Energy-Climate-Economy-Society Nexus: Regional and Global Supply Chains of the World's Food Production

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by

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in
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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Industrial and Systems Engineering.

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Declaration of Authorship

I, Hamidreza SAMADI, declare that this thesis titled, 'Energy-Climate-Economy-Society Nexus: Regional and Global Supply Chains of the World's Food Production ' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
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Date: 23.05.2017

" The value of three things is justly appreciated by all classes of men: youth, by the old; health, by the diseased; and wealth, by the needy."

Omar Khayyam

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Abstract

The food industries have significant regional and global environmental and socioeconomic impacts worldwide.These impacts are often analyzed by policy makers in order to assess and improve the effectiveness of sustainable food production strategies at the regional and global scale. The overarching goal of this thesis is to understand the environmental and socioeconomic impacts of the world largest food producers such as United States, China, India, Brazil, Russia and Europe (Germany, UK, France, Italy, Spain, and Turkey) in terms of energy and climate as well as socioeconomic impacts such as gross value added (GVA)and compensation of employees. Supply chain decompositions analysis and global impact distribution analysis are conducted for selected indicators to represent the distribution of each impact category through supply chain nodes and trading partners. Critical indicators such as GVA vs.energy,GVA vs.climate, and GVA vs. labour compensation are analyzed for food manufacturing industry of countries being analyzed.The results are presented for three supply chain components such as regional on-site impacts, regional supply chain impacts,and global supply chain impacts.The findings of this research will help the policy makers to identify the environmental hotspots as well as determine the regional and global socioeconomic impacts of their economic growth strategies. Overall, the policy makers will be able to understand the feasibility of their investments in terms of environmental and socioeconomic impacts. In this study, the countries with high amount of (GVA) in food industry such as India, China and Russia result in making excessive percentage of carbon emission impact in the environment respectively which clarifying the drawbacks in consumption and controlling energy use to achieve the sustainability development targets in food industry.The greatest single component of greenhouse gas emissions from food industry arises from the production and use of fertilizer, whether as synthetic nitrogen or as manure.

Keywords : Energy-Climate-Economy Nexus; SocioEconomic Impacts; World Input-Output Database; Sustainable Economic Growth; International Trade; Multi region input-output Analysis; Life Cycle Sustainability Assessment; Sustainable Food Supply Chains.

İklim-Ekonomi-Toplum İlişkisi: Dünya Gıda Üretiminin Bölgesel ve Küresel Tedarik Zincirleri

Hamidreza SAMADI

Öz

Gıda endüstrileri, dünya çapında önemli bölgesel ve küresel çevresel ve sosyo-ekonomik etkilere sahiptir. Bu etkiler, bölgesel ve küresel ölçekte sürdürülebilir gıda üretim stratejilerinin etkinliğini değerlendirmek ve iyileştirmek için genellikle politika yapıcılar tarafından analiz edilmektedir.Bu tezin temel amacı,Amerika Birleşik Devletler, Çin, Hindistan, Brezilya, Rusya ve Avrupa (Almanya, İngiltere, Fransa, İtalya, İspanya ve Türkiye) gibi dünyanın en büyük gıda üreticilerinin çevresel ve sosyo-ekonomik etkilerini anlamaktır, ayrıca brüt katma değer (GVA), çalışanların tazminatı, gibi sosyo - ekonomik etkiler anlamaktır.Tedarik zinciri ayrıtırmaanalizi ve küresel etki dağılım analizi , tedarik zinciri düğümleri ve ticaret ortakları aracılığıyla her bir etki kategorisinin dağılımını temsil etmek üzere seçilen göstergeler için yürütülür.Analiz edilen ülkelerin gıda imalat sanayi için GVA vs.enerji, GVA ile iklim ve GVA ile tazminat emek gibi kritik göstergeler analiz edilir. Sonuçlar, bölgesel etkiler, bölgesel tedarik zinciri etkileri ve küresel tedarik zinciri etkileri gibi zinciri bileşenleri için sunulmuştur.Bu araştırmanın bulguları politika yapıcıların çevresel sıcak noktaları belirlemelerine ve ekonomik büyüme stratejilerinin bölgesel ve küresel sosyo-ekonomik etkilerini belirlemelerine yardımcı olacaktır. Genel olarak, politika yapıcılar yatırımlarının fizibilitesini çevresel ve sosyo-ekonomik etkiler açısından anlayabilecektir.

Anahtar Sözcükler : İklim-Ekonomi İlişkisi ; Dünya Girdi-Çıktı Veritabanı Sürdürülebilir Ekonomik Büyüme; Uluslararası Ticaret; Çok uluslu girdi-çıktı analizi; Yaşam döngüsü sürdürülebilirlik analizi; Sürdürülebilir gıda tedarik zincirleri.

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Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

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Abbreviations

AHFF	**A**griculture **H**unting **F**orestry **F**ishing
EE-IOA	**E**nvironmentally-**E**xtended **I**nput-**O**utput**A**nalysis
EU	**E**uropeann **U**nion
EGW	**E**lectiricity **G**as **W**ater supply
FAO	**F**ood **A**griculture **O**rganization
GDP	**G**ross **D**omestic **P**rouduct
GHG	**G**reenhouse **G**as
GVA	**G**ross **V**alue **A**dded
LCA	**L**ife **C**ycle **A**ssesment
MRIO	**M**ulti **R**egion **I**nput-**O**utput
PLCA	**P**rocess **L**ife **C**ycle **A**ssesment
RoW	**R**est -of-the **W**orld
UK	**U**nited **K**ingdom
UN	**U**nited **N**ation
USA	**U**nited **S**tates of **A**merica
WIOD	**W**orld **I**nput-**O**utput **D**atabase

Chapter 1

Introduction

1.1 Food Industries and Sustainability

The demand for food consumption is anticipated to grow by at least 50% over the next four decades.Therefore, the food industry becomes heavily discussed topic all across the world, especially when our future world can be grappling with the challenge of food shortage manufacturing in the future.Issues such as increasing world's population, energy scarcity, and environmental degradation are the principal and critical. In addition, the unsustainable manner of human in diverse industrial activity results in giant destructive effects in several scopes. Increasing food carbon emission, energy evacuation, and climate change require regional and global attentions by countries. The food industry is responsible for high fraction of the energy consumption and carbon footprints emission, therefore requirement to alter the essential patterns in the procedure of food manufacturing, distributing and creating balance between supply and demand is necessary [1]. Hence, most of the governments defined new strategies in order to deal with over consumption and material supply shortages and from this standpoint the current situation result in analysing of global food supply chain.In spite of most likely threats in the future, even European economics cannot pass through reliable route, while by growing energy price and increasing fluctuation in world economy, in 2009,the high number of industries in Europe endured unexpected diminution (up to 20%) [2]. Among the European Union, USA and new found economies such as Brazil, India and Turkey, the food industry is one of the most sophisticated and significant sectors which allocate large scale of both economic value contribution and resource expenditures [3]. In 2010, the proportion of

production and consumption of the food industry in Europe were responsible for 20-30% of environmental effects, consisting of energy use and climate change [2]. According to Food and Agriculture Organization of United Nation's report in 2012 the food industry activates in all across the world encounter with double severely impacted challenges of climate change and widely aggravating climate change within greenhouse gas (GHG) emission; agriculture is accountable for 80-86% all food-related global GHG emissions and 14-24% of total global emissions [42]. By 2050 world's population will presumably surge by 35% [23] while by continuing traditional procedure of food manufacturing without bringing up sustainability approaches; most probably the food system will be turn into one of the major concern all around the world .While resource drawing out and food manufacturing occur in some parts of the world [30], production and consumption fall out in other parts of the world. Hence, in order to implement and examine sustainable supply chain management policies, international supply chain need to be take into consideration.Nevertheless, for capturing the fine perception of ongoing sustainable supply chain management precedences, the economy targets and social perspective of an individual company in long and short term of its manufacturing should be consider [21]. Sustainability challenges in the future of the food industry can be interpreted as subsequent threat for food security, For instance climate change, water scarcity, growing population, soil erosion and affiliation to fossil fuel are almost most prominent and severe concerns. From this standpoint it is beneficial for giant food industries to analyze all different section of supply chain management, however some other researches illustrate partial impact in comparison with upstream supply chain management impacts [26].
The significance of sustainable supply chain management over the last decade has turn it into an inseparable concept worldwide, and also it alter the regional and multi-regional decision making policies [4]. The prominence of enterprise system thinking in supply chain management has risen up due to wide range of effects which originate from diverse segments of food manufacturing industry [13]. The major methods which widely applying for investigating the energy and carbon footprint are life cycle assessment models (LCA) [5].The LCA mighty in analyzing all partial and overall aspects of energy and carbon impacts of product life cycle or in the other word figuring out cradle to grave expression analysis, containing raw material exploitation/processing, production, locomotion, consuming and end of life phases [68].

Nowadays all countries endeavor to manufacture all their primary foods and beverages requirements in their homeland, however the interaction among the countries, including exports and imports provide close relationship. The countries with largest economy playing crucial role in steering this industry in the world. Most of this countries allocate nearly high fraction of their GDP to agriculture and producing food. In this study we considering Chain, United states, India, Brazil, Russia, Germany, France, Italy, Spain, Australia, England and Turkey. Due to evaluating contribution of each of these countries share in manufacturing food, we selected for vital indicators (Carbon emission, Energy consumption, Gross value added and Labor compensation) [52, 67].

1.2 Importance of Sustainable Development and United Nations Sustainable Development Goals related to Food Industry and Scarcity

"Sustainable development is development that purvey the needs of the present without compromising the ability of future generations to provide their own needs" [43, 68].Each country is responsible for its own economy and providing food security for its population, hence the social and economic development directly can be improved or regressed by setting national policies. Therefor, overemphasizing on domestic resources and development strategies cannot provided the fundamental base of sustainable development. Whereas, the developing countries require additional resources from out of their boundaries, in order to boost sustainable development, there is a crucial requirement for important mobilization of resources from wide range of diversity and efficient financing. The United Nations in cooperating with FAO which is specialized UN agency in scheduling long term perspective until 2030 [40]. For instance some of these goals are :

- Attaining food security and improving nourishment by developing sustainable agriculture and food manufacturing.
- Trying to end or decline poverty.
- Providing healthy life with establishing primary medical needs in everywhere.
- Ensuring educational opportunities in equality form.

- Managing water supply and demand sustainability.
- Investing on new generation of energy and ensuring accessibility, affordability, sustainability and reliability for all.
- Construct reactionary infrastructure in facing with sustainability concepts.

Dynamic interaction between the energy consumption and amount of food manufacturing and the impacts of climate change and water deficiency in agriculture, all result in seeking comprehensive approach which can minimize the amount of fossil energy gnaw and increase the level of food production with observing the sustainable development methods. In this path we need to investigate the food manufacturing procedure by applying life cycle assessment, not only by analyzing carbon and energy effects rather focusing on social and economic, for instance the amount of gross value added in food industry illustrate the countries capability in meeting internal requirement or even the capability of country in exporting food [65]. As the global demand for consumption high quality and well nutritious processed is rising because of worldwide population growing and by emerging most developing economics such as India, China and Brazil in the recent decades, the main and severe concern is the fast consuming of global resources such as fossil energy, natural gas and water, which result in irrecoverable consequences. In order to reduce the impacts of food industry in our societies, it is necessary to determine indicators and materials to compute sustainable processing. The main prevalent indicators in calculating environment impacts is greenhouse gas (GHG) emissions ,the water usage and waste can be measure in relation with final product. One of the most sophisticated methods for meeting environmental challenges is P-LCA (Process - based Life Cycle Assessment), nevertheless P-LCA is suitable for evaluating direct environmental footprint, it cannot be assume as component of all upstream suppliers effects in associated with processing, production and distribution of products [31, 39].

In the economic section,considering gross value added in relationship with food industry is significant, while it illustrates measure of value of final food industry in each country. In global economic fluctuation and fast changing world with advance technologies in food industry, all countries endeavor to increase their proportion in total gross added value, such developments lead to measure the sub-sectors of food industry in associate with Gross value added (GVA).

1.3 Methods for sustainability assessment of food production

1.3.1 Sustainable supply chain management and life cycle assessment

Food industry issues have been an area of anxiety and attention for developed and in developing countries. Suppliers, manufactures, distributers and consumers are consisting dependent chain which ignoring each of them result in wrong comprehension. An appropriate analysis of the supply chain concepts in corresponding with the global impacts of the food industry is an essential incumbent in both regional and international dimensions due to ensure the security of food industry in the future perspective. Hence, for better perception the environmental impacts of production, comprise food productions, life cycle assessment (LCA) and environmentally enlarged input-output analysis (EE-IOA) are both of the principal approaches exploited in several projects, involving Environmental impacts of products of the European Union [28]. LCA depicts the consumption and emission of all details of the supply chain from initial resources usage until any environmental exchange in all stages, which is generally known as a "Cradle to Grave" investigation [63].

LCA patterns are largely expanded in order to calculate energy and carbon footprints of food manufacturing segment in associated with its comprehensive life cycle [22]
LCA model has ability of analyzing the all characteristics of energy and carbon impacts of product life cycle which involving the primary material exploitation/ processing, manufacturing, transportation,usage and end of the life stage [14].

1.3.2 Input Output analysis : single and multi region models

Whereas, P-LCA is suitable procedure for measuring direct aspect of environmental impacts, but it cannot acknowledge true proportion of all upstream supplier's impacts which are in a way intertwined with processing,manufacturing, distribution or usage of products [16, 62].

Most of the LCA studies in food industry scope are focused on restricted number of indirect impacts, exclusively in phrase of energy and carbon footprint analysis. Moreover, in

the various number of the study which a similar process-based approach is implemented, it inclines to investigate just direct impacts by ignoring the upstream (Production, transportation, and /or distribution) of food manufacturing industry [6]. The former studies illustrated that P-LCA is facing with substantial drawback in curtailment errors in the case of upstream energy and carbon footprints impacts, which can be 50% or maybe higher [27, 61].

There are several studies which applying a single- region EE-IOA due to approximate impacts of food manufacturing or distribution system. For instance comparing the environmental LCA of final agriculture products with prevalent agriculture approaches in order to calculate impacts of energy and carbon footprint in Australia is one of the remarkable examples, in this study the EE-IOA was applied in comprehensive way in goal of calculating proportion of indirect resource inputs from total upstream manufacturing levels [2]. In the other sophisticated study, a hybrid LCA model merging EE-IOA and P-LCA was implemented in order to compare the potential of global warming and the amount of initial energy use of prevalent wheat production and consider transportation in the USA. In developed model of EE-IOA in the recent study 33 food manufacturing sector's environmental impact were analyzed [2, 26]. The outcomes demonstrated that the over 80% of total carbon, water, energy and ecological footprints during whole period of the life cycle are result from supply chain of these food sectors. [53]

While in the several cases single-region EE-IOA method is applied for analyzing environmental industries [10]. From this standpoint these studies inclination is estimating sustainability impacts in associating with food manufacturing industry, on the other hand most of the countries are following open economics which means importing goods and services from overseas [11].

Hence, the rates of energy usage and carbon footprints are showed in multiple countries I-O tables [6]. In this regard, in various rang of the studies Multi-Regional Input-Output (MRIO) models are became favorite topics in literature and also applied routinely in regional policy making [20, 30]. Currently, there are several global MRIO database in order to implement supply chain methods for considering impacts of carbon emission and energy consumption. For instance World Input-Output Database is one of the most developed global multiregional databases used in recent studies. [50]

1.4 Problem Statement

Food production industry is one of the most discussion topic in these days and policy making about the security of food in the future is main concern in all across the world. In this study we consider world's 12 most high food manufacture country which are playing significant role in providing global food needs. Easily topping the list are China and India, which are the world's biggest producer, importer and consumer of food according to the FAO annual report in 2012 [8]. China also has the world's largest food workforce, with some estimates as high as 315 million laborers. By comparison, the U.S. is the world's third most populous country, with 320 million people [6]. On the other hand no country produces as much as efficiently as the U.S. Despite having a smaller workforce than China, total U.S. agricultural product is almost as high [73]. The Brazilian economy is historically centered on agriculture, particularly sugarcane, dating back to its time as a European colony. 31% of Brazil is used as cropland, largely to produce coffee, sugarcane, soybeans and corn[70]. In addition, most of EU countries such as France, Germany,Italy, Spain and the UK are playing critical contribution in Europe's food manufacturing and distributing [40]. Turkey also has one of the highest export growth rate in the world because agricultural export has tripled during last decade in the recent macro statistical published report by FAO in 2014. Like other countries on the list, Turkey is trying to tackle the problem of food waste [8]. Furthermore, Russian food industry sector is growing sharply in the recent decades and interaction of this growth effects world supply chain assessments [18]. Also Australia as one of the developed countries in the world has the high contribution in exporting fishers and meat productions, which can be named as one of the pioneer in food industry pursuant to Australian food ministry statistics in 2013 [17]. Due to this motivation, this research address the four critical indicators and considering 35 different sectors for each country. In this research we considering global contribution of energy consumption, carbon footprint emission, labour compensation and (GVA) in order to consider the (LCA) in **Cradle-to-Gate Analysis** assessment, which refer to partial product life cycle from resource extraction (Cradle) to the factory (Gate) like the final product before transporting to the market for consuming.

1.5 Research Objectives

- To recognize the fundamental steps in applying supply chain phases such as upstream supplies, onsite manufacturing and etc.)
- To consider the food industry in the conceptual of the Cradle to Gate as partial section of life cycle assessment.
- To evaluate environmental impact based on energy use and greenhouse gas emissions (for regional onsite, regional supply chain and global supply chain).
- To specify relation between energy and carbon footprints, bringing up the role of distinct supply chain stages.
- To consider socio-economic impacts based on GVA, compensation of employees and number of labors based on skill groups (for regional onsite, regional supply chain and global supply chain).
- To calculate supply chain decomposition analysis for environmental and socio-economic indicators for food industries of countries.

Chapter 2

Methodology

2.1 Methods

In a single-region I-O model, the total output of the domestic economy for a given final demand is calculated by using the Leontief's Inverse as follows [42] :

$$x = (I - A^d)^{-1} f$$

Where A^d is the domestic total inter-industry requirements matrix and f represents the total final demand on the economy, where f can be household demand, government demand, investment, and/or a dollar output of a particular sector. Also, x accounts for the total output vector, and I is the identity matrix in which all entries are zero except for the diagonal entries, which are equal to 1. The term $(I - A^d)^{-1}$ is the total requirement matrix, the Leontief Inverse [55].

Using the direct environmental impacts per unit output (represented by M), the total environmental impacts embodied in domestic production (represented by r vector) are formulated as follows [15] :

$$r = M_x = M(I - A^d)^{-1} f$$

Where the **r** vector does not include environmental impacts that may occur in foreign regions due to foreign trade. However, it is also necessary to calculate the global environmental impacts for production, particularly for the environmental impacts (carbon footprint, energy use, etc.) of regional food production with global implications. Today, many countries have become open economies importing goods and services from foreign countries.) [25]. Hence, a MRIO model is required to correctly calculate the environmental impacts of food production, which might indicate higher dependency on global trade from certain perspectives (agricultural products, energy, minerals, etc.) [11, 58]

In this research, we used the WIOD to obtain monetary transactions between the world's major economies, which are grouped under 40 countries. Funded by the 7th Research Programmed of European Commission, this MRIO database includes a time series of symmetric I-O tables for the entire time period from 1995 to 2011 with respect to all 27 EU member states and 13 other major countries, distinguishing among 35 industries and 59 products [6, 24].In the WIOD, a MRIO database is constructed using the Supply and Use Tables at basic prices with a fixed product sales assumption. In this assumption, each product has its own specific sales structure, irrespective of the industry where it is produced. Within the WIOD, all tables are obtained from the National Accounts Statistics, and are based primarily on publicly available data. For more information about the sources and methods used in compiling the WIOD, or about constructing industry-by-industry I-O tables and detailed sector classifications, please refer to to [9]. In a MRIO model, an $A^{RS_{ij}}$ matrix consists of multiple rows that present the input of sector i from country **R (= 1,...,N)** into industry j in country **S(=1,...,N)** . In addition, i and j represent the number of sectors and countries, respectively **(i=35; j=41)** . This matrix is also known as the direct requirement matrix, and each row represents the total inputs from other sectors (domestic inputs plus inputs from other countries) to produce a dollar of output. Overall, the MRIO analysis produces a set of multipliers that show the total environmental impacts based on economic output per dollar, and therefore quantifies a global multinational environmental footprint of supply chains as follows:

$$r = M_x = M(I - A^{RS_{ij}})^{-1} f$$

After the total requirement matrix is derived from the direct requirement matrix using Equation 3, the carbon and energy footprints of the food manufacturing industries can be estimated by multiplying the output of each sector by its carbon or energy impact per million dollars ($M) of economic output. In this study, the MRIO analysis results are presented based on common supply chain phases, such as upstream supply chains, onsite manufacturing, transportation and distribution, and wholesale and retail trade. Equations 4 and 5 present the total carbon emissions and energy use of food manufacturing sectors, respectively: [54]

$$c = C_{dir}x = C_{dir}(I - A^{RS_{ij}})^{-1}f$$

$$e = E_{dir}x = E_{dir}(I - A^{RS_{ij}})^{-1}f$$

Where c is the vector of GHG emissions for each sector and C_{dir} is a matrix with diagonal elements representing the carbon emissions per dollar of output for each sector from 40 major countries and from the rest of the world in general. Similarly, e represents the vector of energy consumption and E_{dir} is a diagonal matrix including the values of energy use per dollar output of each sector. Each element of $C_{\mathbf{dir}}$ and $E_{\mathbf{dir}}$ is simply calculated by dividing the total GHG emissions and energy consumption of a particular sector, respectively, by the total economic output of that sector.

In addition, for GVA and labour of compensation likeness, g represents the vector of GVA consumption and G_{dir} is a diagonal matrix including the values of GVA use per dollar output of each sector. Each element of $G_{\mathbf{dir}}$ and $L_{\mathbf{dir}}$ is simply calculated by dividing the total GVA and Labour of Compensation of a particular sector, respectively, by the total economic output of that sector.

$$g = G_{dir}x = G_{dir}(I - A^{RS_{ij}})^{-1}f$$

$$l = L_{dir}x = L_{dir}(I - A^{RS_{ij}})^{-1}f$$

2.2 Definitions of sustainability indicators and justification of indicator selection (Energy, Carbon, GVA, Employment

Indicators accomplishes several functions in each comprehensive system. They can result in making better decision and cause to simplifying complicate concepts, helping policy makers due to illuminate and make aggregated information database. Whereas indicators can help combine sustainability concept with social, environmental and economic analysis into decision-making, and in this way sustainability indicators can play vital role in helping to measure and evaluate progress toward sustainable development perspective. In this study, we consider four important indicators in the food industry. The food industry is one of the spotlight topics which has a narrow relative with energy consumption, carbon footprint emission, gross value added (GVA) and employment skill category indicators. In the recent decades, the food system is progressively globalized. In order to meet market supply and demands, supply chain phases such as upstream suppliers, wholesale and retail trade and onsite manufacturing. This complexity carries with its opportunities for growth into new markets; however, there are so many barriers [57]. The fundamental reason for choosing energy consumption indicator is evaluating the proportion of different kinds of energy sources in procedure of food manufacturing. According to united nation's annual report in 2006 energy cost consist around 20% of total production costs in developed countries [43].

For instance the energy consumption indicator for food industry in the United States has enhanced 2.36 times during four years from 2002 to 2006 however, the energy indicator in the other manufacturing scopes just 2.1 times incremented in the same during period.For instance the amount of energy consumption based on MJ per ton of final products in meat industry of four developed European countries including Germany, Italy, France and the United Kingdom has dramatically increased from 14% to 48% in 1990s [18]. From this standpoint, by analyzing energy indicator we can amend the food energy consumption pattern in sustainable way. [48]

The impact of CO_2 that result from food manufacturing, is definitely one of the most significant issues in ameliorating environmental responsibility of the food supply chain management. Expect carbon emission in procedure of manufacturing, in our research approach, investing food transportation in different modes such as inland transport, water

transport and air transport are playing important roles. Hence, (LCA) is sophisticated quantitative methods for measuring the carbon footprint [29].

The role of the (GVA) in economy is measuring the contribution to the different sectors of economy such as individual manufacture, industry. In the other words it is the value of the amount of goods and services that have been produced). Moreover, gross value added (GVA) is one of the important factors in evaluating the proportion of total (GDP). Accordingly considering the food industry as one of the huge sector is inevitable. Whereas GVA as one of the productivity factor can be used due to demonstrate countries' ability in using human forces and physical ability [32, 60].

Chapter 3

Results and Discussions

Fig 3.1 presents average of indirect carbon, indirect (Global) and total direct carbon effects in India, Brazil, China, Russia, Australia, the USA, Turkey, France, Germany, Spain, UK and Italy based on per $M basis in 2009. In this analysis the indirect carbon for each country presented the Food, Beverage and Tobacco interaction and determined the portion of food industry's role for each country by using world input output database (WIOD). For instance in this analysis India has highest amount of indirect carbon Impact with 1804 million and Italy has the lowest with 257 (mt CO_2-eqv). For indirect (Global) carbon impact which showing amount of carbon emission by subtracting total amount of carbon (per one million dollar) by summation of 35 sectors of each considered country. The finding shows that Germany had captured the highest amount with 305 (mt CO_2-eqv)' . In addition the total direct carbon also depict carbon impact in food and beverage, which as one can see the highest amount of GHG in this sector belongs to India with 622 (mt CO_2-eqv) ,the second highest amount captured by Turkey with 136 (mt CO_2-eqv) and the lowest amount of carbon emission in this category owned by Brazil.

Fig 3.2 illustrates the average total carbon footprint of each country in 2009. By calculating total footprint emission, the order of countries altered, for instance in the Fig 3.1 (Average carbon footprint based on per $M output in 2009) India had the largest amount of carbon footprint in all direct carbon and Indirect carbon analysis, but in Fig 3.2 China captured the first rank, in addition regarding Indirect (Global) category China was pioneer in both figure, that resulting from the high economy growth and degrees of

influence as the world's new phenomenon economy [72].

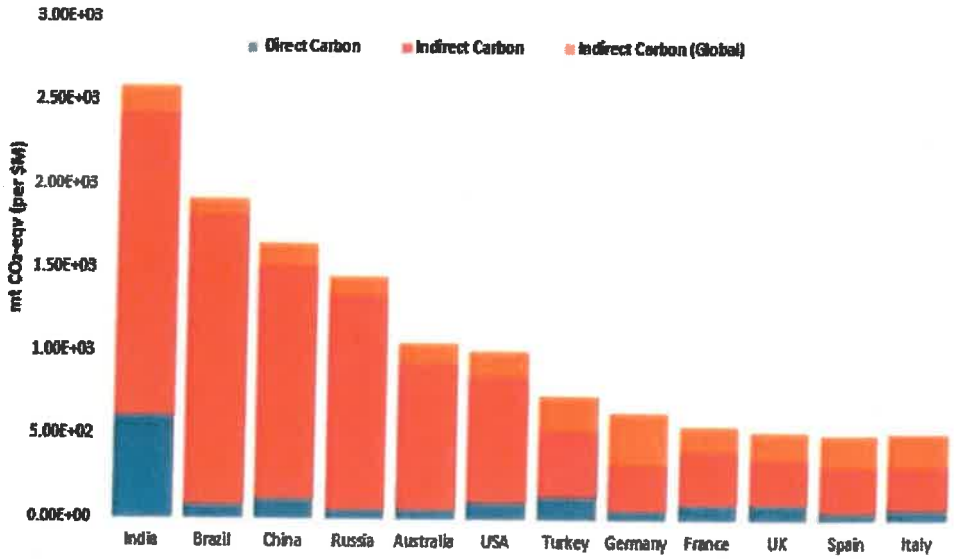

FIGURE 3.1: Presents average of total direct carbon, indirect carbon , indirect carbon (Global) in India, Brazil, China, Russia, Australia, the USA, Turkey, France, Germany, Spain, UK and Italy based on per $M basis in 2009.

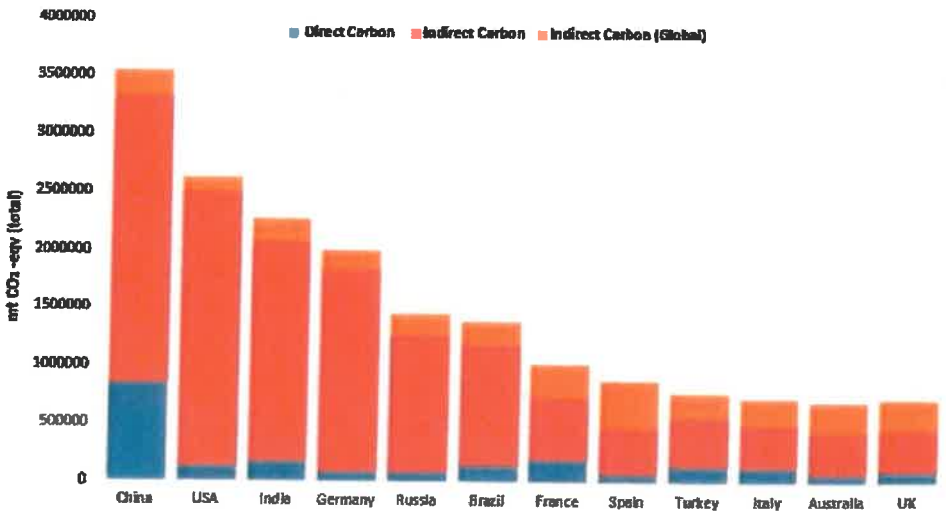

FIGURE 3.2: Presents average of total direct carbon, indirect carbon , indirect carbon (Global) in India, Brazil, China, Russia, Australia, the USA, Turkey, France, Germany, Spain, UK and Italy based on total economic output in 2009.

Finally, The results depicted that the ranking of the countries' in Fig 3.3 (the average total energy consumption in 2009) is alike with their commensurate ranks in Fig 3.2 The most considerable consequence is that Brazil which had higher total direct energy

consumption than Germany in Fig 3.3 had a lower carbon footprint than that of Germany. Simultaneously the other countries retained relatively in the resembling rankings. Although India and Brazil had the highest carbon emission severity per $M of output respectively, but their total emission intensity are much lower in comparison with other countries. Thereby comparing the total carbon emission of studied countries in food industry revealed the economic sizes and outputs of several food sectors.

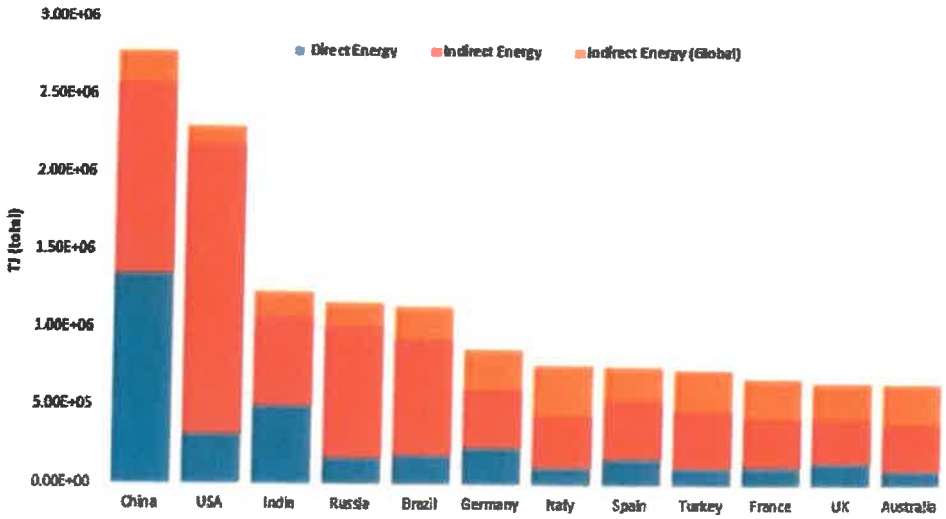

FIGURE 3.3: Presents average of total direct energy, indirect energy , indirect energy (Global) in India, Brazil, China, Russia, Australia, the USA, Turkey, France, Germany, Spain, UK and Italy based on total economic output in 2009.

Fig 3.3 indicates the average total energy usage values of each country in three different analysis in 2009. By comparing Fig.3 (average energy consumption based on per $M output) and Fig 3.4 countries energy usage followed the same behavior, for instance countries such as China, the USA, Russia and Brazil were the leading in terms of energy consumption in both analysis, however based on total energy usage China, the USA and India are the first three top countries. Australia is the only country which shows opposite behavior in term of total energy consumption. Also Spain in the Fig 3.4 captured highest rank in comparison with Turkey and France and conversely Spainâs total carbon emission are much lower than Turkey and France.

Fig 3.4 demonstrates the average energy consumption per $M of economic activity food industry in three different category for each country, indirect energy illustrate average energy usage in food and beverage sector for each country. The leading countries in this

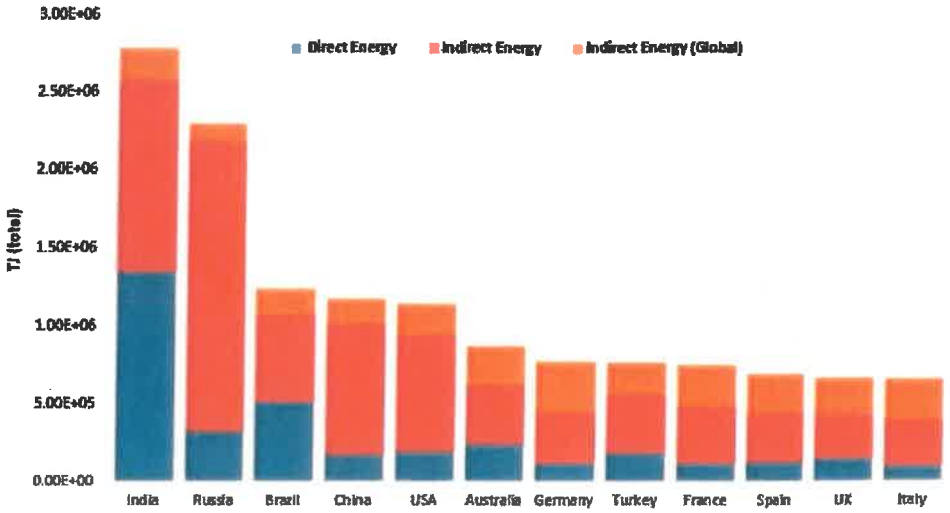

FIGURE 3.4: Presents average of total direct energy, indirect energy , indirect energy (Global) in India, Brazil, China, Russia, Australia, the USA, Turkey, France, Germany, Spain, UK and Italy based on per $M basis in 2009.

term were Russia, India, China and the USA, while in the Germany, France, Italy and UK had very low energy consumption rates in comparison with others. In the second category, total direct energy, the pioneer countries in energy consumption were India, Brazil and Russia respectively. The most critical finding in Fig 3.4 is that China had low energy consumption rates compared to other populated countries. In the last category, indirect global energy consumption Germany, France, Italy and Spain were leading countries respectively. By comparing the carbon footprint and amount of energy consumption in 2009 for each country, the first interesting finding from these two analysis is that the countries with less energy intensive countries (Fig.3) had more carbon footprint emission. For instance Russia was the highest energy intensive (rank first) in Fig 3.4 but simultaneously was not shown in Fig 3.1 to be the most carbon intensive country. Also other countries that captured high carbon impact emission but not energy consumption intensive, such as Brazil, China and Australia. While the least energy consumer countries in food industry such as Spain, Italy and UK are found steady in associated with their total energy consumption in Fig.3.3 Moreover, China, the USA and India were consumed the large scale of total economic output energy in the Fig 3.3 respectively. As one can see Russia captured the highest indirect energy usage with 21.94 TJ in Fig 3.4 that can be resulted from huge source of fossil energy usage in food industry in Russia.

Fig 3.4 indicates the average total energy usage values of each country in three different analysis in 2009. By comparing Fig.3 (average energy consumption based on per $M output) and Fig.4 countries energy usage followed the same behavior, for instance countries such as China, the USA, Russia and Brazil were the leading in terms of energy consumption in both analysis, however based on total energy usage China, the USA and India are the first three top countries. Australia is the only country which shows opposite behavior in term of total energy consumption. Also Spain in the Fig 3.4 captured highest rank in comparison with Turkey and France and conversely Spainâs total carbon emission are much lower than Turkey and France.

Labour compensation is a significant statistical term in national account of each country's economy which clarifying the the sum of gross wages and salaries and employer's social security portion and it can be calculated by dividing compensation of employees in national currency to total hours worked by employees. Figure 3.5 illustrates three different classification according to low, medium and high-skilled. As one can see in the below figure, developed countries in food industry proportionally capture lower ratio in the low-skilled level which can be result from different factors such as population, High-tech farming and level of education. for instance for India the ratio of low level skilled is highest whereas, for the USA with lower population but massive food industry sector, mentioned category is low. In addition, most of the EU countries have more high skilled employees in accordance with their population.

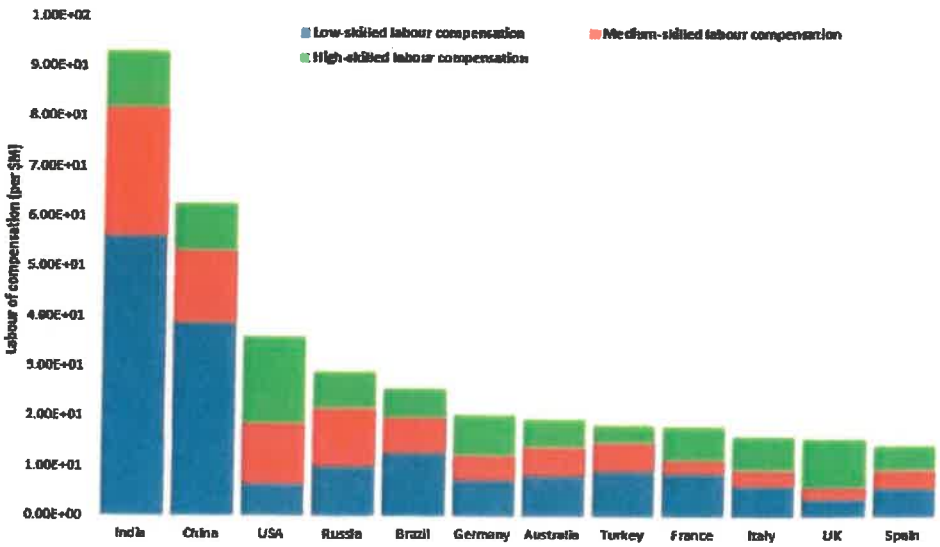

FIGURE 3.5: Presents labour of Compensation according to low-skilled employees, Medium-skilled employees and High-skilled employees based on per $M basis in 2009.

Turkey as one of the developing countries also has high level of low skilled employees in the food industry, but the percentage of medium and high leveled employees according to the United Nation 's yearly report in 2013 has been reduced effectively.

Figure 3.6 illustrate the total labour of Compensation according to low-skilled employees, medium-skilled employees and high-skilled employees based total $M basis in 2009. The USA captured the highest rank in this category which result from the high and medium level skilled employees. China and Australia are in the second and third rank respectively. the main and crucial result in considering total labour of compensation is the high educated employees in the most of study countries.China and India has the highest proportion of low skilled employees in the food industry in 2009. In contrast the UK has the lowest low employees in this industry. In addition by considering the UK population in comparison with other countries in this study, we can figure out that, the ratio of high level skilled employees is more higher than other countries. Most of the European countries in this calculation following similar trend.Germany gained the highest ratio of high level skilled employees in this stage.Brazil as one developing country seems that try to increase the the level of medium and high skilled employees in the upcoming years.

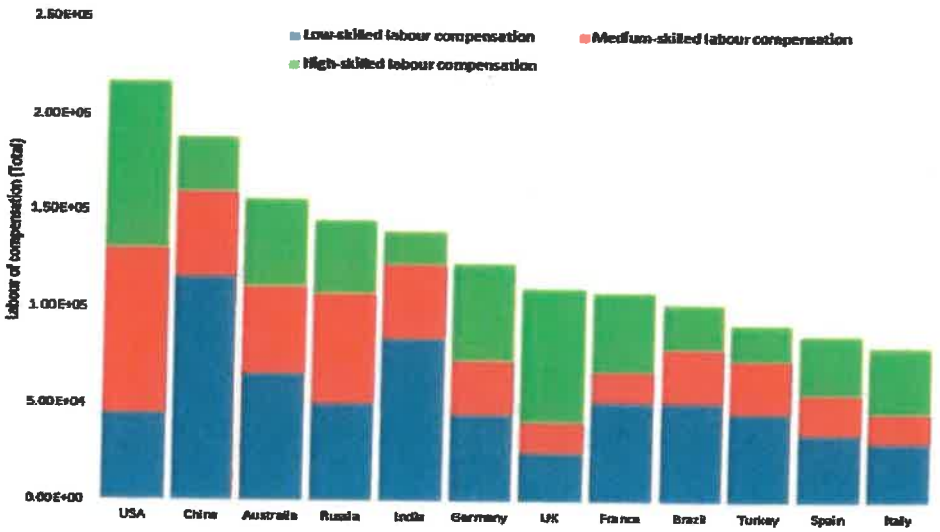

FIGURE 3.6: Presents Total labour of Compensation according to low-skilled employees, Medium-skilled employees and High-skilled employees based on per $M basis in 2009.

Overlay, for countries such as China and India which the amount of wages and salaries with respect to their high workforce population are lower in comparison with developed

countries conversely, the percentage of low-skilled employees are high. On the other hand the Fig 3.6 illustrates significant finding which the UK as one of the developed countries in food industry assigned high faction of labour compensation to the High-skilled employees.

Figure 3.7 displays the GVA for total direct GVA, Indirect GVA and Indirect GVA (Global) for case study countries.The leading countries in this indicator were India, Australia and Russia, the highest ratio of direct carbon is belong to India. In the other hand most of the European countries like Germany, France and the UK follow the equal ratio in these three mentioned category. Also In the second category, indirect GVA India captured the highest ratio in comparison with other countries. Australia, the lowest ratio also belongs to Brazil and most of the European countries as same as the first category are in the same level.Indirect GVA which illustrates the total average of other sectors expect food and beverage industry for each country had captured the low proportion in most of countries. Turkey gained the lowest amount between the study countries.

Figure 3.8 displays the the average total GVA for, total direct GVA, Indirect GVA and indirect GVA (Global) based on per $M basis in 2009. As China and India are populated country and the workforce in all sectors is extremely high. Hence the amount of the value and goods in total is more than other countries with lower population, however the USA as the biggest world economy in this category ranked in the second position. in total GVA most of countries since are developed or emerging economy were following in the same ratio. For instance in the first category, Direct GVA for China is the highest one and Turkey gained the lowest one. but for EU countries and Brazil this category is in the same level.Indirect GVA which included each countries all sectors expected food and beverage industry for China is the highest one and for Brazil is the lowest one. in the last category, Indirect GVA (Global) the highest ratio as same as the before captured by China.

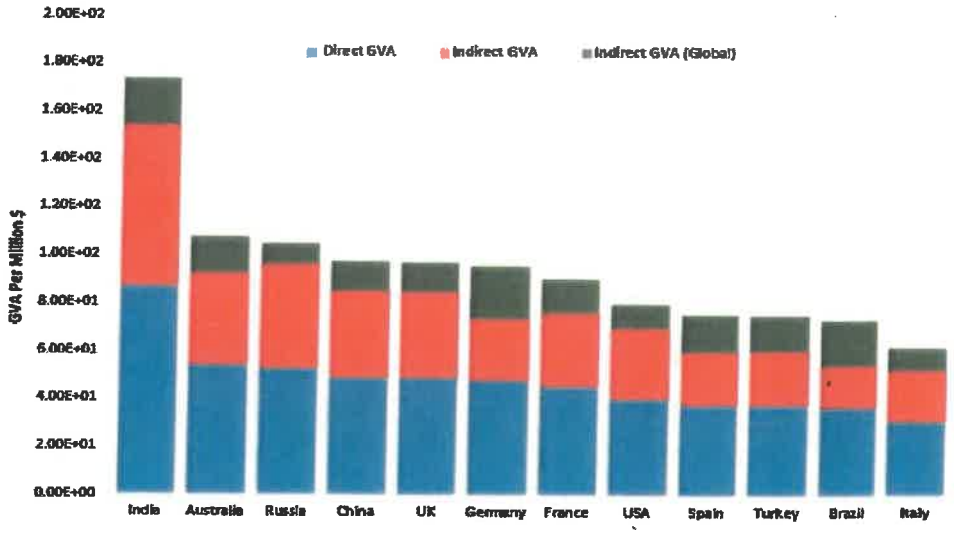

FIGURE 3.7: Presents the average of GVA for total direct carbon, Indirect carbon and indirect carbon (Global) based on per $M basis in 2009.

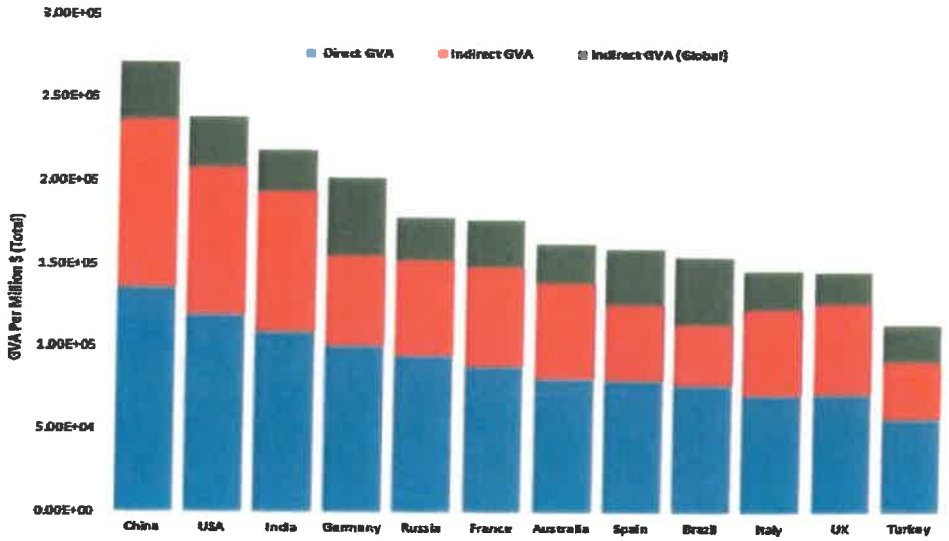

FIGURE 3.8: Presents the average of GVA for total direct carbon, Indirect carbon and indirect carbon (Global) based on per $M basis in 2009.

Fig3.9 presents the percent contributions of top 5 sectors to the carbon in food produce industry in 2009.This decomposition analysis depict the amount of carbon emission in specific way. Almost all countries illustrated agriculture, hunting, forestry and fishing to be the dominate sector. The second highest sector proportion captured by electricity, water and gas supply, in addition Russia had the first rank in this sector. Inland transport was slightly dominate in Russian, Spain, UK, Italy, and USA. Conversely (Brazil, China,

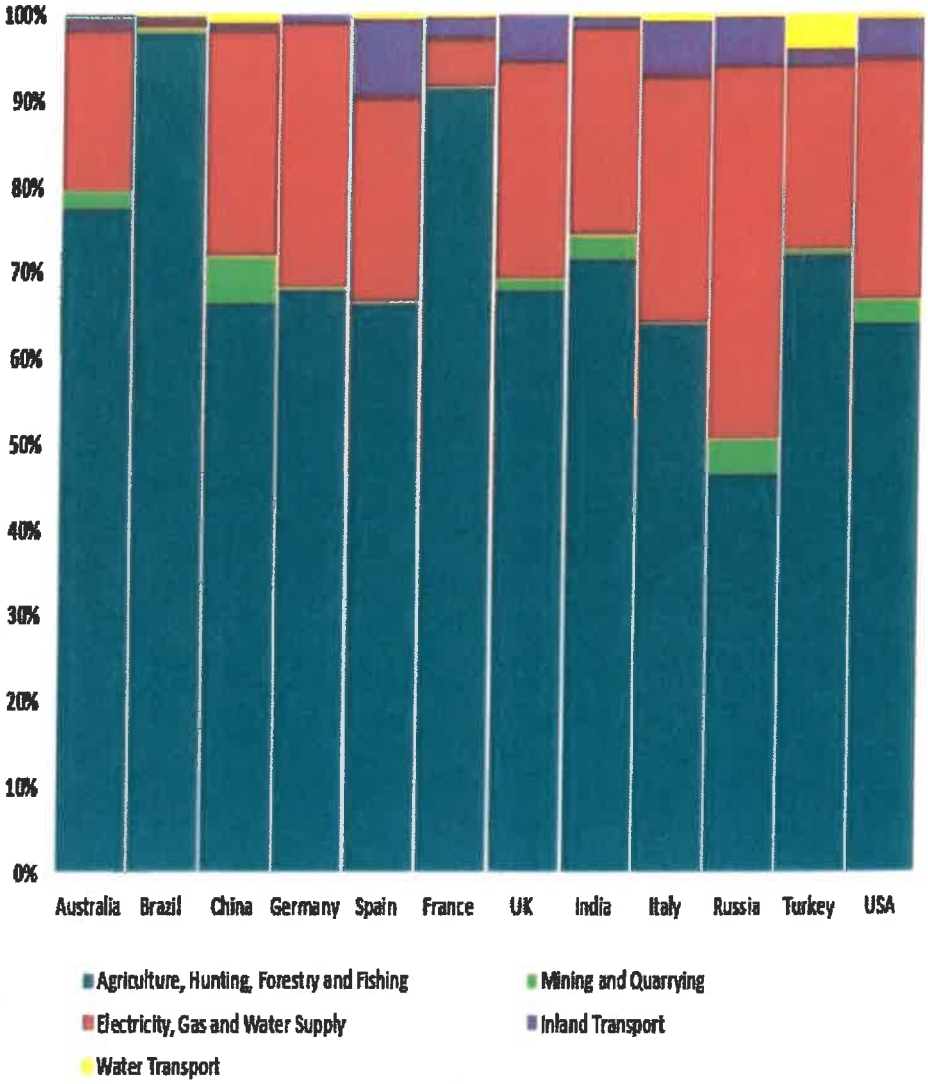

FIGURE 3.9: The percent contributions of different sectors to carbon footprint in food industry in 2009.

Germany, India and Turkey) dominate low proportion. The interesting finding in analyzing carbon footprint emission showed that Turkey is the top country in water transport in comparison with inconsiderable percent contribution of other studied countries. China and Russia contribution in mining and quarrying sector in food manufacturing industry is considerably higher than studied countries.

Figure 3.10 displays the percent contributions of agriculture (hunting and etc.),electricity,gas and water supply, transportation modes (water and inland) and finally coke, refined petroleum and nuclear fuel to energy consumption for studied countries in 2009. Similar

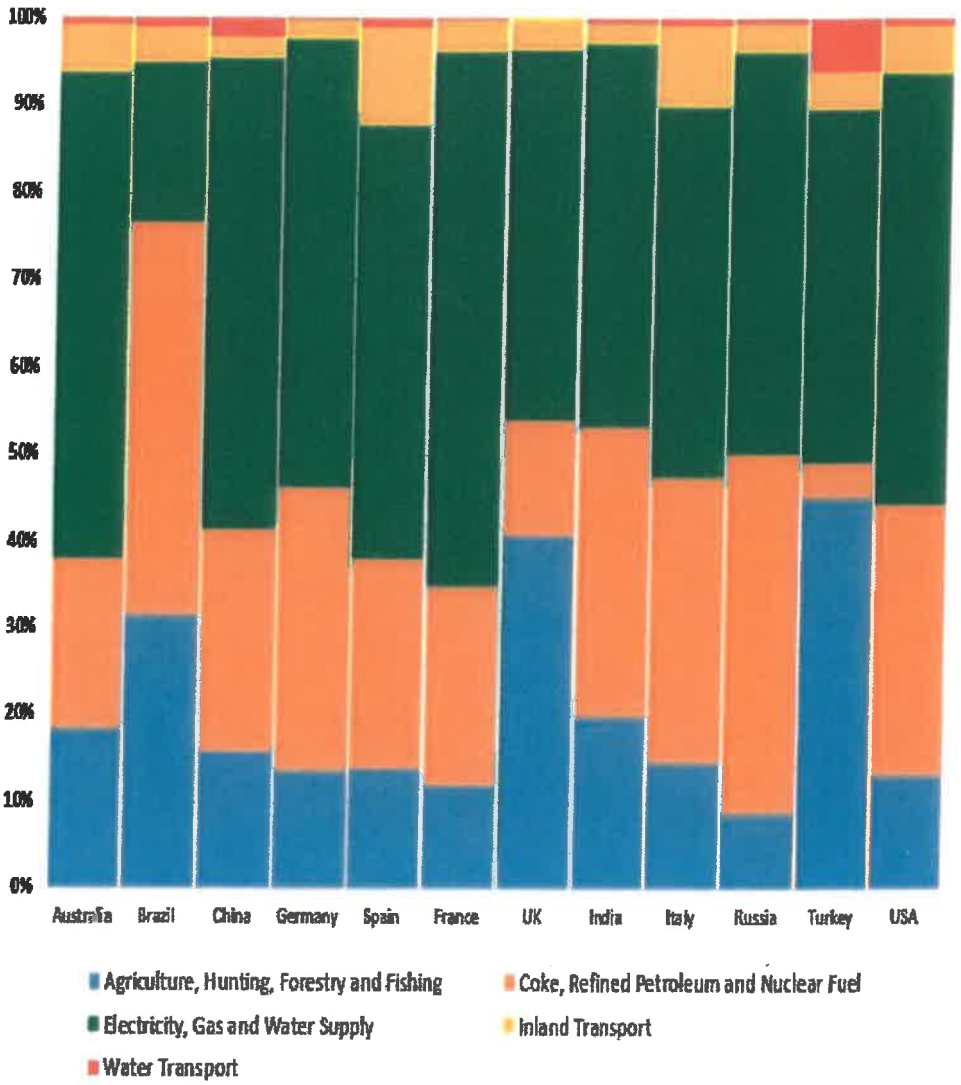

FIGURE 3.10: The percent contribution of top sectors to energy consumption in food industry 2009.

to Fig 3.9 or the carbon footprint of each country,Fig 3.10 reveled the 5 top percent sectors. It was discovered that the highest dominate sector about almost all countries in this analysis were electricity, gas and water supply and the second proportion belonged to coke, refined petroleum and nuclear fuel however, expect for Turkey and the UK for which, coke and refined petroleum were the most inconsiderable percentage respectively. Alike the carbon footprint decomposition analysis in Fig 3.9 inland transport sector have relatively similar proportion expect Australia with slight increase in comparison with Fig 3.10 Also, while Turkey had water transport as the dominate sector in Fig 3.9 by a relatively resemblance fraction, Turkey was dominate by water transport in Fig 3.10.

Figure 3.11 displays the percent contribution of top sectors to the labour of compensation in food industry. Agriculture, Hunting, Forestry, and fishing captured high proportion in all countries.China gained the considerable contribution in comparison with other countries.the second most Important factor which is sophisticated sector and captured the high amount of labour of compensation is Electricity ,Gas and water supply, this sector naturally plays vital role in processing raw materials to final food product.

The difference between the proportion of these two main factor in different Industrial and in developing countries can be resulted from sustainability methods which are implementing due to reach affordable point. For instance in the USA as one can see the mechanism in energy sector planned in order to reduce manpower role so it indicates that the development of new food materials and products traditionally had been substituted by the new approaches. In Turkey which is country with high potential in Agriculture the sum of gross wages and salaries and employer's social security contributions is higher than other sectors. In this evaluation Inland Transport obtained the lowest portion, however for the USA it is more higher in compassion with other countries.

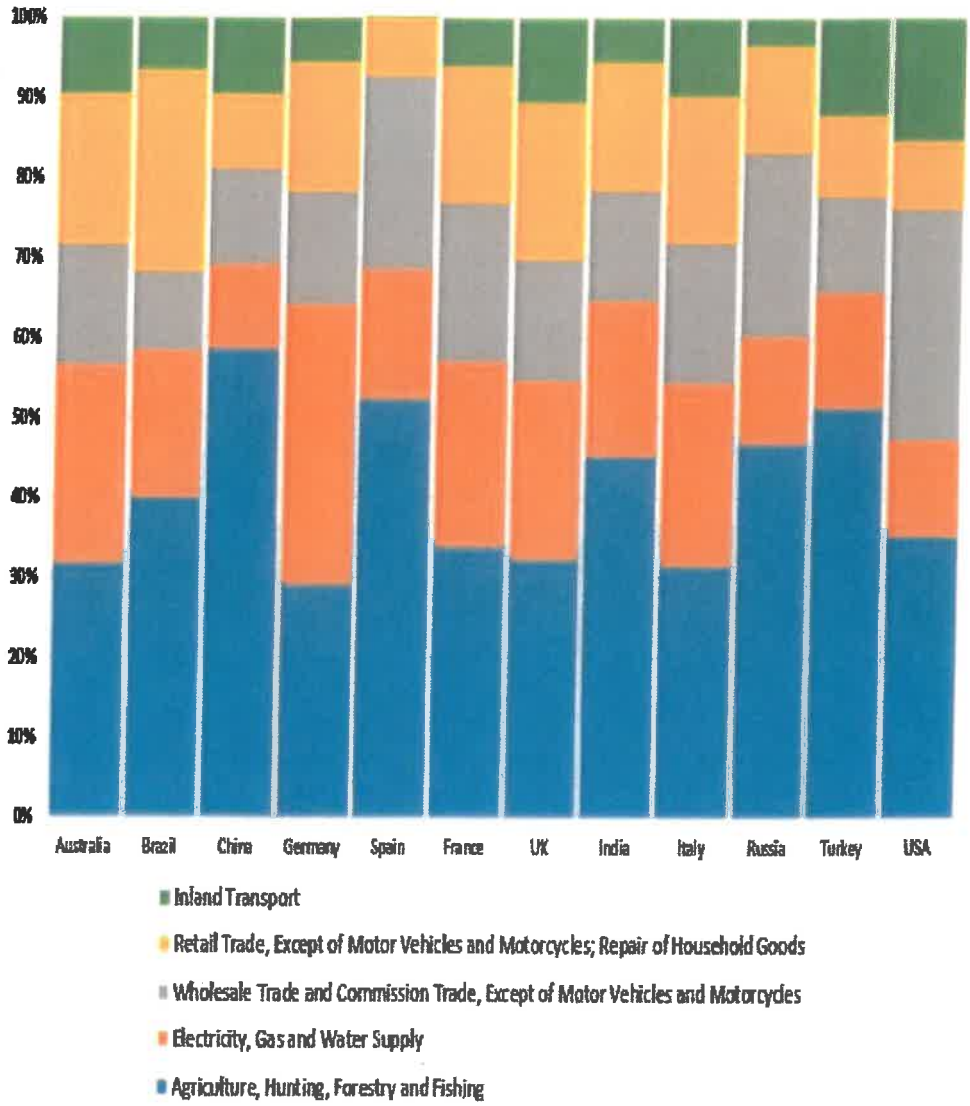

FIGURE 3.11: The percent contribution of top sectors to labour of compensation in food industry 2009.

Fig.3.12 demonstrates the percentage of top sectors percent contribution of top sectors to Gross Value Added GVA in food industry 2009. GVA is a productivity metric in national scale of countries which measures the contribution to an economy of an individual producer, industry, sector or region and the general definition in the scale of national account systems, the GVA is output minus intermediate consumption. For this indicator the Electricity, Gas and Water supply had gained the high proportion. Energy sector as stimulator for food industry played the vital role,the electricity and water are inseparable factors during food process industry. Hence, the added value for this sector in most of countries captured the first rank.

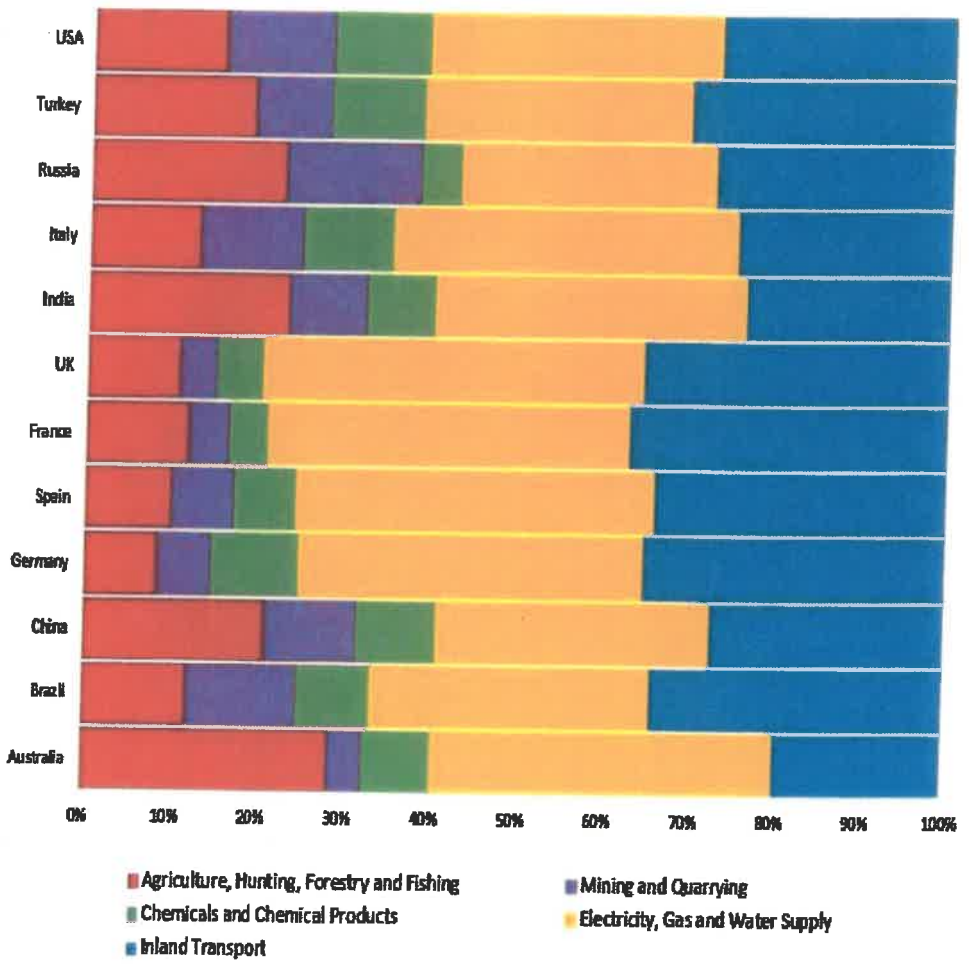

FIGURE 3.12: The percent contribution of top sectors to Gross Value Added (GVA) in food industry 2009.

Figure 3.13 depicts proportion of Gross Value Added (GVA) to total energy consumption in food industry, about studied countries in 2009. Total final energy intensity is defined as total final energy consumption (Electricity, Gas and Water Supply and etc...) in the food industry. Comparing these two indicators illustrate the relative correlation between food manufacturing and amount of value added in the economy of each country. By considering tree main cluster, in the first category India and Russia, in the second class, China and the USA and in the last category countries such as Italy, Australia, UK, Germany, France,Spain Turkey and Brazil are behaving in similar proportion.As one can see India consumed highest amount of energy in the food industry sector, simultaneously GVA is also pretty high by considering India's population. In contrast China by having more population captured higher GVA by consuming approximately half of total energy

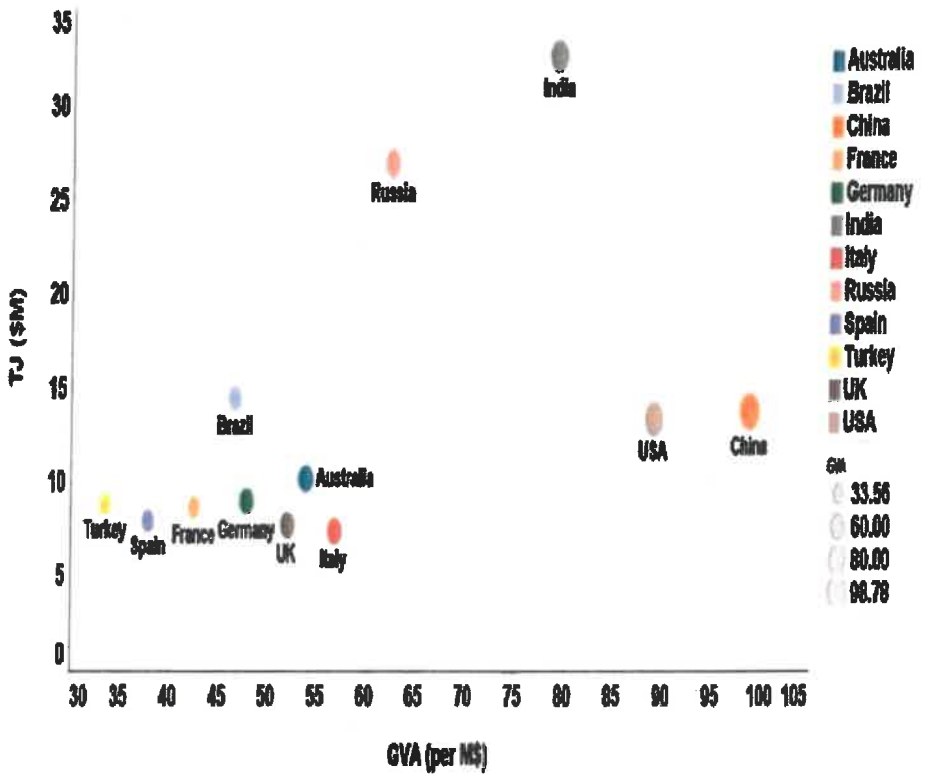

FIGURE 3.13: Contribution of Gross Value added (GVA) vs Total Energy

in comparison with India. Russia consumed nearly high amount of energy and captured less GVA than India, Russia as one of countries which export energy to EU countries and Turkey has inevitable impact on regional and global food industry. Moreover, most of European Union countries in this research are nearly in same situation, where Turkey acquired the lowest amount of GVA and total energy consumption.

Figure 3.14 shows the proportion of Gross Value Added (GVA) to total carbon footprint emission in the food industry, about studied countries in 2009. For the purpose of this study we consider, CO_2 greenhouse gas emission impact which results from different subset in the food industry. This analysis is significant to see the variation of global share of countries in specific sector alike food. Analyzing categorizes countries into three main clusters by a conventional LCA method. In the first category, indication evidence that India,China, and Russia had the greatest shares of carbon emission due to their GVA in economic. For instance China notwithstanding high amount carbon emission captured the highest GVA which specifies huge amount of investment in food infrastructure and endeavors to expand its global contribution in future of this industry. Although, India

also captured great share of carbon emission but the portion of GVA around 20% is less than China. Sustainable and productive food manufacturing in the USA result in low carbon emission impact, and finally Russia in this cluster was found to have the balanced situation in comparison with other countries.

In the second cluster, Brazil is one of the biggest Agricultural producers in the world,

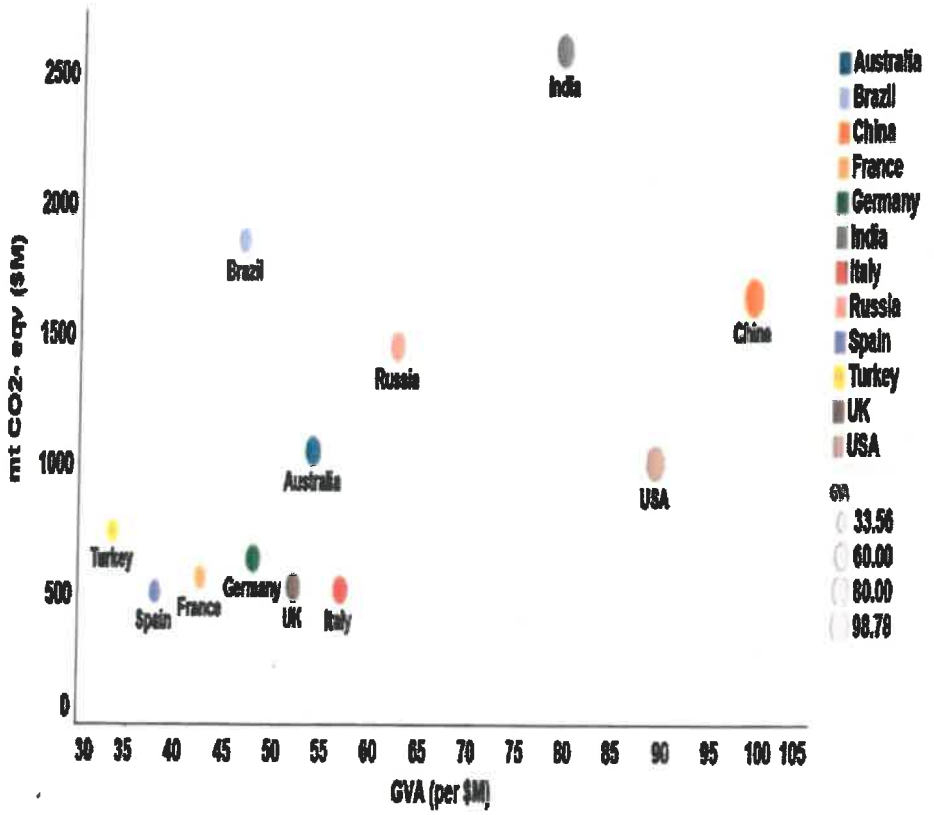

FIGURE 3.14: Contribution of Gross Value Added (GVA) vs Total Carbon

with 635 millions hectares of land cultivation had partly high carbon emission impact. In addition it expects in near future Brazil obtain high GVA in this sector. Australia's food sector is a vital contributor in economic,and foods which are generated from animal products determined high share in carbon emission.Moreover, Agriculture occupies 62% of Australia's land mass. Despite that fact innovation in shifting to produce a more efficient mix of animal products and expanding crops into low-carbon degraded land (World resources report 2013-2014: Interim Findings) result in lower carbon emission impact with high amount of GVA among studied countries.

Fig 3.15 presents the global distributions of impacts for the Turkish food manufacturing

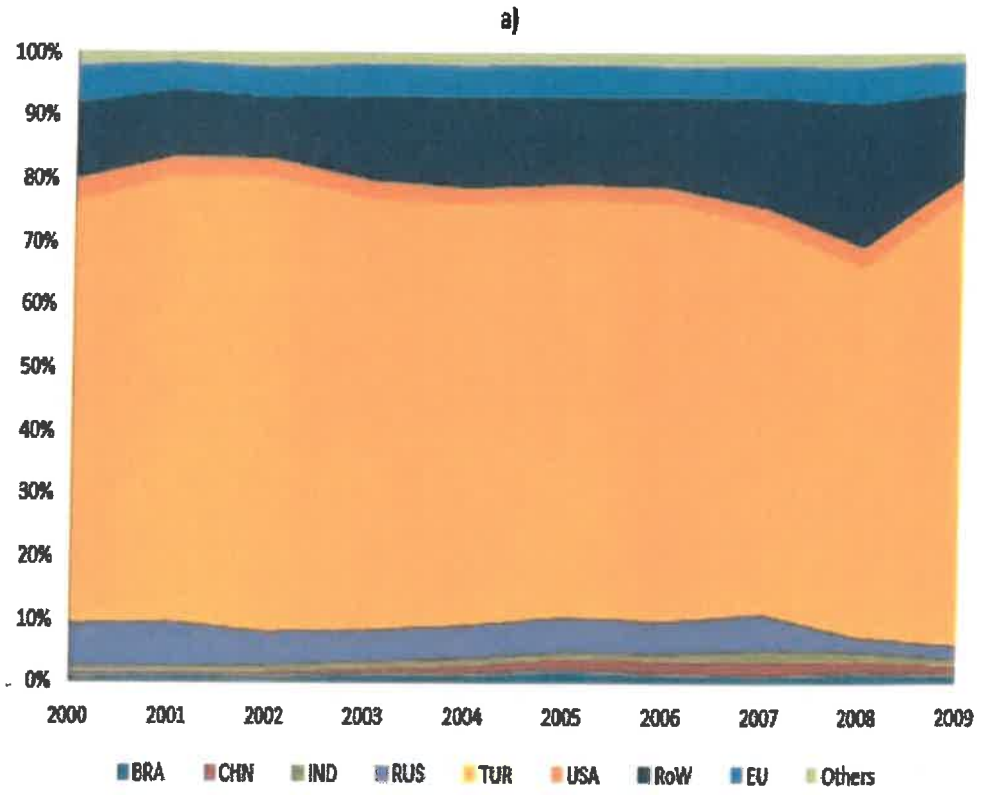

FIGURE 3.15: The global distributions of impacts for Turkish food manufacturing sector a) carbon footprint

sector in terms of carbon footprint and energy use. Fig.3.16 shows the countries with 1% or more of the total supply chain contribution to the overall carbon footprint of Turkish food industry between 2000 and 2009. [2]

The EU member state's contributions were combined as EU, and the countries with less than 1% of the total share were listed as Others. The contributions of the EU, Brazil, and Others were shown to be more or less stable between 2000 and 2009, while China's contribution increased after 2003 and Russia's contribution decreased after 2007. India's share increased by a relatively small margin, while Turkey's own contribution fluctuated in accordance with RoW's fluctuations from year to year, increasing whenever RoW's contribution decreased and vice versa, in fact a remarkable decline in Turkey's contribution and a similarly remarkable increase in ROW's contribution are both evident in 2007. [2]

Figure 3.16 shows the countries with 1% or more of the total supply chain contribution

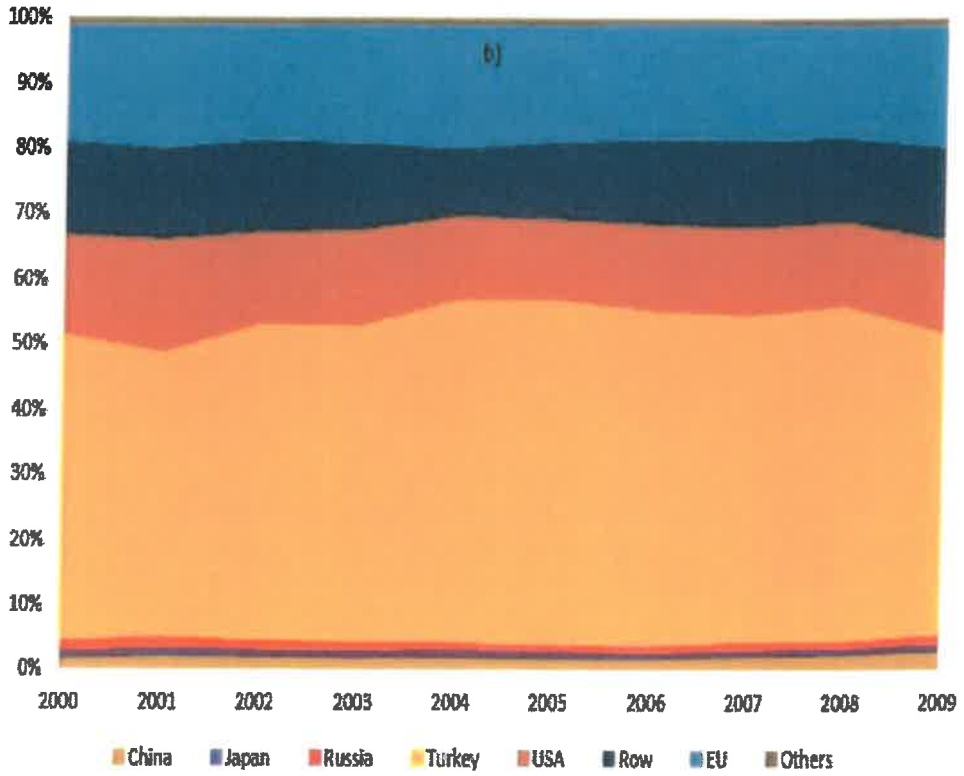

FIGURE 3.16: The global distributions of impacts for Turkish food manufacturing sector b) Energy use

to the energy usage of Turkish food industry between 2000 and 2009. It is important to note that unlike Fig. 3.15 and 3.16 does not include Brazil or India, each of which contributed less than 1% to the energy consumption of Turkish food industry's supply chain. Therefore, in Fig.3.16 both of these countries were included in Others. Furthermore, while Brazil (BRA) and India (IND) were excluded from Fig.3.16 due to having shares of less than 1%, Japan emerged with enough of a contribution early on to be included in the figure. The contributions of EU, RoW, and Others were nearly stable, except that EU's contribution exhibited a slight, but steady increase between 2001 and 2004. Japan's share decreased from year to year while China's share increased, though both countries had relatively small shares compared to the other country categories. A decrease in Turkey's own contribution was evident in 2001 while USA's contribution increased; conversely,from 2001 to 2004, Turkey's contribution proceeded to increase while USA's contribution decreased. [51]

Chapter 4

Conclusion and Recommendations

The research addresses regional and global supply chains of the world's food production in energy, climate, economy and society nexus in the world's largest food producers such as United States, China, India, Brazil, Russia and Europe (Germany, UK, France, Italy, Spain, and Turkey). Furthermore it provides key and significant intuition for policy makers, food industries stakeholders and economic analyzers and researchers. While most of the researchers have been focusing on procedure of different food products and considered regional impacts whereas in this study we consider food industry as unbounded systems which effects other sectors directly or indirectly [17]. Sustainability assessment of food manufacturing by increasing international concern about global warming and carbon footprint emission, future of energy's supply and demand in food industry , concentrating on social and economic aspects of food industry in societies by considering indicators such as (GVA) and labour compensation, are the main criteria in my research. Current study comes to this point that there is extreme correlation between the different sectors and their contribution to carbon emission and energy using. Hence the policy makers and the owner of industries focusing on improvement exigent phases in supply chain in order to reduce carbon emission and diminish energy consumption simultaneously. Besides, Agriculture, Hunting, Forestry and Fishing was generally found to be accountable for the largest portion of energy usage and carbon emission in association with food industry in most of countries [11]. Hence, innovating new methods of irrigation and consuming energy in productive way in AHFF sector can be part of solution in face with food sustainable manufacturing industry. For instance, China launched one of the first and biggest computer-controlled greenhouse systems in 2010 where artificial lights

are used to grow vegetables.

Sustainability assessment studies often encounter with absence of system-level tackle. In the other word, the lack of comprehensive evaluation about system result in making inaccurate decisions by policy makers. Current research's approach address enterprise sustainability assessment that deal with supply chains and global impacts as an umbrella concept which is kind of new research methodology.

The supply chain of food,beverage and tobacco (FBT) sector is responsible for the large contribution of carbon emission with around 88%. By concentrating on AHFF sector within its supply chain, the related solutions are classified under three foremost category: organizing and innovating more efficient solutions in order to diminish carbon emission and nitrogen impact in the agriculture ecosystem. Measuring and managing GHG from crop and livestock production and reducing the irregular use of nitrogenous fertilizer which had the important impact on climate change.

The research is considerable attempt in order to investigate the social and economic analysis of studied countries. Comparing the countries, illustrated the considerable gap between developed countries and in developing. In order to come up with difficulties the researchers emphasize the requirement for improving LCA methods with supplementary economic parameters. From this stand point the existence of strong correlation between the sustainability development and socio- economical parameters are playing parallel role. The amount of total gross value added in food industry somehow illustrates final output minus intermediate consumption. In this study the countries with high amount of (GVA) in food industry such as India, China and Russia result in making excessive percentage of carbon emission impact in the environment respectively which clarifying the drawbacks in consumption and controlling energy use. Amending the traditional food manufacturing procedures and implementing the main steps of supply chain management (Supplier, Procurement, Inventory/Logistic, Distribution and Customer) are solutions due to reach sustainable food industry with appropriate GVA. As of now, recently and future works focus more on integrating the environmental, economic and social dimensions of sustainability into typical life cycle assessment methods.

Energy is one of the essential of technical and economic infrastructure of the society and the progress of production and service sectors. Political attention over the security of supplies, environmental alarms related to global warming and sustainability are expected

to move the world's energy consumption away from fossil fuels. For instance countries such as India and China in addition to respond their high domestic food demand simultaneously they pass in progressive way toward obtaining great share in world's food industry, are highly energy dependent countries and imported the remarkable amount of their energy demand in many sectors, such as food industries from countries like Iran and Russia, in order to create open horizon towards sustainable development in food industry, substituting renewable energy such as solar and wind are vital requirement. Furthermore the results also indicated that the USA and Russia are playing significant role in providing regional and global energy consumption and were the most dominate countries based on total global of energy use of European Union and Turkey. One of the pioneer countries in bio-fuel energy production is Brazil, sugarcane ethanol and bio-electricity generate from leftover fibres, stalks and leaves turn sugarcane as one of the principal source of renewable energy in Brazil and this generation of energy provide 16 percent country's total energy needs [36].

Using time- series WIOD helped us to investigate Energy, Carbon, GVA and Compensation of employee's effects in food industry from aggregated level standpoint . Hence, figuring out the impacts of various sub sectors within the food manufacturing is essential and therefor addressing to MRIO analysis for acute points in I-O tables is a necessity. The outcomes of recently published researches illustrated that due to minimizing found scepticism in LCA consequences the disaggregation of I-O data is premier to aggregating environmental data for specifying I-O multipliers. Thus, in order to obtain ongoing analysis with better-sector precision authors involving socio-economic indicators in addition to energy and carbon factors.

Chapter 5

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