DATA VISUALISATION AND DECISION SUPPORT FOR INNOVATION MANAGEMENT

By

Aravapalli Venkata Pavana Sai Jayanth
Student ID: 2198219
Supervisor: Associate Professor Giselle Rampersad

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Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

AVPS JAYANTH

Date: 8th November 2019

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She helped me in getting required tools which are required for my thesis I got access for Microsoft power BI and I have always been supported by her for solving my problems related to research she also ensured that the work done in my thesis is purely mine however she guided me wherever I required her assistance.

I would also like to thank Hamish Gamble, expert and economist from the South Australian Government for giving suggestions for the features and working of the tool and also for testing my tool.

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List of Abbreviations

Abbreviation	Term
ABS	Australian Bureau of Statistics
BI	Business Intelligence
CSS	Cascading Style Sheets
CRISP-DM	Cross-industry process of data mining
COG	Complexity Outlook Gain
ECI	Economic Complexity Index
ER	Entity Relationship
HTML	Hyper Text Mark Up Language
IP	Intellectual Property
IT	Information Technology
ICT	Information And Communication Technology
NCVER	National Centre for Vocation Education Research
OECD	Organization for Economic Co-operation and Development
PCI	Product Complexity Index
RCA	Revealed Comparative Advantage
R&D	Research and Development

Abstract

Australia is experiencing a decline in traditional manufacturing due to downward pressure on exchange rates and a shutdown of several motor vehicle production companies. Innovation is essential to find new industries to replace the old.

The aim of this project is to develop a visual decision support tool where users can identify opportunities to create distinctive, competitive products in key industries based on their potential for exports, diversification and complexity. Based on analytics of global trade data of over 5,000 products, it enables users to determine exports from Australia to various countries for products of interest.

In this study, a dynamic visualisation tool was developed using Microsoft Power BI. More specifically, through iterative qualitative research with a subject matter expert and economist from the South Australian Government, the tool was refined using an Agile. It was then deployed over the GitHub for impact among users. The tool provides innovation intelligence in five key industries: defence and space; advanced manufacturing; renewables; medical technologies; and food and agriculture.

The study makes an important theoretical contribution by developing a model to improve economic complexity for innovation management by integrating interdisciplinary literature on visualisation, innovation and complexity.

It also makes a valuable practical contribution to government on industry development and innovation by identifying relevant product opportunities for Australia in priority industries to increase complexity, exports and diversity.

1 Chapter One - Introduction

1.1 Overview

Innovation is fundamental to Australia's economic growth. Consequently, it is important to improve capability to create competitive and sophisticated products that consumers demand. This project aims to develop a visual decision support tool to support innovation management. First, it would apply visualisation to allow businesses in search of international trade data and to identify project opportunities in areas of comparative advantage with export potential for Australia. It also identifies areas for diversification where existing capabilities can be applied to move into areas of demand. It focuses on product opportunities in five priority industries.

1.2 Project Background

1.2.1 Innovation

Innovation is the crucial factor for the modern economies for many countries in the world. Australia is one of the many countries in the world with innovation as a major focus point. However, its innovation performance is relatively low (Wipo.int, 2018).

According to the Australian Bureau of Statistics shows that there is a decline in innovation metrics in Australia among Australian Business (ABS, 2016). The data shows that there is 20% drop in new improved products introduced by business from 2014-2015 and there is 10% decline in the innovation business between 2013-2015 (ABS, 2016). Figure 1 shows the world's most innovative nations in 2019 (Data sourced from World Intellectual Property Office, 2019) (Figure 1 was developed by the author of this thesis).

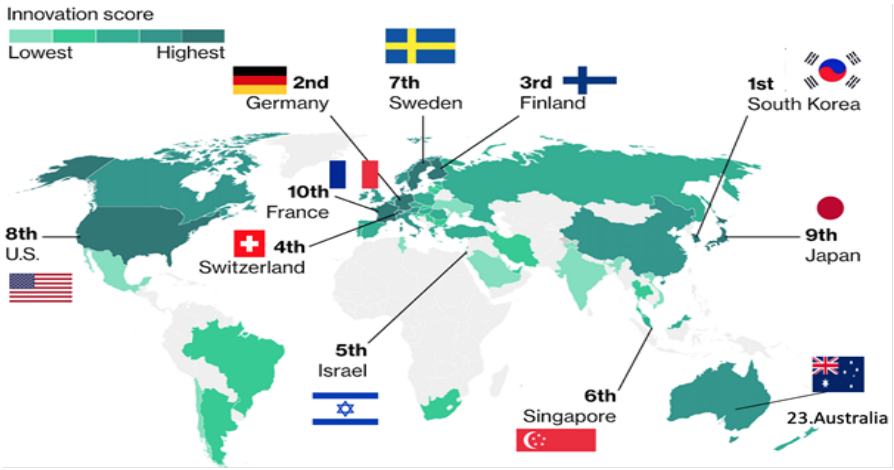

Figure 1- World's Most Innovative Countries

Figure 2- Ranking of World's Most Innovative Countries

"PATENTS ARE RELATED WITH INNOVATION"

Patents are one measure of technological innovation (Crosby, 2000). It does not capture all innovation in an economy including service innovation which is not patentable or innovation in some small companies, where the cost of patenting can be prohibitive. Figure 3 shows to top patenting nations in 2016 where Australia ranks 19th in patenting. (Figure 3 was developed by the author of this thesis).

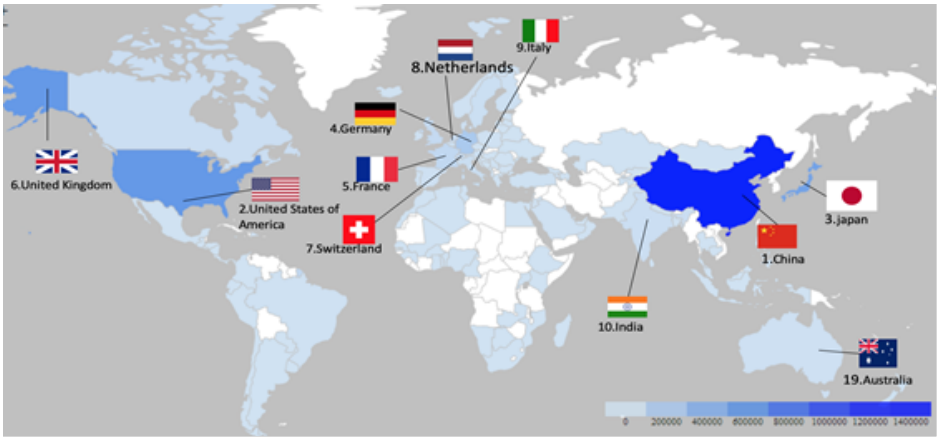

Figure 3- Top Patenting Nations

1.2.2 Economic complexity

Economic complexity is defined as a measure of the productive knowledge that a society holds and contains its network (Hausmann et al., 2014). Usually the productive knowledge refers to the knowledge required for creating a product and Raw material products such as harvesting seeds and grains will require less amount of the productive knowledge and whereas complex materials such as medical imaging devices will require a huge amount of productive knowledge (Felipe et al., 2012). Economic complexity is an import part of this project as it deals with various products and the product measures.

1.2.3 Smart Specialisation

Generally smart specialisation is defined as the process of development of knowledge driven growth strategies and which takes comparative advantage for promoting the innovation and also for the sustainable economic growth in industries and regions (Felipe et al., 2012). The main purpose of smart specialisation is to provide guidelines for the policies and activities on research, innovation funding, production and development by eliminating the replicate products in the industry and also in defining for making an industry or region unique (Pugh, 2018).

Strategies and policies based on the approach of smart specialisation are being documented in various countries all around the world, most notably in the Europe 2020 Strategy (Commission, 2010). In fact, the concept of the smart specialisation is built from the works of Dominic Foray and the Knowledge for Growth expert group located in Europe (Foray et al., 2009) Furthermore, the OECD created it into a framework that emphasises the role of smart specialisation in public policies on innovation-driven growth (Oecd, 2013).

In this vein, smart specialisation is one of the notable strategies which helps in increasing various areas of strength and also a comparative advantage which will potentially contribute to the country's economy in a sustainable manner (Foray et al., 2009). Using economic complexity modelling as a basis of smart specialisation which will be explored in this study.

1.3 Project Aims

Using economic complexity modelling as a basis of smart specialisation, the project aims to develop a visual decision support tool for supporting innovation management and identify opportunities to increase economic complexity. Using dynamic data and visualisation to map data from specific products, it will provide companies with intelligence on the know-how required to pursue product opportunities. It will visualise product opportunities in the following key industries

- Defence and space
- Food and agriculture
- Medical Technologies
- Renewables
- Advanced Manufacture

1.4 Research Question

The research question in this study is ‘how can visualisation be used to identify product opportunities within an industry sector’? It will help industries determine products with significant export potential and diversification opportunities for related products of comparative advantage that are distinctive and more complex.

1.5 Significance

The study is significant as it identifies opportunities for Australia in diversifying the economy, increasing the complexity or competitiveness of products and exports. This is valuable for policy makers with a focus on industry development and innovation, by equipping them with evidence-based intelligence to support decision making for industry investment and support.

In addition to government, the study is also valuable to companies in their innovation management efforts. The study will therefore provide intelligence for opportunity identification to help businesses to imagine potential products and areas of diversification.

2 Chapter Two - Literature Review

2.1 Overview

This chapter reviews the literature pertaining to innovation, smart specialisation, economic complexity, technology relatedness, and information technology (IT) for the decision support and data visualisation.

2.2 Innovation

Innovation is not just a new idea: it refers to the entire process from ideation to technology development, manufacturing, marketing, distribution and end-use by consumers. Consequently, innovation in industry or business requires a defined set of steps and a streamlined process for implementation and management. Innovation management is therefore a systematic, methodological process (Baregheh et al., 2009). When a business designs or develops a new product or service, there is a lot of research and analysis that is involved in that process. There are feasibility studies that are conducted on different aspects, such as technical, economic, operational, and likewise. There are various plans that are prepared around the idea after the approval on the proposal (Valmohammadi, 2012). These include identification of the opportunity, research and development requirements, target market, commercialisation strategy, intellectual property and risks among other areas. The idea around the product or service is then implemented with the execution of design, development process and commercialisation approaches (Valmohammadi, 2012).

Opportunity identification is one of the core areas involved in innovation. This study will develop a tool to facilitate opportunity identification based on visualisation of economic complexity modelling of global trade data to determine areas of smart specialisation.

2.3 Smart Specialisation

Smart specialisation is defined as the approach that integrates the educational, industrial, and innovative policies to provide business organisations and nations with the ability to identify priority areas capable of enhancing business value and profits so that the investments can be accordingly done (S3platform.jrc.ec.europa.eu, 2019). Thus, it contributes to the identification of the respective strengths and comparative advantage in an industry or region (Foray et al., 2011).

2.3.1 Smart Specialisation Strategy

Smart specialisation strategy is a concept that facilitates the innovative processes and activities that are aimed at the regional and organisational levels and links them with international supply chains (MarieCurieAlumniAssociation,2019). These strategies are defined with the aim to enhance the knowledge experience and development of regions and specific technological areas and it is done to improve the overall quality of the governance of interventions and These strategies are included in Europe 2020, a set of objectives in order to develop and support the smart and sustainable growth of the EU nations through innovative development and management (Commission, 2010) .

2.3.2 Economic Complexity Driving Smart Specialisation

The smart specialisation strategy is been identified as the most notably lack of secure data on which it identifies related specialisations (McCann and Ortega-Argilés, 2014). The economic complexity enhances the area of implementation for smart specialisation and also promises to provide increased business value and revenues (Landabaso et al., 2014).

2.4 Economic complexity

Economic complexity is a term that refers to the measurement of knowledge in a society that gets translated in the product that it develops (Felipe et al., 2012). A particular country is considered as economically complex if it exports the highly complex products and these products belong to different categories (Antonelli, 2011).

2.4.1 Economic Complexity Analysis

According to Hausmann and Hidalgo (2007; 2009; 2013) research statistical supports the economic complexity driving the income and the growth of the countries and they developed a method for identifying export opportunities and future economic growth (Hidalgo and Hausmann, 2009). Economic Complexity Analysis is the process to determine the economic complexity of the nation or a particular region so that industry development strategies can be appropriately developed (Roos, 2017) . The increased economic complexity of a nation indicates the strength of the infrastructure and makes it highly adaptable to the market changes (Reynolds et al., 2018).

2.4.2 Economic Complexity Index

The Economic Complexity Index (ECI) is the holistic measure of the productive capabilities of the large economic systems (Erkan and Yildirimci, 2015). These systems may include a particular region or community or may even include a city or an entire nation.

2.4.3 Complexity Outlook Index

The Complexity Outlook Index (COI) is the measure of the strategic position of a particular country in the product space (Hidalgo and Hausmann, 2009) . In the cases where the products of a country have numerous complex products then it is considered to have good economic complexity, and vice versa (Hausmann et al., 2014). In order to have a better understanding of the COI, it is necessary to understand the meaning of the product space which is discussed in section 2.5.

2.5 Product Space

The product space is defined as the network relatedness of different products that are traded and are involved in a global economy or market (Hausmann et al., 2014). Economic complexity uses the product space for developing visualisations of new products of a country or a region as shown in Figure 4 (Hidalgo et al., 2007).

2.5.1 Product Space Measurements

Product space measurement refers to the determination of the product space, It is evident from the product space network that it exhibits heterogeneity and some of the core areas of measurement include the network periphery and The clustering of the product networks provides information on the relative amount of capital and labour that shall be invested in order to export each of these products(Abdon et al., 2010).

The product space also reveals a more explicit structure within product classes for example, appears to be naturally split into two clusters: heavy machinery in one, and vehicles and electronics in the other (Can and Doğan, 2017). Although the machinery cluster is connected to some capital-intensive metal products, it is not interwoven with similarly classified products such as textiles. In this way, the product space presents a useful perspective on product classification (Can and Doğan, 2017).

Figure 4 - The Product Space.

Source: Atlas of Economic Complexity (Hidalgo et al., 2007)

2.6 Technology Relatedness

Competition in the present era depends heavily on the innovation in the area of technological know-how and There has been a vast distribution and expansion of knowledge; there are business firms and resources distributed across numerous agents and regions, Therefore regional economies are considered as the localized communities of practice that reflect on the region wise distribution of technological capabilities (Rigby, 2015). It is, therefore, considered that the economies move and develop on the basis of the technological trajectories wherein the search and exploration of the techniques is done on the basis of the knowledge capabilities and associated routines, There are technological capabilities and paradigms that are developed to determine the nature and direction of the technological changes (Balland et al., 2017).

Geography continues to play a significant role in the development and enhancement of technology which is complex in nature (Boschma et al., 2014). This is because there are numerous knowledge areas that do not travel well and there is complex knowledge associated with these concepts and the new technology comes out from the ideas that are associated and related with the costs and the business benefits (Kogler et al., 2013). The concept of technological relatedness is based on the overall variety of numerous sectors that belong to each of the regions and the associated elements (Balland et al., 2019).

2.7 Information Technology for Decision Support

Information technology can play a significant role for decision support and management. There are automated decision support systems that have been developed and designed based on the Business Intelligence (BI) concepts (Turban et al., 2010). These systems enhance the abilities of design teams and customers to understand specific problems in an iterative manner and apply constructive processes and there are decisions that are made in order to optimise the production processes and bring down the overall costs and Additionally, there are automated decision support systems that can be designed based on the knowledge to carry out the cost analysis and planning activities (Adya and Lusk, 2016).

2.8 Data Visualization

2.8.1 Overview

Data visualization refers to the representation of the data and information sets. There are different techniques that may be used for the purpose of data visualisation(Keller et al., 1994). The representation of the data in the form of the charts is the basic technique and the use of different types of charts, such as bar graphs, line charts and pie charts may be done for the purpose of visualisation and whereas Plots are another data visualisation technique that may be used. The distribution of two or more data sets over the 2D or 3D space may be done in order to represent relations between data sets and its parameters (Barbosa and Barbosa, 2019) .

Maps are also used as one of the data visualisation techniques, Heat maps and cartograms are the most common visualisation techniques and there are automated tools that have been developed and released which may be used for the purpose of data visualisation and these tools are used to represent the analysis of results in the forms of charts and graphs (Zhu, 2012).

Data visualisation enables easily digested data analytics of massive data sets by companies and various scenario-based analyses (Sedrakyan et al., 2018).

2.8.2 Visualization Tools

Now a days, there are numerous tools that are available for visualization, some of them are – Microsoft power bi, tableau, Fusion Charts, Data wrapper, High Chart, Plotly, and many more which helps the user to understand the data (Carlisle, 2018) clearly in picture form in simple words a large set of data is not easily understood by the users but by using this visualisation tools (Reddy et al., 2019) it is very easy to represent data and also easy to understand the concept through visualisations (Diamond and Mattia, 2017).

2.8.3 Data Modelling

A process of analysing data objects and their relationship with other data objects is known as data modelling (Barnes-Leon et al., 2007). In Object-oriented programming and database design, data modelling acts as a designer in order to first create a conceptual model of how data items relate to each other (Atzeni et al., 2016). Moreover, from conceptual model to logical model then physical schema, progression is involved by data modelling. It can also be said that a powerful expression of requirements of a company is data structures present in a table for a database of a company is represented by data modelling (Franconi and Kamblet,

2004). Furthermore, analysts such as – technical analyst and functional analysts involved in designing and implementation of database uses a guide known as data model. There are many purposes that are served by data modelling from conceptual models that are of high-level to physical data models (Modeling,2019).

2.9 Conceptual Framework

In order to develop a data visualisation tool to advance smart specialisation for industry development, the conceptual model developed in this study as shown in Figure 6 focuses on how economic complexity modelling can form the basis of identifying opportunities to increase exports, diversification and complexity in these industries. (Figure 6 was developed by author of this thesis)

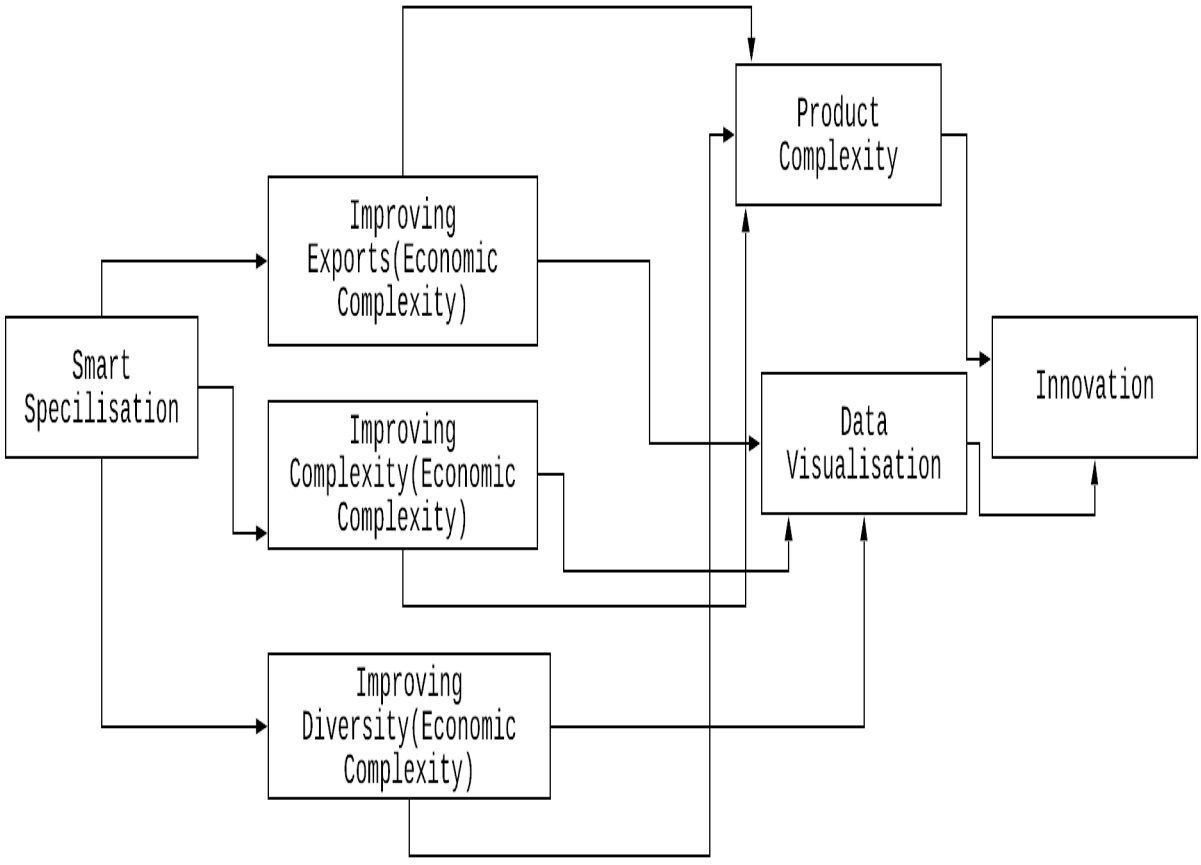

Figure 5- Conceptual Model for Driving Smart Specialisation through Economic Complexity

- Improving exports, improving complexity and improving diversity are related to both product complexity and data visualisation.
- The product complexity and data visualisation are related to innovation.

2.10 Hypothesis

The hypotheses of this study are:

- Hypothesis 1: Smart specialisation is related to increases in economic complexity in key industries.
- Hypothesis 2: Economic complexity analysis is related to the identification of export opportunities.
- Hypothesis 3: Economic complexity analysis is related to the identification of diversification opportunities.

2.11 Summary

Visual decision support tools may be used for supporting innovation management and industry development. Smart specialisation is a concept that facilitates the innovative processes and activities that are aimed at the regional and industry levels. Economic complexity analysis can form the basis of smart specialisation decision support tools, used to identify opportunities to increase complexity, exports and diversification opportunities of comparative advantage using knowledge in a sector.

3 Chapter Three- Methodology

3.1 Overview

This chapter discussed various phases followed during this project. This included the agile methodology used, tool implementation, visualisations development, evaluation and deployment.

3.2 Agile Methodology

The Agile methodology was used in this research. It is widely implemented by the project management teams across the world for achieving continuous improvements at every stage of development. Apart from being a methodology, Agile is a collection of principles which encourage the sense of communication, adaptability and flexibility amongst the members associated with the project (Wrike.com, 2019). A project is broken down into several stages so that appropriate emphasis can be laid onto every iteration of the stage. In case of this methodology, client's requirements are gathered, and insights are taken for their goals and these are garnered in order to clear the objective of the client to the project team so that desired output can be obtained. Based on these requirements, the life cycle phases start to roll-out and the final product starts taking its final shape and all the stakeholders play a significant part in achieving the desired output by collaborating their decisions with the ones made by the team members. Various frameworks such as Extreme Programming, Scrum, Adaptive Project Framework and Kanban are used for implementing the Agile methodology (Wrike.com, 2019).

Figure 6 - Agile Methodology Depiction

(Medium, 2019)

Agile methodologies are simply defined as a group of software methods which are mainly based on iterative and incremental development the main characteristics of agile methodology are planning, iterative, evolutionary development and response for changes and promoting the communications and this incremental requirements further used for refining the design, code and testing all stages of development (Kumar and Bhatia, 2012).

The Agile manifesto defines the process of agile software development based on principles that are been setup by agile software development members they have principles such as satisfying the customer needs, welcoming changing requirements, deliver products by time, The customer and developer work together on basis of need, delivery of working products and make changes if necessary and deliver product (Kumar and Bhatia, 2012).

This study follows agile methodology and its manifesto principles because it has planning of selecting prior industries and gather data related to improving exports, complexity and diversity and few visualisations are developed and changes were made iteratively and during this project all the needs are been specified by the economist Hamish gamble and based on his response the changes are been made and visual decision tool is been produced as part of delivery which is in section 3.6

3.3 Visual Decision Tool Implementation

1. In this project data is gathered from five industries with respect to improving complexity, improving diversity and improving exports categories with the help of Hamish economist.
2. The data contains list of various products, export values, countries, density and complexity outlook gain of the five industries.
3. Later I sorted that data based on products with respect to their countries i.e. I found the countries name and the product names are been found based on their codes.
4. After sorting of the data of various industries the visual decision tool for improving exports, complexity and diversity of five key industries is been developed.
5. The data is been imported to Microsoft power BI tool and five reports are created with three sectors in each named as improving exports, complexity and diversity.
6. The improving exports tab contains Table, pie, tree and world map charts and also a list of countries and products available in that sector.
7. The user can select any product or any country so they can view the required information in the charts for example if user clicks on china, they can view all the

products of defence and space in china. Another example the user clicks on product alloy steel they can view list of alloy steel available in all countries which can be viewed in the visual decision tool link shared in 3.5.

8. All charts in the improving exports tool is interactive and inter linked if we click on one chart all the values in other charts will also changes.
9. This chart will also give potential gain of each product and each country in dollars.
10. Improving complexity, a scatter plot chart is created which contains density at y-axis and cog at x-axis and also contains list of products where user can click on product and can view density and complexity outlook gain of that product.
11. Improving Diversity contains a chord chart where the products and the products within the sector are linked so if a user clicks a product, they can view the products within that sector.
12. Three visualisations are made for five key industries.
13. Later a web page is been created by using HTML, CSS, Java Script which contains the home page with information of five key industries and menu bar for viewing the visualisations from five key industries and also separate page for viewing top product opportunities from all five industries.
14. All visualisation screenshots can be viewed in Chapter 4 and can be viewed in the link provided on section 3.6

3.3.1 Microsoft Power BI

The term BI is an acronym for Business Intelligence which exists to enhance the decision-making abilities for a business and it is a collection of applications, technologies which all work together to collect, integrate, process, analyse and present the business information in a user understandable manner (Ferrari and Russo, 2016). Power BI can be considered as a set of software services or application continuously working to achieve interactive insights from the given data (Lachev and Price, 2018).

In this study Microsoft power BI is been used in creation of various visualisations and also for representing the data in visual form by using various charts like Tree, scatter plot, world map, Chord which are discussed in section 3.4.

3.3.2 HTML Hypertext Mark-up language

HTML stands for Hypertext Mark-up language which is widely used around the world because of the ease of implementation associated with it (Musciano and Kennedy, 1996). It is a basic language which primarily serves the purpose to define the structure of an application. This language uses tags to hold the information such as headings, images, paragraphs and other such elements (Graham, 1995).

In this study HTML is been used in creation of home page of visual decision tool which can be viewed in chapter 4. By using HTML the description of Five key industries is done in the home page and menu bar, Icons and Image frames are been done.

3.3.3 CSS Cascading Style Sheet

CSS or Cascading Style Sheet is a popular language which is used to design the webpages and make them attractive for the user (Lie et al., 2005). It is used in collaboration with HTML, as it provides design to the elements of HTML. It can either be used in the form of internal CSS or external CSS (Naser, 2008). However, with the implementation of internal CSS, the loading time of the page increases drastically (Meyer, 2004).

In this study CSS is been used in creation of home page of visual decision tool styling like various fonts, designs, colours are been created.

3.3.4 JavaScript

JavaScript is a language which is different from Java language. This language is an interpreted language which is primarily used to develop network-centric applications (Flanagan and Novak, 1998). It is an open-source cross platform language which is integrated with HTML for successful implementation (Abu-Naser et al., 2011). Both front-end and back-end software can be developed using this as it offers various frameworks such as Node.js, jQuery and many others (Severance, 2012).

In this study Java script is been used in creation of few buttons and sliders in the visual decision tool.

3.4 Visualisations Developed

3.4.1 World Map

In this study world map is used to locate the export value position of a country by using the longitude and latitude values. It is predominantly used when multiple countries are considered in a single data set and needs to be depicted accordingly (Benford et al., 1999). The interactive world map visualisation implemented in this study by gathered data from defence and space industry is shown in Figure 7.

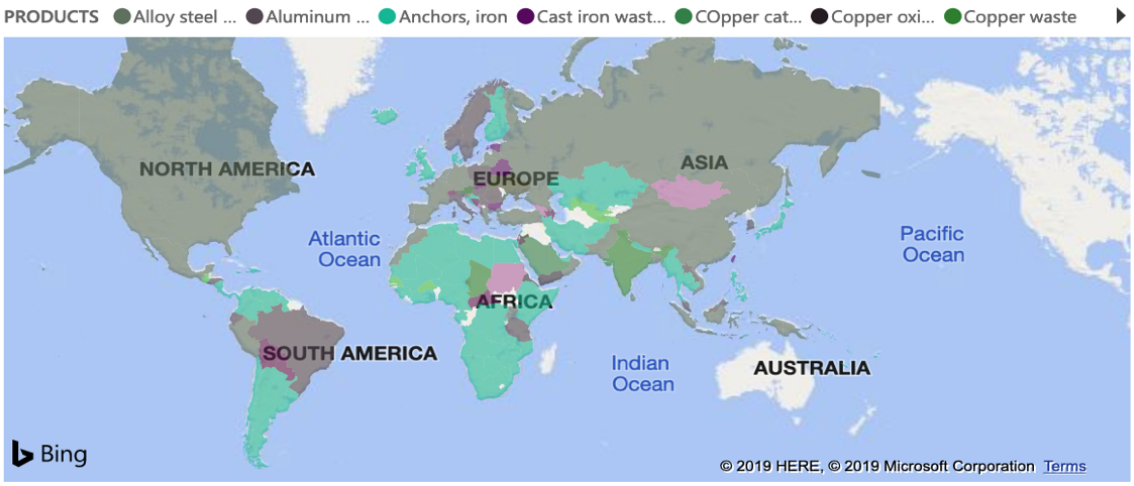

Figure 7- World Map Interactive Visualisation Implemented in this Study

3.4.2 Tree

A tree is a hierarchal system which is used to depict a structure which contains data elements that emerge from another data element. A tree contains nodes and edges. The nodes contain data whereas the edges depict relationship between the data (Uthe, 2009). The dynamic tree visualisation implementation implemented in this study by gathered data from defence and space industry is shown in Figure 8.

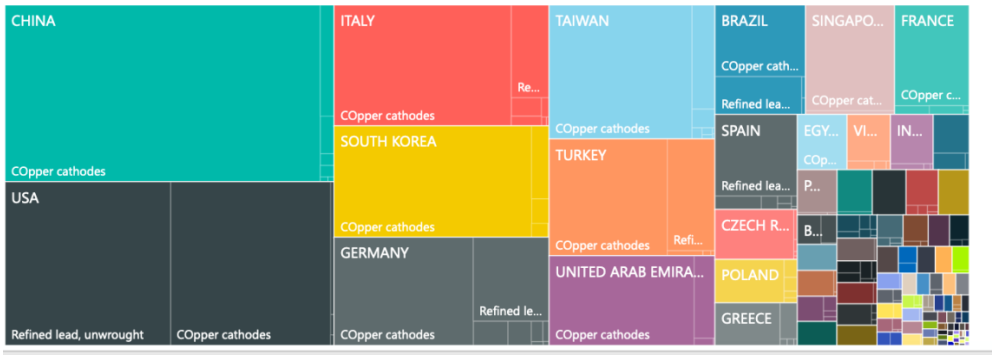

Figure 8- Tree Map Interactive Visualisation Implemented in this Study

3.4.3 Scatter-plot

Scatter plot comprises of two axes i.e. x and y, where each axes represent a distinct set of data. It is primarily used in the cases where the data set given is scattered and each data point is distinct to each other (Keim et al., 2010). The interactive scatter plot visualisation implemented in this study is from the data of advanced manufacture where density is viewed on Y-axis and complexity outlook gain on x-axis is shown in Figure 9.

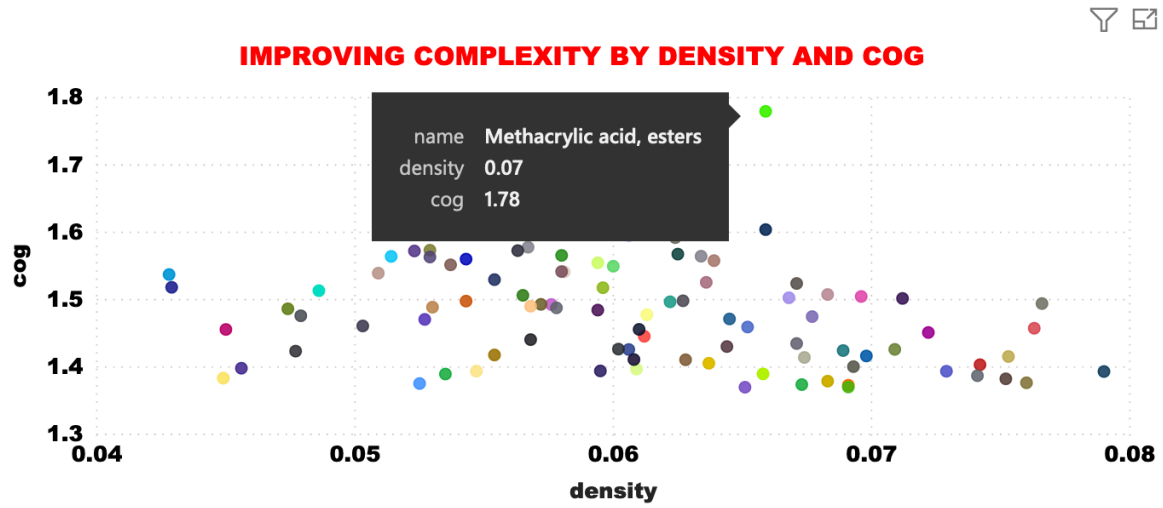

Figure 9- Scatter Plot Interactive Visualisation Implemented in this Study

3.4.4 Chord

Chord diagram is a representation of connections or flow between multiple entities or nodes. Each entity exists at the outer part of the circle. Further, arcs are drawn between the nodes which depict the importance of flow. If an arc is bigger and wider, it is important, and if it is narrow and smaller, it holds low significance (Fabro, 2015).

The dynamic chord visualisation implemented in this study is shown in figure 10 where the user can select the product and can view the products within the sector.

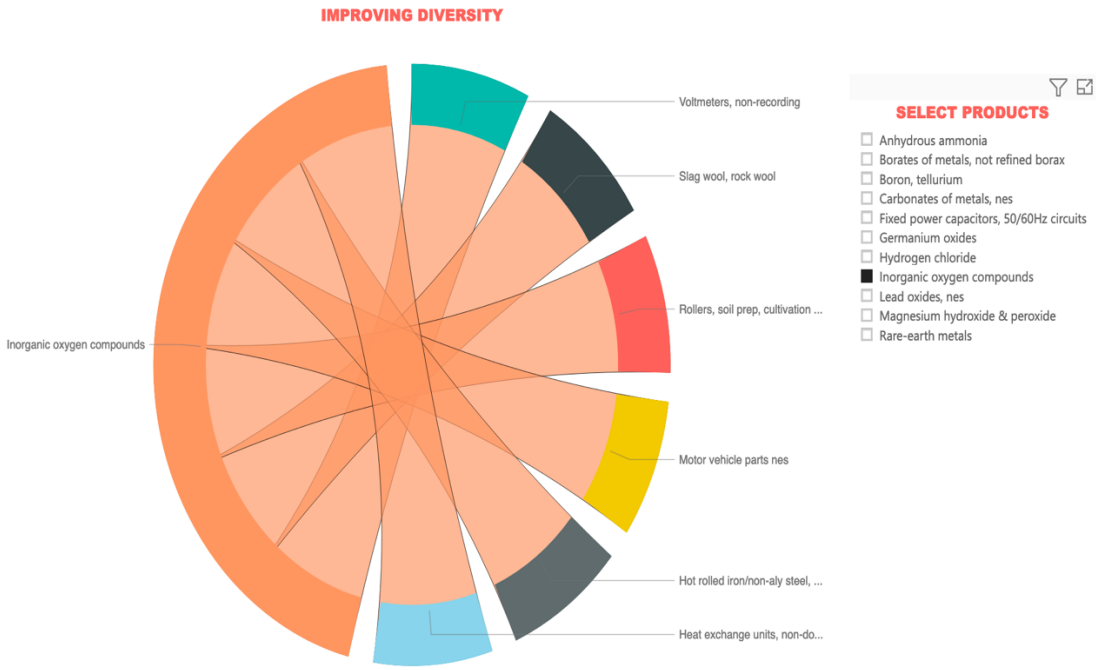

Figure 10- Interactive Chord Visualisation Implemented in this Study

3.4.5 Use case diagram for Menu Top Down

The use case diagram for this study is shown in Figure 11 with details provided in Table 11.

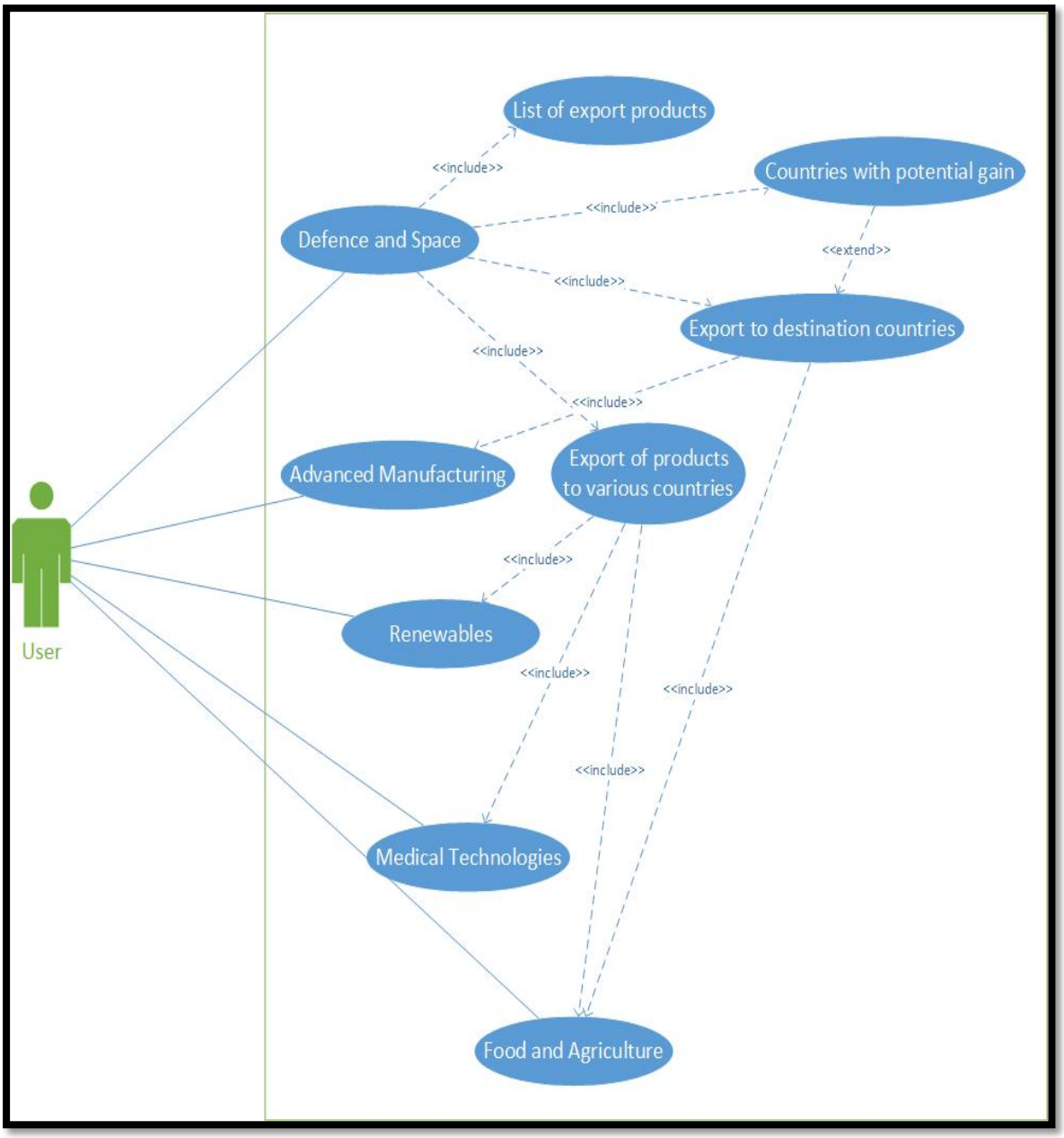

Figure 11- Use Case Diagram for the menu top down in visual decision tool

Key Industries	Actor	Description of key Industries
Defence and Space	User	Defence and space module would provide the user many opportunities for complex technology development for achieving various capabilities which would include frigates, submarines and maritime vessels for the navy.
Advanced Manufacturing		Advanced Manufacturing module would provide user a capability to adopt industry 4.0 in Australian economy for its transition to advanced manufacturing
Renewables		Renewable industries would provide solar, wind, hydro, concentrated solar thermal and their manufactured components that can be used in manufacturing of an industry
Medical Technologies		Medical Technologies modules mainly provides the user information about various technologies which mainly focuses on hearing, stent and sleep technologies.
Food and Agriculture		Food and Agriculture provides the description about various Agricultural technologies such as cutting-edge farm equipment, irrigation and water technologies are also pertinent.

Table 1- Key Industries Description

3.5 Evaluation – User Testing

Evaluation through user testing was conducted by meeting Hamish Gamble (economist) periodically, once per month during April to October 2019, to discuss user requirements and feedback through the entire development of the system. Meetings were conducted with an (Hamish Gamble) Economist, who was a former employee in the South Australian Government, Department of Innovation and Skills, focussing on economic complexity. He therefore provided key informant, subject matter expertise from an economic user perspective. He is currently based at the Australian Industrial Transformation Institute (AITI) in the College of Business Law and Government at Flinders University.

The system was developed though an iterative process based on Agile systems development rather than a waterfall approach. This allowed the incarnation of feedback throughout development in a proactive way.

Specifically, while the system was being development, his feedback pertained to improving the ease of use of the system in terms of implementing key navigation categories of increasing complexity, exports and diversity as well as searching the system by product opportunities and country.

His final comments about the system were:

"*The system has good flow and would be of use to State Government and various industry groups in determining key product opportunities for industry development and investment in South Australia." Economic Complexity Subject Matter Expert*

3.6 Deployment

The website which has been deployed over the GitHub has primarily five domains on which analysis been performed. The domains which are considered in this are Defence & Space, Advance Manufacturing, Renewables, Medical Technologies and Food & Agriculture.

https://avpsjayanth.github.io/examples/main.html

4 Chapter Four- Results

The website which has been deployed over the GitHub has primarily five domains on which analysis have been performed. The domains which are considered are Defence & Space, Advance Manufacturing, Renewables, Medical Technologies and Food & Agriculture as illustrated in the opening webpage for the tool.

The home page contains the menu bar with five industries, Home, about and contact us buttons and below the menu bar it contains two buttons named top product opportunities and learn more and Below that users can see the description of five key industries in the home page and users can see the keep in touch with us

Home page can be viewed and accessed by the link provided in section 3.6.

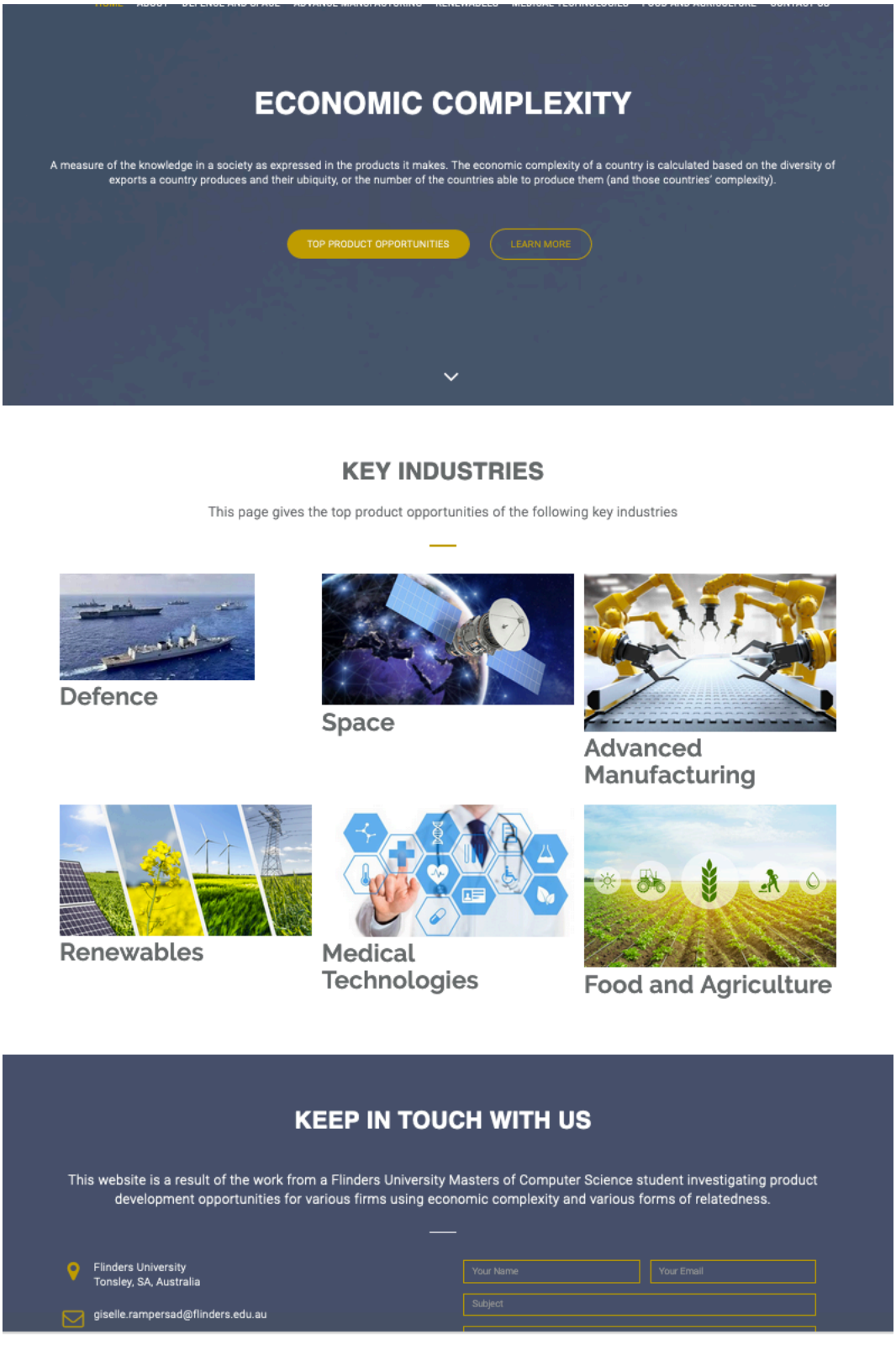

Figure 12- Opening Webpage for the Tool

By clicking each industry user can see the appropriate industry in three categorises improving exports, improving complexity and improving diversity by selecting them user can see the charts.

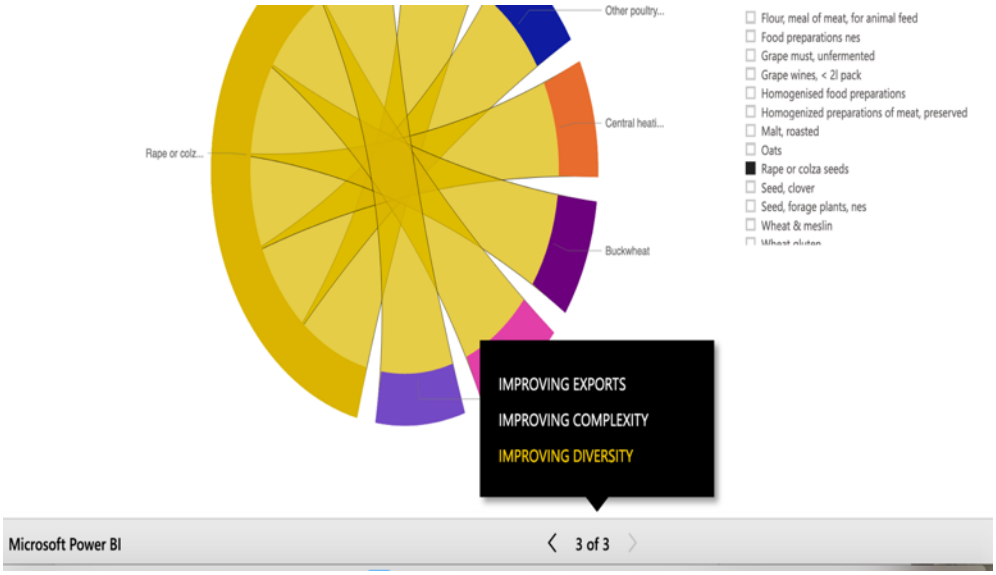

Figure 13- Example of Product Diversification Opportunities in the Tool

By clicking on bottom of page user can select appropriate category and see the different charts.

In this chapter the screenshots of Five key industries are attached in all the three categories of

- Improving exports
- Improving complexity
- Improving Diversity

The implementation of these charts is been discussed in section 3.3.

4.1 Defence and Space

Figure 14 illustrates the Defence and Space visualisation interface that was implemented in the tool

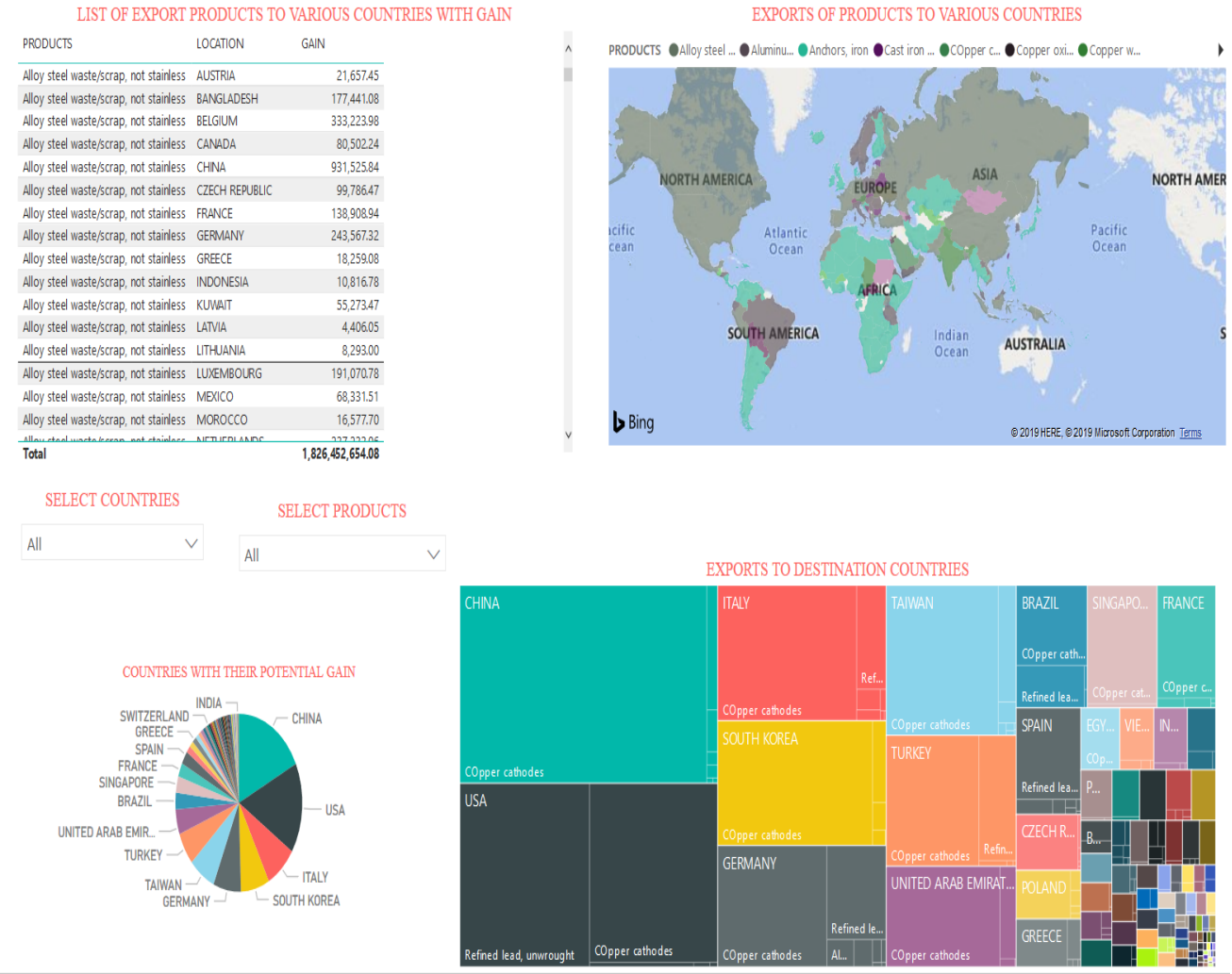

Figure 14- Defence and Space Visualisation Interface Implemented in the Tool

This interface depicts the list of all the products which are exported to various countries in order to gain profits. The list contains, products, location and gain which is earned along with the total profit gained. Also, filters are applied from which the countries and products can be extracted, further these are depicted on the map. Below is a pie chart which displays all the countries based on their potential gain. From this, it can easily be seen that China gained the most profit out of all i.e. $323,550,223.59 (17.71%).

Figure 15 shows the interactive visualisation interface developed as part of this project to show product opportunities to increase complexity within an industry.

Figure 15- Visualisation Interface Developed for Increasing Complexity

All the products are enlisted along with their density and a scatter plot graph is implemented based on the density and complexity outlook gain (COG) of each product. Underneath, average density i.e. 11.71 of all products is depicted along with the average complexity outlook gain i.e. 232.82. A filter is also applied alongside from where density and COG of a specific product can be seen.

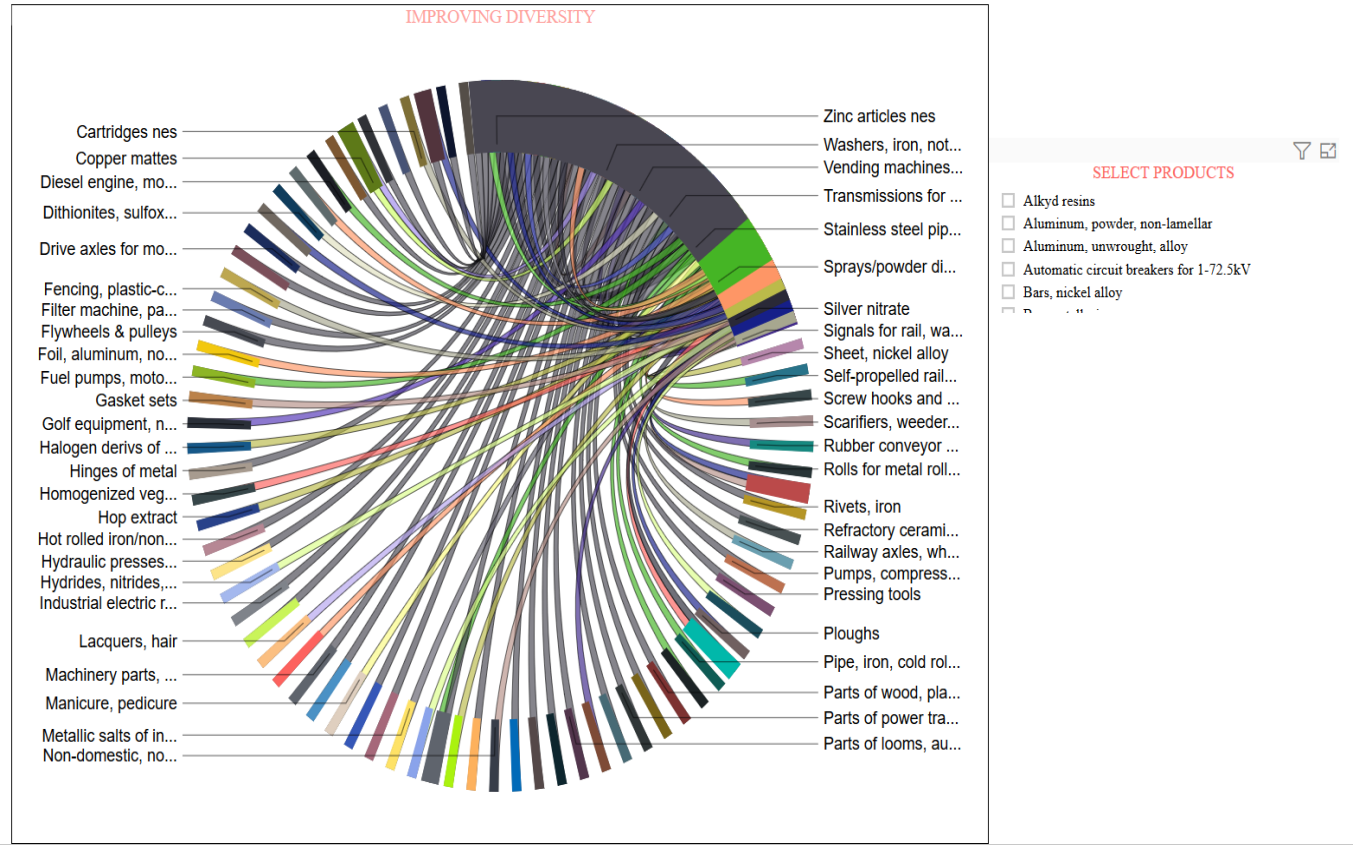

Figure 16- Interactive Visualisation to for Product Diversification

Figure 16 depicts the chord visualisation developed to identify opportunities for product diversification. Also, using a filter of improving diversity, a user can access information on the diversity of a specific product.

4.2 Advance Manufacturing

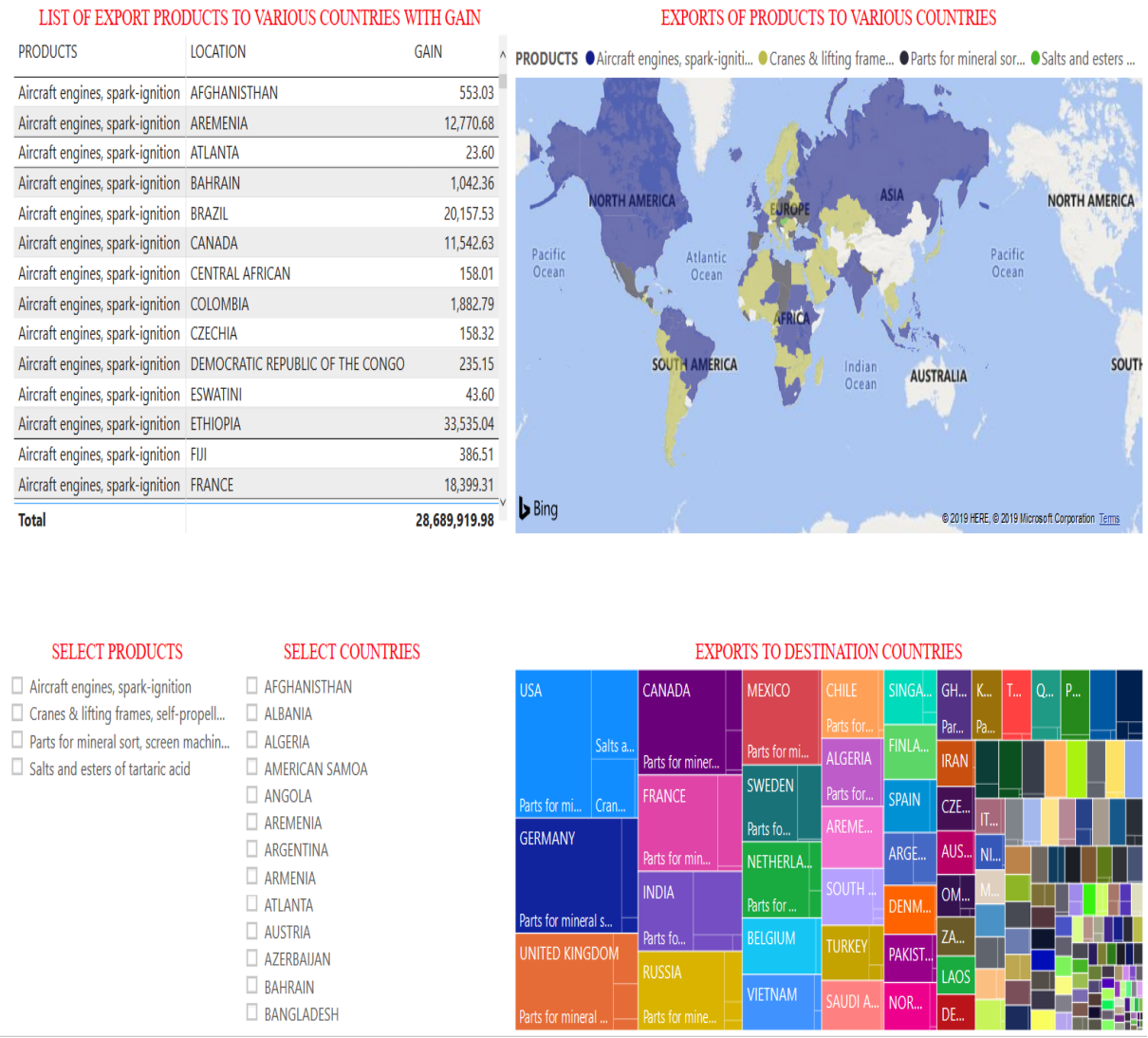

Figure 17- Advanced Manufacturing Visualisation Interface Implemented in the Tool

A list of all the products is displayed along with the location to which they are being exported and the profit they are gaining. A world map depicts all the information obtained from the list. , an area chart is depicted which can be modified according to the filters applied to it.

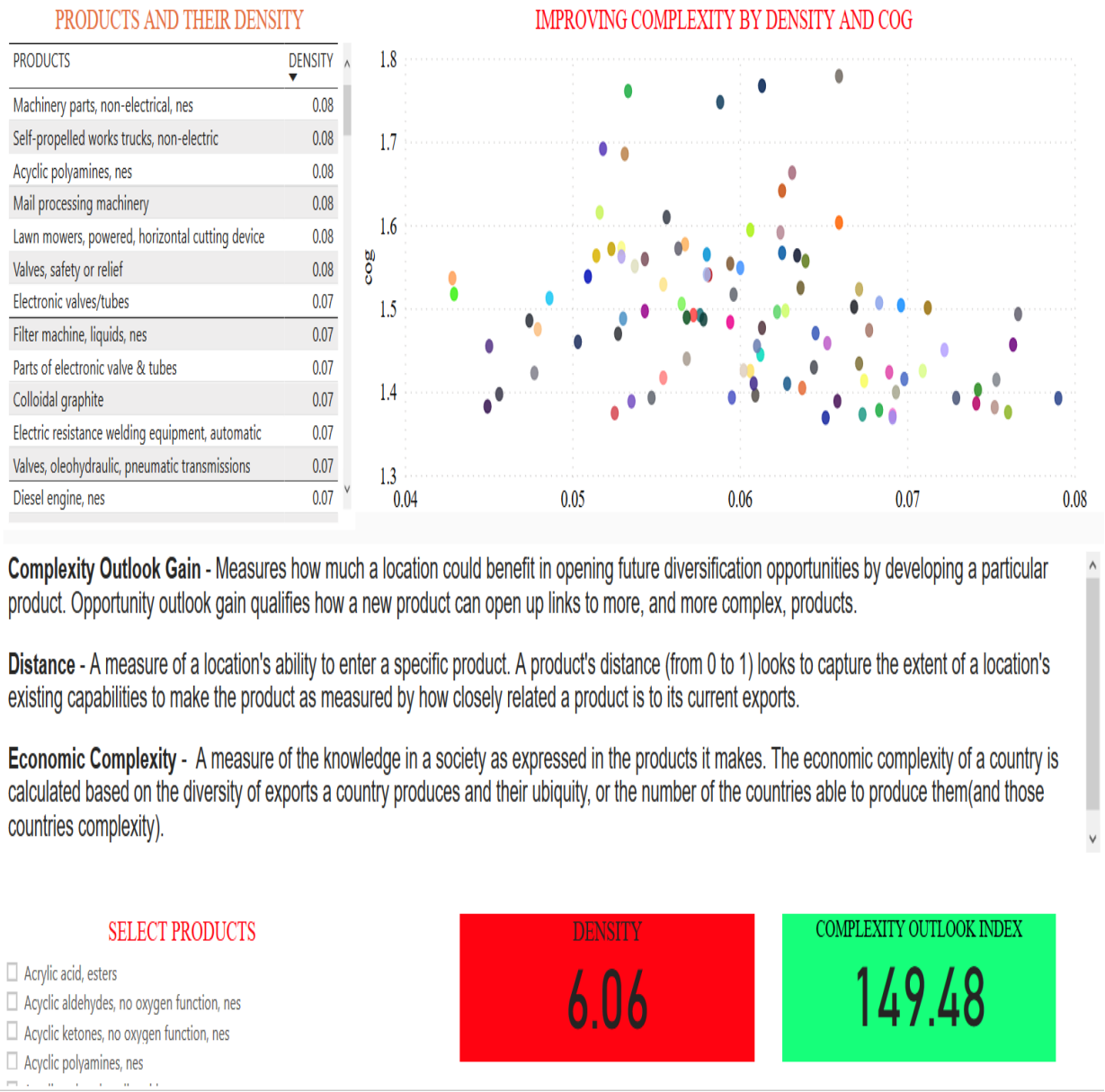

Figure 18- Advance Manufacturing Visualisation Interface Developed for Increasing Complexity

All the products are put in a list along with their densities and further these are depicted on a scatter-plot based on their Complexity outlook gain and density. Average density of products is 6.06, Complexity outlook index averages at 149.48. Custom density and cog value can also be seen by selecting the products from products list.

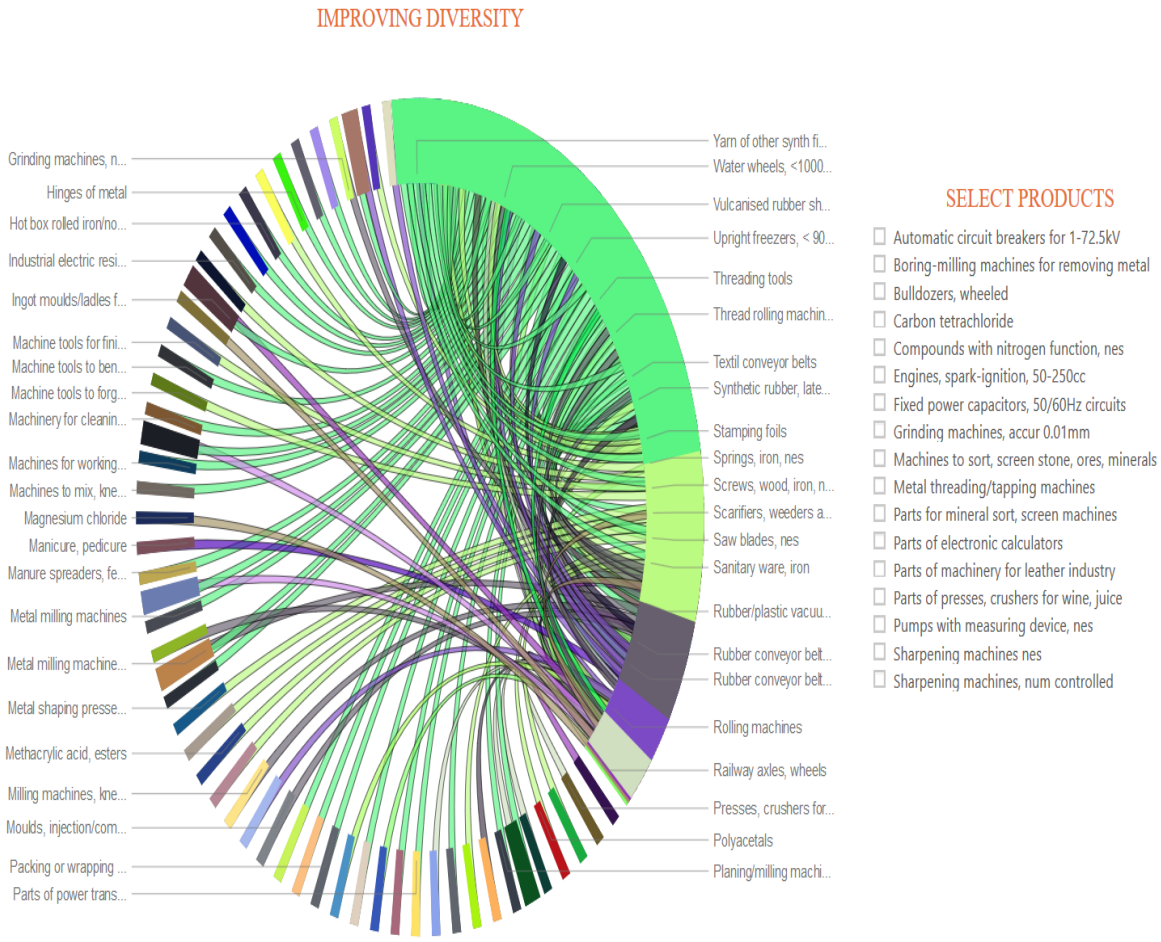

Figure 19- Advance Manufacturing Visualisation Interface Developed for Increasing Diversity

4.3 Renewables

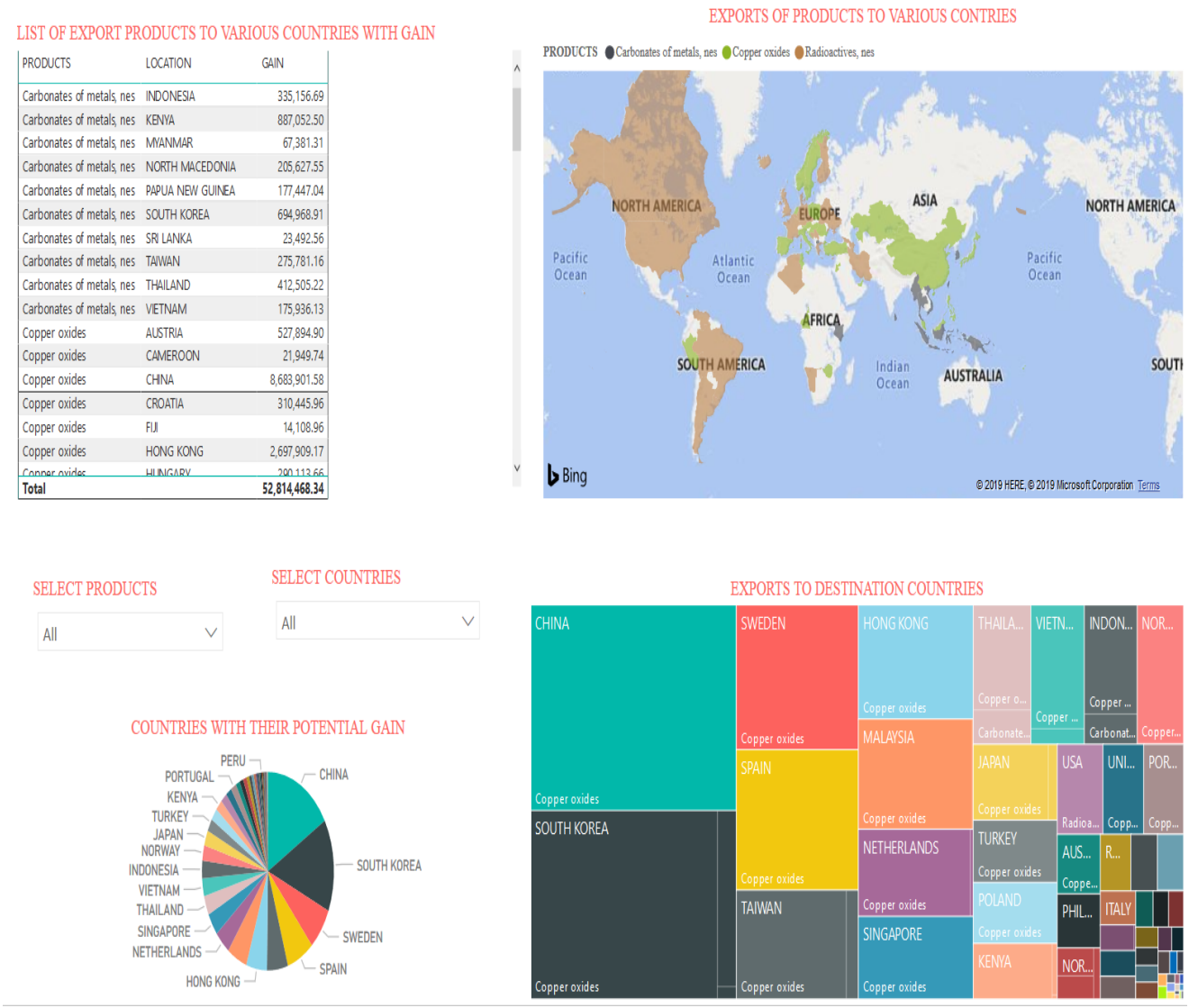

Figure 20- Renewables Visualisation Interface Developed for Increasing Exports

All the renewable products being exported to other countries for profit are displayed in the list along with their location and the gain which is earned from it. Based on the gain, world map is plotted. Underneath, all the potential gains are depicted using pie chart and area chart.

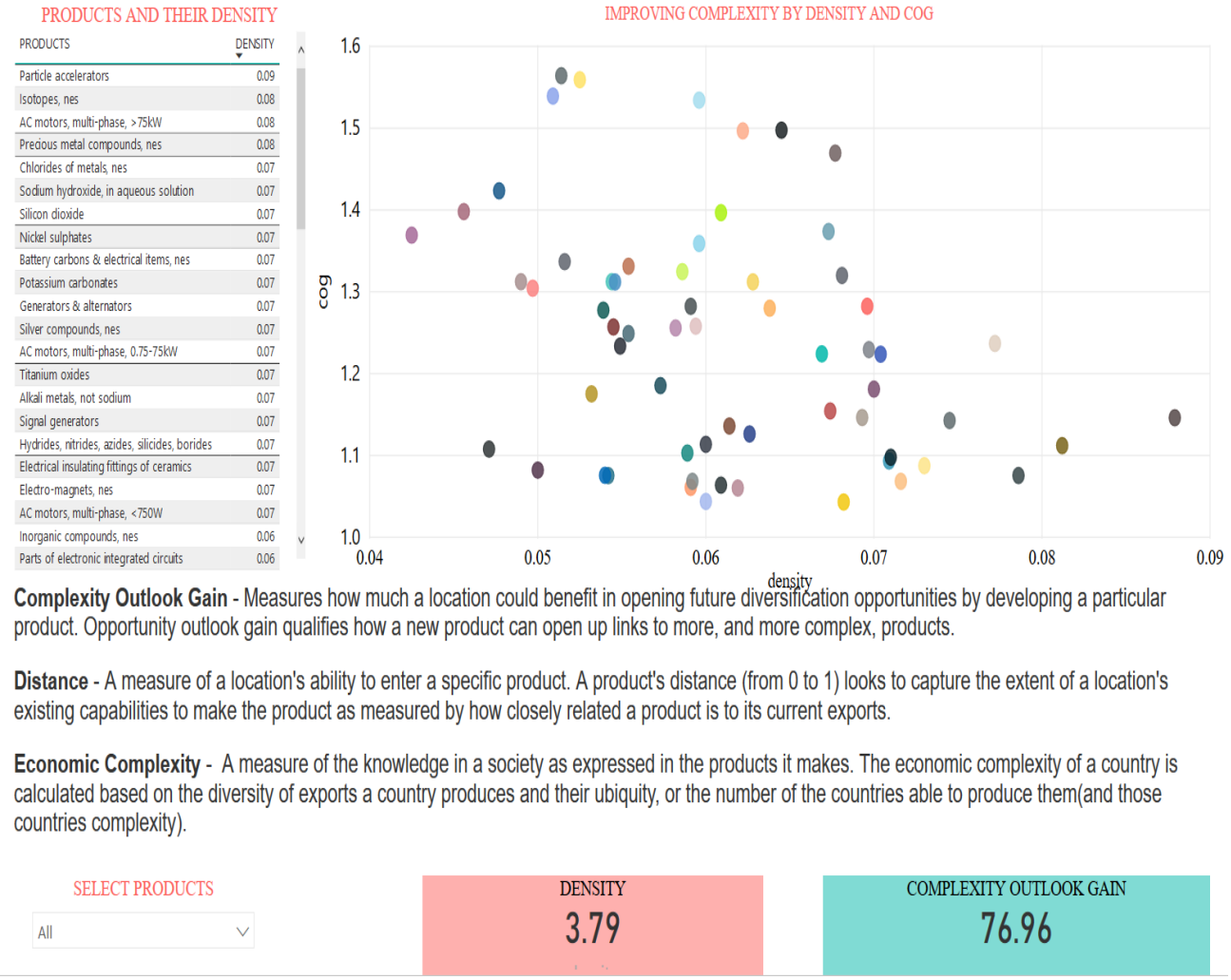

Figure 21- Renewables Visualisation Interface Developed for Increasing Complexity

Products and their densities are displayed in a list and scatter-plot is plotted based on it. The average cog and density are displayed i.e. the density is 3.79 and cog is at 76.96. Density and COG for a specific product can also be seen using filters.

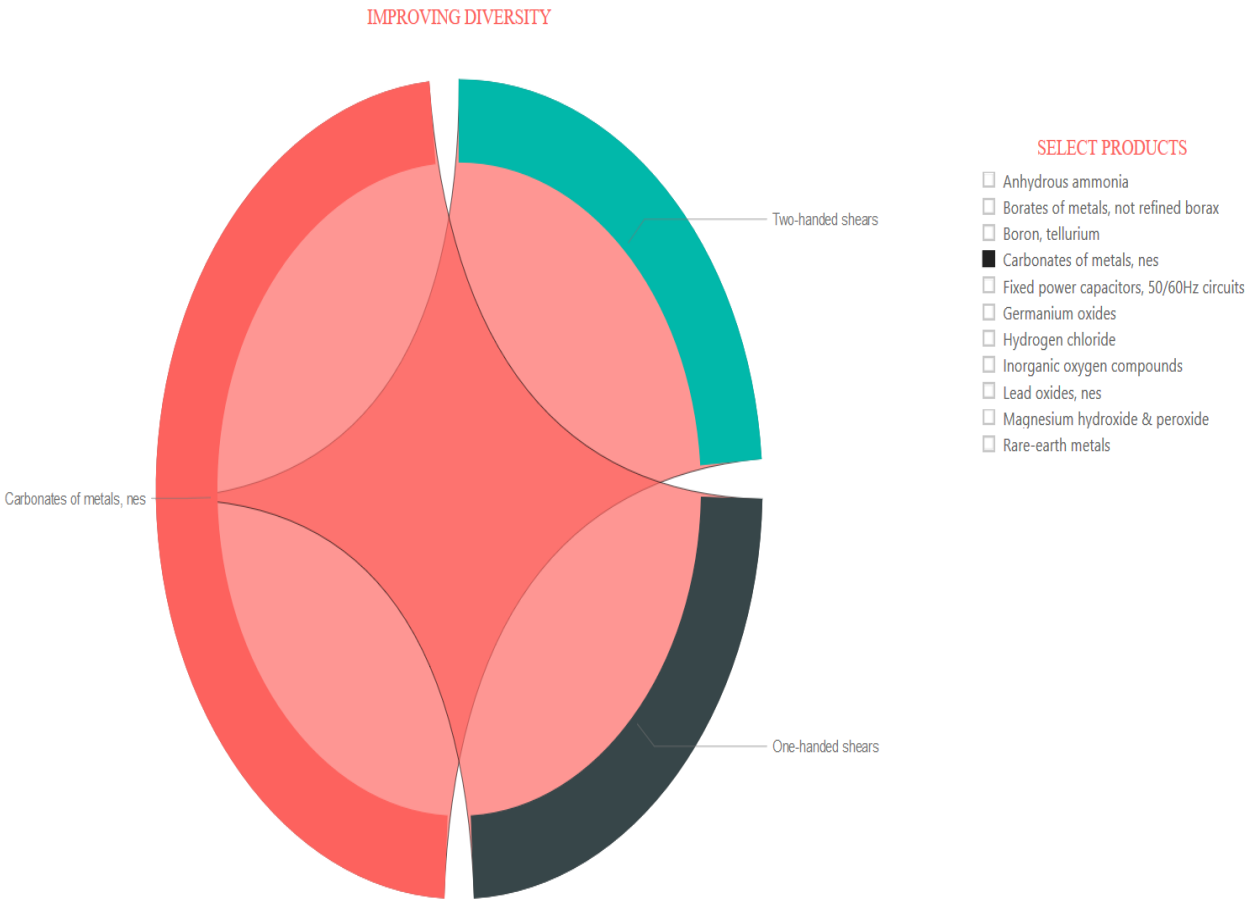

Figure 22- Renewables Visualisation Interface Developed for Increasing Diversity

It can be seen in the above graph that, diversity for Carbonates of metals are depicted. Also, diversity of all the products can be seen altogether.

4.4 Medical Technologies

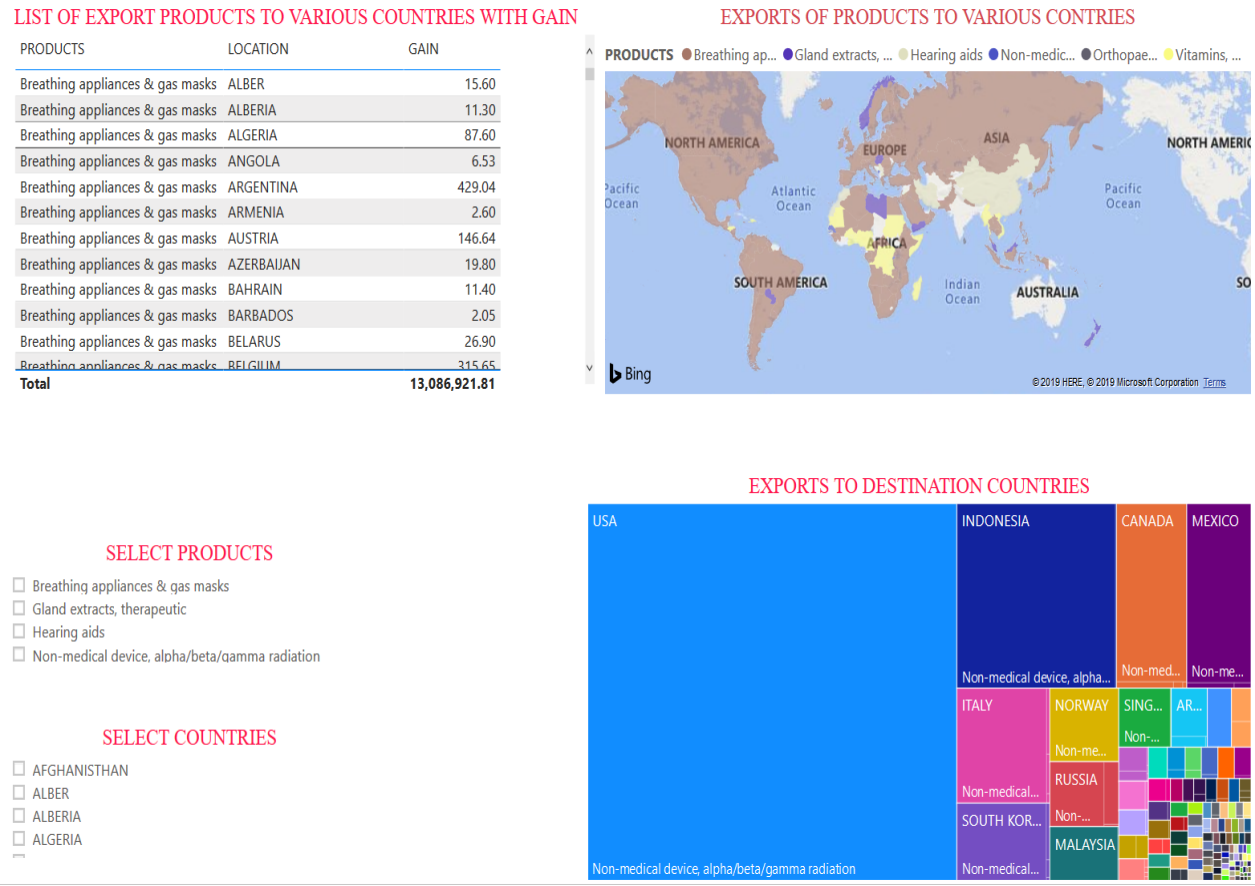

Figure 23- Medical Technologies Visualisation Interface Developed for Increasing Exports

All the medical technologies being exported to other countries are enlisted along with their gains. A country-wise graph is also depicted alongside. Below an area graph is plotted which can be further modified to display specific products for specific countries.

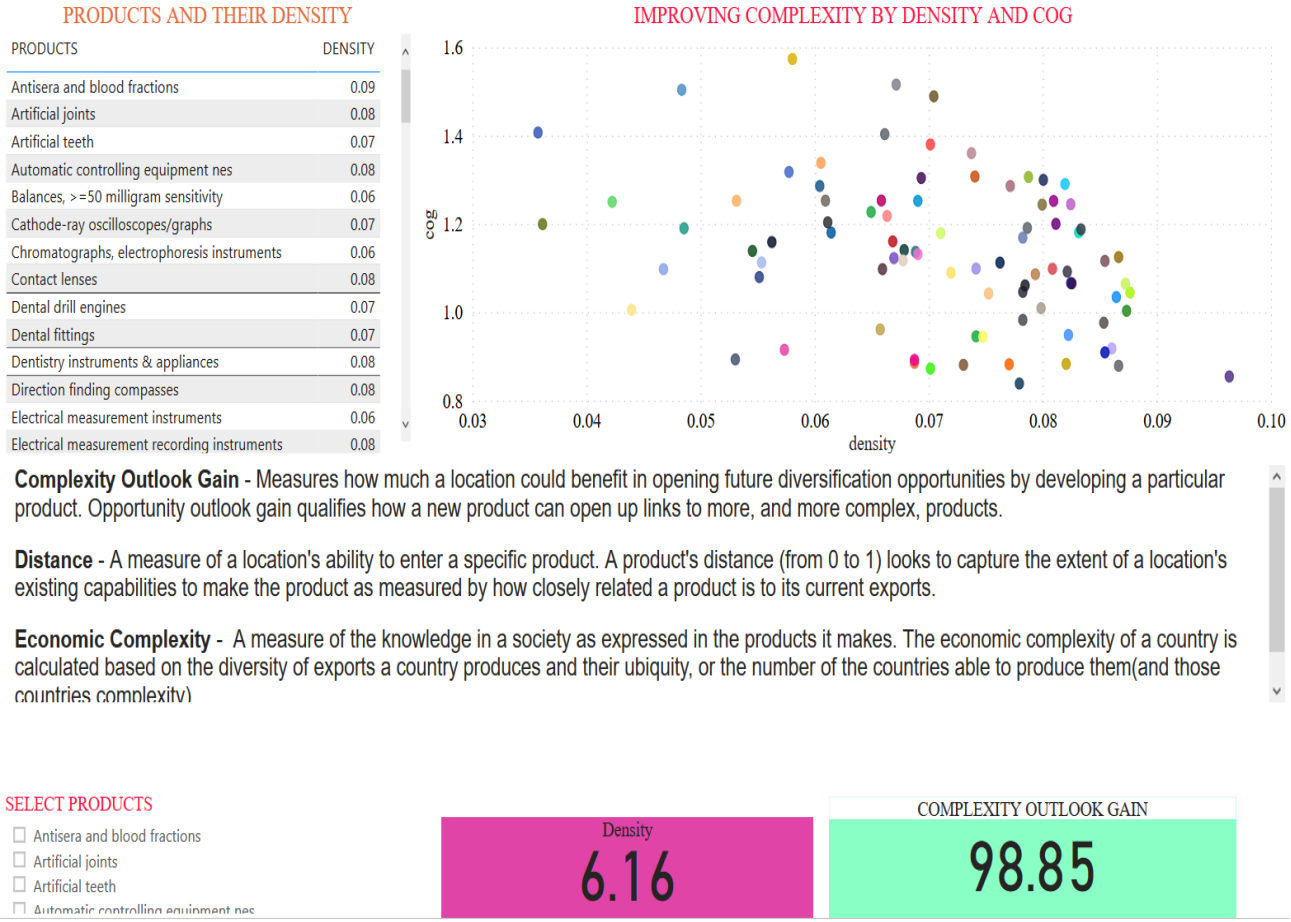

Figure 24- Medical Technologies Visualisation Interface Developed for Increasing Complexity

All the medical technologies are enlisted along with their densities and are depicted on a scatter plot. Average density of all the products is 6.16 and the average COG of all the products is 98.85. Further these can be filtered using the list on the left.

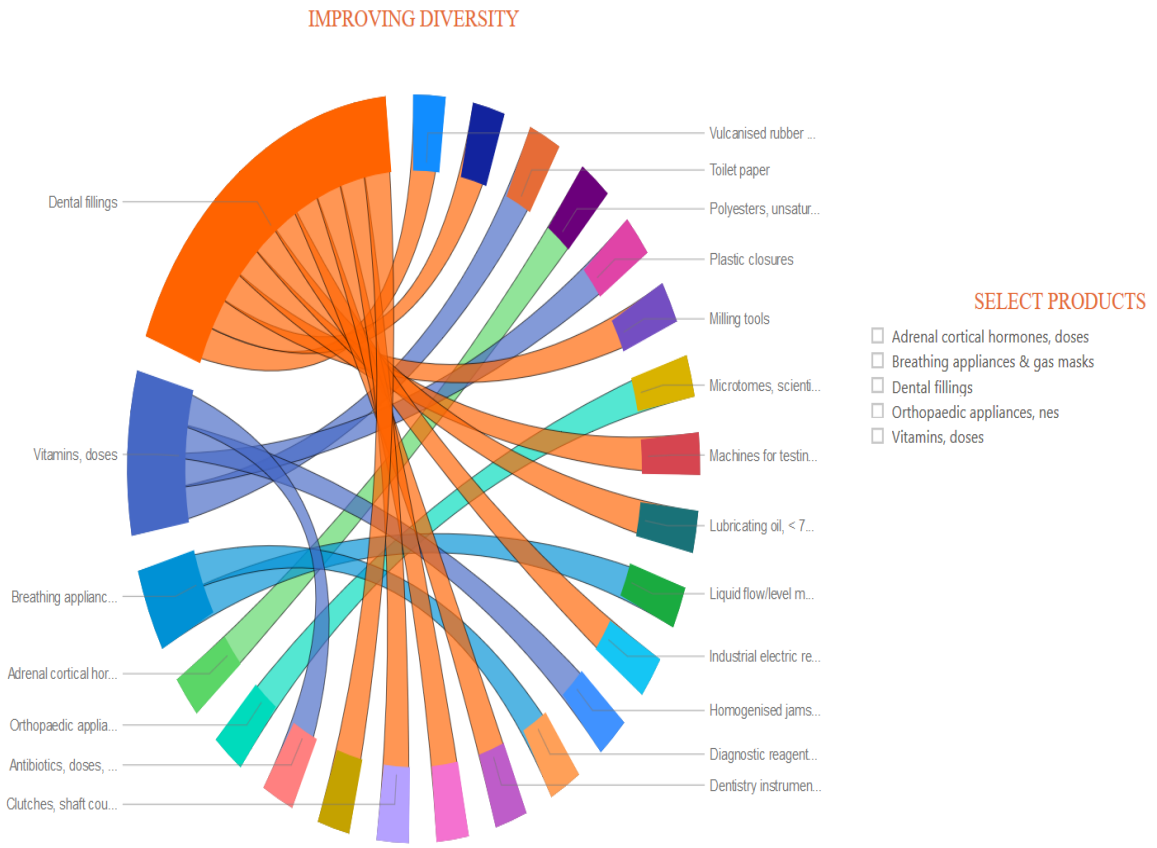

Figure 25- Medical Technologies Visualisation Interface Developed for Increasing Diversity

The above graph displays the diversity of all the products and can be filtered for some specific product as well.

4.5 Food and Agriculture

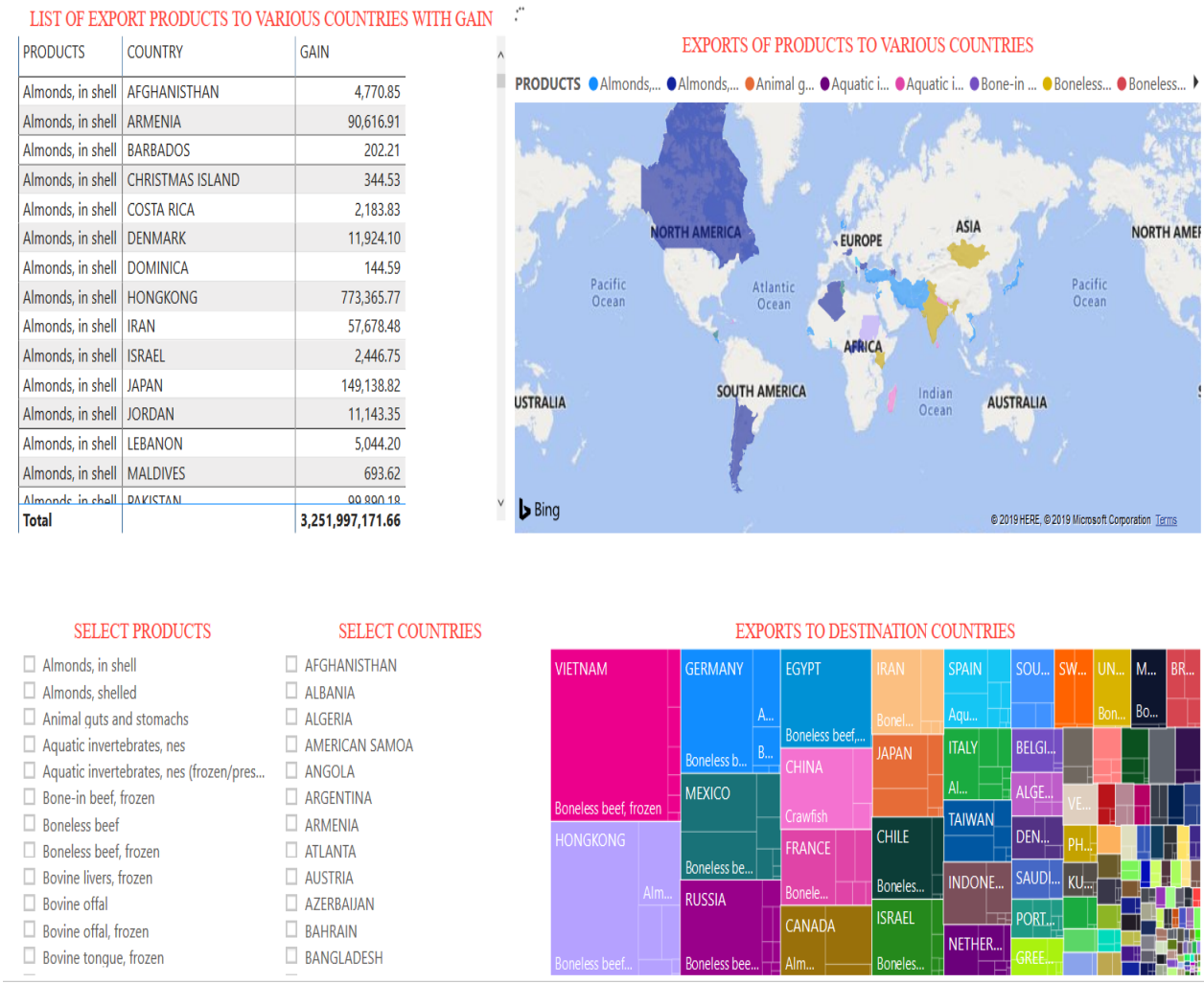

Figure 26- Food and Agriculture Visualisation Interface Developed for Increasing Exports

A list of the products being exported to various countries with gain is displayed along with the world map which depict each product and its share in a country. Below, area graph is depicted with all the products and the countries. Also, these can be modified based on it.

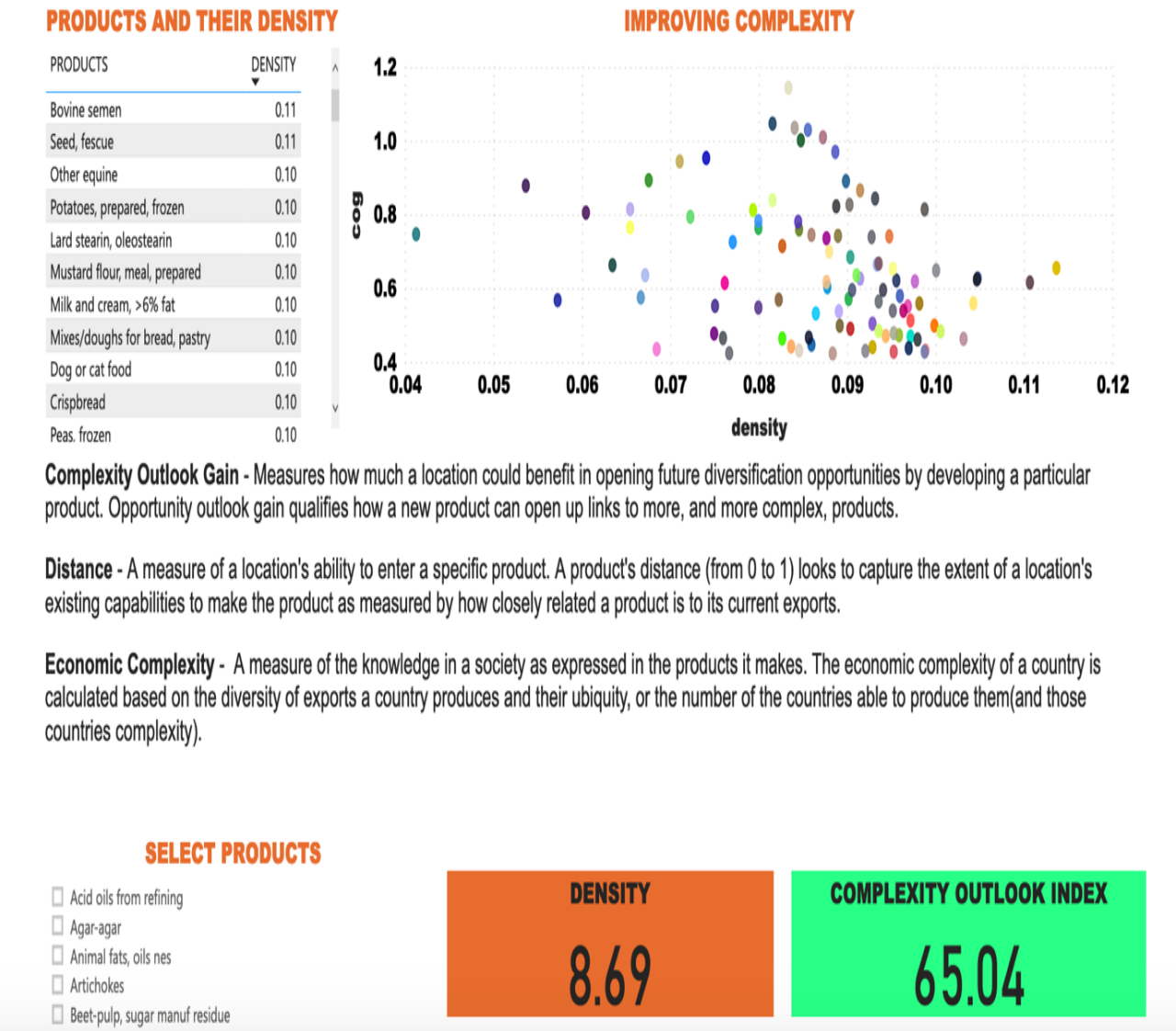

Figure 27- Food and Agriculture Visualisation Interface Developed for Increasing Complexity

All the food and agriculture products are enlisted with their densities and a scatter plot graph is depicted along with it. The average density of all the products is 8.69 and the average cog of all the products is 65.04. These can be filtered using the filter list provided on the left.

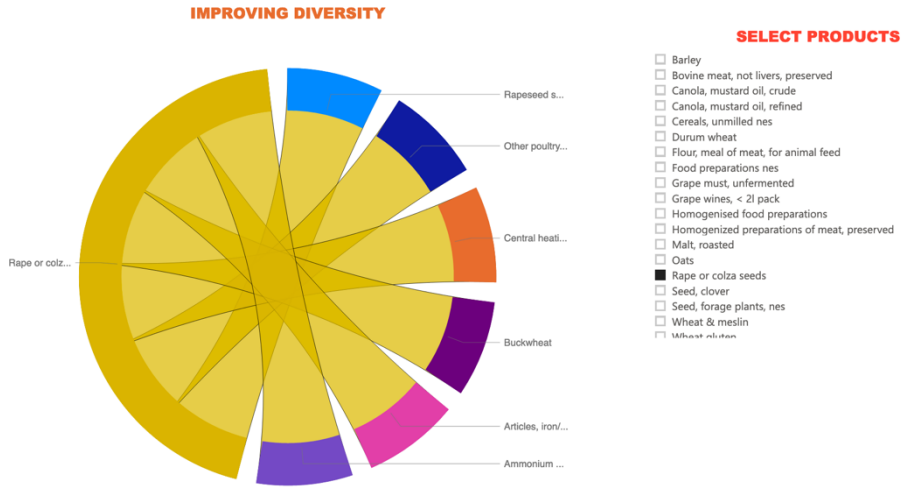

Figure 28- Food and Agriculture Visualisation Interface Developed for Increasing Diversity

In improving diversity chart of food and agriculture the rape or cola seeds are been linked with other poultry, wheat and other related products are shown.

4.6 Product Opportunities

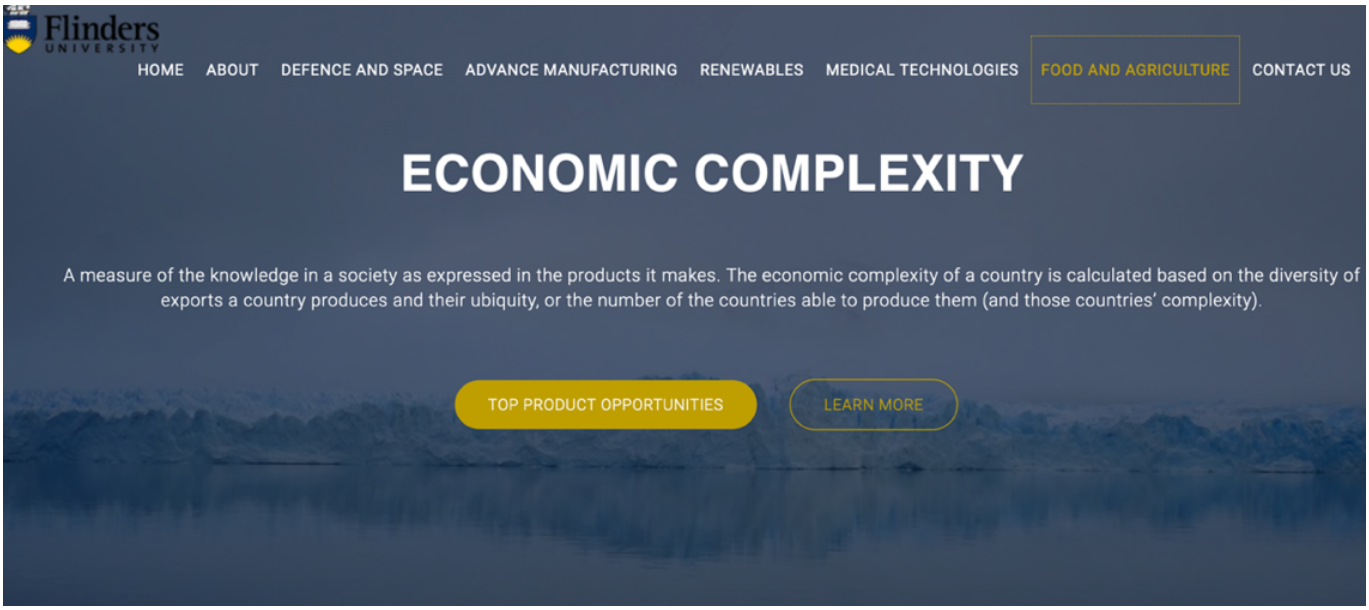

Figure 29- Product Opportunities

On clicking Top product opportunities user can view top Key Opportunities by Industry as follows

S.N.O	INDUSTRY	TOP PRODUCT OPPORTUNITIES
1	Defence	• Autonomous systems • Robotic and Assistive Manufacturing Solutions • ICT Solutions • Wearables • Critical Minerals(Titanium, Lithium)
2	Space	• Satellites(Micro satellites, Integrated Circuits) • Batteries • Vision Systems/cameras/surveillance • Gps- Global Positioning system • Energy Solutions(photovoltaics) • Chemicals and materials(Lithium, rocket fuel).
3	Advance Manufacturing	• Advanced materials and chemicals • Machinary and components • Industry 4.0
4	Renewables	• Batteries • Titanum • Lithium and Rare earth materials • Photovoltaics
5	Medical Technologies	• Medical devices • Assistive Surgical Technologies • Hearing Aid • X-ray and Scanning Technologies
6	Food and Agriculture	• Wine • Cheese • seafood • Gulten free, Dairy free and High protein

Figure 30- Top Product Opportunities in Key Industries

The user after selecting top product opportunities button can see the table of the key industries and their top opportunities.

5 Chapter Six - Conclusions

5.1 Overview

The study developed a dynamic visualization tool for innovation management based on economic complexity modelling. The main results of this study is the identification of product opportunities for Australia in key industries including advanced manufacturing, defence and space, renewables, medical technologies and food and agriculture.

5.2 Addressing the research question

The key research question of this study was how visualisation can identify product opportunities within industry sectors this study research helped in finding significant product opportunities by identifying the areas of improvement and suitable visualisations for various data sets related to the key industries and in developing a visual decision tool by integrating concepts of visualization, innovation and complexity. It also makes an valuable practical contribution to government on industry development and innovation by identifying relevant product opportunities for Australia in priority industries to increase complexity, exports and diversity.

The sub-questions or hypotheses pertained to how smart specialisation influences increases in economic complexity, diversification and exports (as outlined in Section 2.9).

The study answered the research question by first reviewing and integrating the literatures on economic complexity, smart specialisation and visualisation. A dynamic, interactive tool was developed to identify product opportunities in key industries to improve complexity, diversification and exports.

5.3 Research Contributions

This research contributed to the body of knowledge related to visualization by analysing big data using Microsoft power BI for implementing a dynamic tool for innovation management.

5.3.1 Theoretical Contribution

The study makes an important theoretical contribution of developing a visual decision tool to improve economic complexity for innovation management by integrating interdisciplinary literature on visualization, innovation and complexity.

5.3.2 Practical contribution

The study also made a valuable practical contribution to government players associated with industry development and innovation by identifying relevant product opportunities for Australia to increase complexity, exports and diversity. It provided implications for priority industries medical technology, defence, space, renewables, advanced manufacturing and food.

5.4 Limitations

The main limitation of this research is its technical complexity and Additionally, some users may not find it easy to understand the visualisation without having knowledge of economic terms and information used as a basis for the modelling. Nevertheless, the study is significant for relevant target expert users such as economists from government, to make decisions pertaining to industry investment. Thus, the tool is effective as an expert decision intelligence visualisation.

5.5 Future Research

Future research can pertain to deeper analysis of particular product opportunities. This would need further interaction with government stakeholders. By refining the visualisation based on priority products, it would help to improve the narrative, accessibility and ready acceptance of the tool by users as it would directly be linked to their specific interests. Nevertheless, the tool's current focus on industries enables relevance to a broader cross-section of users and government departments. This is useful in facilitating a wider impact from the research and introducing economic complexity modelling as a valuable approach in strengthening the evidence based and intelligence to support decision making for industry development.

References

ABS 2016, 8158.0 - Innovation in Australian Business, 2014 - 15.

Abdon, A., Bacate, M. L., Felipe, J. & Kumar, U. 2010. Product complexity and economic development. *Levy Economics Institute, Working Papers*.

Abu-Naser, S., Ahmed, A., Al-Masri, N., Deeb, A., Moshtaha, E. & Abulamdy, M. 2011. An intelligent tutoring system for learning java objects. *International Journal of Artificial Intelligence and Applications (IJAIA),* 2.

Adya, M. & Lusk, E. J. 2016. Development and validation of a rule-based time series complexity scoring technique to support design of adaptive forecasting DSS. *Decision Support Systems,* 83**,** 70-82.

Antonelli, C. 2011. *Handbook on the economic complexity of technological change*, Edward Elgar Publishing.

Atzeni, P., Bugiotti, F., Cabibbo, L. & Torlone, R. 2016. Data modeling in the NoSQL world. *Computer Standards & Interfaces*.

Balland, P.-A., Boschma, R., Crespo, J. & Rigby, D. L. 2019. Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional Studies,* 53**,** 1252-1268.

Balland, P. A., Boschma, R. A., Crespo, J. & Rigby, D. L. 2017. Smart specialization policy in the EU: relatedness, knowledge complexity and regional diversification. *Knowledge Complexity and Regional Diversification (June 21, 2017)*.

Barbosa, S. D. J. & Barbosa, G. D. J. Introduction to Data Visualization. IFIP Conference on Human-Computer Interaction, 2019. Springer, 527-529.

Baregheh, A., Rowley, J. & Sambrook, S. 2009. Towards a multidisciplinary definition of innovation. *Management decision,* 47**,** 1323-1339.

Barnes-Leon, M. T., Catahan Jr, N. B. & Exley, R. M. 2007. Data modeling using custom data types. Google Patents.

Benford, S., Taylor, I., Brailsford, D. F., Koleva, B., Craven, M. P., Fraser, M., Reynard, G. & Greenhalgh, C. 1999. Three dimensional visualization of the world wide web. *ACM Computing Surveys,* 31.

Boschma, R., Balland, P.-A. & Kogler, D. F. 2014. Relatedness and technological change in cities: the rise and fall of technological knowledge in US metropolitan areas from 1981 to 2010. *Industrial and corporate change,* 24**,** 223-250.

Can, M. & Doğan, B. 2017. The effects of economic structural transformation on employment: an evaluation in the context of economic complexity and product space theory. *Handbook of research on unemployment and labor market sustainability in the era of globalization.* IGI Global.

Carlisle, S. 2018. Software: Tableau and Microsoft Power BI. *Technology| Architecture+ Design,* 2**,** 256-259.

Commission, E. 2010. *Europe 2020: A strategy for smart, sustainable and inclusive growth: Communication from the commission*, Publications Office of the European Union.

Diamond, M. & Mattia, A. 2017. Data visualization: An exploratory study into the software tools used by businesses. *Journal of Instructional Pedagogies,* 18.

Erkan, B. & Yildirimci, E. 2015. Economic Complexity and Export Competitiveness: The Case of Turkey. *Procedia-Social and Behavioral Sciences,* 195**,** 524-533.

Fabro, M. 2015. Diagnostic catheters, guide catheters, visualization devices and chord manipulation devices, and related kits and methods. Google Patents.

Felipe, J., Kumar, U., Abdon, A. & Bacate, M. 2012. Product complexity and economic development. *Structural Change and Economic Dynamics,* 23**,** 36-68.

Ferrari, A. & Russo, M. 2016. *Introducing Microsoft Power BI*, Microsoft Press.

Flanagan, D. & Novak, G. M. 1998. Java-Script: The Definitive Guide. AIP.

Foray, D., David, P. A. & Hall, B. 2009. Smart specialisation–the concept. *Knowledge economists policy brief,* 9**,** 100.

Foray, D., David, P. A. & Hall, B. H. 2011. Smart specialisation from academic idea to political instrument, the surprising career of a concept and the difficulties involved in its implementation. EPFL.

Franconi, E. & Kamblet, A. A data warehouse conceptual data model. Proceedings. 16th International Conference on Scientific and Statistical Database Management, 2004., 2004. IEEE, 435-436.

Graham, I. S. 1995. *The HTML sourcebook*, Wiley New York.

Hausmann, R., Hidalgo, C. A., Bustos, S., Coscia, M., Simoes, A. & Yildirim, M. A. 2014. *The atlas of economic complexity: Mapping paths to prosperity*, Mit Press.

Hidalgo, C. A. & Hausmann, R. 2009. The building blocks of economic complexity. *Proceedings of the national academy of sciences,* 106**,** 10570-10575.

Hidalgo, C. A., Klinger, B., Barabási, A.-L. & Hausmann, R. 2007. The product space conditions the development of nations. *Science,* 317**,** 482-487.

Keim, D. A., Hao, M. C., Dayal, U., Janetzko, H. & Bak, P. 2010. Generalized scatter plots. *Information Visualization,* 9**,** 301-311.

Keller, P. R., Keller, M. M., Markel, S., Mallinckrodt, A. J. & Mckay, S. 1994. Visual cues: practical data visualization. *Computers in Physics,* 8**,** 297-298.

Kogler, D. F., Rigby, D. L. & Tucker, I. 2013. Mapping knowledge space and technological relatedness in US cities. *European Planning Studies,* 21**,** 1374-1391.

Kumar, G. & Bhatia, P. K. 2012. Impact of agile methodology on software development process. *International Journal of Computer Technology and Electronics Engineering (IJCTEE),* 2**,** 46-50.

Lachev, T. & Price, E. 2018. *Applied Microsoft Power BI: Bring your data to life!*, Prologika Press.

Landabaso, M., Mccann, P. & Ortega-Argilés, R. 2014. Smart specialisation in European regions: Issues of strategy, institutions and implementation. *European Journal of Innovation Management*.

Lie, H. W., Bos, B., Lilley, C. & Jacobs, I. 2005. *Cascading style sheets*, Pearson India.

Marie Curie Alumni Association. (2019). Definition of the day: Smart Specialisation Strategy.[online]Available at: https://www.mariecuriealumni.eu/newsletter/definition-day-smart-specialisation-strategy [Accessed 24 Jun. 2019].

Mccann, P. & Ortega-Argilés, R. 2014. Smart specialisation in European regions: Issues of strategy, institutions and implementation. *European Journal of Innovation Management,* 17**,** 409-427.

Meyer, E. A. 2004. *Cascading style sheets: The definitive guide*, " O'Reilly Media, Inc.".

Musciano, C. & Kennedy, B. 1996. *HTML, the definitive Guide*, O'Reilly & Associates.

Naser, S. S. A. 2008. JEE-Tutor: An Intelligent Tutoring System For Java Expressions Evaluation. *Information Technology Journal,* 7**,** 528-532.

Oecd, W. 2013. UNCTAD (2013). *Implications of global value chains for trade, investment, development and jobs,* 20.

Pugh, R. 2018. Questioning the implementation of smart specialisation: Regional innovation policy and semi-autonomous regions. *Environment and Planning C: Politics and Space,* 36**,** 530-547.

Reddy, C. S., Sangam, R. S. & Rao, B. S. 2019. A Survey on Business Intelligence Tools for Marketing, Financial, and Transportation Services. *Smart Intelligent Computing and Applications.* Springer.

Reynolds, C., Agrawal, M., Lee, I., Zhan, C., Li, J., Taylor, P., Mares, T., Morison, J., Angelakis, N. & Roos, G. 2018. A sub-national economic complexity analysis of Australia's states and territories. *Regional Studies,* 52**,** 715-726.

Rigby, D. L. 2015. Technological relatedness and knowledge space: entry and exit of US cities from patent classes. *Regional Studies,* 49**,** 1922-1937.

Roos, G. 2017. Knowledge management, intellectual capital, structural holes, economic complexity and national prosperity. *Journal of Intellectual Capital,* 18**,** 745-770.

Sedrakyan, G., Mannens, E. & Verbert, K. 2018. Guiding the choice of learning dashboard visualizations: Linking dashboard design and data visualization concepts. *Journal of Visual Languages and Computing,* 50.

Severance, C. 2012. Javascript: Designing a language in 10 days. *Computer,* 45**,** 7-8.

Turban, E., Sharda, R. & Delen, D. 2010. Decision support and business intelligence systems (required). *Google Scholar*.

S3platform. (2019). S3 Implementation Handbook - Smart Specialisation Platform. Retrieved from http://s3platform.jrc.ec.europa.eu/s3-implementation-handbook

Uthe, R. T. 2009. Displaying arbitrary relationships in a tree-map visualization. Google Patents.

Valmohammadi, C. 2012. Investigating innovation management practices in Iranian organizations. *Innovation,* 14**,** 247-255.

Wipo.int.(2018).[online]Availableat:https://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2018.pdf [Accessed 2 Dec. 2019].

Wrike.com. (2019). What is Agile Methodology in Project Management?. [online] Available at:https://www.wrike.com/project-management-guide/faq/what-is-agile-methodology-in-project-management/ [Accessed 12 Aug. 2019].

Zhu, Y. 2012. Introducing google chart tools and google maps api in data visualization courses. *IEEE computer graphics and applications,* 32**,** 6-9.