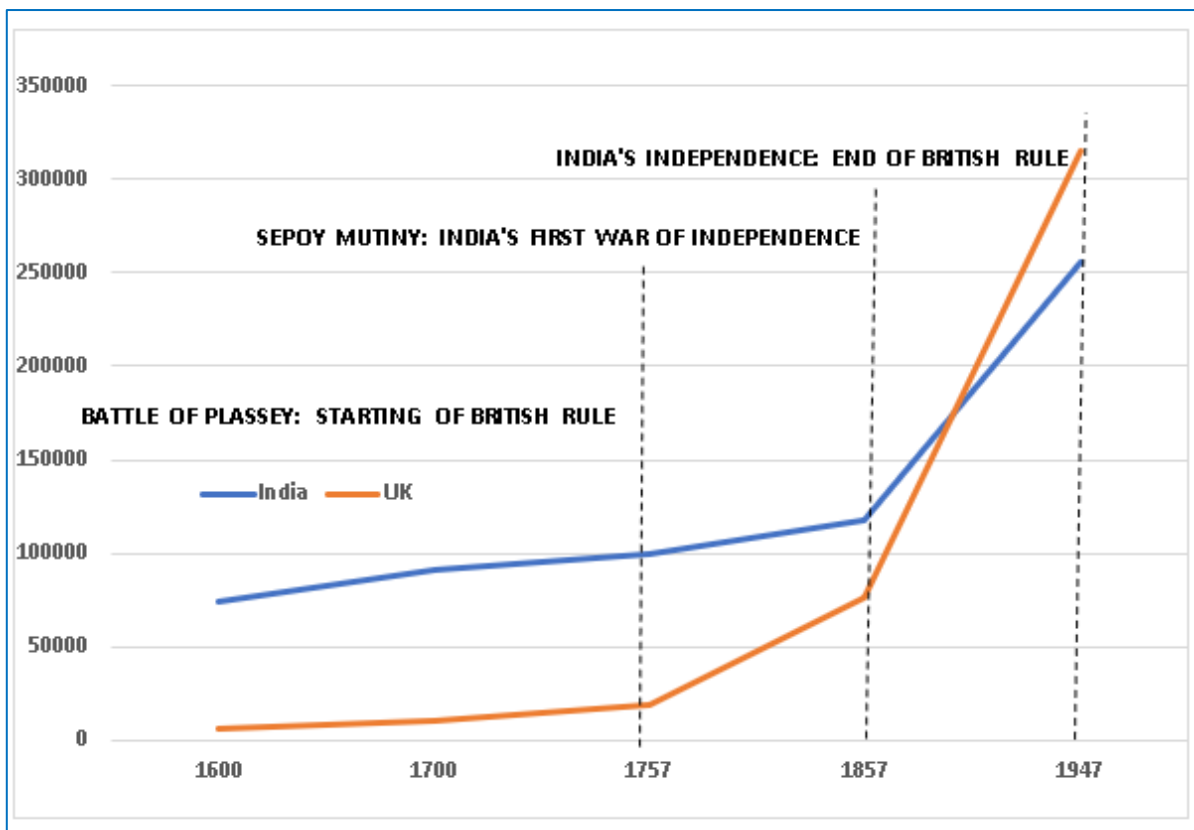
Table 5.1 Comparative Macroeconomic Performance of India and Britain, 1600 -1947

	1600	1700	1757	1857	1947
Per capita GDP (1990 int. dollars)					
India	550	550	540	520	618
United Kingdom	974	1 250	1 424	2 717	6 361
Population (000)					
India	135 000	165 000	185 000	227 000	414 000
United Kingdom	6 170	8 565	13 180	28 187	49 519
GDP (million 1990 int. dollars)					
India	74 250	90 750	99 900	118 040	255 852
United Kingdom	6 007	10 709	18 768	76 584	314 969

Source: Maddison, 2021

The comparison of GDP figures of these two countries has been shown in **Figure 5.1**

Figure: 5.1 Comparison of GDP Figures of India and Britain, 1600 – 1947 (million 1990 int. dollars)



Source: Maddison, 2021

This figure clearly shows how the sharp increase in the GDP of Britain coincided with the stagnating GDP of India during the British rule (1757 -1947). To take a step further, this explains how affluence of Britain can be correlated with the abject poverty that the people of India were subject to for a considerable period of time. Before British occupation, India was far ahead of Britain in terms of GDP figures and within a span of 200 years, the country lost all of its wealth and rendered poor in British hands. All these happened because of the systematic “drain of resources”, which was well planned and executed successfully. In Marxian sense, this “economic drain” can be interpreted as the “primitive accumulation of capital”¹⁶ by Britain for its transformation from a “feudalistic economy” to a “capitalistic economy.”

“We have seen how money is changed into capital; how through capital surplus-value is made, and from surplus-value more capital. But the accumulation of capital presupposes surplus-value; surplus-value presupposes capitalistic production; capitalistic production presupposes the pre-existence of considerable masses of capital and of labour power in the hands of producers of commodities. The whole movement, therefore, seems to turn in a vicious circle, out of which we can only get by supposing a primitive accumulation (previous accumulation of Adam Smith) preceding capitalistic accumulation; an accumulation not the result of the capitalistic mode of production, but its starting point” (Marx, 1867)

There is no wonder that the Indian economy was in an impoverished state, at the time the country was finally successful in throwing out the British rulers after an intense episode of freedom movement, which etched a glorious period in the epoch of World history.

The focus of this thesis however zeroes in on the period immediately after the Independence (1947), when India started preparation for developing a solid structural foundation of the country through prudent policy formulation to mitigate damages inflicted by 200 years of colonial extortions. The most important issue to highlight is the exemplary role that our nationalist leaders played at that time in shaping the bedrock on which the juggernaut of the Indian economy still moves. The thesis has also made a brief assessment of the role and prudence of subsequent policy-making functionaries and a few path breaking economic policies implemented over the last 75 years since Independence. The feasibility and

¹⁶ Marx, Karl (1867) *Capital: A Critique of Political Economy, Volume I, Book One: The Process of Production of Capital, Chapter 26: The Secret of Primitive Accumulation*; Progress Publishers, Moscow, USSR

sustainability of some recent policies have also been tested in terms of the economy-wide impacts associated with these policies.

5.2 Government policies in India immediately after Independence

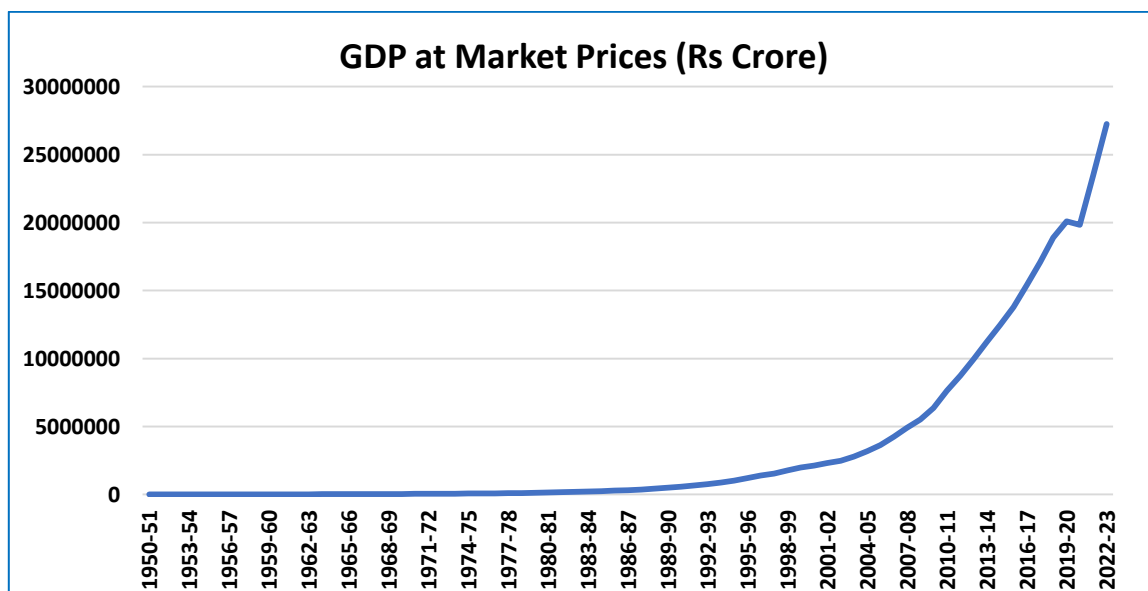
Vitalising the Indian economy from perennial stagnancy was an upheaval task in front of the leaders of the country, who were also engaged in laying the structural foundation of the country for the future. When the country embarked on a journey towards higher growth orbits, some visionary leaders were at the helm of the highest policy-making body of the “first government” formed after Independence. Some eminent economists and statisticians also shared responsibility and made significant contributions to nation-building by helping the government in developing short-term and long-term economic policies and devising “planning techniques” for the newly formed government of India. The grounding stones of the Indian economy were laid by a group of highly erudite people, who were not only well-versed in scientific thinking of the Western world but also had a deep understanding of the traditional value-based systems that prevailed for centuries in this ancient land that harboured one of the most advanced civilisations of the World. The intrinsic resilience of the Indian economy is largely attributed to the collective knowledge and dedication of a group of highly capable people, who designed the unique policy-making framework for the country.

The name that comes first in this regard is Pandit Jawaharlal Nehru - the first Prime Minister of independent India. Pandit Nehru was the chief architect in designing a planned economic development model for India. The economic policies developed under his leadership gave top priority to developing the country’s production capacities. During the colonial period, the indigenous production system of India was intentionally kept undeveloped. As a result, the country remained highly dependent on imports from the Western world. Pandit Nehru opined that rapid industrialisation was the only way for import substitution. The theoretical ground of his vision was reinforced by the “Mahalanobis model,” developed by another legendary son of the soil, Prof. Prasanta Chandra Mahalanobis, who is also known as the “Father of Indian Statistics.” The “Mahalanobis model” established that the country at its initial phase of development should give top priority to the “heavy industries” sector to bolster the productive capacity of the domestic industries. Collectively, the components of the Nehru-Mahalanobis model are the following:

- i) A mixed economy, characterised by the existence of both public and private sectors in the production system. However, operations in certain strategic sectors remain exclusive to the public sector only
- ii) Emphasis on developing the basic and heavy industries.
- iii) Economic planning based on long-term development strategy.
- iv) Unbalanced growth model which conjectures that the benefits of industrialisation percolate to other sectors of the economy.

India’s economic policies in the initial period after independence were highly influenced by the “Nehru-Mahalanobis model.” The “Planning Commission” was set up in 1950 with the responsibility to formulate “Five-year Plans” for the country. The commission developed 12 five-year plans in total, before being replaced by the National Institution for Transforming India (NITI Aayog) in 2014. The Second Five Year Plan (1956 -61) was based on the “Mahalanobis model” of economic development. In this plan, maximum investible resources were allocated to “basic and heavy industries.” The “Nehru-Mahalanobis model” of economic development was largely successful in fulfilling its mission. The country was able to depart from the stagnating growth rate of the previous era (often referred to as the “Hindu Rate of Growth”) and embarked on a steadily accelerating growth path. The GDP of Indian economy from 1950-51 to 2020 -22 in **figure 5.2**

Figure 5.2 GDP of Indian economy from 1950-51 to 2020 -22



Source: National Accounts Statistics of India (2011-12 Series), EPWRF

5.3 Government Policies during 1990s

Economic Reform, 1991: During 1990-91, the Indian economy again started showing signs of stagnancy. Economic policies based on Nehru-Mahalanobis model could not move the country in tandem with the global economic progress. There are mainly three reasons behind this policy weakness in Indian economy at the end of 1980's:

- 1) Economic policies based on Nehruvian model was highly centralised with very little scope for private investor to flourish. Due to limited government resources, total investment of the country was always falling short. The virtuous circle of “investment-growth -investment” disappeared from the economy
- 2) Investment in “heavy industries” started were no longer the top priority of the country. After four decades of second five-year plan, the country developed its heavy industries like Steel, Cement and Power
- 3) Free flow of global trade became extremely necessary to capitalise on vibrant global demand.

In July 1991, Government of India introduced “economic reforms” in the form of a set of ‘stabilization’ and ‘structural adjustment’ policies. Subsequently, the ‘Discussion Paper on Economic Reforms’ was released by the Ministry of Finance in July 1993, stating the basic objective of economic reform as follows:

“...to bring about rapid and sustained improvement in the quality of the people of India. Central to this goal is the rapid growth in incomes and productive employment... The only durable solution to the curse of poverty is sustained growth of incomes and employment... Such growth requires investment: in farms, in roads, in irrigation, in industry, in power and, above all, in people. And this investment must be productive. Successful and sustained development depends on continuing increases in the productivity of our capital, our land and our labour. Within a generation, the countries of East Asia have transformed themselves. China, Indonesia, Korea, Thailand and Malaysia today have living standards much above ours... What they have achieved, we must strive for.”

(Ministry of Finance, Government of India, 1993)

The implementation of economic reform brought a sea change in Indian economy. Country's GDP figure started to grow at an astounding rate. **Figure 5.2** clearly shows this fantastic growth in terms of a steep ascent of the economy to a high-income orbit.

5.4 Percentage Changes in GDP and Per Capita GDP of India

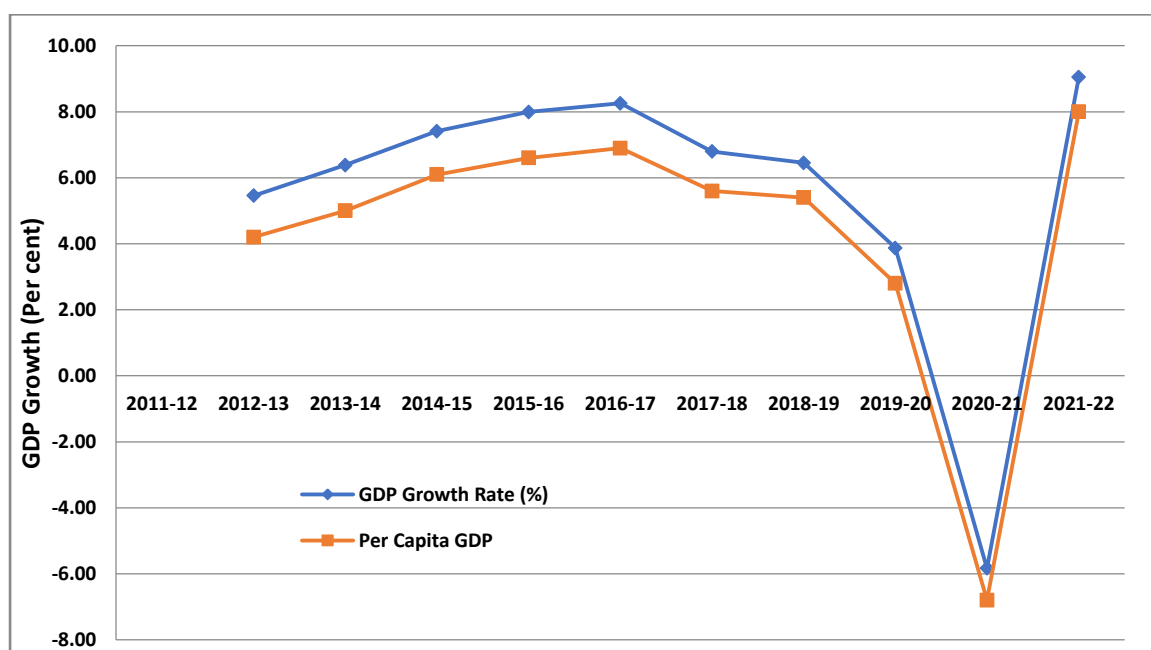
The macroeconomic policy formulations in India changed over time apropos to changes in the economic situation of the country. The new growth policies on which this thesis has focused is from 2011 till date. Two most important policies initiated by the Government of

India during this period were ‘Make in India’ (2014) and ‘Atmanirbhar Bharat Abhiyaan’ (2020). And this study keeps relevance primarily to these two policies. Two most important objectives of this thesis are:

- i) To achieve the growth targets of different sectors of the economy (as envisaged by the Government of India); new growth policies were introduced with adequate provision of funding. However, to tick the targeted growth rate; other sectors of the economy also need to grow due to strongly interdependent industry structure. This thesis seeks to capture the economy wide impact of Government expenditure aiming at some ambitious growth targets.
- ii) Measuring impact on ‘key resource’ sectors is the primal motive of this thesis.
- iii) The aspiration to touch 5 Trillion dollar economy can only be achieved when requirement of key resources are met. And this could be made possible in two ways: either by increasing domestic production or by importing from other countries. Increasing domestic production is highly contingent upon natural endowment of these resources. In that case the only option is to import.

The crux of the entire course of action is to build a strong supply chain of key resources, in the economy. However, to understand the perspective of new growth policies, changes in the economic situation of the country must be introspected.

Figure 5.3 Growth Rate (%) of GDP in India from 2011-12 to 2021-22



Source: National Accounts Statistics 2023; Ministry of Statistics and Program Implementation | Government of India (mospi.gov.in); Figure created by author

5.4 New Growth Policies: Make in India and Atmanirbhar Bharat Abhiyaan

5.4.1 Make in India

During 2012-13 the country was facing an adverse situation where GDP growth rate had fallen to its lowest level in a decade and Indian economy was tagged as one of the 'Fragile Five'. The country was on the brink of severe economic failure; desperately in need of a big push. The Per Capita GDP also followed the suit of GDP growth rates. (Figure 5.3)

'Make in India' initiative was launched in September 2014 by the Prime Minister, Mr. Narendra Modi as a response to this crisis. The programme was designed to facilitate investment, foster innovation, enhance skill development, protect intellectual property and build best in class manufacturing infrastructure in the country. The motto of 'Make in India' campaign was to attract investments from across the globe and strengthen India's manufacturing sector.

"I want to tell the people of the whole world: Come, make in India. Come and manufacture in India. Go and sell in any country of the world, but manufacture here. We have skill, talent, discipline and the desire to do something. We want to give the world an opportunity that come make in India," ~ Prime Minister of India, Mr Narendra Modi, Independence Day speech on August 15, 2014.

The programme led by the Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce and Industry, Government of India; focused on 25 sectors. These included: *automobiles, automobile components, aviation, biotechnology, chemicals, construction, defence manufacturing electrical machinery, electronic systems, food processing, IT & BPM, leather, media and entertainment, mining, oil and gas, pharmaceuticals, ports and shipping, railways, renewable energy, roads and highways, space, textile and garments, thermal power, tourism and hospitality and wellness*¹⁷

The government provided various incentives such as tax exemptions and subsidies to companies that invest under this initiative.

The economic situation improved considerably after initiation of 'Make in India'. Growth rates of both GDP and Per Capita GDP took upward turn (**Figure: 5.3**)

¹⁷ www.makeinindia.com

5.4.2 Atmanirbhar Bharat Abhiyaan

During 2020-2021, the Indian economy again started losing the growth momentum and the signs of economic stagnation became evident with low growth and high employment rate. As a result, government of India embarked on a massive investment drive and introduced a new mission to give a strong boost to the Indian economy. On 12th May 2020, the Prime Minister Mr. Narendra Modi raised a clarion call to the nation giving a kick start to the *Atmanirbhar Bharat Abhiyaan* (self-reliant India campaign) and announced the special economic and comprehensive package of INR 20 lakh crores - equivalent to 10% of India's GDP – to fight COVID-19 pandemic in India. This mission was the dictum of new India envisaged by the Hon'ble Prime Minister Shri Narendra Modi in 'Make in India' programme back in 2014. 'Make in India' did not attach any significant financial commitment from Government (apart from some incentives). The '*Atmanirbhar Bharat Abhiyaan*' however involved a massive financial package to give a thrust to local manufacturing, local markets and local supply-chains- thus propagating Hon'ble PM's vision of 'vocal for local'. The entire scheme focused on providing impetus to the 'Make in India' initiative and transforming local Indian companies into global brands. This comprehensive economic package primarily intended to strengthen following **five (5) pillars** of 'self-reliant' India¹⁸:

1. Preparing for a **quantum leap in the economy**. The government's goal is to make India a USD 5 Trillion economy by 2025.¹⁹
2. Developing **world class infrastructure** to enable the economy to achieve the target of a **USD 5 Trillion GDP**. More than INR 100 lakh crore were committed by the Government to be invested in infrastructure development in India over the next five years.²⁰
3. **Modernising systems**; based on 21st-century technology-driven arrangements.
4. Capitalise on the competitive advantage of the country owing to its **vibrant demography**.
5. Taking measures to **boost demand** to its fullest extent.

Subsequent to Prime Minister's announcement, Finance Minister Mrs. Nirmala Sitharaman provided details about the five tranches of economic package under *Atmanirbhar Bharat Abhiyaan*. She has provided the detailed break-up of Rs. 20,97,053 crore package one by one. Brief information about these five tranches are presented in **Table 5.2**.

¹⁸ <https://www.makeinindia.com/atmanirbhar-bharat-abhiyaan>

¹⁹ <https://pib.gov.in/PressReleasePage.aspx?PRID=1623391>

²⁰ <https://pib.gov.in/newsite/PrintRelease.aspx?relid=192134>

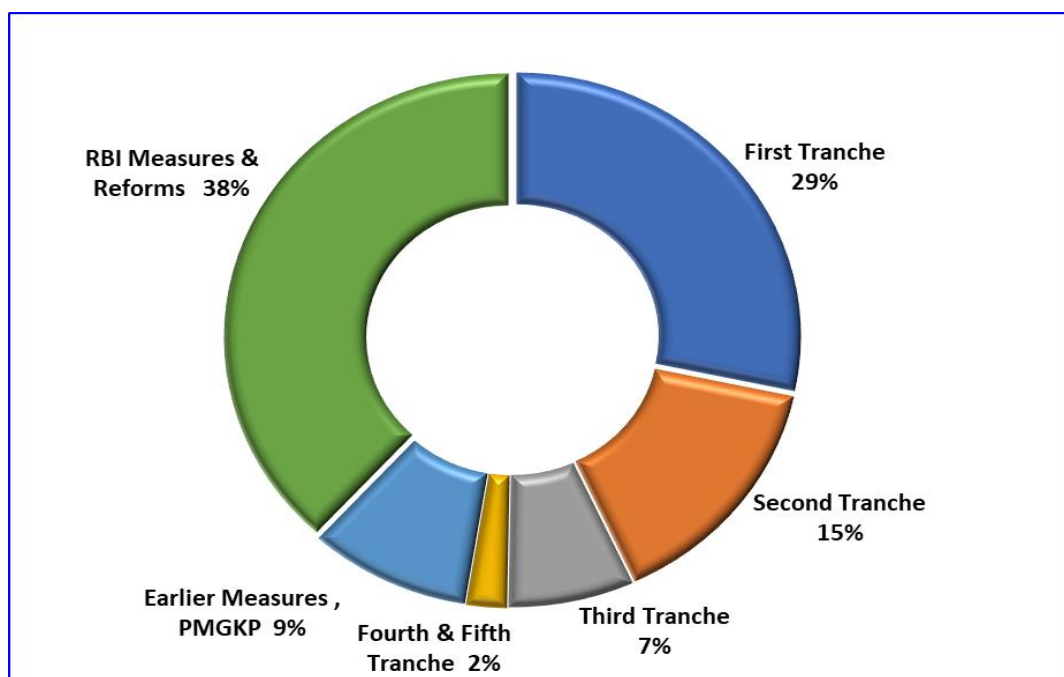
Table 5.2 Brief Description about Five Tranches of *Atmanirbhar Bharat Abhiyaan*

Sr. No.	Tranche Number	Fund Allotted (in Rs. Crore)	Focus Sector / Beneficiary
1.	First	594550	Focused on firming India’s economic backbone – the MSME Sector
2.	Second	310000	Poor, including migrants and farmers
3.	Third	150000	Agriculture
4.	Fourth	8100	Schemes for 8 Sectors
5.	Fifth and Final	40000	For MGNREGA Fund

Source: Website of Atmanirbhar Bharat Abhiyaan

Figure 5.4 gives some important insights into the allocation of funding in five tranches.

Figure 5.4 Percentage Share of Fund Allotted in Five Tranches and Other Measures



Source: <https://aatmanirbharbharat.mygov.in>; Graph Created by Author

In fact the fourth tranche actually keeps relevance to this thesis. It has coverage of eight sectors which are of interest to this study. Some of the important sectors are:

- | | |
|---|---|
| i) Coal and Mining Commercialisation | v) Distribution Companies in UTs (Power Distribution) |
| ii) Defense Production | vi) Social Infrastructure Development via Viability Gap Funding |
| iii) Minerals Sectors | vii) Space Sectors |
| iv) Air space management (Civil aviation, Airports and MRO) | viii) Atomic Energy Reforms |

Figure 5.4 clearly reveals that least percentage of funding was allotted to fourth tranche. Moreover nearly 47% of the fund accounted either for RBI Measures and Reforms or some earlier mission already executed. Hence, the fiscal part of the package was almost half of what actually announced. From this, we can arrive at two important recommendations:

- 1) More funding is required for sectors mentioned under fourth tranche. Because these sectors are too important for the Indian economy due to high multiplier values and strong linkages.
- 2) Total funding should also be increased, since outcome of ‘*Atmanirbhar Bharat Abhiyaan*’ has been positive.

In fact, along with “*Atmanirbhar Bharat Abhiyaan*,” the government of India introduced many new policies and schemes in last ten years. A brief list of these policies is given below:

• <i>Digital India</i>	• <i>Skill India</i>
• <i>Kaushal Vikas Yojana</i>	• <i>Smart Cities Mission</i>
• <i>Pradhan Mantri Awaas Yojana</i>	• <i>Stand Up India</i>
• <i>Mission Shakti</i>	• <i>Ujala Yojana</i>
• <i>Mudra Yojana</i>	• <i>Ujjwala Yojana</i>
• <i>National Water Mission</i>	• <i>Ujwal Discom Assurance Yojana</i>

The coverage of “*Atmanirbhar Bharat Abhiyaan*” has been included many functional sectors of Indian economy. And in this regard, the Performance Linked Incentive (PLI) Scheme played an instrumental role.

At this moment, it can be safely stated that Government of India has embarked on a fascinating journey towards higher growth trajectory by adopting a synchronised policy framework, which can be best described as: “Ensuring self-reliance with Sustainability.” There is a strong perspective behind this part our study. Hence, it is extremely crucial to highlight them here:

As per claims made by Secretary, DPIIT in a Press Conference, the Performance Linked Incentive (PLI) Scheme introduced by Prime Minister, Narendra Modi with the objective of making India 'Aatmanirbhar' was a game changer for the country’s growth narrative. It was claimed that mainly because of PLI Schemes, there was a significant increase of 76% in FDI in the Manufacturing sector in FY 2021-22 (USD 21.34 billion) compared to previous FY 2020-21 (USD 12.09 billion). The PLI schemes was built on the foundation of 14 sectors

with an incentive outlay of Rs. 1.97 lakh crore to strengthen their production capabilities and help create global champions. The driving force behind the latest set of schemes and missions initiated by Government of India is primarily based on the concept of “*export promotion*” and “*import substitution*”. Schemes like “*Atmanirbhar Bharat Abhiyaan*” primarily zero in on achieving “*self-reliance*” of the economy in terms of a significant reduction in the total import burden. Simultaneous implementation two policy drives, viz. “Export Promotion” and “Import Substitution,” have further been accompanied by the pressing need for reducing the carbon-footprints of the manufacturing activities in the country, with due cognizance to global treaties.

5.5 Impact Analysis Using a Modified Input-Output Model

As already mentioned, a ‘modified Input-Output framework’ has been used in this thesis to estimate the requirement of non-fuel minerals that Government Schemes like “*Atmanirbhar Bharat Abhiyaan*” entails. At the outset, the production targets (in Rs. Crores) of different sectors of the Indian economy have been presented in **Table 5.3**

Table 5.3 Growth Forecast In Different Sectors Of The Economy Targeted Demand / Supply Figures Across Sectors

Sr. No	Product/Sector (Projected Year for Achieving Production Target)	Sector No (as in expanded IO table)	Production Target (Rs. Crore)
1.	Textile And Apparel (2026)	37	1583270.00
2.	Chemicals (Excl. Fertilizer) (2030)	42	3191539.00
3.	Fertilizers (2032)	43	138380.00
4.	Pharmaceuticals (2030)	44	1083290.00
5.	Cement (2027)	45	389824.64
6.	Iron & Steel (2030)	47	1558996.01
7.	Capital Goods (2025)	50	2083250.00
8.	Electrical Cables, Wires & Appliances (2029)	51	2455985.09
9.	Batteries (2030)	52	166993.32
10.	Transport, Vehicles & Transport Equipment (2029)	54	4036755.19
11.	Gems & Jewellery (2029)	55	1004543.15
12.	Construction (2025)	57	11666200.00
13.	Electricity (2032)	58	1330908.56

Sources: Computed by the author on the basis of information available from websites of concerned Ministries and other Non-Ministerial authentic sources

The ‘*Atmanirbhar Bharat Abhiyaan*’ and some other ‘self-reliant policies’ collectively entail these production targets for different sectors. These figures are mostly available with the websites of the relevant ministries and also some other related government agencies’ websites like India Brand Equity Foundation (<https://www.ibef.org/>); Invest India (<https://www.investindia.gov.in/>); NITI Aayog (<https://www.niti.gov.in>); Department of Economic Affairs (<https://dea.gov.in/divisionbranch/economic-division>); Press Information Bureau (<https://pib.gov.in/indexd.aspx>); Newspaper Reports, Parliament Question & Answer (<https://sansad.in/ls/questions/questions-and-answers>), Industry Bodies and Associations, etc.

The **logical framework** of the ‘Impact Analysis’ executed in this thesis can be delineated as follows:

1. The ‘*Atmanirbhar Bharat Abhiyaan*’ along with some recent growth oriented macroeconomic policies adopted by Government of India entails some sector specific production targets. These targets have been set keeping in mind a bigger target, i.e to achieve USD 5 Trillion GDP figure by 2025
2. It is assumed that the funding and various incentives through ‘self-reliant’ policies of Government of India would enable sectoral players to collectively achieve these production targets
3. However, achieving production targets would entail huge requirement for ‘non-fuel minerals’ through economy-wide impact of output increase. These non-fuel minerals are also ‘key resources’ of Indian economy
4. Increased requirement of ‘key resources’ can only be met, if domestic production increases. However, production of ‘key minerals’ is highly constrained by limited reserves of natural endowments
5. If increase in domestic production of ‘key minerals’ is not possible, the country will have to depend on imports. This will not only cause import dependence, but also involve huge cost burden on country’s exchequer. In case of imports, supply chain vulnerability can emerge as a critical issue
6. Hence, the feasibility and long run continuity of growth oriented policies like ‘*Atmanirbhar Bharat Abhiyaan*’ will depend on a large number of factors and it requires a judicious approach by Government of India

5.6 Summary of Result

This thesis has tested feasibility of growth targets set by macroeconomic policies of Government of India focusing on huge growth rates. We have studied the economy-wide impacts of following thirteen (13) sectors as follows:

1. <i>Textile And Apparel</i>	8. <i>Electrical Cables, Wires & Appliances</i>
2. <i>Chemicals (Excl. Fertilizer)</i>	9. <i>Batteries</i>
3. <i>Fertilizers</i>	10. <i>Transport, Vehicles & Transport Equipment</i>
4. <i>Pharmaceuticals</i>	11. <i>Gems & Jewellery</i>
5. <i>Cement</i>	12. <i>Construction</i>
6. <i>Iron & Steel</i>	13. <i>Electricity</i>
7. <i>Capital Goods</i>	

The results of this impact analysis for 13 sectors have been presented in **Tables A7 to A19: Appendix.**

From this 13 tables, we have calculated the required growth rate of a key mineral by looking at the highest growth that can simultaneously satisfy demand from all the sectors to achieve targeted production level, as envisaged by ‘*Atmanirbhar Bharat Abhiyaan*’. The maximum production of ‘key minerals’, simple growth rate required per annum (%) and CAGR (%) figures have been presented in **Table 5.4**. Three more tables (**Table 5.5; 5.6 and 5.7**) were drawn on the basis on Table 5.4. These tables have been quite insightful for our analysis:

Table 5.4 The Maximum Production of ‘Key Minerals’, Simple Growth Rate Required per Annum (%) and CAGR (%) Figures

Sr. No	ALL SECTORS	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1.	Copper Ore	56013.62581	433.65	73.23
2.	Crude Petroleum	3828284.45	327.07	65.6
3.	Manganese Ore	60711.53	140.49	45.35
4.	Coal And Lignite	1306776.38	129.41	43.59
5.	Bauxite	38513.31	100.31	38.37
6.	Chromite	26901.56	94.29	37.16
7.	Gold Ore & Gold	3826.52	94.29	37.16
8.	Lead conc.	11911.57	94.29	37.16
9.	Silver	18852.43	94.29	37.16
10.	Tin conc.	10.68	94.29	37.16
11	Zinc conc	40941.97	94.29	37.16
12	Limestone	148661.15	83.06	34.74
13	Non-Ferrous Basic Metals (Incl. Alloys)	1350746.66	72.23	32.18
14	Iron Ore	426341.92	68.42	31.22
15	Gems & Jewellery	993207.99	67.31	30.93

Figure 5.5 Required Productions of Key Minerals to Satisfy Demand from All the Sectors

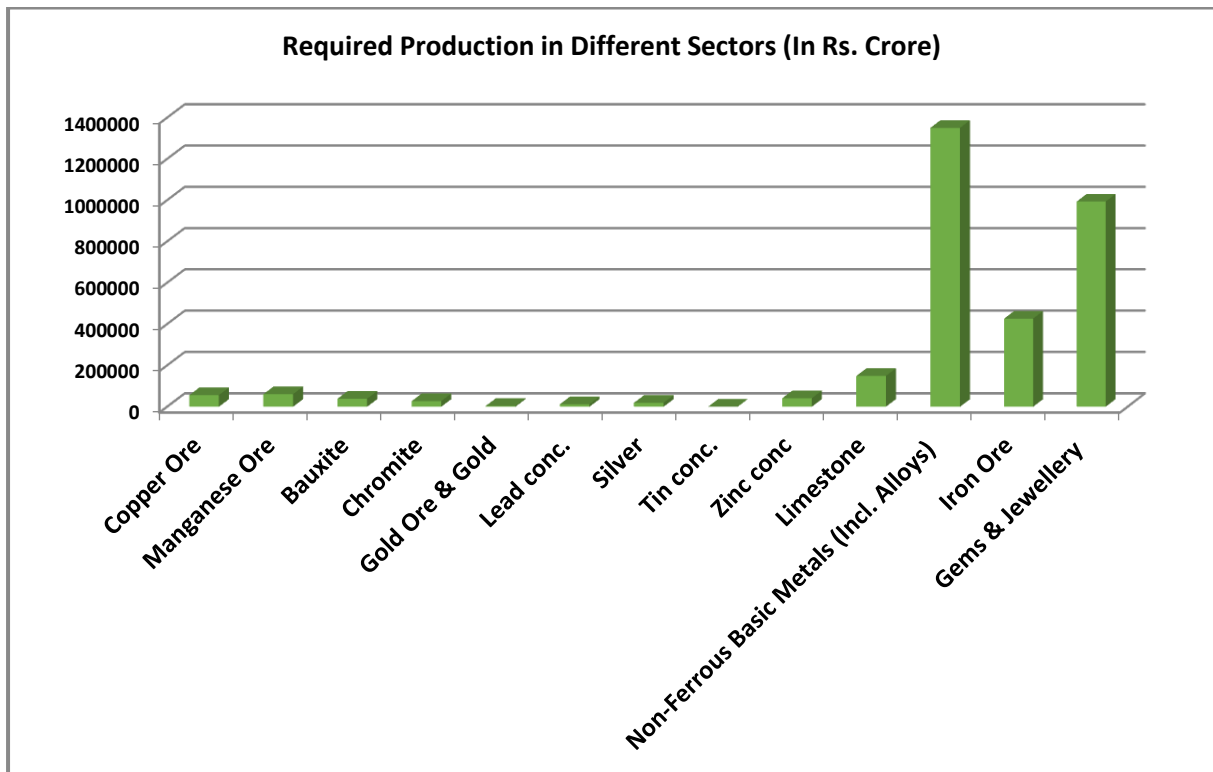


Figure 5.6 Simple Growth Rate Required per Annum of Key Minerals to Satisfy Demand from All the Sectors

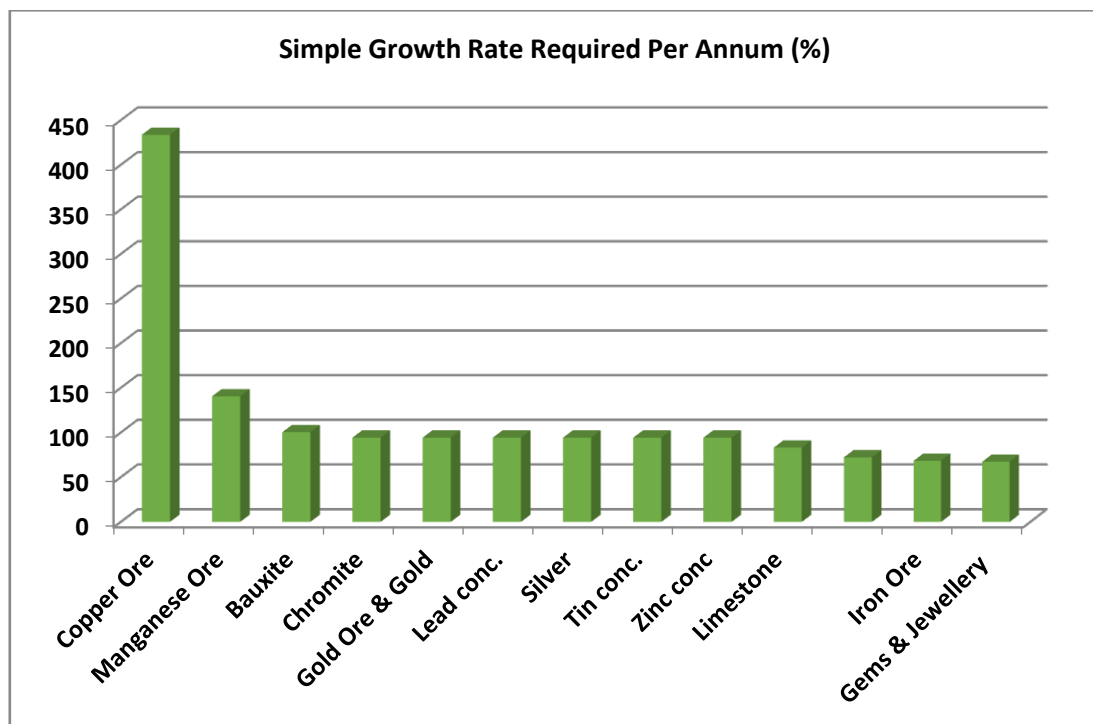
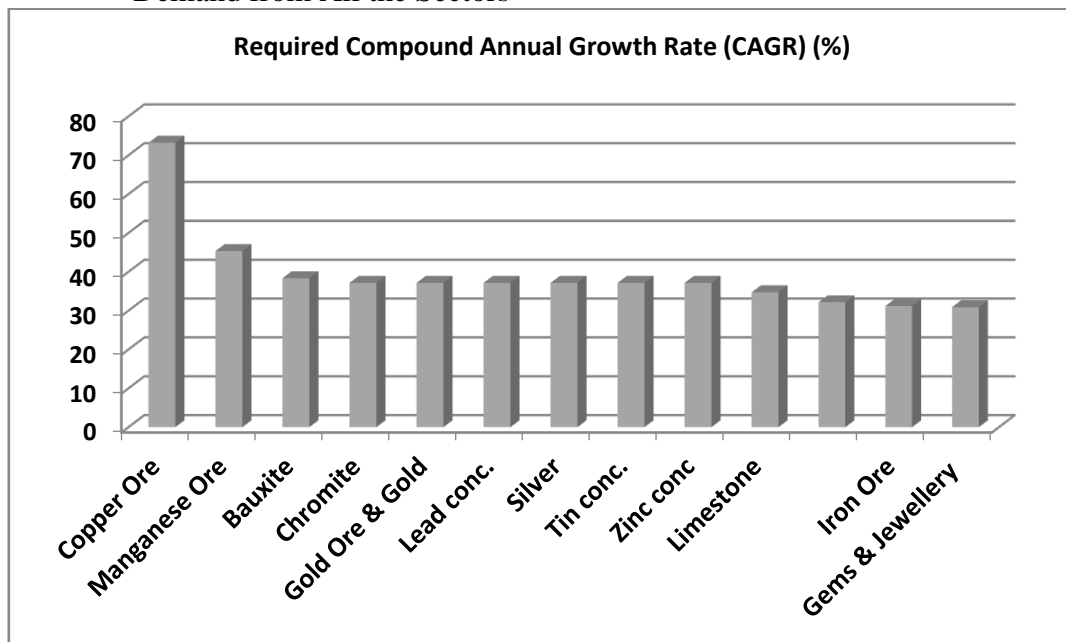


Figure 5.7 Compound Growth Rate Required per Annum of Key Minerals to Satisfy Demand from All the Sectors



Source: Author's Calculation

From these three figures it is evident that:

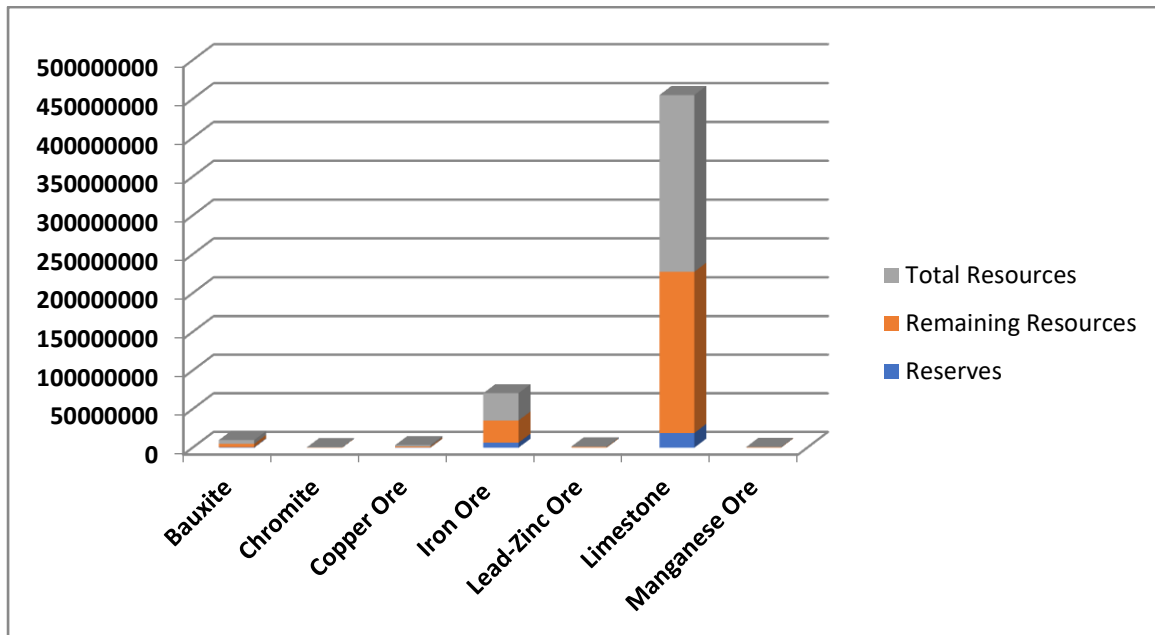
- 1) Almost all the sectors need to grow remarkably to sustain individual growth plans
- 2) In almost all cases Copper Ore and Manganese Ore have been the binding constraints. These two are key ingredients to many manufacturing units
- 3) The huge growth in “Electrical & Electronic Components” requires adequate supply of these two mineral resources
- 4) In terms of production volume; ‘Non-ferrous Basic Metals (incl. Alloys)’, ‘Gems and Jewelry’, ‘Iron Ore’ and ‘Limestone’ are needed to be produced in large scale
- 5) Impact analysis points out that 5 minerals are most important ‘non-fuel minerals’ in regards to country’s growth strategy. These key minerals are: ‘Copper Ore’, ‘Manganese Ore’, ‘Bauxite’, ‘Chromite’ and ‘Gold Ore and metal’. The economy would require these key minerals to such an extent, so that their domestic production need to grow at a facinating pace to meet sudden surge in demand
- 6) More specifically, Copper Ore and Manganese Ore has come out to be the most crucial minerals and enabler to achieve USD 5 Trillion GDP.

Now, let us look at the ‘Reserve Position’ and degree of ‘Self sufficiency’ of these ‘key minerals’ on the basis of country’s natural endowments:

The reserve position of minerals in India has been presented in **Table 20: (Appendix)**.

Figure 5.8 has been drawn on the basis of Table 20

Figure 5.8 Total Resources, Remaining Resources and Reserves (all in thousand tonnes) of the ‘Key Minerals’ in Indian Context



Sources: Mineral Yearbook of India (last few years), IBM

From figure 5.8, it is quite clear that apart from **Limestone** and **Iron Ore**, India does not have adequate amount of key resources to support future growth initiatives . This is a serious structural vulnerability in terms of country’s natural endowments. Policy makers need to be extremely cautious about this weakness, whenever any new growth policies are introduced. The vulnerability of Indian economy in terms of availability of key minerals can also be substantiated by data on ‘Degree of Self-sufficiency in Principal Minerals & Metals’ available with Ministry of Mines, Government of india (**Table A21: Appendix**). This table shows that India has only 50% and 40% self-sufficiency for its two most important key minerals, i.e Copper and Manganese respectively.

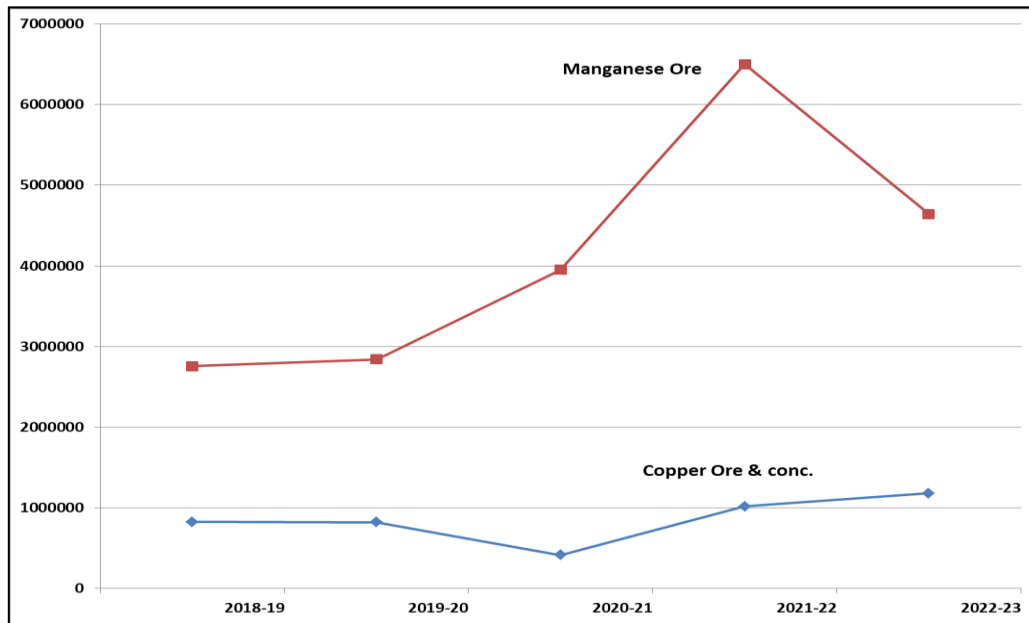
5.7 Observations

- 1) Considering the reserve position, it is easily observable that these two resources are most extensively used “key resources” in India’s growth story
- 2) Exports of copper ores & concentrates decreased considerably by 39% to 82,463 tonnes during 2020-21 from 2,12,659 tonnes in 2019-20. Government should immediately stop exports of the particular grade of Copper Ore , to fully cater the huge domestic demand that the ongoing government projects entail.

The export and Import of Export of MCDR Minerals during 2018-19 to 2022-23 has been presented in **Table A22** and **Table A23: (Appendix)** respectively.

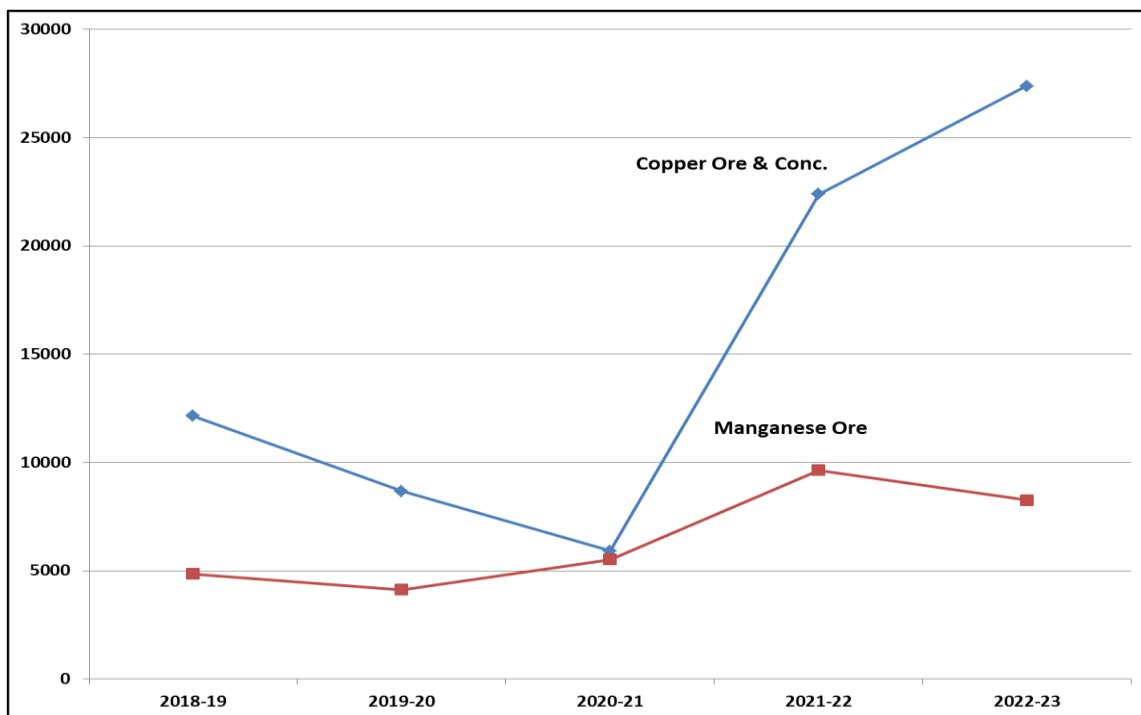
To get a more clear picture, we have plotted Quantity and Value of Import of Copper and Manganese and presented in **figure 5.9 and 5.10** respectively.

Figure 5.9 Quantity of Import (tonnes) of MCDR Minerals^ during 2018-19 to 2022-23



^ MCDR Minerals are the minerals listed in Mineral Conservation and Development (Amendment) Rules, 2021; Source: Ministry of Mines, Government of India

Figure 5.10 Value of Import (Rs. Crore) of MCDR Minerals during 2018-19 to 2022-23



Source: Ministry of Mines; Government of India, # Graph created by author

Figure 5.9 and 5.10 reveal that:

- i) Larger amount of Manganese Ore is imported. However, its import value is much lower than that of Copper Ore
- ii) Import value of Copper Ore (in Rs. Crore) has sky rocketed manifold since 2020-21; though the quantity of import increased marginally. This hints towards a probable upsurge in price of Copper Ore in global market.
- iii) On the other hand, quantity imported of Manganese ore has suddenly plummeted from 2020-21, though the import value decreased at a much lower rate.

India's copper production not only serves the domestic market but also contributes to the country's export earnings. Copper and copper products are exported to various countries. However, India also imports a significant amount of copper, mainly in the form of copper concentrate, to meet its domestic demand, especially for manufacturing and industrial use. The demand for copper in India is driven by various sectors, including electrical, electronics, construction, transport, and telecommunications, reflecting the metal's importance in infrastructure, renewable energy projects, and manufacturing.

5.8 Copper Ore and Manganese Ore: Two Key Enablers of India's Growth Story

This thesis has clearly pointed out that 'Copper Ore' and 'Manganese Ore' are two key enablers of India's growth dynamics. Hence, some more details about these two key minerals can unravel important insights about Indian economy. However at the outset; we need to understand why these two minerals are so important for the Indian economy.

5.8.1 Copper Ore

5.8.1.1 Uses of Copper Ore in Industry

In India, copper ore finds extensive use across various industries due to its excellent electrical and thermal conductivity, corrosion resistance, and malleability. Key industries utilizing copper ore include:

1. Electrical Industry: Copper is used in manufacturing electrical wires, cables, motors, transformers, and generators.
2. Electronics and Telecommunications: In this sector, copper is essential for producing electronic items, circuit boards, broadband, and communication cables.
3. Construction and Infrastructure: Copper is employed for plumbing, roofing, cladding materials, as well as electrical wiring in buildings and architectural elements.

4. Automotive Industry: Copper finds its applications in manufacturing motors, wiring, radiators, connectors, and brakes for conventional vehicles. In electric vehicles (EVs), copper is utilized in batteries, wiring, and inductive charging systems.
5. Renewable Energy: Copper is crucial for generators, cables, and transformers used in solar, wind, and hydro power plants.
6. Defense and Aerospace: Various components for defense equipment and aerospace applications are manufactured using copper.
7. Heavy Machinery and Equipment: Copper is used in the production of heavy machinery and industrial equipment like conveyors, hydraulic systems, and air conditioning systems.
8. Consumer Goods: Copper is employed in home appliances, cooking utensils, and various decorative items.
9. Railways and Metro Projects: In these projects, copper is essential for electrification, signaling systems, as well as power supply and grounding systems in metro projects.

5.8.1.2 Copper's Role in Energy Transition

Copper ore is integral to the transition towards sustainable and renewable energy sources. Its significance is evident in various key areas:

1. Renewable Energy Systems: Copper is essential in the construction and operation of renewable energy systems, such as solar panels, wind turbines, and hydroelectric power plants. It is used in wind turbine generators, photovoltaic cells, and electrical wiring, significantly impacting the efficiency of these systems in generating and transmitting electricity.
2. Electric Vehicles (EVs): Copper plays a vital role in the electrification of vehicles. It is heavily relied on in electric motors, batteries, and charging infrastructure, with an average electric car using about four times more copper than a conventional one.
3. Energy Storage: Copper is crucial in energy storage solutions, enhancing the efficiency and connectivity of batteries and storage technologies, which are essential for balancing the intermittency of renewable energy sources.
4. Energy Efficiency: Copper contributes to improving the efficiency of energy use in heating, cooling, and lighting systems, thereby reducing the energy demand and carbon footprint of buildings and industrial processes.
5. Grid Infrastructure: Upgrading and expanding the electrical grid requires substantial amounts of copper to accommodate renewable energy inputs. This includes the

development of smart grid technologies, enhancing the efficiency and reliability of the grid by integrating renewable energy sources.

6. Green Building: Copper is employed in green building practices for plumbing, roofing, and electrical applications due to its durability and recyclability, contributing to the sustainability of building materials.

5.8.1.3 Copper Sector in India: Issues and Concerns

The copper sector in India is currently facing challenges but also holds promising opportunities for growth. The problems and concerns include:

- Limited Domestic Reserves and Production: India has relatively limited copper ore reserves, accounting for only 2% of the global reserves and production contributing to just 0.2% of the global output. The shutdown of the Thoothukudi copper smelter, a major facility in India, led to a significant drop in production, forcing the country to become a net importer after almost two decades.
- Global Supply Chain Vulnerabilities: The global copper supply chain is concentrated in countries like Chile and Peru, posing risks due to geopolitical factors and potential disruptions in the supply chain.

5.8.1.4 Opportunities in Copper Sector of India

- Growing Demand and Government Initiatives: The Indian copper sector stands to benefit from increasing global demand and rising copper prices, particularly from key markets like China. Changes in mining regulations are anticipated to encourage private sector investments in the industry.
- International Collaboration and Investment: India is exploring international partnerships to secure a stable copper supply. Initiatives like sending industry delegations to copper-rich countries such as Zambia indicate a strategic approach to mitigating supply vulnerabilities and reducing import dependence.

Overall, India's copper industry aims to address supply constraints, capitalize on government reforms, and engage in international collaborations to enhance domestic production and decrease reliance on imports. By prioritizing sustainable strategies and strategic investments, India's copper sector can drive growth and align with its economic objectives successfully.

5.8.2 Manganese Ore

5.8.2.1 Manganese Sector in India: An overview

Manganese ore is an important material in iron and steel metallurgy, where it is used both in the ore form and as ferromanganese. Steel Industry accounts for approximately 90% of the world demand for manganese. This indicates strong growth of Steel Industry in the country as steel is the principal market accounting for 65 to 70% manganese consumption. Exports of manganese ore (total) increased by 40% to 82363 tonnes in 2020-21 from 58198 tonnes in 2019-20. Out of the total exports in 2020-21, only 10 tonnes of manganese ore having +46% Mn of value of Rs. 3,30,000 was exported. Government needs to take immediate steps to curb on export of Manganese Ore. Otherwise; all ambitious missions implemented by the government will soon face severe shortage of Manganese Ore. The manganese sector in India faces a mix of challenges, opportunities, and growth prospects aligned with global trends, technological advancements, and infrastructure development:

5.8.2.2 Challenges and Concerns

1. Market Consolidation: The manganese industry in India is dominated by a few major players, posing barriers for smaller companies entering or competing effectively in the market.
2. Production Decline: Manganese production in India witnessed a decline between 2017 and 2020, indicating potential issues in mining efficiency, resource availability, or market demand that require attention.

5.8.2.3 Opportunities

1. Rising Demand for Electric Vehicles: The global shift towards electric vehicles is anticipated to boost the demand for manganese, a key component in battery production, presenting a significant growth opportunity for the manganese sector in India.
2. Infrastructure Development: Government policies promoting infrastructure development like foreign direct investment (FDI) in the construction sector could spur demand for manganese in steel production and other applications.
3. Global Market Influence: The increasing industrial production and market expansions in countries like China offer export opportunities for Indian manganese producers to tap into the growing demand.

5.8.2.4 Future Trends:

- **Electrical Batteries:** The anticipated growth in the use of manganese in electrical batteries, particularly for electric vehicles and energy storage solutions, will shape the future demand and evolution of the manganese sector.

The manganese sector in India stands at a pivotal juncture, poised for substantial growth by addressing challenges, leveraging opportunities, and adapting to global market trends, especially in the context of technological advancements and infrastructure developments.

CHAPTER 6: INDIA'S PARTICIPATION WITH GLOBAL VALUE CHAINS (GVC)

6.1 Introduction to the topic

International trade and the connection with Global Value Chains (GVCs) also plays an instrumental role in shaping the 'economic resilience' of the economy through a supply chain mechanism of 'key resources.

'The most important deciding factor at present is probably the issue of sustainability. Global 'climate change' has emerged as the scariest threat to the existence of mankind. International bodies like United Nations (UN) are pressing all the countries across the globe to significantly reduce the 'carbon footprints' associated with manufacturing activities. Systematic transitions from the "fuel based" energy system to "material based" energy system is the recent global trend to reduce CO2 emissions in the process of electricity generation by countries including India. However, 'material based' energy system entails huge requirement of non-fuel minerals.

In today's highly globalized world, the output produced by an economy does not only depend on domestically available inputs but also depends on imported inputs sourced from other countries. Import of inputs happens mainly in two situations:

- a) Inadequate Availability: Some inputs are not at all available domestically due to a lack of natural endowment. In some cases, internal supply is below what is required; hence the remaining amount is imported. Since minerals are sparsely distributed across the globe, the imports of fuel and non-fuel minerals constitute a major part of import basket of industrial inputs. In case of India, most of the Crude Oil requirement are met by imports. The self-sufficiency quotient was only 15.6% in 2020-21. It further fell to 12.7% in 2022-23 (P)²¹
- b) Issue of quality: In many cases, the domestically available inputs are not of the desired quality. In such situations, countries are compelled to import good quality inputs from foreign countries. For example, despite being the second largest producer of coal²², India has to import metallurgical coal from Australia for steel production.

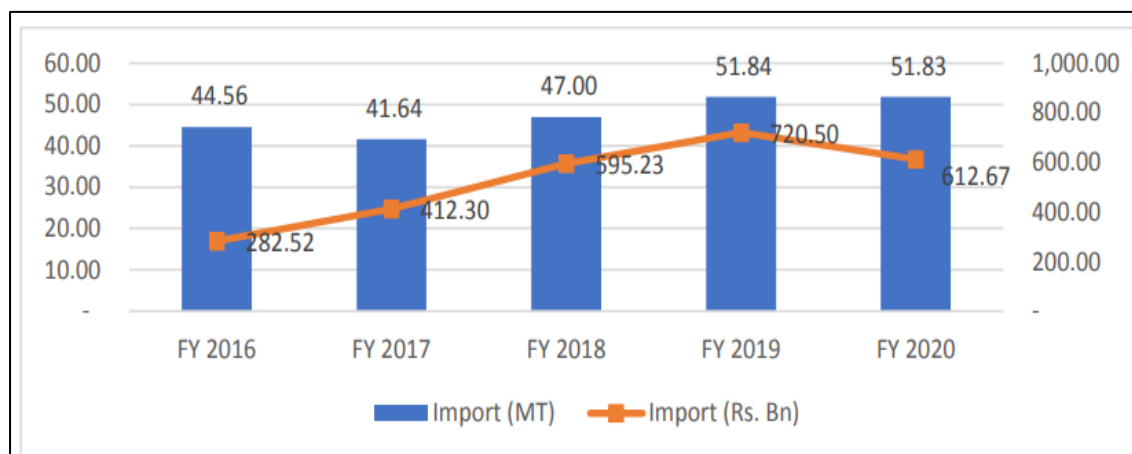
²¹ Snapshot of India's Oil & Gas data; Monthly Ready Reckoner, March 2023, Petroleum Planning & Analysis Cell, Ministry of Petroleum & Natural Gas, Government of India

²² The all-India Production of coal during 2022-23 was 893.19 MT with a positive growth of 14.77% (Ministry of Coal, 2023).

Coal available in India is of medium grade and has high heating capacity. This type of coal is suitable for electricity generation but not for steel production. For Steel production “Coking Coal” (or metallurgical coal) is required, which is of better quality due to a higher carbon content, as well as a lower level of sulphur, phosphorous and alkalis. India has a reserve of around 35 billion tonnes of Coking Coal, which is grossly inadequate to feed the huge demand from the Steel industry. As a result, around 70% of the demand for Coking Coal in the country is imported from foreign countries, mainly Australia. As per observation of the report by the Inter-Ministerial Committee (IMC) constituted by the Ministry of Coal, Government of India:

“Since domestic coking coal is of high ash variety and the demand for coking coal in India is much higher than domestic production, about 50 MT coking coal is imported by the country on an annual basis. During FY 2021, total 51.29 MT of coking coal was imported into the country. The Indian steel industry fulfils ~70% of its coking coal requirements through imports. Growth in steel production is expected to push up demand for metallurgical coking coal to 75 MT in FY 2023. Consequently, the share of imports is expected to remain over 76-77% in FY 2022 and FY 2023. In absolute terms, coking coal imports are expected to increase to 58 MT in FY 2023 from 47 MT in FY 2018. Almost 70% of the coking coal in the country is imported from Australia, leaving India highly dependent on Australia for supply of a critical raw material to the steel industry and exposing the industry to price volatility vulnerability.” (IMC Report on Augmentation and Consumption of Domestic Coking Coal by Steel Sector, (Report by IMC Constituted by Ministry of Coal), Inter-Ministerial Committee, 7-16-2021)

Figure 6.1 Annual Imports of Coking Coal in India



Source: IMC Report, Ministry of Coal 2021

The import of crucial inputs acts like a pivot that connects the cross-border supply chains. Economic integration with other countries happens through these cross-border supply chains. For industrial activities to flourish, economic integration is extremely necessary to realise the full potential of an economy. However, the pandemic explicitly manifested that dependence on imported inputs has some serious flip sides. Covid19 has made it evident that situations like the pandemic can seriously impair the growth prospect of a country through “supply chain disruptions”.

Firstly, upstream industries operating from foreign countries supply necessary inputs to the export-producing industries of the country. This is called “backward linkages”. The “backward linkage” captures the direction of causation if linkages are explained in terms of a “demand side model”

On the other hand, the concerned country supplies the domestically produced commodities as inputs to the downstream industries of trading partners. This is called “forward linkages”. The “forward linkage” captures the direction of causation if linkages are explained in terms of a “supply side model”.

In a nutshell, the production system of each country relies heavily on output produced by other countries through “forward” and “backward” linkages. The dependence of export-producing industries on imported inputs is very significant in this regard because it gives a fair measure of the degree of connectedness among a group of countries through the ‘supply chain’. Hence a quantitative measure of the “import content of export” can be very useful, not only in terms of ascertaining the degree of connectedness but also in terms of identifying “key industries” that play instrumental roles in shaping the entire framework of “economic integration” in a highly globalized geopolitical scenario. The economy-wide impact of any supply-chain disruption is immediately transmitted through innumerable webs of interconnected backward and forward linkages creating a rippling effect encompassing the global economy.

Understanding Value Added: Value added refers to the additional value created at a particular stage of production. It is the difference between the output value and the value of intermediate inputs used in the production process. In essence, it measures the contribution of labor and capital to the production process, excluding the materials and services consumed.

Final Demand: Final demand represents the total demand for goods and services that are not used as intermediate inputs in production. It includes household consumption, government

expenditure, investment in capital goods, and net exports. Final demand is the end-point of the production chain, where goods and services are consumed by the end-users.

6.2 Global Value Chains (GVCs) & Value Chain Integration

Global Value Chains (GVCs) refer to the range of production activities from design, manufacturing, marketing, and distribution, up to the sale to end-consumers, which are split among several firms across different countries. Countries engage in GVCs either by backward or forward linkages. The GVC participation index provides an estimation of how much an economy is connected to global value chains for its production and foreign trade. Backward linkages are formed when a country imports foreign inputs to produce goods and services they export. Forward linkages are formed when a country exports domestic inputs to countries in charge of downstream production. It captures the domestic value added contained in inputs sent to third economies for further processing and export through supply chains.

6.2.1 Measurement of Participation in GVCs

Participation of an economy in Global Value Chain (GVC) can be assessed in terms of following three parameters:

i) **Forward Linkage:** Value-Added Share in Exports (VAS_{Exp})

The concept of **Value Added Share in Export** refers to the portion of the value of exported goods or services that is added by the exporting country. This metric is important because it helps in understanding the economic benefit that a country derives from its export activities.

i) **Backward Linkage:** Value-Added Share in Final demand (VAS_{FD})

The concept of Value Added Share in Final Demand (**VA_{FD}**) is a crucial aspect of economic analysis, particularly in the context of input-output models and the study of global value chains. It helps in understanding how the value added by each industry contributes to the final demand for goods and services. This note delves into the basics of this concept, its significance, and its implications for economic policy and business strategy.

ii) **Import Content of Exports**

The import content of exports refers to the share of imported inputs in a country's overall exports. It reflects the extent to which a country relies on foreign inputs in

its export production. This measure is also known as the “foreign value-added share of gross exports” and is expressed as a percentage. It is a reliable indicator of international “backward linkages” in global value chains. In simpler terms, it tells us how much of a country’s exported goods or services contain components or materials that were imported from other countries. The higher the import content of exports, the more interconnected a country is with the global economy. This measure is essential for understanding a country’s economic relationships, trade dependencies, and participation in global supply chains. It helps policymakers and analysts assess the impact of international trade on a nation’s economy

OECD provides a comprehensive definition of ‘Import Content of Export’ as follows: *‘Import content of exports is defined as the share of imported inputs in the overall exports of a country, and reflects the extent to which a country is a user of foreign inputs. The measure is also often referred to as the ‘foreign value-added share of gross exports’ and is defined as the foreign value-added in gross exports divided by total gross exports, in percentage. It is considered as a reliable measure of international ‘backward linkages’ in analyses of global value chains.’* (OECD 2024)²³

To measure impact of various trade policies on the equilibrium condition in the economy, these parameters are calculated (*In all cases, the trade (export/import) of a country captures exports to all trading partners as well as bilateral export of the country with some selected partners*)

6.3 Logical background of our Study: Relation between Value Chain Integration and Key Sector

The degree of connectedness of an industry with the rest of the world is often suitably measured by quantifying the ‘backward’ and/or ‘forward’ linkages associated with it. Quite interestingly, with higher values of backward and/or forward linkages, some industries (sectors) are always found to wield stronger influence in determining the underlying dynamics of the economic systems. These industries act as a fulcrum for spreading the ‘economy-wide impact’ of both ‘internal’ and ‘external’ impulses brought about by “internal policy changes” and “external supply chain shocks” respectively. Since these industries play

²³ OECD (2024), Import content of exports (indicator). doi: 10.1787/5834f58a-en

“key roles” in both destabilizing and subsequently delineating the required set of counteracting stabilizing policy prescriptions to the government, we can conveniently identify these sectors as “key sectors” (as conceptualized at the beginning of this study). Most importantly, any cardinal measurement of ‘forward’ and ‘backward’ linkages can make the difficult task of identifying “key sectors” much easier. Identification of “Key Sectors” using this intricate logic has been ratified in various literatures, including the most authentic and pioneering one²⁴ by Ronald E. Miller and Peter D. Blair.

6.4 Details of the Study

This thesis has investigated into the degree of economic integration of Indian economy with East Asian countries (as a consolidated block of 7 countries). In this study we have measured extent of “Value Chain Integration” using trade figures between India and East Asia. The lists of East Asian countries taken into consideration are:

1) China	5) Taiwan
2) Japan	6) Hong Kong
3) South Korea	7) Macao
4) Mongolia	

6.4.1 Trade Relationship between India and East Asian Countries

Table 6.1: Export of India to East Asian Countries (\$ Million)

S.No.	Country / Region	2021-2022	2022-2023	%Growth
1.	China P RP	21,259.79	15,306.10	-28.00
2.	Hong Kong	10,984.80	9,892.61	-9.94
3.	Japan	6,176.77	5,461.34	-11.58
4.	Korea RP	8,085.03	6,654.10	-17.70
5.	Macao	12.04	4.35	-63.87
6.	Mongolia	25.94	33.90	30.72
7.	Taiwan	2,756.63	2,637.47	-4.32
	Total	49,301.00	39,989.88	-18.89
	India's Total	422,004.40	451,070.00	6.89

Source: Export-Import Data Bank, Ministry of Commerce and Industry, Government of India

²⁴ Ronald E. Miller and Peter D. Blair (2009). *Input–Output Analysis - Foundations and Extensions*. Second Edition Cambridge University Press

From **Table 6.1** it is clearly visible that India's export to East Asian countries has plummeted significantly in recent years. Barring Mongolia, export figures followed a landslide.

Table 6.2 Import of India from East Asian Countries (\$ Million)

S.No.	Country / Region	2021-2022	2022-2023	%Growth
1.	China P RP	94,570.57	98,505.77	4.16
2.	Hong Kong	19,096.61	18,274.95	-4.30
3.	Japan	14,399.77	16,495.32	14.55
4.	Korea RP	17,477.20	21,227.32	21.46
5.	Macao	20.11	13.40	-33.38
6.	Mongolia	0.54	0.94	73.01
7.	Taiwan	6,234.48	8,264.30	32.56
	Total	151,799.29	162,782.00	7.24
	India's Total	613,052.04	715,968.89	16.79

Source: Export-Import Data Bank, Ministry of Commerce and Industry, Government of India

However, from import side, **Table 6.2** shows that barring few countries (Hong Kong, Macao), import figures have registered positive growth. India's trade relationship between Macao and Hong Kong has deteriorated over time.

6.4.2 Reasons behind India's Deteriorating Trade Relationship with Macao and Hong Kong

India's trade relationship with Macao and Hong Kong, both being Special Administrative Region (SAR) of China, is influenced by a variety of factors ranging from economic policies and market dynamics to geopolitical tensions. India's relationship with China has faced several challenges and tensions over the years, including border disputes and strategic competition in Asia. Since Macao is a SAR of China, these broader geopolitical issues can indirectly affect India-Macao trade relations, leading to a cautious approach in economic engagements. Moreover, the enactment of the National Security Law in Hong Kong by the Chinese government has led to concerns about the region's autonomy and freedoms. This could potentially impact the confidence of Indian businesses in Hong Kong as a stable and predictable place to conduct business.

Although trade between these two countries are miniscule (only 2.41% of India's total volume with East Asia) this study has considered to take into consideration of both the countries to make coverage of East Asia comprehensive. We have tried to incorporate all

countries falling under the geographical boundary of East Asia, whatever miniscule their trade relationship may be.

6.5 Calculation of Indices

6.5.1 Forward Linkages

a) Forward Linkage: Value-Added Share in Exports

The formula for calculating VAS_{Exp} is:

$$VAS_{Exp} = \alpha_j^v * (I - A_d)^{-1} * ES_i$$

Variables	Notation / Formula	Matrix/Vector Dimensions
Ratio of Value Added (RVA) of j-th Sector:	$a_j^v = \frac{V_j}{X_j}$	Row Vector (1 x 38)
Gross Value Added of j-th Sector:	V_j	Row Vector (1 x 38)
Output of j-th Sector:	X_j	Row Vector (1 x 38)
Identity Matrix:	I	Sq. Matrix (38 x 38)
Domestic Input Coefficient Matrix:	A_d	Sq. Matrix (38 x 38)
Exports of i-th Commodity:	E_i	Col. Vector (38 x 1)
Total Export (All Commodities):	$E = \sum E_i$	
Export Share of i-th Commodity:	$ES_i = \frac{E_i}{E}$	Col. Vector (38 x 1)
Total Export to k-th Region*	E_k	
Total Export to World *	E_{World}	
Export Ratio of k-th Region:	$E' = E_k/E_{World}$	
Final Demand from i-th Sector:	FD_i	Col. Vector (38 x 1)
Total Final Demand (All Commodities):	$FD = \sum FD_i$	
Final Demand Share:	$FDShare = \frac{FD_i}{FD}$	Col. Vector (38 x 1)

(*Source: GTAP Data)

b) Forward Linkage: Value-Added Share in Final demand (VAS_{FD})

$$VAS_{FD} = a_j^v * (I - A_d)^{-1} * FD$$

Variables	Notation / Formula	Matrix/Vector Dimensions
Import of i-th Commodity	M_i	
Total Import (All Commodities)	$M = \sum M_i$	
Import Coefficient	$m = \frac{M_i}{M}$	Col. Vector (1 x 38)
Total Import from k-th Region*	M_k	
Total Import from World*	M_{World}	
Import Ratio of k-th Region*	$m_k = \frac{M_k}{M_{World}}$	

(*Source: GTAP Data)

6.5.2 Backward linkage: Import Content of Export for i-th Commodity ((X_Mⁱ)

Import of Intermediate Goods for Production of i-th Sector from k-th Region

$$M_k^i = m * m_k * M$$

Export of i-th Sector (Product) as Intermediate Goods for Production to k-th Region

$$X_k^i = E * E' * X$$

Import Content of Export is measured as:

$$X_M^i = M_k^i / X_k^i$$

6.6 Database

This study used Input-Output tables and data on Export, Final Demand, and Value added from version 11 of the GTAP database.

The centrepiece of the Global Trade Analysis Project is the GTAP Data Base, a fully documented, publicly available global database containing complete bilateral trade information, transport and protection linkages. The GTAP Data Base represents the world economy and is utilized by thousands worldwide as a key input into most applied general

equilibrium (AGE) analysis of global economic issues. An overview of GTAP 11 is available from the open access journal:

Maksymchepeliev, A, Erwinorong,A and Dermensbrugghe,V (2022), *The Global Trade Analysis Project(GTAP) Data Base: Version 11*, Journal of Global Economic Analysis, Volume 7 (2022), No. 2, pp. 1-37, <https://jgea.org/ojs/index.php/jgea/article/view/181>

According this journal,

“The Data Base reconciles different data sources at a global scale for analytical use and provides time series data on value flows, volumes, and various tax instruments. GTAP 11 offers a time series of 5 reference years (2004, 2007, 2011, 2014, and 2017), distinguishes 65 sectors in each of 141 countries and 19 aggregate regions—with extensive individual countries accounting for 99.1% of world Gross Domestic Product (GDP) and 96.4% of world population. The exhaustive nature of GTAP’s economic activity coverage facilitates its use in economy-wide studies of global economic issues

.....The geographical coverage of the GTAP 11 Data Base has increased to 160 regions—141 individual countries and 19 composite regions—with the addition of 20 new countries mostly from the Middle East and Africa. Its construction relies on contributed datasets from a large network of individuals, GTAP Board member agencies, and institutions from around the world. Increasing the representation of countries and sectors in GTAP depends on data availability. Also, in order to improve the time-series dimension of the Data Base, continuous development and contribution of IOTs are critical in order to capture structural changes over time. For historical reference years (i.e., 2004, 2007, 2011 and 2014), we rebuild the GTAP Data Base with the latest methodologies and updated inputs. For example, the 2014 reference year available in both GTAP Data Base version 10 and 11 will show differences owing to new sources for services trade data, different treatment to energy data, or perhaps the IOT was updated for GTAP 11.” (Maksymchepeliev, A, Erwinorong,A and Dermensbrugghe,V, 2022)

6.7 Results

6.7.1 Forward Linkage: VAS_{Exp} and VAS_{FD}

First, we have calculated Ratio of Value Added (RVA) and Export Share (ES) of 38 sectors that we have categorised as per our ‘Aggregation Scheme’, using Input-Output table of 2019-19. These two indices are required to be calculated for the measurement of ‘Forward’ and ‘Backward’ linkages.

Table A24: Appendix provides Calculation of Ratio of Value-Added (RVA) in India

Table A25: Appendix provides Export Share (ES) Matrix

Our calculations based on Table A24 and Table A25 show that both value Added Share in Export (VAS_{Exp}) and Value Added Share in Final Demand (VAS_{FD}) – i.e measures of Forward Linkages in traded goods and services between India and East Asian countries are very high (0.9).

6.7.2 Calculation of Backward Linkage

Table A26: Appendix shows Import Content of Export for i-th Commodity (X_M^i)

From Table A26 it is evident that the overall import content of export from India to East Asia is 1.20

Observations

1. Among first 10 sectors in terms Import Content of Export. Five (5) are ‘Non-fuel minerals (Manganese ore, Limestone, Copper Ore, Bauxite and Other Metallic Minerals) and one (1) is ‘Fuel Mineral’(Coal). This result corroborates our previous results which identified Manganese ore, Limestone, Copper Ore and Bauxite as India’s ‘Key Resources’.
2. Hence India has immense opportunity to strengthen value chain integration in these minerals.

6.8 Checking Robustness

The measurement of value-added share in exports is facilitated by methodologies like the Input-Output analysis and data from sources such as the World Input-Output Database (WIOD) and the Organisation for Economic Cooperation and Development (OECD)'s Trade in Value Added (TiVA) database. These analyses take into account the direct and indirect contributions of various sectors to export products, offering a comprehensive view of economic contributions beyond simple export figures.

TiVA (Trends in International Value Added) Data is a comprehensive statistics initiative of the OECD, that aims to measure international trade in services. The data tool tracks value added in various industries across countries and regions, enabling policymakers, businesses, and researchers to analyze and compare trade and economic activity internationally. TiVA Data covers over 400 industries, including a range of services such as finance, healthcare, and information and communication technology. The data estimations are based on the

availability of source data and incorporate complementary economic indicators like GDP, employment, and inflation.

As mentioned by OECD²⁵, TiVA data provide insights into:

1. Domestic and foreign value added content of gross exports by exporting industry
2. Services content of gross exports by exporting industry, by type of service and value added origin
3. Participation in global value chains (GVCs) via intermediate imports embodied in exports (backward linkages) and domestic value added in partners' exports and final demand (forward linkages)
4. Industrial activity's *global orientation*, i.e. the share of industry value added that meets foreign final demand
5. Country and industry origins of value added in final demand, including the origin of value added in final consumption (by households and government) and in Gross Fixed Capital Formation (investment by businesses)
6. Bilateral trade relationships based on flows of value added embodied in domestic final demand
7. Inter-regional and intra-regional relationships
8. Domestic value added content of imports

In this thesis, we have zeroed in on the third point, i.e. Participation in global value chains (GVCs) via intermediate imports embodied in exports (backward linkages) and domestic value added in partners' exports and final demand (forward linkages)

Table A27: Appendix shows Trade in Value Added (TiVA) 2023 edition: Principal Indicators

Table A28: Appendix shows Calculation of forward and Backward Linkages from TiVA database

The measure of 'backward Linkage' (Intermediate Imports Embodied in gross Exports) in Table reveals that the value is 1.12 in 2019. This is very close to value obtained by us (Forward Linkage = 0.9 and Backward Linkage = 1.20). This firmly confirms robustness of our analysis done in previous section.

In addition to that, calculations from TiVA provide some other important insights into the picture.

²⁵<https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm#Tiva%20Indicators:%202023%20Edition>

- i) Linkage effects for 'Mining and Quarrying' sector are much higher than overall linkages
- ii) Linkage effects for 'Mining and extraction of energy producing products' are highest in this category, indicating India's dependence on 'fuel minerals'
- iii) Forward Linkage for 'Mining and extraction of energy producing products' is much higher than the backward linkage. This implies India is more integrated from 'Supply Side' by exporting 'Mining and extraction of energy producing products' to East Asian countries.

6.9 Conclusion

The study unravelled few significant findings from an analysis on the measure of Backward and Forward Linkages, Value Addition and Import Content of Export in trade for India. It revealed that among the first 10 sectors in terms of Backward Linkages, five are 'Non-fuel minerals' (Manganese ore, Limestone, Copper Ore, Bauxite, and Other Metallic Minerals), and one is 'Fuel Mineral' (Coal). The values of Forward and Backward Linkages have been calculated as 0.9 and 1.20 respectively. This outcome supports previous results that recognized Manganese ore, Limestone, Copper Ore, and Bauxite as India's 'Key Resources'. Consequently, the analysis underscores a substantial opportunity for India to enhance its value chain integration in these mineral sectors.

Further insights from TiVA calculations reveal that the backward linkage value of 1.12 in 2019 is almost in line with the previously obtained values of 0.9 for forward linkage and 1.20 for backward linkage, thus validating the robustness of the analysis. The results of the study focusing on the sector of 'Mining and Quarrying' and the sub-sector of 'Mining and extraction of energy producing products' reveals that the linkage effects are significantly higher in the 'Mining and Quarrying' sector compared to overall linkages. Among this sector, the 'Mining and extraction of energy producing products' shows the highest linkage effects, underscoring India's reliance on fuel minerals. Notably, the forward linkage in this sub-sector is much higher than the backward linkage, indicating India's greater integration into the supply side by exporting these products to East Asian countries.

As GVCs are currently undergoing transition, driven by several factors like the need for diversification due to the pandemic and ensuring supply chain security due to strategic reasons. This has opened significant opportunities for India to step up in existing value chains and capture greater market share. Putting results of our study into perspective, the thesis

corroborated that India has the potential to increase its participation in global value chains (GVCs) by focusing on 'key mineral sectors'. Suitable government policies are also required for streamlining its customs and trade procedures and involving its extensive micro, small, and medium enterprises (MSME) sector in collaborations with global lead firms. With ongoing mega infrastructure initiatives and a strategic focus on new free trade agreements, the country is well-positioned to enhance its engagement in GVCs. Additionally; India boasts various sectors with ample production capabilities that can be scaled to meet the demands of export-oriented production. This study confirms that focusing on some strategic non-fuel minerals (key resources) can usher growth through economic integration with GVCs.

CHAPTER 7: DISCUSSION OF RESULTS AND CONCLUSION

The central idea of this thesis revolves around the concept of 'Key Resources' and its importance in determining growth momentum of an economy. By 'key resources' we mean some naturally occurring non-fuel minerals which are substantially used as key ingredients in various production processes. The fundamental macroeconomic structure of an economy largely depends on the geological endowment of these 'key resources' that the country is naturally bestowed with. Even in today's highly complicated economic structure, which is typically characterised by intricate interplay of complex and intertwined production lines, the intrinsic strength of the economy still originates from the deposition of the 'key resources' and their derived products.

7.1 Theoretical Background: Relationship between Mineral Resources and GDP Growth

There are broadly two categories of economic theories that propose a relationship between a country's growth rate and its mineral resources. The first category, posits a positive relationship whereas the second category implicates negativity in the long-run. Under "natural resource rents" hypothesis, which suggests that countries with abundant natural resources tend to have higher GDP growth rates due to the rents they receive from the sale of these resources. Another theory is the "immiserating effects" theory, which posits that the exploitation of natural resources can lead to an initial increase in a country's GDP, but ultimately results in economic stagnation and poverty for the country's population.

The Neo-Classical Model of Economic Growth developed by Solow and Swan, emphasizes that minerals contribute to capital accumulation but face diminishing returns. The theory suggests that increasing capital or labour has only a temporary impact on growth. To boost growth in the long run, we need increased investment and technological progress. It is also often argued that while minerals are essential for development, sustainable practices are crucial. Environmental concerns suggest that resource degradation and global warming may seriously constrain long-term economic growth. In summary, mineral resources can significantly impact economic growth, but effective management, technological progress, and responsible policies are essential for sustainable development

Throughout the various stages of an economy's development, a consistent supply of mineral resources is deemed essential, especially during the initial and reformative growth phases

where the importance of raw materials is significantly high. These steady supplies are fundamental for achieving satisfactory industrial sector growth rates. Industrialization lays the groundwork for a robust physical infrastructure, which in turn, propels the economy to higher levels of development. In this context, the development of heavy industries, which depend heavily on strategic non-fuel minerals (like iron ore and bauxite) and fuel minerals (such as coal), is crucial.

7.2 Global Perspective: Current Trends

The most important trend that has been observed globally in 21st Century, particularly in post - Covid era –has been the drastic shift of energy systems from being ‘fuel based’ to ‘mineral based’. The energy transition denotes the move from reliance on fossil fuels to the adoption of renewable energy sources. Countries worldwide, including India, have begun to navigate this energy transition, moving towards cleaner, more sustainable energy sources, and have achieved varying degrees of success in this transformation. This shift began to pick up steam in the latter half of the 20th century, driven by factors such as environmental concerns, technological progress, and policies favouring renewable energy. This change is pivotal in the fight against climate change. The recent COP28 conference has been a landmark event in global climate policy, marking the first official acknowledgment of fossil fuels as the main contributor to climate change. This acknowledgment highlights the critical need for swift decarbonisation efforts across the globe. In light of the grave warnings about climate change's progression, participating nations have pledged to steer their energy systems away from fossil fuels. The aim is for this transition to be just, well-organized, and fair, focusing on urgent actions during this decisive decade. The objective is to adhere to scientific advice and reach net-zero emissions by 2050. This ground-breaking agreement heralds the fossil fuel age's decline, underlining the necessity of united actions to combat climate change.

Since the energy transition process entails huge requirements of ‘non-fuel minerals ‘(key resources’), a massive skirmish has already started among countries over territorial dominance. The disputes in the South China Sea and the unrest in several African nations highlight the global scramble for resources, including essential minerals. Some nations have recognized the critical importance of these minerals, sparking a renewed rush to discover new mineral deposits. This trend isn't new for countries such as the UK and France, which have seen similar cycles of resource exploration in the past. This shift towards seeking alternative resources stems from a broader change in the global growth model, driven by the urgent need

to address unsustainable industrial practices that have contributed significantly to global warming. This looming threat has the potential to cause irreversible harm to the Earth's atmosphere, leading to severe economic impacts.

Another important trend that has been observed globally is growing tendency of the countries to get integrated with some Global Value Chains (GVCs). This trend has become more prominent in post-Covid era, since most of the countries suffered badly from supply-chain disruptions during the pandemic. Economic integration with **Global Value Chains (GVCs)** and **Regional Value Chains (RVCs)** has become imperative for development in current international geo-political scenario. Although the Asia-Pacific region is home for many interconnected trade blocs (like ASEAN, BIMSTEC, Mekong Ganga Cooperation etc) and subject to famous “Noodle-Bowl” effect, integration with regional value chains is not satisfactory. Present external policies of Government of India (like ‘Act East Policy,’ ‘Neighborhood First Policy’ etc) are largely focused on economic integration with regional value chains in the immediate neighborhood. Manufacturing value chains are particularly very important in this respect. Based on non-fuel mineral resource endowments in neighboring countries, India can further induce trade driven growth through optimal resource management. Optimality should also be matched with environmental sustainability and feasibility aspects. Exchange of ‘Non-fuel Minerals’ within countries of Indian sub-continent could be a game-changer and ‘Pareto-Optimal’ in economic sense.

7.3 Case Study of India: *Ensuring Self-Reliance with Sustainability*

Beginning in the late 1980s and more notably with the 1991 economic reforms, India initiated a pivotal shift in its economic policy and federalism framework from a centrally controlled approach towards one promoting market-driven growth, ushering in an era of 'competitive federalism.' This shift was accentuated by efforts to encourage states to compete for investments, innovation, and development. In 2014, the Planning Commission was replaced by the NITI Aayog, a move designed to nurture both 'cooperative' and 'competitive federalism,' and lay the groundwork for significant initiatives such as "Make in India." This initiative aimed to establish India as a leading manufacturing hub on the global stage. Additionally, the "Atmanirbhar Bharat Abhiyaan" (Self-Reliant India Mission), launched in response to the economic challenges posed by the COVID-19 pandemic in May 2020, marked a novel approach by equally prioritizing foreign and domestic investments in driving economic growth. The mission sought to position India as an appealing destination for

investment through strategic policy support and infrastructure enhancements, capitalizing on advantages such as affordable labor and substantial market demand to stimulate income, employment, and GDP expansion.

The driving force behind the latest set of schemes and missions initiated by government of India is primarily based on the concept of “export promotion” and “import substitution” for rapid growth of an economy. Schemes like “Atmanirbhar Bharat” primarily zero in on achieving “self-reliance” of the economy in terms of a significant reduction in the total import burden. Simultaneous implementation two policy drives, viz. “Export Promotion” and “Import Substitution”, have further been accompanied by the pressing need for reducing the carbon-footprints of the manufacturing activities in the country, with due cognizance to global treaties.

Prime Minister Narendra Modi has set more ambitious goals for 2030, aiming to achieve 500 gigawatts of renewable energy capacity, cut the emissions intensity of India's economy by 45%, and reduce carbon dioxide emissions by one billion tonnes. These objectives are challenging yet achievable, as India's transition to clean energy is already in progress. The nation has surpassed its pledge from the COP 21- Paris Summit, achieving 40% of its power capacity from non-fossil sources nearly nine years ahead of schedule. Additionally, the contributions of solar and wind energy to India's energy portfolio have significantly increased. Thanks to technological advances, consistent policy support, and a dynamic private sector, constructing solar power plants has become more cost-effective than coal-fired ones. Renewable energy in India is expanding faster than in any other major economy, with the capacity expected to double by 2026. India is also emerging as one of the leading global producers of modern bioenergy, with ambitious plans to enhance its usage across various sectors. The International Energy Agency (IEA) anticipates that India will soon surpass Canada and China to become the third-largest ethanol market globally, following the United States and Brazil.

Hence, it is now clear that government of India has embarked on a fascinating journey to reach a much higher growth trajectory synchronised with energy transition initiatives. This can be best described as “Ensuring Self-Reliance with Sustainability”.

For the policies looking at “import substitution” by indigenous products, the manufacturing base of the country must expand significantly in both extensive and intensive way. This implies more production lines need to evolve and each production process need to extend and encompass production of various sub-categories of the principal product. In both cases, huge

quantity of mineral resources is required in a time bound manner. Here the question often arises regarding the justification of massive exploitation of country's valuable resources within a very short spell of time, mostly within a political cycle of five years. A prudent policy can never indulge in over utilisation of valuable resources, unless the situation demands a big push in manufacturing activities of the country to take-off for a significantly higher growth trajectory through the complex interplay of backward and forward linkages and the multiplier process. But even then, if the underlying mathematics somehow goes wrong, the chances of economic collapse remain prevalent in future.

The "export promotion" policies also involve similar concerns pertaining to chances of over utilisation of resources. Additionally, policy makers need to introspect trade policies related to export of fuel and non-fuel minerals with greater caution. Implications of trade agreements (bilateral, FTA, RTA etc) involving exchange of valuable minerals needs to be adjudged in the perspective of the economy, which has already embarked on a huge drive for resource-led growth. A systematic analysis is required in the context of Indian economy.

7.4 Major Findings of our Research

This thesis zeroes in on a specific set of 'non-fuel minerals' that have been playing a decisive role in the growth dynamics of Indian economy in the 21st century. These minerals are also found to have a strategic role in shaping up a new global order in terms of economic strengths and geopolitical dominance. Countries having access to these minerals are believed to be at the helm of the future journey towards higher growth trajectories in coming years. Since these resources are sparsely available and scattered unevenly across the globe, the competition among the countries has steepened and given rise to a large number of conflicts and territorial disputes. Our study has made an endeavour to unravel India's position in this context.

The most important part of this thesis has been the identification of 'key resources' of Indian economy using three methods:

- i) Calculation of 'Backward' and 'Forward Linkages' using Rasmussen's Multiplier Approach
- ii) Determination of 'most important' resources by application of 'Principal Component Analysis' (PCA).
- iii) Measurement of economic integration in terms of 'forward' and 'backward' linkages with Global Value Chains (GVCs) using GTAP database

7.4.1 Backward and Forward Linkages

The most important part of this Chapter has been the identification of 'key resources' of Indian economy using two methods. The first method is the calculation of 'Backward' and 'Forward Linkages' and the second one is the determination of 'most important' resources by application of 'Principal Component Analysis' (PCA). Results obtained from both the methods ascertained following eight (8) non-fuel minerals as the 'key resources' for the Indian economy:

Bauxite, Chromite, Copper Ore, Gold Ore and Conc., Iron Ore, Lead Conc., Manganese Ore, Silver

These minerals have been found to have strong linkage effects (Backward / Forward) and also capture maximum influence in country's growth momentum. The most import finding in this case is that all of these resources have strong 'backward linkages'. This implies these resources have strong linkages with the economy from demand side. This indicates towards high domestic demand of 'key resources' due to:

- i) A huge and rapidly growing manufacturing base of Indian economy.
- ii) Accelerating industrialization process and a structural shift from 'agricultural' to 'manufacturing' activities.
- iii) Increase in export of commodities that requires sizable amount of these non-fuel minerals as inputs.

Stronger 'backward linkages' implies that these eight 'key resources' develop the productive capacity of the economy in both intensive (more production of the commodities) and extensive (production of more commodities) ways.

7.4.2 Impact Analysis

The Government of India has initiated a bold journey towards enhancing its economic growth by implementing a unified policy strategy, known as 'Ensuring self-reliance with Sustainability.' A key policy under this strategy is the '*Atmanirbhar Bharat Abhiyaan*' (2020), which unveiled a substantial incentive package of Rs. 20 lakh crores. The goal of this policy is to energize domestic manufacturing in various sectors with the collective aim of reaching a GDP of USD 5 Trillion by 2025. To meet these ambitious manufacturing targets, there will be a considerable demand for both fuel and non-fuel minerals. This research has carried out 'impact analyses' to reveal the extensive economic implications of increased manufacturing activities, focusing particularly on the demand for 'non-fuel minerals.' It evaluated the

possibility of meeting these manufacturing targets by analyzing the reserves of non-fuel minerals within the country. The analysis identified that the production of five critical non-fuel minerals—*Copper Ore, Manganese Ore, Bauxite, Chromite, and Gold Ore and metal*—is essential for the nation's economic expansion plan. Notably, *Copper Ore and Manganese Ore* emerged as the most crucial minerals necessary for attaining the ambitious GDP target of USD 5 Trillion by 2025.)

7.4.3 Economic Integration with GVCs

Global Value Chains (GVCs) encompass the series of production steps from design and manufacturing to marketing, distribution, and ultimately the sale to the final consumer, with these tasks distributed across multiple firms in various countries. Countries participate in GVCs through either backward or forward linkages. The GVC participation index measures the extent to which an economy is integrated into global value chains based on its production and international trade activities. Backward linkages occur when a country imports inputs from abroad to produce goods and services for export. In contrast, forward linkages arise when a country exports its domestic inputs to other nations responsible for subsequent stages of production. This approach assesses the domestic value added by inputs exported for additional processing and incorporation into supply chains for export by other economies.

The degree of connectedness of an industry with the rest of the world is often suitably measured by quantifying the ‘backward’ and/or ‘forward’ linkages associated with it. Quite interestingly, with higher values of backward and/or forward linkages, some industries (sectors) are always found to wield stronger influence in determining the underlying dynamics of the economic systems. These industries act as a fulcrum for spreading the ‘economy-wide impact’ of both ‘internal’ and ‘external’ impulses brought about by “internal policy changes” and “external supply chain shocks” respectively. Since these industries play “key roles” in both destabilizing and subsequently delineating the required set of counteracting stabilizing policy prescriptions to the government, we can conveniently identify these sectors as “key sectors” (as conceptualized at the beginning of this study). Most importantly, any cardinal measurement of ‘forward’ and ‘backward’ linkages can make the difficult task of identifying “key sectors” much easier.

The results of our research in this regard shows that five (5) ‘non-fuel minerals (*Manganese ore, Limestone, Copper Ore, Bauxite and Other Metallic Minerals*) are among the first 10

sectors in terms Import Content of Export. This result conforms to the results obtained from calculation of ‘Forward and Backward Linkages’ and Principal Component Analysis (PCA). The measure of ‘backward Linkage’ (Intermediate Imports Embodied in gross Exports) using Economic Cooperation and Development (OECD)'s Trade in Value Added (TiVA) database also conforms to results obtained from GVA analysis using GTAP database. In addition to that, calculations from TiVA provide some other important insights into the picture.

- i) Linkage effects for ‘Mining and Quarrying’ sector are much higher than overall linkages
- ii) Linkage effects for ‘Mining and extraction of energy producing products’ are highest in this category, indicating India’s dependence on ‘fuel minerals’
- iii) Forward Linkage for ‘Mining and extraction of energy producing products’ is much higher than the backward linkage. This implies India is more integrated from ‘Supply Side’ by exporting ‘Mining and extraction of energy producing products’ to East Asian countries.

7.4.4 Consolidated Results

We have consolidated results obtained from following methods:

- i) Calculation of ‘Backward’ and ‘Forward Linkages’
- ii) Determination of ‘most important’ resources by application of ‘Principal Component Analysis’ (PCA).
- iii) Measurement of economic integration in terms of ‘forward’ and ‘backward’ linkages with Global Value Chains (GVCs) using GTAP database
- iv) The insights from the ‘impact analyses’ have also been incorporated in results

Next, we have assigned scores as follows:

Table 7.1 Score Table

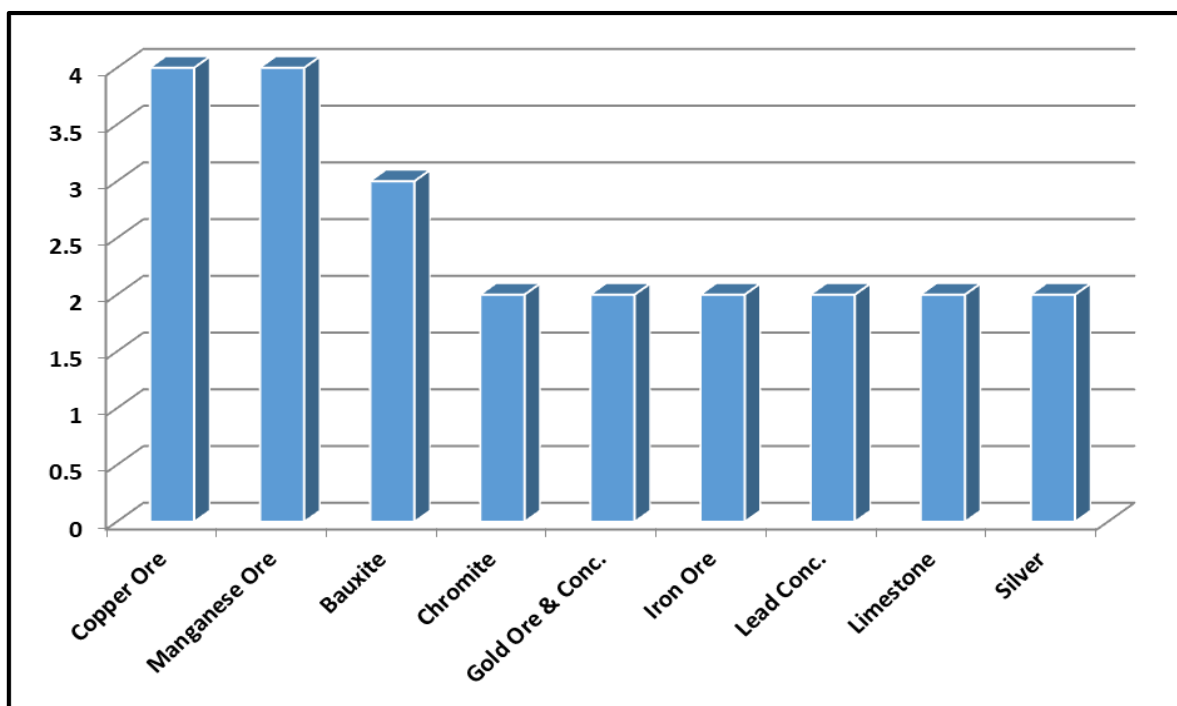
Sr. No	Result	Score
1.	Identified as ‘key resource’ by any ONE of above method	1
2.	Identified as ‘key resource’ by any TWO of above method	2
3.	Identified as ‘key resource’ by any THREE of above method	3
4.	Identified as ‘key resource’ by ALL FOUR methods	4

Minerals having high score from scoring method ascertained a set of non-fuel minerals as the ‘key resources’ of the Indian economy.

Table 7.2 Identification of Key Resources

Sr. No	Minerals	Dependent on inter-industry Demand	Dependent on inter-industry Supply	PCA	Impact Analysis	GVC	Total Score
1	Bauxite	1		1		1	3
2	Chromite	1		1			2
3	Copper Ore	1		1	1	1	4
4	Gold Ore & Conc.	1		1			2
5	Iolite		1				1
6	Iron Ore	1		1			2
7	Lead Conc.	1		1			2
8	Limestone	1				1	2
9	Manganese Ore	1		1	1	1	4
10	Moulding Sand		1				1
11	Non-Ferrous Basic Metals		1				1
12	Salt (Rock)		1				1
13	Selenite		1				1
14	Silver	1		1			2
15	Tin Conc.	1					1
16	Vermiculite		1				1
17	Zinc Conc.	1					1

Source: Author's Calculations

Figure 7.1 Identification of Key Resources in India

These minerals have been identified as ‘most powerful’ in garnering country’s growth momentum. These ‘key minerals’, are further represented into following three categories,

depending on their total score to represent their intrinsic capacities to influence growth of Indian economy:

Key Minerals:

- Top Category (2): Copper Ore; Manganese Ore
- Middle Category (1): Bauxite
- Bottom Category (6): Chromite; Gold Ore & Conc; Iron Ore; Lead Conc.; Limestone; Silver

The most important finding in this case is that all of these resources have strong 'backward linkages'. Stronger 'backward linkages' implies that these 'key resources' develop the productive capacity of the economy in both intensive (more production of the commodities) and extensive (production of more commodities) ways. This indicates towards high domestic demand of 'key resources' due to:

- i) A huge and rapidly growing manufacturing base of Indian economy.
- ii) Accelerating industrialization process and a structural shift from 'agricultural' to 'manufacturing' activities.
- iii) Increase in export of commodities that requires sizable amount of these non-fuel minerals as inputs.

7.4.5 Other Findings

Our study indicates that during the pandemic period, countries exporting "fuel minerals" have seen a notable improvement in their economic status compared to those exporting "non-fuel minerals." This trend suggests that countries focusing on non-fuel mineral exports are more susceptible to disruptions in the supply chain. Therefore, these disruptions pose a significant threat to such countries, emphasizing the need for governments to develop contingency plans to mitigate potential export disruptions. Consequently, it's wise to minimize reliance on long-distance shipping of export goods. This also means that economic ties with Regional Value Chains (RVCs) should be prioritized over Global Value Chains (GVCs), suggesting that India, for example, should strengthen its trade relations with regional groups like ASEAN and BIMSTEC, rather than with far-off partners like the EU.

Moreover, diversifying export markets is crucial. Should there be any obstacle in one export destination; alternative markets could help absorb the surplus, ensuring steady revenue flow. Encouraging local industries that use non-fuel minerals can be challenging. While focusing on domestic markets might seem beneficial, it risks two major issues. Firstly, the World

Trade Organization (WTO) may challenge such protectionist measures as they contravene global trade rules, potentially leading to punitive actions. Secondly, selling domestically rather than exporting could result in considerably lower profits, adversely affecting the nation's treasury.

Our research has raised a concern about the mismatch in mineral statistics published by three Government bodies: Indian Bureau of Mines (IBM), Ministry of Mines (MoM) and Central Statistical Organisation (CSO) of India. Authenticity of database is always a serious issue, as any economic research based on this data may result in completely misleading outcomes. Considering gravity of the problem, Ministry of Mines should immediately make an effort to synchronise all datasets and facilitate flow of symmetric information in public domain and to make database tenable to academic research and analysis. Ministry can come up with a single databank or repository-portal to ensure access to officially authenticated and updated data to all stakeholders and academic researchers (like the 'Export-Import Databank' provided by Ministry of Commerce and Industry).

7.5 Conclusion

India's shift towards clean energy not only holds considerable economic promise but also positions the country as a potential leader in the renewable energy domain, especially in battery technology and green hydrogen, with an expected market value of up to \$80 billion by 2030. Achieving a sustainable, low-carbon economy requires significant international support and investment—specifically, the International Energy Agency (IEA) estimates a need for \$160 billion annually until 2030, a tripling of current levels, to reach net-zero emissions by 2070. Beyond merely reducing greenhouse gas emissions, this transition aims to enhance the quality of life for Indians through balanced, well-crafted policies that ensure affordability, security, and environmental sustainability. Green hydrogen, crucial for decarbonizing hard-to-abate industries, is at the heart of India's strategy to create a demand for 5 million tonnes of green hydrogen, thereby avoiding 28 million tonnes of CO₂ emissions initially, with the potential to prevent 400 million tonnes by 2050 as the green hydrogen economy matures.

Global Value Chains (GVCs) are in a state of flux, influenced by factors such as the need for diversification in the wake of the pandemic and the pursuit of supply chain security for strategic purposes. This shift presents a prime opportunity for India to elevate its role within these value chains and secure a larger market presence. Our study supports the view that India is poised to expand its involvement in GVCs, particularly through emphasizing the 'key

mineral sectors.' Implementation of appropriate government policies to streamline customs and trade procedures, as well as engaging the broad micro, small, and medium enterprises (MSME) sector in partnerships with leading global firms, is essential. With its commitment to major infrastructure projects and a strategic emphasis on negotiating new free trade agreements, India is in a strong position to deepen its participation in GVCs. The country also has several industries with the potential to scale up production to fulfil export demands. Our findings highlight that prioritizing strategic non-fuel minerals (key resources) can drive growth and facilitate economic integration with GVCs.

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APPENDIX: A

Table A1: Devices and Materials Needed For Implementation of ‘Clean Energy Technology’

Recommended Strategies (IPCC)	Required Devices and Materials
Electricity	
Adoption of Smart-Grid Technologies	Transformers
Energy Storage	Batteries Anode in Electrolysers Cathode in Electrolysers Proton Exchange Membrane (PEM) Electrolysers Solid Oxide Electrolysers
Energy Efficiency improvements	Cables, Wires Catalytic Converters
Land Transport	
Electric Vehicles	Batteries Permanent-magnet Synchronous Motors of EVs
Switching to Low- And Zero-GHG Emitting Fuels (e.g., Hydrogen, Ammonia, Bio-Based and Other Synthetic Fuels)	Hydrogen Fuel Plants CNG
Construction	
Low-Emission Construction Materials	Low-carbon bricks (40% Fly Ash) Green tiles Structural timber Hempcrete Hempcrete
Electrification (e.g., Electro thermal Heating, Heat Pumps)	Heating Mantle

Source: Sixth Assessment Report AR6, ICCP 2023 and Own Research

Table A2: List of Minerals Required To Manufacture Devices and Materials To Implement ‘Clean Energy Technology’

MINERAL	DEVICE
ALUMINIUM	Electricity Networks: Wires, Cables, Transformers; Low-carbon Bricks; Heating Mantle; Heat Pumps
ARSENIC	Photo Voltaic Cells
CADMIUM	Photo Voltaic Cells
CHROMIUM	Concentrated Solar Power and Geothermal Power Generation
COBALT	Battery: Cathode in Electrolysers
COPPER	Electricity Networks: Wires, Cables, Transformers; Concentrated Solar Power; Carbon-negative Concrete
DYSPROSIUM	Wind turbines and Permanent-magnet Synchronous Motors of EVs
GALLIUM	Photo Voltaic Cells
GRAPHITE	Battery: Anode in Electrolysers
INDIUM	Photo Voltaic Cells and Proton Exchange Membrane (PEM) Electrolysers
IRON	Low-Carbon Bricks; Heat Pumps
LANTHANUM	Solid Oxide Electrolysers
LITHIUM	Battery: Anode in Electrolysers and Anode in All Solid-State Batteries
LIMESTONE	Carbon-negative Concrete
MANGANESE	Concentrated Solar Power, Battery
MOLYBDENUM	Geothermal Power Generation
NEODYMIUM	Wind Turbines
NEODYMIUM	Permanent-magnet Synchronous Motors of EVs
NICKEL	Battery, Alkaline Electrolysers, Hydrogen Fuel Plants, Geothermal Power Generation; Concentrated Solar Power
PALLADIUM	Catalytic Converters
PLATINUM	Proton Exchange Membrane (PEM) Electrolysers, Catalytic Converters
PRASEODYMIUM	Wind Turbines, Permanent-magnet Synchronous Motors of EVs
SILICON	Photo Voltaic Cells; Low-carbon Bricks
TELLURIUM	Photo Voltaic Cells
TERBIUM	Permanent-magnet Synchronous Motors of EVs
TITANIUM	Geothermal Power Generation
YTTRIUM	Solid oxide electrolysers
ZIRCONIUM	Electrolysers
ZIRCONIUM	Solid oxide electrolysers

Source: IEA, 2023 and Own Research

Table A3: Aggregation Scheme

Aggregation Sector No.	New Sector Names	IOTT Sector Number
1	<i>Agriculture, Livestock & Natural Resource</i>	(1 -29)
2	<i>Coal And Lignite</i>	30
3	<i>Natural Gas</i>	31
4	<i>Crude Petroleum</i>	32
5	<i>Iron Ore</i>	33
6	<i>Manganese Ore</i>	34
7	<i>Bauxite</i>	35
8	<i>Copper Ore</i>	36
9	<i>Other Metallic Minerals</i>	37
10	<i>Limestone</i>	38
11	<i>Mica</i>	39
12	<i>Other Non-Metallic Minerals</i>	40
13	<i>Food, Food Products & Other Consumables</i>	(41 -55)
14	<i>Textile And Apparel</i>	(56-62)
15	<i>Leather & Leather Products</i>	(63-64)
16	<i>Wood & Rubber Products</i>	(65-68)
17	<i>Rubber Products</i>	69
18	<i>Plastic Products</i>	70
19	<i>Chemicals (Exc.. Fertilizer)</i>	(71-74, 76,77,79-81)
20	<i>Fertilizers</i>	75
21	<i>Pharmaceuticals</i>	78
22	<i>Cement</i>	82
23	<i>Non-Metallic Mineral Products</i>	83
24	<i>Iron & Steel</i>	(84 -86)
25	<i>Non-Ferrous Basic Metals (Incl. Alloys)</i>	87
26	<i>Miscellaneous Metal Products</i>	89
27	<i>Capital Goods</i>	(88, 90-95,100,110)
28	<i>Electrical Cables, Wires & Appliances</i>	(96, 98)
29	<i>Batteries</i>	97
30	<i>Precision Tools & Equipment</i>	(99 -103)
31	<i>Transport, Vehicles & Transport Equipment</i>	(104 -109)
32	<i>Gems & Jewellery</i>	111
33	<i>Miscellaneous Manufacturing</i>	112
34	<i>Construction</i>	113
35	<i>Electricity</i>	114
36	<i>Public Infrastructure</i>	(115,116,120-125)

37	<i>Financial Services</i>	(127, 128)
38	<i>All Other Services</i>	(117-119, 126, 129-140)

Source: Author's Calculation

TABLE A4: Mineral* Production in India, 2018-19

PRODUCTION (IBM Data)
(By Mineral Groups & Minerals)

		(Rs. Crores)	
All Minerals		1461266117	146126.61
Sr. No	Total Metallic Minerals	642120754	64212.075
1	Chromite	36850747	3685.0747
2	Gold Ore & Gold	5241705	524.1705
3	Lead conc.	16316914	1631.6914
4	Zinc conc	56083827	5608.3827
5	Silver	25824756	2582.4756
6	Tin conc.	14627	1.4627
		(TOTAL)	14033.258
	Other Metallic Minerals		50178.818
		(Crores)	
	Total Non-Metallic Minerals	97400700	9740.07
1	Phosphorite	3883571	388.3571
2	Diamond	539062	53.9062
3	Fluorite (graded)	8117	0.8117
4	Garnet (abrasive)	1746756	174.6756
5	Graphite (r.o.m.)	36233	3.6233
6	Iolite	684	0.0684
7	Kyanite	15757	1.5757
8	Sillimanite	564498	56.4498
9	Limeshell	27780	2.778
10	Magnesite	408287	40.8287
11	Marl	349420	34.942
12	Moulding sand	4145	0.4145
13	Salt (rock)	160	0.016

Already included in IO

1	Bauxite
2	Copper Ore
3	Iron Ore (Total)
4	Manganese Ore

Already included in IO

1	Limestone
2	Mica

14	Selenite	5812	0.5812
15	Siliceous earth	50205	5.0205
16	Vermiculite	3709	0.3709
17	Wollastonite	172013	17.2013
		(TOTAL)	781.6209
	Other Non-metallic Minerals		8958.4491

19 Minor Minerals****

721744663 72174.466

* Excluding the minerals declared as prescribed substances under the Atomic Energy Act,1962

\$ Excludes the value of fuel minerals

** Sulphur is excluded on the ground that it is obtained as by-product from fertilizer plants and oil refineries

*** Figures for earlier years have been repeated as estimates, wherever necessary, because of non-receipt of data from respective State Governments

Other than BSM (Beach Sand Minerals)

Source: Indian Minerals Yearbook 2020; 59th Edition

(Part- I : General Reviews)

Production (Advance Release)

Government of India, Ministry of Mines, Indian Bureau of Mines

January, 2022

Table A5 Input-Output Transaction Table (61 X 61) - 2018-19

(Values in Rs. Crores)

S.No.	Industry	Product	Total intermediate use	PFCE	GFCE	GFCF	CIS	Valuables	EXP	TFUSE	TFUSE - all margins	Output at Basic Prices	Production Taxes less Subsidies	Output at Purchaser's Price (PP)
1	Agriculture, Livestock & Natural Resources		1954566	2675066	0	6357	38403	0	102680	2822506	1796518	3751085	-100174	3650911
2	Coal And Lignite		401643	3117	0	0	2716	0	1226	7059	-252550	149093	748	149841
3	Natural Gas		64124	0	0	0	997	0	0	997	-6677	57447	257	57705
4	Crude Petroleum		986893	0	0	0	77366	0	0	77366	-801271	185623	738	186361
5	Iron Ore		108574	0	0	0	2851	0	9731	12582	-25061	83513	295	83808
6	Manganese Ore		14380	0	0	0	179	0	34	213	-7941	6438	27	6466
7	Bauxite		8623	0	0	0	157	0	305	461	-3317	5306	22	5329
8	Copper Ore		15778	0	0	0	-527	0	1672	1146	-13146	2632	11	2643
9	Chromite		5386	0	0	0	219	0	104	323	-1747	3639	15	3654
10	Gold Ore & Gold		766	0	0	0	31	0	15	46	-249	518	2	520
11	Lead conc.		2385	0	0	0	97	0	46	143	-774	1611	7	1618
12	Zinc conc		8197	0	0	0	334	0	158	492	-2659	5538	23	5561
13	Silver		3775	0	0	0	154	0	73	226	-1225	2550	11	2561
14	Tin conc.		2	0	0	0	0	0	0	0	-1	1	0	1
15	Limestone		37017	0	0	0	320	0	495	815	-12173	24844	148	24992
16	Mica		463	0	0	0	61	0	0	61	-24	439	0	440
17	Phosphorite		462	0	0	0	20	0	31	51	-75	387	2	389
18	Diamond		64	0	0	0	3	0	4	7	-10	54	0	54
19	Fluorite (graded)		1	0	0	0	0	0	0	0	0	1	0	1
20	Garnet (abrasive)		208	0	0	0	9	0	14	23	-34	174	1	175
21	Graphite (r.o.m.)		4	0	0	0	0	0	0	0	-1	4	0	4
22	Iolite		0	0	0	0	0	0	0	0	0	0	0	0
23	Kyanite		2	0	0	0	0	0	0	0	0	2	0	2
24	Sillimanite		67	0	0	0	3	0	5	7	-11	56	0	56
25	Limeshell		3	0	0	0	0	0	0	0	-1	3	0	3
26	Magnesite		49	0	0	0	2	0	3	5	-8	41	0	41
27	Marl		42	0	0	0	2	0	3	5	-7	35	0	35
28	Moulding sand		0	0	0	0	0	0	0	0	0	0	0	0
29	Salt (rock)		0	0	0	0	0	0	0	0	0	0	0	0
30	Selenite		1	0	0	0	0	0	0	0	0	1	0	1
31	Siliceous earth		6	0	0	0	0	0	0	1	-1	5	0	5

(Table A5: Continued)

32	Vermiculite	0	0	0	0	0	0	0	0	0	0	0	0
33	Wollastonite	20	0	0	0	1	0	1	2	-3	17	0	17
34	Minor Minerals	85836	0	0	0	3674	0	5789	9462	-13947	71889	326	72215
35	Other Minerals	181353	0	0	0	7762	0	12230	19992	-29467	151886	689	152575
36	Food, Food Products & Other Consumables	576475	1486762	0	0	13978	0	153117	1653857	1118055	1694530	926	1695456
37	Textile And Apparel	394469	570561	0	0	10414	0	275058	856033	541767	936236	823	937059
38	Leather & Leather Products	28031	87353	0	0	586	0	38717	126656	71900	99931	103	100034
39	Wood & Rubber Products	520753	117489	0	44155	23004	0	26608	211255	-27178	493575	482	494057
40	Rubber Products	124181	21584	0	0	7422	0	22429	51434	-14175	110006	80	110086
41	Plastic Products	381892	47875	0	0	1698	0	56240	105814	-112301	269592	196	269787
42	Chemicals (Exc.. Fertilizer)	1969296	503838	0	0	64488	0	548173	1116499	-84748	1884548	990	1885538
43	Fertilizers	139023	0	0	0	922	0	1038	1960	-29039	109984	83	110067
44	Pharmaceuticals	162070	163149	0	0	12178	0	103303	278629	182229	344299	477	344775
45	Cement	360782	6844	0	0	11138	0	2882	20864	-76270	284512	289	284801
46	Non-Metallic Mineral Products	200168	0	0	0	5686	0	27130	32815	-36839	163329	166	163495
47	Iron & Steel	1415284	0	0	35112	38415	0	87134	160662	-246767	1168517	607	1169124
48	Non-Ferrous Basic Metals (Incl. Alloys)	298959	0	0	0	6792	0	46849	53641	-99774	199184	91	199276
49	Miscellaneous Metal Products	228905	842	0	51578	2402	0	19827	74649	-36057	192848	152	193000
50	Capital Goods	593234	22711	0	939033	13432	0	195417	1170594	375198	968432	872	969304
51	Electrical Cables, Wires & Appliances	171902	3057	0	192655	2665	0	46749	245126	722	172624	124	172748
52	Batteries	28919	0	0	30450	1141	0	2748	34339	1714	30634	22	30655
53	Precision Tools & Equipments	99143	27578	0	250566	1189	0	36975	316307	115815	214957	121	215078
54	Transport, Vehicles & Transport Equipments	476144	250156	0	467332	11410	0	164328	893226	409613	885757	722	886479
55	Gems & Jewellery	58347	236386	0	0	991	226104	282042	745523	138783	197131	89	197219
56	Miscellaneous Manufacturing	576976	177191	0	44485	20265	0	41925	283867	35131	612106	468	612575
57	Construction	857943	170520	70670	2964396	17033	0	28461	3251080	2979740	3837683	8089	3845773
58	Electricity	687073	157942	0	0	0	0	0	157942	164443	851516	-5505	846011
59	Public Infrastructure	509198	644772	20366	0	0	0	92571	757710	1606375	2115572	-34129	2081443
60	Financial Services	820166	557075	0	0	0	0	52653	609728	496948	1317114	650	1317764
61	All Other Services	2023760	3359661	1954515	542303	0	0	1280750	7137230	9083687	11107447	76527	11183974
	Total	17591766	11291529	2045552	5568422	402340	226104	3766294	23300241	17175129	34766896	-43345	133682695
	Total Outlay	34766896	11291529	2045552	5568422	402340	226104	3766294	23300241	17175129	34766896		

Table A6: PCA Calculations

(Sorted out Eigen Values (in descending order))

	Eigen Values	Proportion (%)	Cumulative Proportion (%)
<i>L2</i>	54.08	40.97	40.97
<i>L3</i>	28.20	21.37	62.33
<i>L4</i>	21.00	15.91	78.24
<i>L5</i>	11.12	8.42	86.66
<i>L1</i>	7.50	5.69	92.35
<i>L6</i>	4.53	3.43	95.78
<i>L7</i>	3.69	2.80	98.58
<i>L8</i>	1.88	1.42	100.00
<i>L9</i>	0.00	0.00	100.00
<i>L10</i>	0.00	0.00	100.00
<i>L11</i>	0.00	0.00	100.00
<i>L12</i>	0.00	0.00	100.00
<i>L13</i>	0.00	0.00	100.00
<i>L14</i>	0.00	0.00	100.00
<i>L15</i>	0.00	0.00	100.00
<i>L16</i>	0.00	0.00	100.00
<i>L17</i>	0.00	0.00	100.00
<i>L18</i>	0.00	0.00	100.00
<i>L19</i>	0.00	0.00	100.00
<i>L20</i>	0.00	0.00	0.00
<i>L21</i>	0.00	0.00	0.00
<i>L22</i>	0.00	0.00	0.00
<i>L23</i>	0.00	0.00	0.00
<i>L24</i>	0.00	0.00	0.00
<i>L25</i>	0.00	0.00	0.00
<i>L26</i>	0.00	0.00	0.00
<i>L27</i>	0.00	0.00	0.00
<i>L28</i>	0.00	0.00	0.00
<i>L29</i>	0.00		0.00
SUM	132.00		

Key Non-Fuel Minerals

<i>L2</i>	Chromite
<i>L3</i>	Copper ore & conc
<i>L4</i>	Gold ore and conc.
<i>L5</i>	Iron ore
<i>L1</i>	Bauxite
<i>L6</i>	Lead cone.
<i>L7</i>	Manganese ore
<i>L8</i>	Silver

Important Minerals*

<i>L9</i>	Tin conc
<i>L10</i>	Zinc cone.
<i>L11</i>	Diamond
<i>L12</i>	Fluorite-
<i>L13</i>	Garnet (abrasive)
<i>L14</i>	Graphite (r.o.m.)
<i>L15</i>	Iolite
<i>L16</i>	Kyamte
<i>L17</i>	Limeshell
<i>L18</i>	Limestone
<i>L19</i>	Magnesite

No Positive Impact On Economy**

<i>L20</i>	Marl
<i>L21</i>	Moulding Sand
<i>L22</i>	Phosphorite
<i>L23</i>	Salt (rock)
<i>L24</i>	Selenite
<i>L25</i>	Siliceous earth
<i>L26</i>	Sillimanite
<i>L27</i>	Vermiculite
<i>L28</i>	Wollastonite
<i>L29</i>	Minor Minerals@

Source: Author's Calculations

Table A7: Required Growth In Other Sectors To Commensurate Targeted Growth In Textile and Apparel Sector (In Order Of Importance)

<i>Sr. No</i>	<i>Sectors</i>	<i>Required Production (In Rs. Crore)</i>	<i>Simple Growth Rate Per Annum (%)</i>	<i>CAGR (%)</i>
1.	Copper Ore	56013.62581	338.03	54.78
2.	Crude Petroleum	3132092.917	264.56	49.73
3.	Manganese Ore	43563.61681	96.10	31.41
4.	Coal And Lignite	848746.0408	78.21	28.20
5.	Tin conc.	7.714648358	72.36	27.04
6.	Chromite	19436.0125	72.36	27.04
7.	Gold Ore & Gold	2764.607293	72.36	27.04
8.	Lead conc.	8605.951582	72.36	27.04
9.	Zinc conc	29580.02351	72.36	27.04
10.	Silver	13620.62702	72.36	27.04
11.	Bauxite	27229.10447	68.86	26.32
12.	Gems & Jewellery	976946.6832	65.93	25.69
13.	Non-Ferrous Basic Metals (Incl. Alloys)	806875.117	50.85	22.12
14.	Limestone	90455.02715	44.02	20.27
15.	Iron Ore	280024.3018	39.22	18.87

Source: Author's Calculations

Table A8 : Required Growth In Other Sectors To Commensurate Targeted Growth In Chemical Sector

<i>Sr. No</i>	<i>Sectors</i>	<i>Required Production (In Rs. Crore)</i>	<i>Simple Growth Rate Per Annum (%)</i>	<i>CAGR (%)</i>
1.	Copper Ore	55390.05	182.23	31.91
2.	Crude Petroleum	2407934.33	108.84	26.24
3.	Manganese Ore	42802.56	51.34	18.79
4.	Coal And Lignite	818526.56	40.82	16.74
5.	Tin conc.	7.63	38.93	16.34
6.	Chromite	19222.81	38.93	16.34
7.	Gold Ore & Gold	2734.28	38.93	16.34
8.	Lead conc.	8511.55	38.93	16.34
9.	Zinc conc	29255.55	38.93	16.34
10.	Silver	13471.22	38.93	16.34
11.	Bauxite	26861.11	36.93	15.89
12.	Gems & Jewellery	975615.97	35.90	15.65
13.	Non-Ferrous Basic Metals (Incl. Alloys)	796736.78	27.27	13.43
14.	Limestone	88365.02	23.24	12.23
15.	Iron Ore	276660.84	21.03	11.50

Source: Author's Calculations

Table A9 Required Growth In Other Sectors To Commensurate Targeted Growth In Fertilizer Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1.	Copper Ore	55882.95	155.63	32.02
2.	Crude Petroleum	3089308.71	120.33	29.13
3.	Manganese Ore	43403.48	44.16	18.94
4.	Coal And Lignite	843065.25	35.80	17.06
5.	Tin conc.	7.70	33.30	16.43
6.	Lead conc.	8586.05	33.30	16.43
7.	Silver	13589.12	33.30	16.43
8.	Chromite	19391.06	33.30	16.43
9.	Gold Ore & Gold	2758.21	33.30	16.43
10.	Zinc conc	29511.61	33.30	16.43
11.	Bauxite	27151.41	31.67	16.00
12.	Gems & Jewellery	976659.95	30.42	15.66
13.	Non-Ferrous Basic Metals (Incl. Alloys)	804737.28	23.39	13.53
14.	Limestone	90009.80	20.18	12.42
15.	Iron Ore	279327.09	18.04	11.60

Source: Author's Calculations

Table A10 Required Growth In Other Sectors To Commensurate Targeted Growth In Pharmaceuticals Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1.	Copper Ore	56345.52	185.53	32.12
2.	Crude Petroleum	3202426.42	147.75	29.55
3.	Manganese Ore	43869.39	52.85	19.06
4.	Coal And Lignite	857437.32	43.19	17.24
5.	Chromite	19548.01	39.75	16.51
6.	Gold Ore & Gold	2780.54	39.75	16.51
7.	Lead conc.	8655.54	39.75	16.51
8.	Zinc conc	29750.47	39.75	16.51
9.	Silver	13699.11	39.75	16.51
10.	Tin conc.	7.76	39.75	16.51
11.	Bauxite	27408.38	37.87	16.10
12.	Gems & Jewellery	977619.72	35.99	15.67
13.	Non-Ferrous Basic Metals (Incl. Alloys)	812108.81	27.97	13.63
14.	Limestone	91193.80	24.28	12.55
15.	Iron Ore	282061.17	21.61	11.70

Source: Author's Calculations

Table A11: Required Growth In Other Sectors To Commensurate Targeted Growth In Cement Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1.	Copper Ore	55840.46	252.70	46.50
2.	Crude Petroleum	3101907.57	196.39	42.19
3.	Manganese Ore	43258.72	71.48	26.89
4.	Coal And Lignite	833477.95	57.38	24.00
5.	Chromite	19363.84	54.02	23.24
6.	Silver	13570.05	54.02	23.24
7.	Gold Ore & Gold	2754.34	54.02	23.24
8.	Lead conc.	8574.00	54.02	23.24
9.	Zinc conc	29470.19	54.02	23.24
10.	Tin conc.	7.69	54.02	23.24
11.	Bauxite	26803.97	50.64	22.44
12.	Gems & Jewellery	976534.23	49.42	22.14
13.	Non-Ferrous Basic Metals (Incl. Alloys)	804059.12	37.96	19.06
14.	Limestone	86061.48	30.80	16.80
15.	Iron Ore	278855.01	29.24	16.27

Source: Author's Calculations

Table A12: Required Growth In Other Sectors To Commensurate Targeted Growth In Iron & Steel Sector

Sr. No.	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1	Copper Ore	53647.09	176.21	31.53
2	Crude Petroleum	3003054.45	137.98	28.80
3	Manganese Ore	36378.77	42.27	17.05
4	Tin conc.	7.32	36.97	15.90
5	Chromite	18437.13	36.97	15.90
6	Gold Ore & Gold	2622.52	36.97	15.90
7	Lead conc.	8163.66	36.97	15.90
8	Zinc conc	28059.81	36.97	15.90
9	Silver	12920.62	36.97	15.90
10	Gems & Jewellery	974620.06	35.85	15.64
11	Bauxite	25848.74	35.19	15.48
12	Coal And Lignite	646117.83	30.31	14.26
13	Non-Ferrous Basic Metals (Incl. Alloys)	762228.07	25.70	12.98
14	Limestone	82339.16	21.04	11.51
15	Miscellaneous Metal Products	591545.73	18.79	10.73

Source: Author's Calculations

Table A13: Required Growth In Other Sectors To Commensurate Targeted Growth In Capital Goods

Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1 Copper Ore	54473.91	328.28	65.66
2 Crude Petroleum	3092112.02	260.97	59.78
3 Manganese Ore	42403.10	93.10	36.89
4 Coal And Lignite	828592.08	75.96	33.08
5 Tin Conc.	7.55	70.45	31.72
6 Chromite	19019.01	70.45	31.72
7 Gold Ore & Gold	2705.29	70.45	31.72
8 Lead Conc.	8421.31	70.45	31.72
9 Zinc Conc	28945.37	70.45	31.72
10 Silver	13328.39	70.45	31.72
11 Bauxite	26508.69	66.59	30.73
12 Gems & Jewellery	975994.58	65.85	30.54
13 Non-Ferrous Basic Metals (Incl. Alloys)	779848.55	48.59	25.53
14 Limestone	88725.71	42.86	23.62
15 Iron Ore	271901.10	37.60	21.73

Source: Author's Calculations

Table A14: Required Growth In Other Sectors To Commensurate Targeted Growth In Electrical Cables, Wires & Appliances Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1	Copper Ore	89493.19	330.02	42.28
2	Crude Petroleum	3367994.10	171.44	33.62
3	Electrical Cables, Wires & Appliances	2118809.82	112.74	28.50
4	Manganese Ore	59685.06	82.70	24.94
5	Tin Conc.	10.68	63.93	22.15
6	Chromite	26901.56	63.93	22.15
7	Gold Ore & Gold	3826.52	63.93	22.15
8	Lead Conc.	11911.57	63.93	22.15
9	Zinc Conc	40941.97	63.93	22.15
10	Silver	18852.43	63.93	22.15
11	Bauxite	38513.31	62.58	21.92
12	Non-Ferrous Basic Metals (Incl. Alloys)	1350746.66	57.81	21.10
13	Coal And Lignite	983692.13	55.98	20.76
14	Gems & Jewellery	984113.53	39.92	17.44
15	Limestone	113913.21	35.85	16.45

Source: Author's Calculations

Table A15: Required Growth In Other Sectors To Commensurate Targeted Growth In Battery Manufacturing Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1.	Copper Ore	57423.81	189.25	32.35
2.	Crude Petroleum	3124885.95	143.95	29.26
3.	Manganese Ore	44197.94	53.31	19.14
4.	Coal And Lignite	851288.18	42.82	17.16
5.	Tin conc.	7.84	40.23	16.62
6.	Chromite	19740.13	40.23	16.62
7.	Gold Ore & Gold	2807.86	40.23	16.62
8.	Lead conc.	8740.61	40.23	16.62
9.	Zinc conc	30042.86	40.23	16.62
10.	Silver	13833.75	40.23	16.62
11.	Bauxite	27686.01	38.34	16.20
12.	Gems & Jewellery	977036.39	35.97	15.66
13.	Non-Ferrous Basic Metals (Incl. Alloys)	829779.11	28.78	13.85
14.	Limestone	91317.26	24.32	12.56
15.	Batteries	111322.70	23.95	12.45

Source: Author's Calculations

Table A16 Required Growth In Other Sectors To Commensurate Targeted Growth In Transport, Vehicles & Transport Equipment Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1,	Copper Ore	65926.93	240.49	38.00
2,	Crude Petroleum	3352723.90	170.62	33.56
3,	Manganese Ore	52008.94	70.78	23.23
4,	Transport, Vehicles & Transport Equipment	6874633.20	67.61	22.74
5,	Coal And Lignite	987185.42	56.21	20.81
6,	Chromite	22349.79	51.42	19.90
7,	Gold Ore & Gold	3179.07	51.42	19.90
8,	Lead Conc.	9896.12	51.42	19.90
9,	Zinc Conc	34014.55	51.42	19.90
10,	Silver	15662.58	51.42	19.90
11,	Tin Conc.	8.87	51.42	19.90
12,	Bauxite	31886.74	50.09	19.64
13,	Gems & Jewellery	987145.00	40.08	17.48
14,	Non-Ferrous Basic Metals (Incl. Alloys)	989403.30	39.67	17.38
15,	Iron Ore	352784.56	32.24	15.50

Source: Author's Calculations

Table A17 Required Growth In Other Sectors To Commensurate Targeted Growth In Gems & Jewellery Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1.	Copper Ore	56303.64	203.92	35.84
2.	Crude Petroleum	3117291.11	157.94	32.59
3.	Manganese Ore	43715.96	57.90	21.11
4.	Coal And Lignite	847103.16	46.82	18.97
5.	Tin Conc.	7.78	43.89	18.34
6.	Lead Conc.	8682.51	43.89	18.34
7.	Silver	13741.80	43.89	18.34
8.	Chromite	19608.92	43.89	18.34
9.	Gold Ore & Gold	2789.20	43.89	18.34
10.	Zinc Conc	29843.18	43.89	18.34
11.	Bauxite	27351.99	41.55	17.82
12.	Non-Ferrous Basic Metals (Incl. Alloys)	808462.19	30.59	15.04
13.	Gems & Jewellery	767882.31	28.95	14.57
14.	Limestone	90632.51	26.48	13.82
15.	Iron Ore	280130.06	23.54	12.87

Source: Author's Calculations

Table A18: Required Growth In Other Sectors To Commensurate Targeted Growth In Construction Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1	Copper Ore	71113.42	433.65	73.23
2	Crude Petroleum	3828284.45	327.07	65.60
3	Manganese Ore	60711.53	140.49	45.35
4	Coal And Lignite	1306776.38	129.41	43.59
5	Bauxite	37241.94	100.31	38.37
6	Tin Conc.	9.62	94.29	37.16
7	Silver	16976.06	94.29	37.16
8	Chromite	24224.07	94.29	37.16
9	Gold Ore & Gold	3445.67	94.29	37.16
10	Lead Conc.	10726.03	94.29	37.16
11	Zinc Conc	36867.05	94.29	37.16
12	Limestone	148661.15	83.06	34.74
13	Non-Ferrous Basic Metals (Incl. Alloys)	1062429.68	72.23	32.18
14	Iron Ore	426341.92	68.42	31.22
15	Gems & Jewellery	993207.99	67.31	30.93

Source: Author's Calculations

Table A19 Required Growth In Other Sectors To Commensurate Targeted Growth In Electricity Sector

Sr. No	Sectors	Required Production (In Rs. Crore)	Simple Growth Rate Per Annum (%)	CAGR (%)
1.	Copper Ore	56116.50	156.32	26.54
2.	Crude Petroleum	3136820.12	122.30	24.29
3.	Manganese Ore	43662.23	44.47	15.86
4.	Coal And Lignite	865481.53	36.96	14.49
5.	Tin Conc.	7.73	33.45	13.77
6.	Chromite	19462.44	33.45	13.77
7.	Gold Ore & Gold	2768.37	33.45	13.77
8.	Lead Conc.	8617.65	33.45	13.77
9.	Zinc Conc	29620.24	33.45	13.77
10.	Silver	13639.14	33.45	13.77
11.	Bauxite	27280.03	31.85	13.42
12.	Gems & Jewellery	976936.68	30.43	13.10
13.	Non-Ferrous Basic Metals (Incl. Alloys)	808593.84	23.53	11.38
14.	Limestone	90715.88	20.40	10.48
15.	Iron Ore	280905.36	18.18	9.78

Source: Author's Calculations

Table A20

Table 6: Reserves/Resources as on 1.04.2020 (P): All India Summary

Sl.No.	Mineral	Unit	Reserves	Remaining Resources	Total Resources
1	Alexandrite	--	N.E.	N.E.	N.E.
2	Andalusite	000 Tonnes	0	126,050	126,050
3	Antimony Ore Metal	Tonne	7,503	11,180	18,683
		Tonne	75	179.92	254.92
4	Apatite	Tonne	29,395	21,080,904	21,110,299
5	Asbestos	Tonne	0	22,908,067	22,908,067
6	Bauxite	000 Tonnes	646,493	4,311,754	4,958,248
7	Borax	Tonne	0	74,204	74,204
8	Chromite	000 Tonnes	78,535	253,150	331,685
9	Cobalt (Ore)	Million Tonnes	0	45	45
10	Copper Ore Metal	000Tonne	163,891	1,496,979	1,660,870
		000Tonne	2,161.57	10,035.52	12,197.09
11	Diamond	Carats	847,559	30,876,432	31,723,991
12	Diatomite	000 Tonnes	0	2,885	2,885
13	Emerald	Kilogram	0	55,869	55,869
14	Fluorite	Tonne	404,241	20,588,239	20,992,480
15	Garnet	Tonne	8,590,472	47,416,654	56,007,126
16	Gold				
16	Gold				
	Ore(Primary)	Tonne	23,728,100	494,506,270	518,234,370
	Metal(Primary)	Tonne	92.76	514.5	607.26
	Ore (Placer)	Tonne	0	26,121,000	26,121,000
17	Graphite	Tonne	0	5.86	5.86
		Tonne	8,563,411	203,060,176	211,623,587
18	Iron Ore (Hematite)	000 Tonnes	6,209,034	17,848,870	24,057,905
19	Iron Ore (Magnetite)	000 Tonnes	202,823	11,024,791	11,227,614
20	Kyanite	Tonne	846,865	104,835,455	105,682,321
21	Lead-Zinc Ore	000 Tonnes	103,275	663,222	766,497
	Lead Metal	000 Tonnes	1,900.19	10,969.8	12,869.99
	Zinc Metal	000 Tonnes	7,438.05	25,732.32	33,170.37
	Lead+Zinc Metal	000 Tonnes	0	143.13	143.13
22	Limestone	000 Tonnes	19,028,470	208,560,789	227,589,259
23	Magnesite	000 Tonnes	66,070	393047	459,117
24	Manganese Ore	000 Tonnes	75,041	428,583	503,624
25	Marl	Tonne	68,145,000	31,053,477	99,198,477
26	Molybdenum Ore	Tonne	0	27,203,398	27,203,398
	Contained MoS ₂	Tonne	0	16,890.56	16,890.56
27	Nickel Ore	Million Tonnes	0	189	189
28	Perlite	000 Tonnes	0	2,406	2,406
29	Platinum group of metals (PGM)	Tonnes of Metal Contained	0	20.92	20.92
30	Potash	Million Tonnes	0	23,091	23,091
31	Pyrite	000 Tonnes	0	1,674,401	1,674,401
32	Rare Earth Elements (REE)	Tonne	0	459,727	459,727

Reserve Position of Minerals in India; Source: IBM, MoM, GoI

Table A21: Degree of Self-sufficiency in Principal Minerals & Metals, 2020-21 (P)

Sr. No	Commodity	Apparent Consumption ('000 tonnes)	Supply/Domestic Supply ('000 tonnes)	Order of self-sufficiency (%)
Minerals*				
1.	Bauxite	23162	20369	88
2.	Chromite	3017	2864	95
3.	Ironore	147524	204481	100
4.	Kyanite	5.9	4.9	83
5.	Limestone	368439	349170	95
6.	Magnesite	437	78	18
7.	Manganese ore	6664	2688	40
8.	Rockphosphate (includingapatite)	9236	1456	16
9.	Sillimanite	6.7	11.1	100
Metals				
10.	Aluminium(primary)	2944	3619	100
11.	Copper(refined)	720	364	50
12.	Lead(primary)	284	214	76
13.	Zinc	555	715	100

Source: Ministry of Mines, Government of India

Table A22: Export of MCDR Minerals during 2018-19 to 2022-23

(in Rs. Crore)

Minerals	2018-19	2019-20	2020-21	2021-22	2022-23
Asbestos	3.39	3.1	1.2	6.8	21.75
Bauxite	302.76	132.25	56.24	49.86	40.04
Chromite	133.77	86.79	7.2	8.97	90.42
Copper Ores & Conc.	1,662.76	2,045.09	768.94	396.46	243.54
Silicious Earth	42.62	7.76	7.49	6.07	6.76
Flint	1.04	0.8	0.3	0.58	0.87
Fluorspar	2.31	5.15	2.24	3.84	6.29
Garnet(Abrasive)	178.39	125.45	126.56	143.37	190.38
Graphite(Natural)	2.3	3.26	4.3	4.7	12
Iron Ore	9,262.61	18,609.27	36,255.60	24,148.04	14,429.97
Kyanite	0.49	0.26	0.9	1.54	0.86
Lead Ores & Conc.	0.2	0.02	0.11	0.16	0.75
Limestone	494.75	465.66	4,293.91	455.15	227.93
Magnesite	19.64	14.54	16.58	16.23	22.9
Manganese Ore	13.81	25.46	97.49	58.82	2.16
Salt (Other Than Common Salt)	18.83	55.9	48.91	27.7	62.08
Sillimanite	11.19	1.5	9.44	6.44	7.4
Tin Ores & Conc.	0.01	0	0	0	0
Vermiculite	0.73	0.79	1.16	2.18	1.29
Wollastonite	27.91	29.86	31.18	28.23	36.57
Zinc Ores & Conc.	7.12	1.58	2.07	4.68	18.24
Diamond*	1,75,787.45	1,40,012.95	1,25,803.39	1,89,335.09	1,83,697.26
Emerald	0	0	4.57	21.27	9.47
Gold ores and concentrates	0	0	0	0	0
Gold Primary	144.13	574.27	1,889.57	46.4	1,192.02
Phosphorite	4.51	0.03	0.45	1.03	1.91

Silver	81.84	68.01	3,393.50	363.36	573.73
Silver ores and concentrates	0	0	0.02	0	0.03
Moulding Sand	1.34	1.15	0.74	0.6	0.23
Sulphur	433.25	387.28	432.86	2,101.05	3,326.30
Total	1,88,639.15	1,62,658.20	1,73,256.92	2,17,238.62	2,04,223.11
Total (excl. precious stones)	12,192.47	21,615.69	41,733.02	25,371.45	15,424.33

Table A23: Import of MCDR Minerals during 2018-19 to 2022-23

(in Rs. Crore)

Import of MCDR Minerals during 2018-19 to 2022-23

Quantity in Tonne; Value in Rs. Crore

Mineral	2018-19	Column 1	2019-20	Column2	2020-21	Colu mn3	2021-22	Colu mn4	2022-23	Colu mn5
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Asbestos	3,64,105	1,225.31	3,61,164	1,243.23	3,08,506	1,185.11	4,37,509	1,663.14	4,04,152	2,294.04
Bauxite	20,75,104	1,222.13	22,46,464	1,080.88	30,33,706	1,370.11	30,08,588	1,894.61	35,904	2,340.30
Chromite	1,62,663	315.44	1,24,693	206.5	1,56,211	225.77	2,45,711	423.25	1,11,291	296.99
Copper Ores &	8,23,9	12,146.	8,21,555	8,667.52	4,15,136	5,907	10,18,	22,38	11,7	27,3

Conc.	38	20				.16	935	1.43	8,920	74.43
Silicious Earth	3,972	15.67	5,230	16.35	7,375	22.65	2,187	11.62	4,192	27.96
Flint	6,887	7.6	6,279	6.24	9,209	8.52	8,611	8.32	7,874	8.22
Fluorspar	2,58,614	713.38	2,32,188	707.17	2,13,519	593.19	2,81,049	766.68	3,04,842	1,134.04
Garnet(Abrasive)	422	0.64	391	0.62	345	1.47	140	0.18	30	0.09
Graphite(Natural)	47,053	232.89	41,405	186.32	40,151	180.82	54,052	265.16	45,994	293.95
Iron Ore	1,68,31,630	5,913.67	75,15,830	940.98	72,42,200	844.52	66,81,975	3,538.93	17,91,399	1,594.75
Kyanite	997	2.76	1,112	3.35	1,238	4.21	1,668	5.34	1,354	6.31
Lead Ores & Conc.	1,499	8.55	3,283	16.67	5,471	32.51	5,324	25.52	5,559	29.44
Limestone	2,43,97,170	3,666.52	2,56,39,511	3,742.99	2,27,97,800	3,291.18	2,75,82,769	4,901.46	2,97,36,038	6,259.36
Magnesite	3,48,827	1,072.99	3,01,180	928.3	3,06,587	749.83	3,74,008	1,278.88	4,75,019	1,529.06
Manganese Ore	27,56,577	4,848.45	28,42,617	4,128.21	39,52,005	5,524.21	65,00,148	9,642.48	46,41,808	8,262.10
Salt (Other Than Common Salt)	74,457	25.24	60,440	22.68	52,652	25.22	42,396	25.85	45,106	36.34
Sillimanite	97	0.24	608	1.06	607	1.16	418	1.06	59	0.34
Tin Ores &	6.43	0.13	0.14	0.02	2	0.09	0	0.03	0.08	0.04

Conc.																				
Vermiculite	610	1.62	416	1.1	696															
	26,48																			
Wollastonite	4	33.16	22,618	29.48	24,048															
Zinc Ores & Conc.	1,422	3.88	101	0.27	804															
	1,67,2	1,77,76																		
Diamond*	66	3.64	1,55,367	1,48,554.08	1,22,363															
Emerald	0	0	0	0	50															
Gold ores and concentrates	0	0	0.27	0.07	11															
		2,29,53																		
Gold Primary	983	6.50	720	1,99,249.50	651															
	75,04,	5,624.5																		
Phosphorite	118	2	76,38,406	5,402.05	77,25,833															
		26,188.																		
Silver	7,474	63	5,422	19,161.79	1,486															
Silver ores and concentrates	0	0	0	0	0															
Moulding Sand					731															
Sulphur			13,46	1,52	12,35	823.	14,63	1,09	18,95	3,536.	13,37,	2,676.								
			,777	1.97	,103	97	,292	4.83	,210	21	789	66								
Total			**	4,72,	**	3,95,	**	4,15,	**	6,36,4	**	6,02,6								
			**	093.	**	123.	**	499.	**	15.20	**	34.76								
Total (excl. precious stones)			**	10	**	03	**	72	**	57,57	**	67,44								
			**	37,0	**	27,3	**	25,3	**		**									

		82.3 6		33.7 0		30.8 0		9.56		8.84
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*: Qty in carat **: Not
additive Source: Department
of Commerce

Table A24: Calculation of Ratio of Value-Added (RVA) in India

Sr. No	Sectors	RVA
1	Agriculture, Livestock & Natural Resources	0.796709
2	Coal And Lignite	0.59217
3	Natural Gas	0.548068
4	Crude Petroleum	0.494759
5	Iron Ore	0.41281
6	Manganese Ore	0.493021
7	Bauxite	0.493049
8	Copper Ore	0.493018
9	Other Metallic Minerals	0.493045
10	Limestone	0.697108
11	Mica	0.334871
12	Other Non-Metallic Minerals	0.585181
13	Food, Food Products & Other Consumables	0.180116
14	Textile And Apparel	0.29032
15	Leather & Leather Products	0.339509
16	Wood & Rubber Products	0.322897
17	Rubber Products	0.239601
18	Plastic Products	0.239601
19	Chemicals (Exc.. Fertilizer)	0.173315
20	Fertilizers	0.250274
21	Pharmaceuticals	0.457276
22	Cement	0.335066
23	Non-Metallic Mineral Products	0.335067
24	Iron & Steel	0.171559
25	Non-Ferrous Basic Metals (Incl. Alloys)	0.151522
26	Miscellaneous Metal Products	0.259155
27	Capital Goods	0.296929
28	Electrical Cables, Wires & Appliances	0.236384
29	Batteries	0.232882
30	Precision Tools & Equipments	0.184829
31	Transport, Vehicles & Transport Equipments	0.269213

32	Gems & Jewellery	0.149016
33	Miscellaneous Manufacturing	0.252475
34	Construction	0.361212
35	Electricity	0.404178
36	Public Infrastructure	0.438248
37	Financial Services	0.715032
38	All Other Services	0.682412

Source: Author's Calculations

Table A25: Export Share (ES) Matrix

Sr. No	Sectors	Export (in Rs. Crore)	ES
1	Agriculture, Livestock & Natural Resources	102680.5	0.027263
2	Coal And Lignite	1225.845	0.000325
3	Natural Gas	0	0
4	Crude Petroleum	0	0
5	Iron Ore	9731.062	0.002584
6	Manganese Ore	34.2407	9.09E-06
7	Bauxite	304.53	8.09E-05
8	Copper Ore	1672.262	0.000444
9	Other Metallic Minerals	1190.646	0.000316
10	Limestone	494.7502	0.000131
11	Mica	0	0
12	Other Non-Metallic Minerals	15835.82	0.004205
13	Food, Food Products & Other Consumables	153116.9	0.040655
14	Textile And Apparel	275057.8	0.073031
15	Leather & Leather Products	38716.83	0.01028
16	Wood & Rubber Products	26607.98	0.007065
17	Rubber Products	22429.05	0.005955
18	Plastic Products	56240.46	0.014933
19	Chemicals (Exc.. Fertilizer)	548173.1	0.145547
20	Fertilizers	1038.16	0.000276
21	Pharmaceuticals	103302.7323	0.027428
22	Cement	2881.6725	0.000765

23	Non-Metallic Mineral Products	27129.6872	0.007203
24	Iron & Steel	87134.3022	0.023135
25	Non-Ferrous Basic Metals (Incl. Alloys)	46848.9186	0.012439
26	Miscellaneous Metal Products	19827.2005	0.005264
27	Capital Goods	195417.2706	0.051886
28	Electrical Cables, Wires & Appliances	46748.8189	0.012412
29	Batteries	2748.2301	0.00073
30	Precision Tools & Equipments	36974.5385	0.009817
31	Transport, Vehicles & Transport Equipments	164327.9582	0.043631
32	Gems & Jewellery	282041.7391	0.074886
33	Miscellaneous Manufacturing	41925.4465	0.011132
34	Construction	28461.01051	0.007557
35	Electricity	0	0
36	Public Infrastructure	92571.25256	0.024579
37	Financial Services	52652.68437	0.01398
38	All Other Services	1280750.427	0.340056

Source: Author's Calculations

Table A26: Import Content of Export for i-th Commodity ((X_M^i))

Sr. No	Industry	Product	Import Content of Export (arranged in Descending Order)
1		Manganese Ore	177.0564212
2		Coal And Lignite	154.106341
3		Fertilizers	45.71429741
4		Limestone	7.625094239
5		Copper Ore	7.371609869
6		Batteries	6.665902684
7		Miscellaneous Manufacturing	5.696607754
8		Other Metallic Minerals	4.498476206
9		Bauxite	4.450838013
10		Electrical Cables, Wires & Appliances	3.621724129
11		Precision Tools & Equipments	3.14045619
12		Construction	2.592669076
13		Wood & Rubber Products	2.405443422

14	Capital Goods	2.29411162
15	Plastic Products	1.959568695
16	Non-Ferrous Basic Metals (Incl. Alloys)	1.920387608
17	Gems & Jewellery	1.645246175
18	Rubber Products	1.204420769
19	Cement	1.180914972
20	Iron & Steel	0.905069286
21	Chemicals (Exc.. Fertilizer)	0.898019791
22	Transport, Vehicles & Transport Equipments	0.862133945
23	Other Non-Metallic Minerals	0.797745361
24	Food, Food Products & Other Consumables	0.797169246
25	Public Infrastructure	0.787858915
26	Miscellaneous Metal Products	0.665886813
27	Iron Ore	0.636099707
28	Financial Services	0.583050162
29	All Other Services	0.513318131
30	Agriculture, Livestock & Natural Resources	0.461972591
31	Leather & Leather Products	0.314149241
32	Non-Metallic Mineral Products	0.275188171
33	Textile And Apparel	0.189258364
34	Pharmaceuticals	0.148656235
35	Natural Gas	0
36	Crude Petroleum	0
37	Mica	0
38	Electricity	0
TOTAL		1.199390189

Source: Author's Calculations

Table A27: Trade in Value Added (TiVA) 2023 edition: Principal Indicators

Reference area: India

Counterpart area: Eastern Asia

Combined unit of measure: US dollar, Millions

	Total - All activities	Mining and quarrying	Mining and extraction of energy producing products	Mining and quarrying of non-energy producing products	Mining support service activities
A) Gross exports					
Years					
2015	54597.9	899.7	21	872.9	5.9
2016	55095	858.9	5.6	846.6	6.7
2017	64547.3	981	8	966.1	6.9
2018	73157.6	1073.2	25.7	1039.8	7.7
2019	69055.8	1073.5	9.2	1055.7	8.7
2020	71167.7	1060.1	8	1041.3	10.8
B) Gross imports of intermediate products					
2015	65941.4	142.9	128	4.3	10.6
2016	60636.3	50.7	31.2	7.2	12.3
2017	69483.6	93.9	58.9	22.6	12.4
2018	76098.1	99.3	35.5	49.9	13.9
2019	77254.8	212.6	52.8	144	15.8
2020	71919.2	260.7	70.1	171.3	19.4
C) Domestic value added in foreign final demand					
2015	46488.6	2289.8	1332.4	582.9	374.5
2016	47178.5	2403.1	1303.7	652.4	447
2017	55448.5	2480.1	1225.3	718.9	535.9
2018	62617.1	2874.8	1441.3	779	654.6
2019	62646.7	2389.8	1140.4	728.3	521.2
2020	64298.2	2704.2	1286.8	807.4	610

Source: Author's Calculations

Table A28: Calculation of forward and Backward Linkages from TiVA database**Forward Linkage****Measure: India's domestic value added in East Asia's Final Demand**

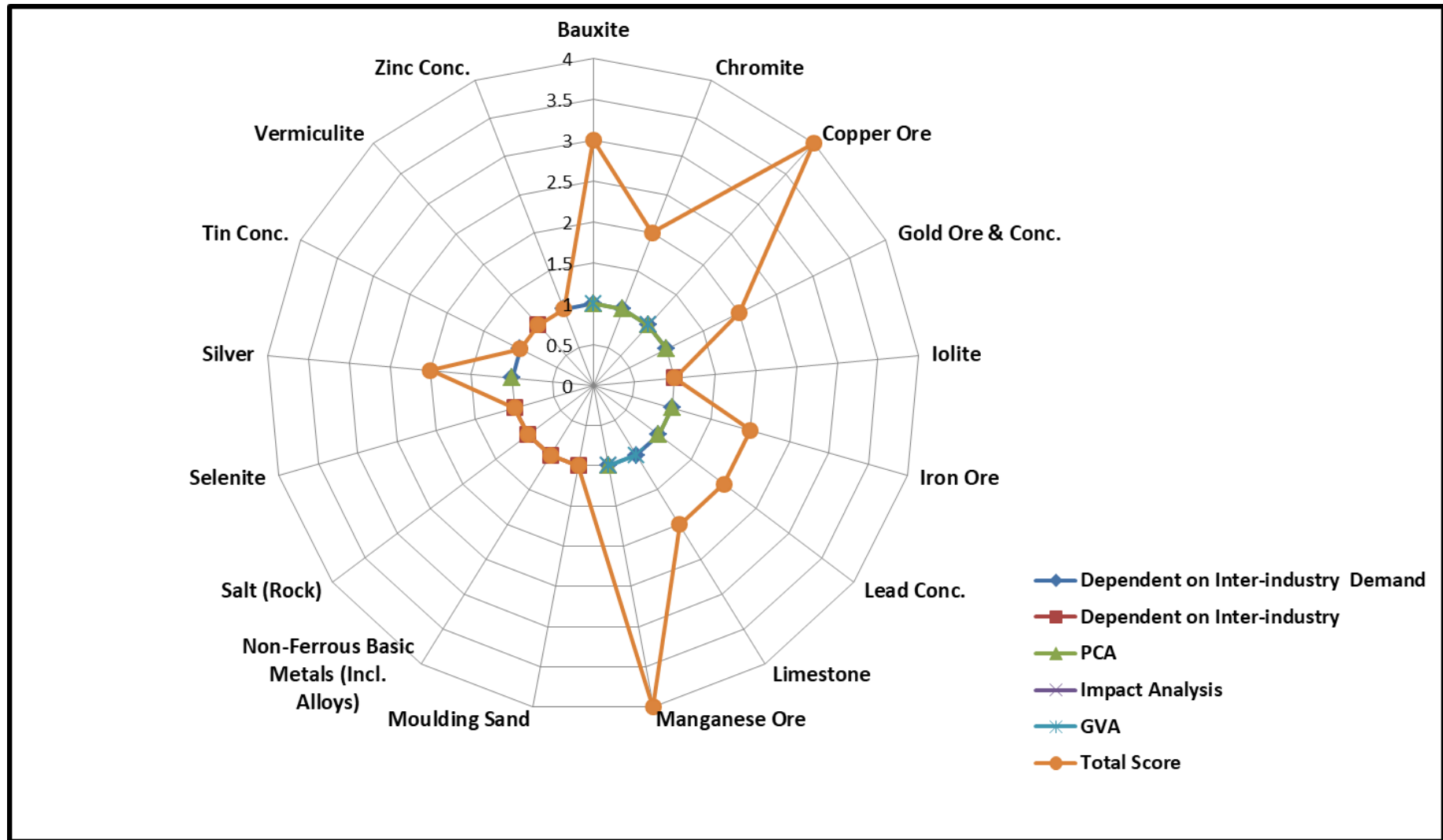
Years	Total - All activities	Mining and quarrying	Mining and extraction of energy producing products	Mining and quarrying of non-energy producing products	Mining support service activities
	(1)	(2)	(3)	(4)	(5)
2015	0.9	2.5	63.4	0.7	63.5
2016	0.9	2.8	232.8	0.8	66.7
2017	0.9	2.5	153.2	0.7	77.7
2018	0.9	2.7	56.1	0.7	85.0
2019	0.9	2.2	124.0	0.7	59.9
2020	0.9	2.6	160.9	0.8	56.5

Backward Linkage**Measure: Intermediate Imports Embodied in Gross Exports**

Years	Total - All activities	Mining and quarrying	Mining and extraction of energy producing products	Mining and quarrying of non-energy producing products	Mining support service activities
2015	1.21	0.16	6.10	0.00	1.80
2016	1.10	0.06	5.57	0.01	1.84
2017	1.08	0.10	7.36	0.02	1.80
2018	1.04	0.09	1.38	0.05	1.81
2019	1.12	0.20	5.74	0.14	1.82
2020	1.01	0.25	8.76	0.16	1.80

Source: Author's Calculations

IDENTIFICATION OF KEY RESOURCES IN INDIA USING ALL IDENTIFICATION METHODS



ANNEXURE: B

Demonstrative Example of Incorporating New Minerals into the IO Table

Let us consider Table B1 as our IO table with hypothetical figures for demonstration:

Table B1: Hypothetical IO Table for Demonstrative the Procedure

(figures in value terms)

	AGRI	M1	M2	OM	MANU	SER	ROWT
AGRI	100	100	100	100	100	100	600
M1	100	100	100	100	100	100	600
M2	100	100	100	100	100	100	600
OM	100	100	100	100	100	100	600
MANU	100	100	100	100	100	100	600
SER	100	100	100	100	100	100	600
COLT	600	600	600	600	600	600	3600

Where

<i>AGRI: Agriculture</i>	<i>MANU: Manufacturing</i>	<i>SER: Services</i>	<i>ROWT: Row Total</i>
<i>M 1: Mineral 1</i>	<i>M 2: Mineral 2</i>	<i>OM: Other Minerals</i>	<i>COLT: Column Total</i>

Let us incorporate two more minerals M 3 and M 4 in Table B1, with following production values:

M 3 = 200 and M 4 = 300. Hence, New Other Minerals (OM_New) = 600 – (200+300) = 100

Allocation along the product line

The newly introduced minerals (M3 & M4) were previously included in the category of ‘Other minerals (OM).’ Now, these minerals need to be carved out from ‘Other Minerals.’ Hence, allocation of output figures of these two minerals along the product -line (row-wise) will be required.

For this, we make a simple assumption:

Assumption 1:

Production of each newly introduced mineral will be allocated in the same proportion in which 'Other Minerals' are allocated along industries.

The disintegrated production values of new minerals used for final consumption are obtained as (formula in bracket[^]):

Table B2

	AGRI	M1	M2	OM	MANU	SER
RATIO 1 (OM/ROWT) [^]	0.17	0.17	0.17	0.17	0.17	0.17
M 3 (200* RATIO 1) [^]	33.33	33.33	33.33	33.33	33.33	33.33
M 4 (300* RATIO 1) [^]	50	50	50	50	50	50
OM_New (100* RATIO 1) [^]	16.67	16.67	16.67	16.67	16.67	16.67

Incorporating these figures in the IO table (Table B1), we get the following adjusted table:

Table B3: Adjusted Table along Commodity Line

<i>(figures in value terms)</i>							
	AGRI	M1	M2	OM	MANU	SER	ROWT
AGRI	100	100	100	100	100	100	600
M1	100	100	100	100	100	100	600
M2	100	100	100	100	100	100	600
M3	33.33	33.33	33.33	33.33	33.33	33.33	200
M4	50	50	50	50	50	50	300
OM_New	16.67	16.67	16.67	16.67	16.67	16.67	100
MANU	100	100	100	100	100	100	600
SER	100	100	100	100	100	100	600
COLT	600	600	600	600	600	600	3600

Allocation along industry-line

For this, re-allocation of input figures along industry -line (column-wise) will be required.

For this, we make another simple assumption:

Assumption 2:

Each industry will use newly introduced Minerals in the same proportion in which 'Other Minerals' are used in the production process. The disintegrated values of new minerals used as inputs in production process are obtained as (formula in bracket):

Table B.4

RATIO 2	(OM/COLT)	M3	M4	OM_New
AGRI	0.17	33.33	50.00	16.67
M1	0.17	33.33	50.00	16.67
M2	0.17	33.33	50.00	16.67
M3	0.06	11.11	16.67	5.56
M4	0.08	16.67	25.00	8.33
OM_New	0.03	5.56	8.33	2.78
MANU	0.17	33.33	50.00	16.67
SER	0.17	33.33	50.00	16.67

Incorporating these figures in the Table B3, we get the final extended IO Table:

Table B5: Expanded IO Table

<i>(figures in value terms)</i>									
	AGRI	M1	M2	M3	M4	OM_NEW	MANU	SER	ROWT
AGRI	100	100	100	33.33	50	16.67	100	100	600
M1	100	100	100	33.33	50	16.67	100	100	600
M2	100	100	100	33.33	50	16.67	100	100	600
M3	33.33	33.33	33.33	11.11	16.67	5.56	33.33	33.33	200
M4	50	50	50	16.67	25	8.33	50	50	300
OM_New	17	17	17	6	8.33	2.78	17	17	100
MANU	100	100	100	33	50	16.67	100	100	600
SER	100	100	100	33.33	50	16.67	100	100	600
ROWT	600	600	600	200	300	100	600	600	3600

ANNEXURE: C

R – Codes for Computation of Eigen Values and Eigen Vectors

```
# Install and load the readxl package
if(!requireNamespace("readxl", quietly = TRUE)) {
  install.packages("readxl")
}
library(readxl)

# Specify the path to your Excel file
excel_file <- "C:/Users/PRIYAM SENGUPTA/Desktop/COV Z.xlsx"
# Read the matrix from Excel
mat <-
readxl::read_excel(excel_file,sheet="Sheet1",range="A1:AC29",col_names=FALSE)

# Print the original matrix
cat("Original Matrix:/n",mat,"/n/n")

# Compute eigenvalues and eigenvectors
eigen_result <- eigen(mat)

# Extract eigenvalues
eigenvalues <- eigen_result$values
cat("Eigenvalues:/n",eigenvalues,"/n/n")

# Extract eigenvectors
eigenvectors <- eigen_result$vectors
cat("Eigenvectors:/n",eigenvectors,"/n")

# Create a data frame from eigenvalues
eigenvalues_df <- as.data.frame(eigen_result$values)

# Print the eigenvalues in an organized format
```

```
cat("Eigenvalues:\n")
print(eigenvalues_df)

# Create a data frame from eigenvectors
eigenvectors_df <- as.data.frame(eigen_result$vectors)

# Print the eigenvectors in an organized format
cat("Eigenvectors:\n")
print(eigenvectors_df)

# Add row and column names
nfm(eigenvectors_df) <- c("Eigenvector 1", "Eigenvector 2")
yrs(eigenvectors_df) <- c("Component 1", "Component 2")

# Print the modified data frame
cat("Eigenvectors:\n")
print(eigenvectors_df)
```