IS THERE A RELATIONSHIP AMONG OVERALL NUTRITIONAL QUALITY INDEX, CARBON FOOTPRINT AND THE PRICE OF FOOD?

by

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The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "IS THERE A RELATIONSHIP AMONG OVERALL NUTRITIONAL QUALITY INDEX, CARBON FOOTPRINT AND THE PRICE OF FOOD?" by Qiumei Lin in partial fulfilment of the requirements for the degree of Master of Arts.

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To my dear family-Botong Lin (Father) and Qiu Lin (Sister)

To my dear friends-Qin Xu, Jing Zhong and Qiaojie Chen

Thank you for your support!

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ABSTRACT

This study explores the relationship among the overall nutritional quality index (ONQI), the carbon footprint and price of 90 different foods. The ONQI and carbon footprint measure the healthiness and environmental impact of a food, respectively. Two models are estimated. The first is a hedonic model of the food price and two characteristics: ONQI and carbon footprint. A positive relationship between price and carbon footprint is found, implying higher priced foods have a larger environmental impact. The second model is a regression of ONQI on price and carbon footprint. A negative, non-linear relationship between ONQI and carbon footprint is found. This implies there is a complementary relationship between the healthiness of food and its environmental impact. Both models show that healthier food is also higher priced. This could explain why poorer consumers are less healthy than richer consumers, and why taxing food would disproportionately impact the health of the poor.

LIST OF ABBREVIATIONS USED

CCA	Climate Change Act
CF	Carbon Footprint
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
EU	European Union
FDA	Food and Drug Administration
FSA	Food Standards Agency
GHG	Greenhouse Gas
GLS	Generalized Least Square
GPO	Government Printing Office
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
H_2O	Water Vapor
IPPC	Intergovernmental Panel on Climate Changes
LCA	Life Cycle Assessment
N_2O	Nitrous Oxide
O_3	Ozone
ONQI	Overall Nutritional Quality Index
P	Price
PAS	Publicly Available Specification
PFCs	Perfluorocarbons
SF_6	Sulphur Hexafluoride
TLS	Traffic Light System
UK	United Kingdom
UPC	Universal Product Code
US	United States
USDA	United States Department of Agriculture

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CHAPTER 1 INTRODUCTION

1.1 FOOD LABELS

Nowadays, food labels are widely used to help manufacturers sell their products and inform consumers of the information about the products such as their nature and composition. Therefore, food labels have been a useful tool to assist consumers to make wise choices on various types of products. Food labels can also prevent confusion between different types of food products and help protect consumers from misuses, risks and abuses (Cheftel, 2005). In addition, the information that the labels pass on to consumers have developed over time. Numerous and complex food labels have been advocated by different pressure groups. These groups include public authorities, food companies, retail groups and consumer organizations (Cheftel, 2005). Moreover, the information on food labels usually consist of marketing information (e.g. brand, selling price, weight and quality), ethical concerns (e.g. genetically modified foods), safety information on ingredients and additives, nutrition information, announcements of potential allergens and health and nutrition claims (Cheftel, 2005). Cheftel (2005) claims that label information must not be covered, blurred or disturbed by other written or pictorial matter. That is, the information on labels has to be placed somewhere easily visible, clearly readable and ineffaceable. What’s more, it is really important to keep the information accurate and visual because it can prevent fraud and promote fair trade.

1.2 FOOD LABELS AND HEALTH

Food labels are an important tool to help people understand the health benefits of a nutritious diet. Therefore, food nutrition labeling has been introduced to help people choose some particular foods they need for their health. For example, foods labeled as "low fat" will help consumers limit their intake of fat. On the other hand, "high in calcium" will help consumers increase their intake of calcium (Legault et al., 2004).

Nowadays, in the U.S., it has been mandatory to have nutrition labeling on most processed and packaged foods; however, some foods are exempt from the nutrition labeling requirements. This is why there are not nutrition labels on all food packages. Four exemptions are 1) Nutrition labeling is not required if the foods consist of insignificant amounts of all required nutrients. For example, coffee and bottled water are not requested to be labeled (U.S. Government Printing Office (GPO), 2012); 2) Foods also do not need nutrition labeling if the types of foods are under the small-business exemption (U.S. GPO, 2012); 3) It is also not required to use nutrition labeling if foods have limited surface to put the nutrition labeling on them. In this case, it is suggested to provide the telephone number or address for consumers to achieve the required information on nutrition (U.S. GPO, 2012); and 4) Foods in the voluntary nutrition labeling program can be exempt from the labeling regulations. For example, some unprocessed foods, such as the raw, unprocessed seafood, packaged and chilled salads and other types of cut produce do not need the nutrition labeling (U.S. GPO, 2012).

Since the introduction of the Nutritional Labeling and Education Act in 1990, several major changes in the mandatory food labeling regulations have been regulated in the United States (U.S.). Firstly, the nutrition labeling has to be on most food. Secondly, the level of nutrients in a food should be in terms based on the definitions established by the Food and Drug Administration (FDA). Thirdly, the claims of the relation between nutrients and diseases or health-related conditions need to be verified (Legault et al., 2004).

There are three main claims identified on food labels: health claims; structure/ function claims; and nutrient content claims. Legault et al. (2004) estimated that there were about 4.4% of food products sold with health claims on the packages during 2000-2001. Health claims play an important role in telling people the relationship between nutrition and disease (Legault et al., 2004). Legault et al. (2004) also reported that about 6.2% of food products had structure/function claims on their packages in 2000-2001. The structure/function claims inform people about how a nutrient or dietary ingredient affects a structure or function of a body. For instance, calcium is good for bone building and the claim of “high in calcium” will help consumers increase their intake of calcium. It is a food manufacturer’s responsibility to make sure that structure/function claims are real and not misleading. This does not require prior FDA approval (Legault et al., 2004). Approximately 33.7 % of food products sold from 2000-2001 had nutrient claims on their packages. The nutrient content claims tell people about the nutrient content of the food products by listing them on the packages, such as the amount of energy, total fat, saturated fat, cholesterol, sodium, dietary fibre or sugars in the food. There were other types of nutrient claims available in the market, such as “high” claims, “good source” claims, “more” claims and “light/lite” claims (Legault et al., 2004).

As a part of the National Nutrition Monitoring and Related Research Program, the Food Label and Package Survey (FLAPS) includes interconnected activities which consist of the information on food and nutrient consumption and the nutritional status of the US population. According to the data from FLAPS, it was estimated that 98.3% of the FDA – regulated processed, packaged foods sold per year had nutritional labels in 2000-2001. In addition, 1.7% of those products had nutrition labeling exemptions. In the U.S., it is the FDA’s responsibility to protect the public’s health and make sure that foods are safe, healthy, and sanitary and honestly labeled (Legault et al., 2004).

Obesity has been one of the most pandemic and disturbing diseases in most of the world in recent decades. Both adult and child obesity rates are increasing markedly and globally, especially in all high income countries, such as the United States, the United Kingdom, New Zealand and Canada (OECD 2007). This situation is troubling because obesity is associated with elevated health problems such as insulin resistance, metabolic syndrome and type 2 diabetes (Smed et al., 2005). Experts agree that improvements in activity levels and dietary patterns are the key to promote health and prevent diseases. In order to achieve healthy dietary patterns, governments encourage consumers to choose more ‘fruits and vegetables’ and governments also instituted policies, such as fat taxes and thin subsidies, to help consumers obtain more healthful eating patterns (Katz et al., 2007).

Considerable evidence has indicated that there are relationships between diet and the development of chronic diseases, including heart disease, stroke, obesity and diabetes. In order to reduce the prevalence of chronic diseases in the world, the food manufacturers have been encouraged to reduce the usage of saturated fatty acids, trans fatty acids, sodium and sugar by the World Health Organization (WHO, 2004). Generally, there are two main ways available for consumers to stay healthy. The first one is to reduce nutrients such as saturated fatty acids, trans fatty acids, sodium and sugar to improve the product composition. The other one is to motivate consumers to make healthier choices by using labeling to help them distinguish the healthier products from less healthy products. Front-of-pack nutrition labeling can assist consumers in making wise decisions and could be used across different countries (Feunekes et al., 2008). However, some researchers think that the widespread increase of the overweight adult population in the US is due to the increased attention on consumption of low-fat foods but not the quantity of food consumed and total energy intake (Legault et al., 2004).

Unfortunately, different standards (such as fat tax and thin subsidy) in public policy lead to confusion for consumers when they make choices among competing foods in their diets. Therefore, it is necessary to make a consistent standard to help consumers make good decisions. If not, it is difficult and confusing for consumers to decide which food is healthier within or across specific food categories. The overall nutritional quality index (ONQI) may make it easier for consumers to make wise decisions about their diet patterns. The ONQI has been used for evaluating the overall nutritional quality of foods and has been applied to over 40,000 individual foods and beverages (Katz et al., 2010).

Not only has this public policy had an effect on the consumers' decisions, but also affects the producers' responses.

1.2.1 A Potential Health Labeling-ONQI Score

The ONQI is an algorithm designed to generate a single summative score to evaluate the "overall nutritional quality" of a food to help consumers make good dietary choices. It is designed to improve consumers' diet patterns and thus their health. ONQI is based on both the micronutrient and macronutrient composition and some other macronutritional properties (Katz et al., 2007). More than 30 different micronutriental and macronutritional properties have been taken into account to develop this score. Micronutrients can be separated into two groups: numerator nutrients and denominator nutrients. Generally, numerator nutrients have a good effect on health; that is, higher values of these nutrients will lead to an increase of the ONQI score. The nutrients include fiber, folate, Vitamin A, Vitamin C, Vitamin D, Vitamin E, Vitamin B12, Vitamin B6, potassium, calcium, zinc, omega-3 fatty acids, total bioflavonoids, total carotenoids, magnesium and iron. However, denominator nutrients, including saturated fat, trans fat, sodium, sugar and cholesterol, are thought to have a negative impact on health and higher values of denominator nutrients will generally result in a lower ONQI score. The ONQI score also measures the macronutrient factors in terms of the quality and density of nutrients (such as protein quality, fat quality, glycemic load and energy density) and the strength of their association with specific health conditions (NuVal LLC, 2012[1]). The ONQI scores for individual food and beverages varies from less than 1 to over 8000 but are converted to a 1 to 100 scale for consumer use. This scale 1-100 is called NuVal score, which is used to simplify presentation of the ONQI to consumers, while preserving the exact rank order of all foods. The higher the score, the healthier the food is (Katz et al., 2009).[1]

1.2.2 Advantages of Using ONQI Score

The ONQI summarizes a large amount of nutrient information within a single overall value and therefore may help consumers cut though the confusing nutrition information in foods. The ONQI algorithm is the scientific engine behind the NuVal System whose score varies from 1 to 100. Based on the score on the shelf tag, consumers can compare overall nutrition at a glance the same way they compare prices within and across specific food categories, so it can help consumers make good decisions about food more quickly and easily (NuVal LLC, 2012[1]). By doing so, the ONQI provides a tool for consumers to consume less trans fat, saturated fat, sugar, salt and calories and consume more fiber, vitamins, minerals and antioxidants (Katz et al., 2009). According to an ex-post evaluation method, the higher level of ONQI is associated with the declining incidence of heart problems, diabetes, cancer and other diseases in the US (Katz et al., 2010).

1.2.3 Disadvantages of Using ONQI score

The ONQI cannot be perfectly precise. Katz et al. (2009) claimed that "the nutrient composition of foods is never determined or reported with perfectly accuracy, and error bars are permissible around FDA-approved entries on the Nutrition Facts Panel". The ONQI level can be varied for different groups based on age, race and gender. However, there is only one ONQI score that will be used to label the food. For example, whole milk is good for newborn babies, but may not be good for adults. Therefore, the score should

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[1] The relative weight assigned to each component in an index can affect the way different products are ranked by the index. The thesis does not examine the effects of changing the weight used in the ONQI.

be high for newborn babies. It is difficult to use only one ONQI score to label the whole milk for all people. It is also difficult for consumers to know the ONQI score for combined food groups. Consumers often have a meal with several different types of food. For example, using lettuce, bread and meat to make a hamburger, consumers can get the ONQI for each food item from the shelf tag, but they cannot get a score for the combined food (hamburger) by themselves. Even though the hamburger with ONQI on the label might be available in some food markets, the score might be different between the hamburger made at home and the one bought from the market. Some people might like more lettuce and less meat; however, some others might be different. Therefore, it is really difficult to use the ONQI to score them and it is not clear if the consumers are eating healthily in their diets, or not. That is, the 1-100 NuVal scale was specifically developed for the scoring of the individual foods and not the entire diet (Katz et al., 2009).

In order to increase the score of ONQI, some producers try to get rid of bad ingredients and add good ones. However, is it really healthier to do this? For example, some producers might use sweeteners to replace sugar in their recipes but some artificial sweeteners are bad for the liver. Even though artificial sweeteners might help increase the ONQI score, it might not be good for people's health. Also, the ONQI score cannot tell the exact nutrient of ingredients in food. Sometimes, consumers might be allergic to some ingredients, but they cannot read it if the label is only based on the ONQI score. Even though the food has a high ONQI score, it does not mean it is healthy for these consumers.

Therefore, the ONQI is a tool used to evaluate the overall nutritional quality of foods, which make it faster and easier for consumers to make good choices. However, there still exist several issues concerning the ONQI. For example, the ONQI cannot account directly for the quantity eaten or the diverse combinations in which foods may be consumed. The ONQI is required to be used appropriately to obtain maximum benefit for consumers (Katz et al., 2009). Moreover, more researches need to be explored in future studies to make the ONQI more reasonable and convincing.

Even though it is true that there are some issues concerning the ONQI score, it cannot be ignored that the ONQI score is still a valuable indicator to show the healthiness of food. There is no indicator that is perfect. Nowadays, ONQI scores have not yet been used for labeling but it might be applied for labeling in the future to address the concern of consumers' health. Even though it is not used as a label, it can still be used as an indicator of healthiness of foods for research uses. Since the ONQI score is an important measurement of the healthiness of foods, it is used as a health indicator in this study.

1.3 Food Labels and Environment

Climate change has been one of the most serious problems around the world. Some findings have shown that climate change has potentially led to the increase of temperatures of air and ocean, the melting of snow and ice and the rise of sea levels. Moreover, climate change also affects natural systems, such as plant and animal ranges moving upwards and the changing of fishes and algae due to the higher ocean temperature (Brewer, 2009). These issues could be caused by large amounts of greenhouse gas (GHG) emissions. The GHGs in the Earth's atmosphere include: water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and others. Each type of GHG has different effects on climate change. Among those GHGs, CH_4 has the greatest greenhouse effect on climate. However, CO_2 is the most important of the human-caused GHGs, with much greater quantities in the atmosphere than CH_4. Therefore, most researchers focus on CO_2 emissions reduction to mitigate climate change in the world (Brewer, 2009).

The Intergovernmental Panel on Climate Change (IPPC) found that the GHG emissions from people have increased by 70% from 1970 to 2004. Moreover, Brewer (2009) claimed that the GHG emissions have continued to increase through this century. According to the United Kingdom (UK) Climate Change Act (CCA) in 2008, the UK government has been requested to reduce the GHG emissions by 80% by 2050, using 1990 as the baseline reference date (DECC, 2012).

Therefore, reduction of GHG emissions has been at the top of the environmental policy agenda. The term, carbon footprint, has been introduced to measure people's environmental impact through their activities. People need to reduce their carbon footprints to decrease GHG emissions (Weidema et al., 2008). There are many means which have been suggested to reduce GHG emissions, such as efficient use in energy and fuel. Besides, a variety of policies and innovations have been introduced to mitigate GHG emissions. For example, carbon taxes and carbon footprint labels have been addressed to control GHG emissions (Brewer, 2009).

Much of the literature about calculating a carbon footprint does not explore the possibility that there may be different methods of producing the same product. One method may not produce as much CO_2 and CH_4 as another method. For example, suppose that the raising of cattle is found to cause a large carbon footprint. Could the cattle industry use an alternative method of raising cattle that produces less CH_4? Or, must the cattle industry be reduced because it is not feasible to reduce the CH_4 that is produced by each animal? The matter of using methods of production that produce a smaller carbon footprint is worth examing, but it is not explored in this thesis.

Carbon taxes might mitigate some serious issues related to global warming. Nowadays, it is still not clear if and when carbon taxes will be taxed due to the following problems. Firstly, a carbon tax would only target CO_2 emissions but not other GHGs such as CH_4, N_2O and O_3. Secondly, a carbon tax would not solve GHG emissions due to changes in land use, such as deforestation (unless a payment for maintaining forests is included as an instrument). These two points are important when considering agriculture because agriculture emits large amounts of GHG, which have great effects on climate change, such as N_2O emissions from soils and CH_4 emissions from ruminants (Edward-Jones et al., 2008). Thirdly, there is no international agreement on a carbon tax, so some countries would seek to impose import taxes on products from countries that do not participate. Finally, some forms of carbon accounting would be needed to implement the carbon taxes. Therefore, a carbon labeling scheme can complement the approaches of taxation and regulation (Brenton et al., 2009).

On the other hand, Garnett (2009) thought food is the most essential sector, so standards and practices need to be developed on food to mitigate the carbon emissions and then improve the environment at the national and international level. Nowadays, it is voluntary to use both the process of carbon footprinting and carbon labeling of food products in the UK. These processes have been looked upon as good models to improve the environment (Alves and Edwards, 2008).

1.3.1 Carbon Footprint

Carbon footprint is a new term developed over the last few years in the UK. This term has been widely and quickly used by nongovernmental organizations, companies and various private initiatives, in many countries, to stimulate consumers' growing concern for issues related to climate change. However, it is surprising that it has not been adequately defined in scientific literature, so many different suggestions about the definitions and calculations of the carbon footprint have been presented (Weidema et al., 2008).

Wiedmann and Minx (2008) suggested that carbon footprint should only measure the total amount of CO_2 emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. They believed that the amount of CO_2 emissions account for most of the GHGs associated with the climate change. However, based on recent studies, most of the definitions of carbon footprint currently include non-carbon emissions and a CO_2 equivalent indicator is used instead to measure the carbon footprint. For example, Ball (2008) defined the carbon footprint as the amount of CO_2 and other GHGs emissions when the products are made, shipped, stored and used by consumers. Baldo et al. (2009) claimed that the carbon footprint is a total amount of CO_2 and other GHG emissions related to a product along its supply chain. It included its use phase and its end-of-life management. The carbon footprint is currently measured by converting the whole GHG emissions to an aggregated value of 'CO_2-Equivalent'. This measurement of the carbon footprint is quite similar to the global warming potential (GWP) indicator used in life cycle assessment (LCA). On a product level, the LCA helps determine a product's carbon footprint. That is, the GWP in an LCA ideally includes emissions associated with production, transportation, storage, use, recycling, disposal and loss rates (Weidema et al., 2008).

The UK is a world leader in the use of carbon footprints. The introduction of Publicly Available Specification (PAS) 2050 has provided the definition of carbon footprint with an official approval by the UK Government. According to PAS 2050, the carbon footprint is defined by measuring all GHGs related to a process or product. It converts each individual GHG emission into a single value of 'CO_2-Equivalent' by using the global warming potential (GWP) of the individual gases over a 100-year period. Based on the Kyoto Protocol, the global warming potentials of the six different GHGs (CO_2, CH_4, N_2O, Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF6)) are 1, 21, 310, 140-11700, 9200-6500 and 23900, respectively. Therefore, the non-carbon dioxide gases could be converted into CO_2 equivalents. This calculation applies for any system or product. The unit of the carbon footprint can be expressed in kg or tonnes of CO_2-Equivalent per kg or tonne of output (Lillywhite and Collier, 2009; East 2008).

In order to ensure that a company will not miss some emissions or count emissions twice, three scopes of emissions have been introduced. Scope One emissions include the direct emissions occurring within the organizational boundary of a company. The organizational boundary of a company can be determined under two approaches: the equity share and the control approach. Under the equity share approach, a company (with joint ownership) accounts for emissions from operations based on the share of equity in the operation. Under the control approach, a company (with complete ownership) accounts for 100% of the GHG emissions from operations. Scope Two emissions include the emissions from the generation of purchased electricity. These scope emissions are considered as indirect emissions which occur within the organizational boundary. Scope Three emissions include a company's activities in the wider economy. Therefore, the emissions from products or services purchased by an organization are included under Scope Three. For example, the emissions from transportation of a product paid by the company from a factory to market would be included under Scope Three and also considered as indirect emissions which occur within the organizational boundary (World Resource Institute & World Business Council for Sustainable Development, 2008).

It is useful to calculate the carbon footprint because carbon footprint can be used for labeling. The labels can help consumers increase their awareness of environmental protection. As mentioned before, carbon footprint only measures the environmental impacts that are related to climate change. Even so, carbon footprint is still a tool that is widely used to measure the food impacts (Kaval, 2011). Hence, carbon footprint, in this study, will be used to measure the environmental impacts of various types of foods.

1.3.2 Carbon Labeling

In order to mitigate climate change, several policies and innovations, such as the carbon labeling, have been designed to control GHG emissions. The carbon labeling is a rapidly developing mechanism for GHG emission reduction. At present, the available science concerning carbon labeling is small, but growing. It includes the measurement of carbon emissions from the production of products or services and passes on that information to people, such as consumers and decision-makers of the company, who are concerned about the impact of their choices on global warming. The carbon labeling provides a value that helps people put all those carbon footprints in perspective. It is a useful means to lead us to a low carbon society. Therefore, carbon labeling is an instrument that enables consumers to join the battle against climate change (Brenton et al., 2008).

Theoretically, carbon labeling could play an important role in achieving carbon emission reductions and be a useful complement to other environmental policies. Unfortunately, there are currently no agreed international standards on the methodology of the measurement of the carbon footprint. The PAS 2050 published a standard methodology in the UK in late 2008 (BSI, 2008). In addition, some other countries have been developing several other carbon accounting frameworks. However, none of these methodologies is legally binding now. Therefore, considerable variation in methodology and results is emerging due to the absence of an agreed international standard (Edward-Jone et al., 2009). Without an agreed standard, different companies calculate their products' carbon footprint in different ways. Consumers might get confused when they purchase products based on the carbon footprint labels from different companies. Only the carbon footprints of varied products from the same company can be compared. In addition, many products' global warming potentials not only depend on how they are made but how they are used. Products should be purchased from store nearest to consumers. It is not efficient to buy one tin of peanuts with 88 g CO_2 instead of 90 g CO_2 if it involves driving a car to and from a shop 1 km away because it would generate 200 times more CO_2 than the difference of 2 g CO_2 that would be saved. Therefore, the easiest way to cut carbon emissions may be to buy less of a product or use it in a way that is less convenient (Ball, 2008). In general, consumers also make purchasing decisions based on other criteria, such as the price of a product, its functionality or the contribution it makes to their quality of life (Schmidt, 2009). Therefore, people may not always choose the lowest carbon footprints of products when they also consider their prices and functionalities to their lives.

In industrial production, the estimation of carbon footprints is relatively precise due to the constant relationship between inputs and outputs and the tightly controlled process. Since carbon footprints tend to focus on energy use, carbon footprint could be reduced by decreasing the use of electricity, gas or diesel. On the contrary, the carbon footprints could vary dramatically in agricultural production even for the same crop and region. This could be due to the biological, geological and climatic differences in the locations and varied inputs where individual crops are grown. Thus, it might be a problem to use only one value to represent the carbon footprints of an agricultural product by labeling (Lillywhite and Collier, 2009). Moreover, secondary data are usually used to estimate carbon footprints instead of primary data which is expensive and time-consuming to collect because of the long and diverse agriculture supply chain. Therefore, it might not be a precise process to estimate GHG emissions in agricultural production. Since the estimation of carbon footprint is a relatively new science, few practitioners exist and data auditing systems have not yet been established (Lillywhite and Collier, 2009). Therefore, this might be a problem for the implementation of carbon labeling on products, especially agricultural products.

Compared to high-income countries, low-income countries face greater difficulties in exporting in a climate-constrained world where carbon emissions need to be measured and certification is needed to participate in carbon labeled trade. Therefore, products produced locally might have an advantage in terms of carbon emissions because they do not need long-distance transportation. Since the exported products in low-income countries are typically produced by relatively small firms and tiny farms, it is hard for low-income countries to afford the cost of certification to participate in the carbon-labeling schemes (Brenton et al., 2008; Brenton et al., 2009). The difficulties may arise due to the different labeling criteria in the world. Therefore, low-income countries would face many problems in exporting in a climate-constrained world.

To conclude, carbon labeling is a new developing science which provides information that helps people put all those carbon footprints in perspective. It would be a useful means to lead consumers to a low carbon society. However, carbon labeling also faces many challenges, such as the absence of an international agreement on carbon footprint calculations. Therefore, further exploration through the cooperation of different countries is needed.

1.4 Research Questions

Though many studies have been conducted to investigate how healthy labeling and environmental labelling affect consumers' behaviors, there is no study available for estimating the relationship between health and environment labels. Therefore, in this paper, the relationship between healthy and environmental labeling on food will be considered. In addition, it must be determined whether pricing can predict health information for products. Therefore, the research questions would be as follows:

1) Is there a trade-off relationship between ONQI scores (potential health label) and carbon footprint (voluntary environmental label) of foods?
2) Is there a trade-off relationship between ONQI scores (healthiness) and prices of foods?

1.5 Organization

The following chapters are organized as follows. Chapter 2 shows a literature review on consumers' response to health and environmental labeling. Chapter 3 demonstrates the data sources and their limitations. Chapter 4 describes methodology used in this thesis. Chapter 5 presents the results. Chapter 6 draws conclusions about this study and suggests some possible further studies.

CHAPTER 2 LITERATURE REVIEW

This chapter includes two sub-sections. The first sub-section shows how consumers respond to health labeling, and the other one describes consumers' response to environmental labeling.

2.1 Consumers' Response to Nutrition Labeling

Marietta et al. (1999) conducted a research to examine college students' knowledge, attitudes and behaviors regarding the 1990 Nutritional Labeling and Education Act food labels by surveying 208 undergraduate students at a Midwestern university. They found that knowledge score had a positive relationship with attitudes to labels and use of labels. It was reported that there were about 95% of students who thought labels were useful when making food choices; however, many of them distrust nutrition claims. They also found that approximately 70 % of college students looked at the Nutritional Facts label while purchasing a product for the first time. In addition, college students with a positive attitude toward labels were generally more likely to use the labels. Moreover, female students were usually more likely to read labels than male students.

Feunekes et al. (2008) conducted two studies on how consumers respond to the various types of front-of-pack nutrition labeling formats. The first study investigated the levels of the consumers' understanding, liking and the believability on the different nutrition labeling formats; this focused on people from the UK, Germany, Italy and the Netherlands. The other study emphasised how the different labeling formats affect consumers' decision-making by concentrating on people from Italy and the UK. Based on these two studies, it was found that there was no significant difference between the consumer usage and friendliness of simpler and more complex nutrition labeling formats. Consumers spent less time evaluating the simpler nutrition labeling formats (e.g. Healthier Choice Tick, Smileys and Stars) than the more complex labeling formats (e.g. GDA scores, Wheel of Health and Multiple Traffic Light). Therefore, it seems more appropriate to use simple nutrition labeling formats so consumers can make quick decisions based on the labels.

Balcombe et al. (2010) investigated the consumers' responses to the Traffic Light System (TLS) which was introduced by the Food Standards Agency (FSA). They conducted a choice experiment to examine consumers' willingness-to-pay for reductions in the various nutrients, as indicated by the TLS. The TLS focused on four main nutrients in terms of fat, sugar, saturates and salt in processed food. There are three kinds of color in the TLS. A red light means a large amount of an undesirable component such as fat or sugar. An amber light means a medium amount of this particular component and a green light indicates that the level of the undesirable component is low. Consumers in the UK strongly reduced the consumption of those foods that showed a Red Light. They also found that consumers were more concerned with salt and saturated fats, rather than fat and sugars, when they were judging nutrient content. Based on these results, it would seem that TLS plays an important role in consumers' shopping behavior and it is easy for consumers to understand TLS label information. However, it is not clear whether consumers are really responding to the information content related to the TLS or whether they are simply observing a decision based on the colour scheme used. Therefore, further study is needed.

Grunert and Wills (2007) reviewed a variety of researches on consumers' responses to nutrition information on food labels in the European Union (EU) -15 countries. These studies were conducted during the period of 2003-2006. They found that most consumers were interested in nutrition information on food labels across various situations and products. In addition, consumers preferred the labels with simplified information on them, while they might have their own preferences on the formats of labeling. Moreover, most consumers believed that they understood the most common signposting formats and they could replay the key information shown on the labels in an experimental situation. However, in a real-world shopping situation, there is limited evidence about how front-of-pack information would be used and how it will influence consumers' dietary patterns.

2.2 CONSUMERS' RESPONSE TO ENVIRONMENTAL LABELING

Gadema and Oglethorpe (2011) conducted a survey to investigate whether carbon footprinting and labeling food products can help consumers make 'greener' purchasing decisions and whether it is an effective way to achieve a low carbon society in the future. In this study, they found that approximately 72% of UK supermarket shoppers strongly preferred to have carbon labels on the packages of food. However, about 89% of these consumers had difficulties in understanding and interpreting the labels; and it could be due to poor communication and market proliferation. In addition, they thought that it was inappropriate to use consumers' guilt to push them to make food decisions based on the carbon footprint of products. Moreover, they thought it necessary to build an effective connection between food policy and food market actors to drive a targeted and coherent carbon labeling policy because it would give consumers chances to make informed choices, especially within food product categories.

Grankvist et al. (2004) conducted an experiment on how consumers' respond to the environmental positive vs. negative labels by using two labels. The first label stated that "Choose this product; it is better for the environment than the average product". The other one pronounced, "Do not choose this product; it is worse for the environment than the average product". They found that consumers would be influenced by these two labels equally if they had strong interest in environmental protection. What's more, they discovered that consumers were more likely to be influenced by the negative label if they were only moderately interested in environmental protection. Besides, consumers were not influenced by these two labels if they were not interested in environmental issues.

Even though many studies have been carried out by researches on consumers' responses to health labels or environmental labels, there is no study available on the relationship between health labels and environmental labels. Therefore, it is worthwhile to study the relationship between health and environment.

CHAPTER 3 DATA

This chapter describes three data sources used in this study. Firstly, the data on ONQI scores was obtained from the company, NuVal LLC. Secondly, the food carbon footprints were gathered from a website built by CleanMetrics Corp. Finally, the prices of foods were collected from a Superstore in Truro, NS, Canada.

3.1 ONQI SCORES DATA

In 2008, NuVal LLC was built as a joint venture by Topco Associates, LLC, Griffin Hospital of Derby, Connecticut, a non-profit community hospital and home to the Yale-Griffin Prevention Research Center. It was formed to help consumers make easy and wise decisions on food choices by using a single number instead of comprehensive nutritional information. The ONQI score varies from 1 to 100. The higher the score, the healthier the food is (NuVal LLC, 2012[2]). The company has already provided some ONQI scores on their website (http://www.nuval.com/scores); however, the number of ONQI scores is limited. Therefore, the data can be requested from the company of NuVal LLC. The Universal Product Codes (UPCs) and descriptions of foods were collected at a Superstore. If the product is a commodity item, such as apples or chicken breast, only that description needs to be provided, as detailed as possible. These UPCs and descriptions were sent to the company and then the ONQI scores of these foods were provided.

Unfortunately, there are several limitations to the data. First of all, the company required the UPCs of the foods to pull out the ONQI scores data. The UPCs collected in Canada cannot be found in their database. This could be because the ONQI scores have not been calculated for Canadian foods. Therefore, some packages of foods with UPCs from the USA were obtained and therefore, the number of observations is still limited. Secondly, the company cannot provide all the data required in this study because they have not yet calculated the ONQI scores of all foods. Thirdly, for the cheese group, they do not find matched UPCs, so the approximate ONQI scores were provided for medium cheddar cheese, Swiss cheese and mozzarella cheese.

3.2 Carbon Footprints Data

The data on the carbon footprint of foods was provided by the CleanMetrics Corp, which was built to deal with the technical problems in environmental performance and sustainability via software products and services (CleanMetrics Corp, 2011). The data is available on the website (http://www.foodemissions.com/foodemissions/Calculator.aspx). There are five steps on the website to calculate the carbon footprints of foods. The first step is to choose a food category. Nine food categories are listed in the pull-down box. They are Beans & Pulses, Dairy, Fish & Shellfish, Fruits, Grains, Meat & Poultry, Nuts, Oils & Fats and Vegetables. The second step is to choose a food commodity. It is quite aggregated. For example, they only have the commodity of beef, but not T-bone steak or ground beef. The third step is to set long-distance truck transport (miles). It is set at 0 miles because it is assumed that the commodities are sold locally. After this step, the quantity purchased by consumers (pounds) must be selected. In this step, one pound is used to maintain simplicity. Finally, consumer waste percentage has to be chosen. In this step, it is set at zero because it is assumed that consumers did not waste any of their foods. Then, clicking the button for "calculate food emission" is done. The results will be shown below, consisting of production emissions, transport emissions and waste emissions. The transport emissions are equal to 0.01 kg of CO_2e (CO_2e = CO_2 equivalent units) per pound because they are sold locally. The production of emissions is defined as the emissions which come from the production of emissions from initial planting to farmgate. All these carbon emissions are reported here in Kg of CO_2e per pound, which include major GHGs such as CO_2, CH_4 and N_2O. Packaging and cooking are excluded (CleanMetrics Corp, 2011).

Compared to the food guide pyramid from the U.S. Department of Agriculture (USDA), the carbon footprint food categories in CleanMetrics are relatively similar. As discussed, there are six food categories in the food guide pyramid. Each food category provides some nutrients which consumers need. It is claimed that no one food category is more important than another. Therefore, in order to obtain good health, consumers should choose food from all these categories. The top tip of the pyramid demonstrates that fats, oils and sweets should be consumed sparingly. Under the tip of the pyramid, there are two categories of foods. The first category includes milk, yogurt and cheese. The other one consists of meat, poultry, fish, dry beans, eggs and nuts. Foods in these two categories are rich in protein, calcium, iron and zinc. The following lower level of the pyramid also contains two food categories: fruits and vegetables. Since they are abundant in vitamins, minerals and fiber, it is suggested that consumers choose more of these. The lowest level of the pyramid shows the category of food from grains that includes breads, cereals, rice and pasts. It is suggested to eat the most of these foods each day (USDA, 2005).

On the other hand, the foods in the CleanMetrics Corp are separated into 9 categories; that is, 1) Bean &Pulses, 2) Dairy, 3) Fish & Shellfish, 4) Fruit, 5) Grains, 6) Meat & Poultry, 7) Nuts, 8) Oils & Fats, and 9) Vegetables (CleanMetrics Corp, 2011). It is clear that Category 7 is at the top tip of the food guide pyramid. In addition, Categories 1, 2, 3, 6 and 7 are the same as the categories in the second level of food guide pyramid. Categories 4 and 9 are the same as those in the third lower level of the pyramid. Finally, Category 5 is at the bottom of food guide pyramid. Therefore, carbon footprint categories might be disaggregated based on the food guide pyramid.

The main constraint of the data on the website is the limited number of data. A license is needed to access to their main database. Due to the limited budget, only the data on the website was used.

3.3 PRICES DATA

The price of each item of food was collected at a Superstore in Truro on June 19th, 2012 with the assistance of a staff member who worked in that Superstore. However, there are several restrictions on the data of food prices. First of all, there are different units of prices in the data. For example, milk and yogurt is measured as $/item (they might have different litres in each item) but the prices of meat and poultry are measured as $/kilogram. Secondly, the prices of food items might be different due to the different brands. For instance, the price of 2 litres of skim milk from Scotsburn is $3.45 but the price for Farmers is \$4.39. The prices of varied types of milk in the same brand are usually the same. Therefore, in this project, the price of each type of milk in the same brand of Scotsburn was collected in this project. Similarly, the prices for yogurt and cheese with different flavors but in the same brand are usually the same. Finally, some prices of commodities are not available, especially for the meat and poultry. This might be because some commodities are not available on the day when the data was collected.

CHAPTER 4 METHODOLOGY

This chapter describes the methods used to explore the relationship among health, environment and the price of food. In this study: the ONQI score of food is used as a proxy, to estimate the healthiness of food products; the carbon footprint is used to indicate the food environmental impacts; and finally, price is used to estimate price directly. There are four main categories of food which are considered in this study: fruit and vegetables; meat and poultry; fish and shellfish and dairy. The details of foods are listed in Appendix A.

There are three main reasons to conduct this study. Firstly, it is important to estimate the relationship among health, environment and the price because it is possible to find a relationship among them in this study. Secondly, based on the results of the relationship, it can be found whether there are trade-off relationships among health, environment and the price of food. Finally, according to the results, it is possible to demonstrate whether the possible labels of ONQI scores and carbon footprint could be complementary in nature. Since there is no available information about the causal effects among health (ONQI score), environment (carbon footprint) and the price of food, the price and ONQI score are used as dependent variables in the two models in the next two sections, respectively. That is, the first model is a hedonic pricing model, where price is dependent variable and proxies for health and the environmental impact of the food item are independent variables. The second model is a regression of healthiness of food (ONQI score) on price and its environmental impact (carbon footprint). Hence, the two models shown in the next two sections are used to explore the relationship among health, environment and the price of food.

4.1 HEDONICS

The hedonic pricing model has been used to decompose the price of an item into separate factors that determine the price. To put it at its simplest, a hedonic equation is a regression of price on characteristics of an item (Makpezzi, 2003). In this study, a hedonic model of food price will be applied,

$$P=f(H, E) \qquad (1)$$

where f(H,E) represents a function with two inputs (H and E) and P is the output of the function; H, E and P indicate the health, environmental impacts and the price of foods, respectively.

As ONQI score and carbon footprint are proxies of healthiness and environmental impacts of foods, respectively, Equation 1 can be transformed into Equation 2,

$$P=f(ONQI, CF) \qquad (2)$$

where P is a function of ONQI and CF; and the P, ONQI and CF stand for price, ONQI score and carbon footprint of foods, respectively.

4.1.1 Interpretations of Hedonics

In Hedonics, the food price is determined by two inputs such as health and environment. The ONQI score and carbon footprint of food are used as proxies of healthiness and environmental impacts of foods. Given the food carbon footprint, if there is a positive relationship between price and ONQI score of foods (that is, healthier foods are more expensive), it will be difficult for poor consumers to have access to the healthier foods. On the contrary, if there is a negative relationship between price and healthiness of foods (that is, healthier foods are cheaper), it is good for both poor and rich consumers. However, this situation would be difficult to achieve, because it might need government support by providing subsidies on the healthier foods and taxes on unhealthier foods. In addition, if there is a positive relationship between price and the carbon footprint of a food, it implies higher priced foods have larger environmental impacts.

4.2 Potential Implications for Food Labeling

As mentioned before, ONQI scores have not yet been used for labeling and the carbon footprint is still a voluntary label for producers' uses. Therefore, in this study, ONQI score and carbon footprint are assumed to be two potential labels, which measure health and environmental impacts of foods, respectively. In order to explore the statistical relationship between health (ONQI Score) and environmental (Carbon Footprint) labels, we estimate the following equation,

$$ONQI=f(P, CF) \qquad (3)$$

where ONQI is a function of P and CF, and the ONQI, P and CF stand for ONQI score, price and carbon footprint of foods, respectively.

4.2.1 Interpretations of Potential Implications for Food Labeling

In order to estimate the relationship between health and environmental labels, Equation 3 is explored. Given the price, if there is a trade-off relationship between health and environmental labels (that is, foods with higher levels of carbon footprint would be healthier to consumers), it is not good for consumers because it will be difficult for consumers to make decisions about choosing healthier foods or environmentally friendly foods. However, even though it is hard to make decisions in this case, most consumers would finally choose healthier food for their own concerns, instead of selecting those foods which are friendly to the environment. On the other hand, if there is no trade-off relationship between health and environmental labels (that is, foods with lower levels of carbon footprint would be healthier to consumers), this will be good for consumers because consumers can choose healthier foods without worrying about its environmental impacts due to the lower levels of carbon footprint.

Besides, the interpretation of the relationship between price and healthiness of foods here is similar to Hedonics. Given the food carbon footprint, if there is a positive relationship between price and healthiness of foods (that is, healthier foods are more expensive), it is bad for poor consumers because they cannot afford the healthier foods. In this case, if the government imposes a tax on the unhealthy food, it will be regressive. That is, it would be more difficult for poor consumers because they still could not afford the healthier foods but they would have to spend more on the unhealthier food than before the taxation. On the contrary, if there is a negative relationship between price and healthiness of foods (that is, healthier foods are cheaper), it is good for both poor and rich consumers because more consumers can afford to eat more healthily. Hence, in order to find the relationship between health, environment and price, the regressions above will be explored by using Generalized Least Squares (GLS) in Gauss.

CHAPTER 5 RESULTS

This chapter compares the ONQI scores of foods within groups and then compares ONQI scores and carbon footprints between groups. Finally, the regression results are analyzed in detail and possible distortions in food labeling by using aggregate carbon footprint are discussed.

5.1 Comparisons of ONQI Scores within Groups

Figure 1 shows the ONQI scores of different fruit (oranges, peaches, strawberries, apples, bananas-yellow and grapes).

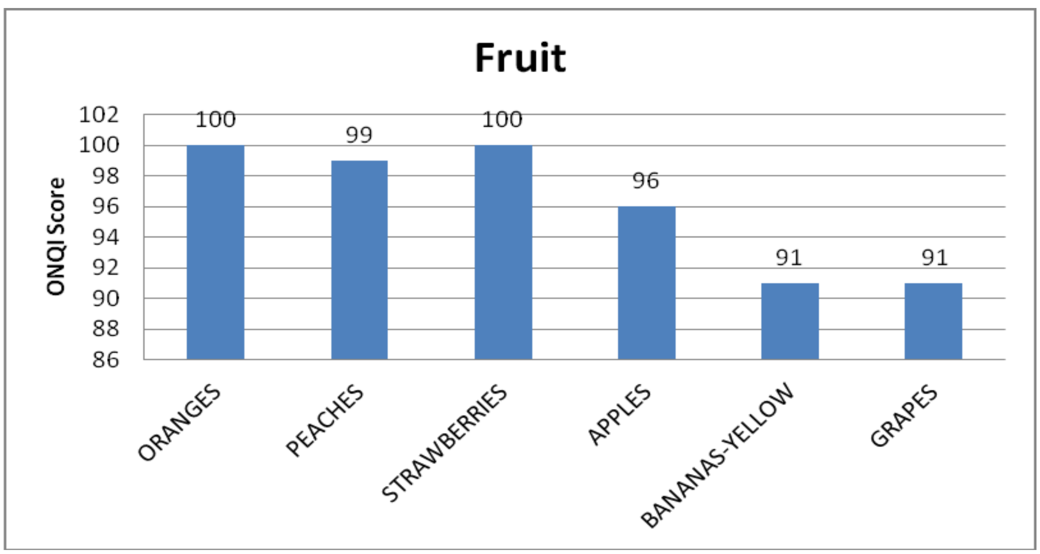

Figure 1 The ONQI scores in the fruit group, where 1≤ONQI≤100. 1 indicates the lowest possible nutritional value and 100 indicates the highest possible nutritional value. (Data Source: NuVal LLC, 2012[3])

As can be seen from Figure 1, all these fruits have ONQI scores larger than 90, which represents that they are healthy foods. Oranges and strawberries have the highest ONQI score of 100, followed by peaches and apples with ONQI scores of 99 and 96, respectively, and then bananas and grapes with an ONQI score of 91. Since they are all healthy fruit, consumers can choose the type of fruit based on their own preferences.

Figure 2 illustrates the ONQI scores of vegetables (broccolis, cabbages, carrots, lettuce-iceberg, potato, and tomato-regular-red).

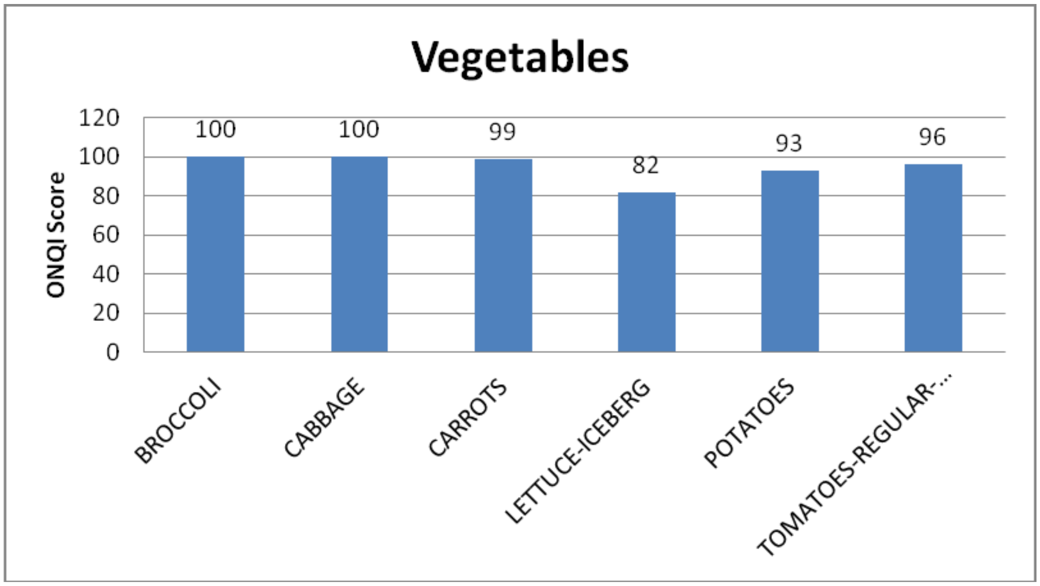

Figure 2 The ONQI scores in the vegetables group. (Data Source: NuVal LLC, 2012[3])

From Figure 2, these vegetables are also healthy foods due to the ONQI scores which are higher than 80. Broccoli and cabbage are healthier vegetables, with ONQI score of 100, than carrots, tomatoes and potatoes, with ONQI scores of 99, 96 and 93, respectively. Lettuce has the lowest ONQI score of 82. For health concerns, consumers should choose the type of vegetable with higher ONQI scores. Since all these vegetables have high ONQI scores, consumers can choose any of them with their own preferences.[2]

Figure 3 shows the ONQI scores of fish and shellfishes (salmon, shrimp and tuna).

[2] See footnote 1.

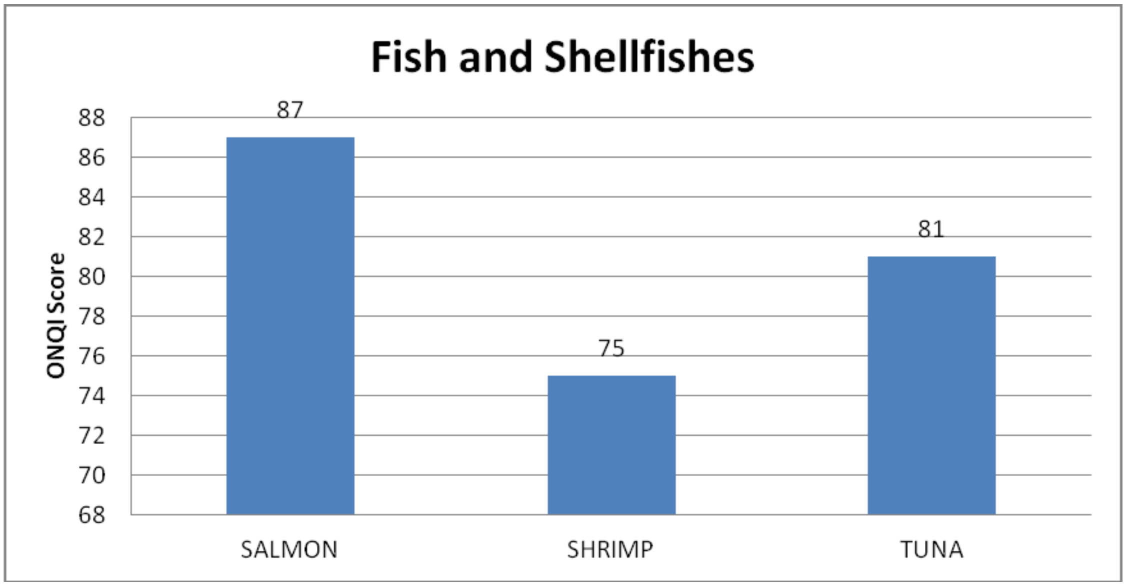

Figure 3 The ONQI scores in the fish and shellfishes group. (Data Source: NuVal LLC, 2012[3])

According to Figure 3, it is clear that salmon has the highest ONQI score (87), followed by tuna with ONQI score of 81, and then shrimp with ONQI score of 75. Based on the ONQI scores, it is suggested to eat more salmon than tuna and shrimp.[3]

Figure 4 shows the ONQI scores of turkey parts (whole turkey, chilled whole turkey, boneless and skinless whole turkey with fillets removed, turkey breast, skinless turkey breast, turkey wing with bone-in and skin-in, drumstick with bone-in and skin-in, turkey thigh and boneless and skinless turkey thigh).

[3] The ONQI tends to assign lower values to food products derived from animals than it does to fruit and vegetables. See footnote 1.

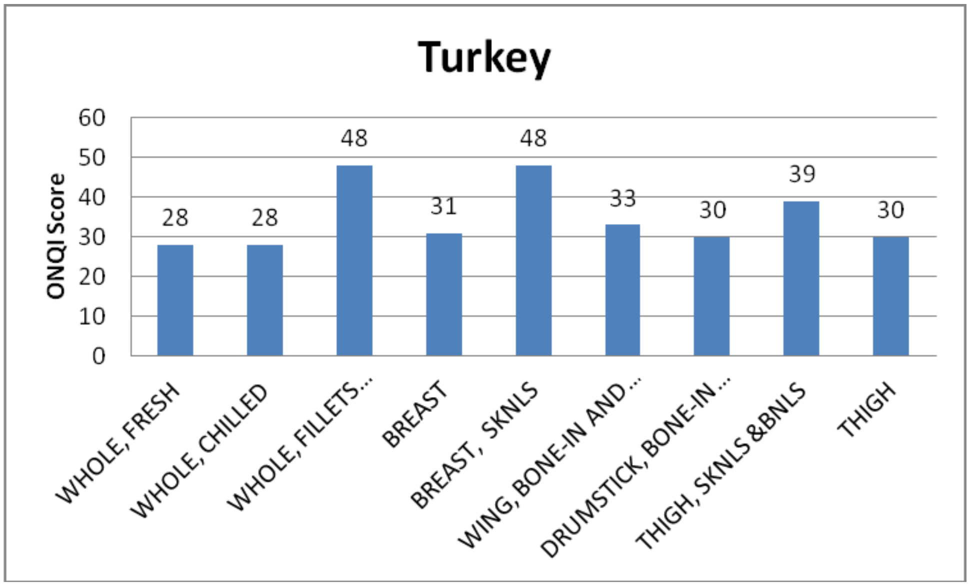

Figure 4 The ONQI scores in the turkey group. (Data Source: NuVal LLC, 2012[3])

In Figure 4, it is obvious that ONQI scores of turkey parts are less than 50, which means they are not quite healthy food. Whole turkey (fillets removed, boneless and skinless) and breast (skinless) has the highest ONQI score of 48. For the rest of the turkey parts, boneless and skinless turkey thigh has a relatively higher ONQI score of 39. The ONQI scores of other types of turkey parts are around 30, which vary from 28 to 33. Moreover, boneless and skinless turkey parts have higher ONQI scores than those with bone-in and skin-in. From this figure, boneless and skinless whole turkey has a higher ONQI score of 48 than those with bone-in and skin-in (28). In addition, boneless and skinless turkey breast had an ONQI score of 48 which is higher than those with bone-in and skin-in (31). Besides, boneless and skinless turkey thigh has an ONQI score of 39, but turkey thigh with bone-in and skin-in has a lower ONQI score of 30.

Figure 5 shows the ONQI scores of chicken parts (whole chilled turkey, boneless and skinless whole chicken, chicken breast, skinless chicken breast, boneless and skinless chicken thigh, chicken leg with bone-in and skin-in, chicken wing with bone-in and skin-in, chicken drumsticks with bone-in and skin-in and giblets).

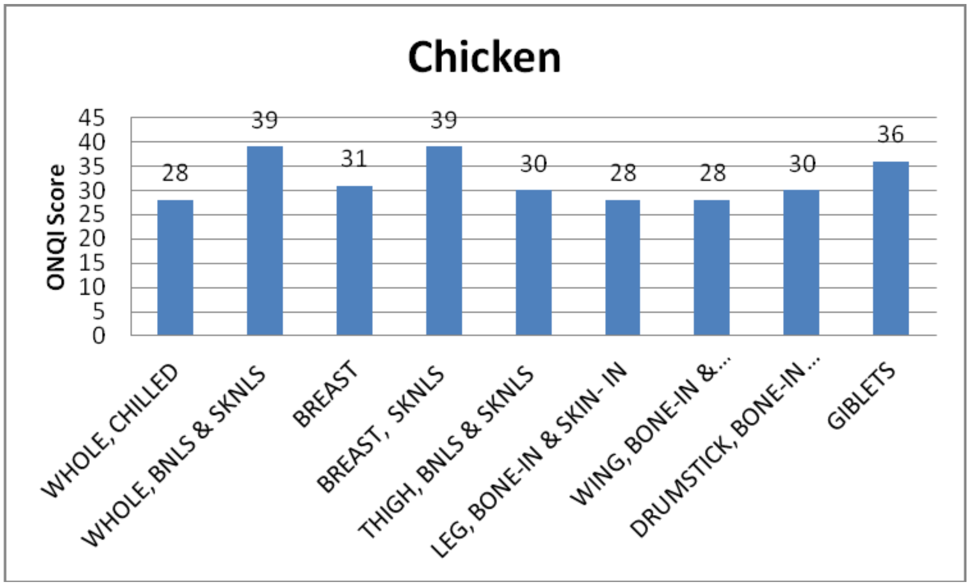

Figure 5 The ONQI scores in the chicken group. (Data Source: NuVal LLC, 2012[3])

Based on Figure 5, chicken parts have relatively low levels of ONQI scores which are lower than 40. The results here are quite similar to those from turkey parts. Whole chicken (boneless and skinless) and chicken breast (boneless and skinless) have the highest ONQI score of 39. Except for giblets (with ONQI score of 36), the ONQI scores for the rest of the chicken parts are between 28 and 31. Besides, boneless and skinless chicken parts have higher ONQI scores than those with bone-in and skin-in. For example, boneless and skinless whole chicken has an ONQI score of 39, which is higher than those with bone-in and skin-in (28). Also, skinless chicken breast (39) has a higher ONQI score than those with bone-in and skin-in (31).

Figure 6 shows the ONQI scores of different types of milk (skim milk, 0.5% reduced fat milk, 1% reduced fat milk, 2% reduced fat milk and whole milk).

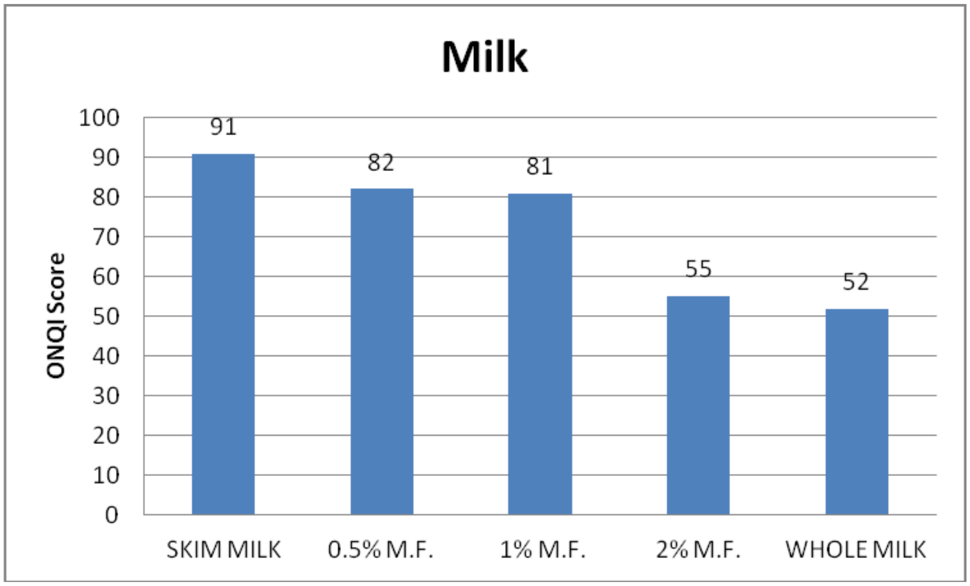

Figure 6 The ONQI scores in the milk group. (Data Source: NuVal LLC, 2012[3])

It is apparent from Figure 6 that skim milk is the healthiest milk, with an ONQI score of 91. With the increase of fat level in the milk, the ONQI score decreases; that is to say, it is unhealthier to have a higher level of fat in the milk. The milk with 0.5 % fat has an ONQI score of 82, which is higher than 1% fat milk, 2% fat milk and whole milk with ONQI scores of 81, 55 and 52, respectively.

Figure 7 shows the ONQI scores of cheese (medium cheddar cheese, Swiss cheese, Mozzarella cheese).

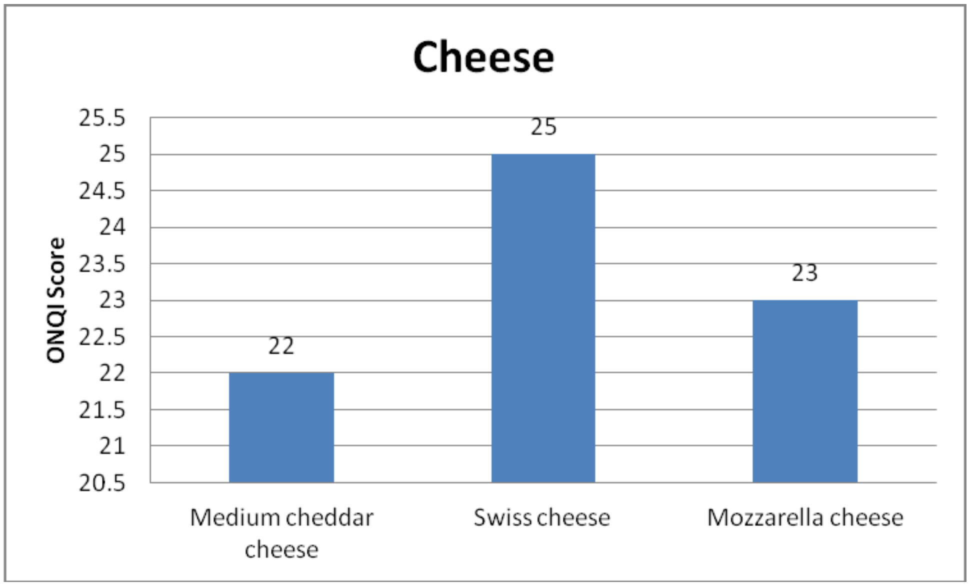

Figure 7 The ONQI scores in the cheese group. (Data Source: NuVal LLC, 2012[3])

From Figure 7, it is clear that these three types of cheese have quite low ONQI scores. They are not healthy food. Swiss cheese (25) has a relatively higher ONQI score than Mozzarella cheese and Medium cheddar cheese with ONQI scores of 23 and 22, respectively. In accordance with the ONQI scores, it is advisable to consume less cheese. If consumers have to purchase cheese, they can choose the cheese with a higher ONQI score, such as Swiss cheese.

Figure 8 shows the ONQI scores of different types of yogurt (low fat strawberry yogurt, fat free red raspberry yogurt, fat free Greek yogurt exotic fid, low fat yogurt mousse, Greek yogurt peach and Cabot Greek yogurt plain).

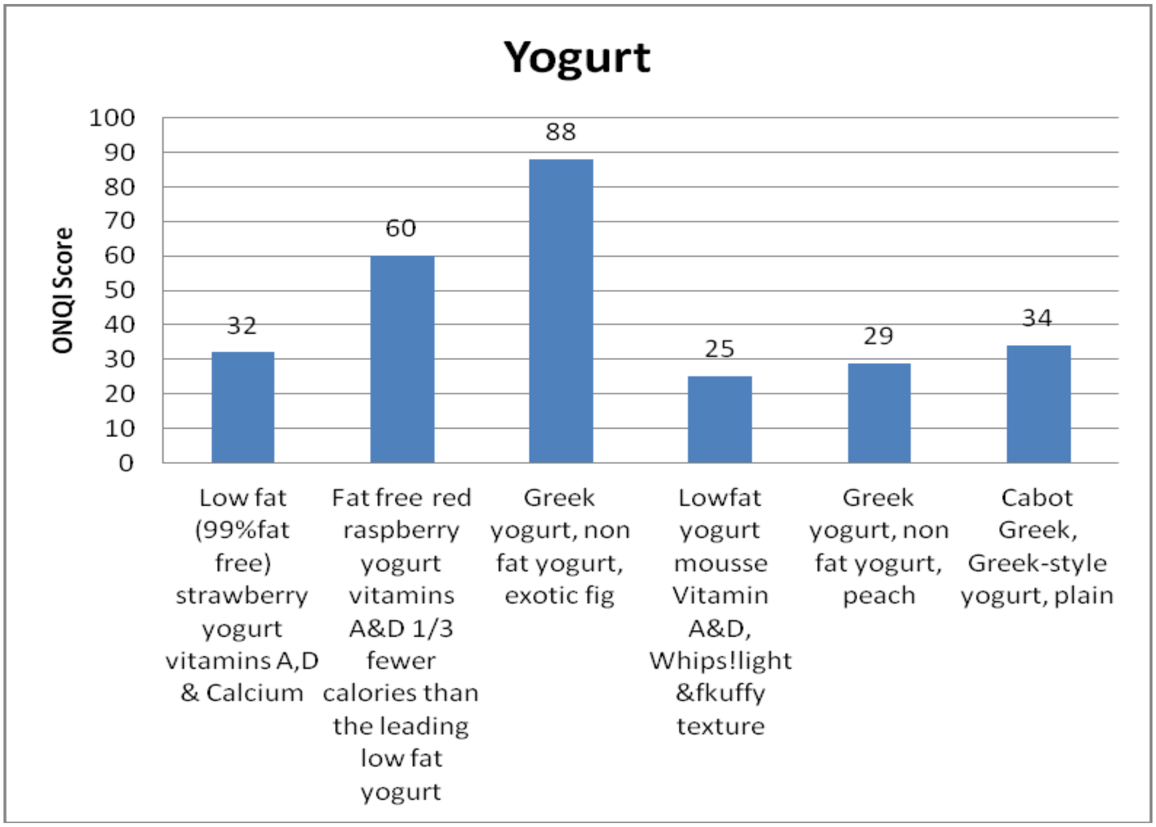

Figure 8 The ONQI scores in the yogurt group. (Data Source: NuVal LLC, 2012[3])

As can be seen from Figure 8, the ONQI scores of different types of yogurt vary from 25 to 88. Due to the scattered distribution of ONQI scores, it is truly necessary to make a good choice when choosing the type of yogurt. Greek yogurt (non fat yogurt, exotic fig) has the highest ONQI score of 88. After this, fat free raspberry yogurt has an ONQI score of 60. Other types of yogurt have quite low levels of ONQI scores, which vary from 25 to 34. Therefore, consumers should consume more Greek yogurt (non fat yogurt, exotic fig) and fat free raspberry yogurt rather than other types of yogurt.

Figure 9 shows the ONQI scores of pork parts.

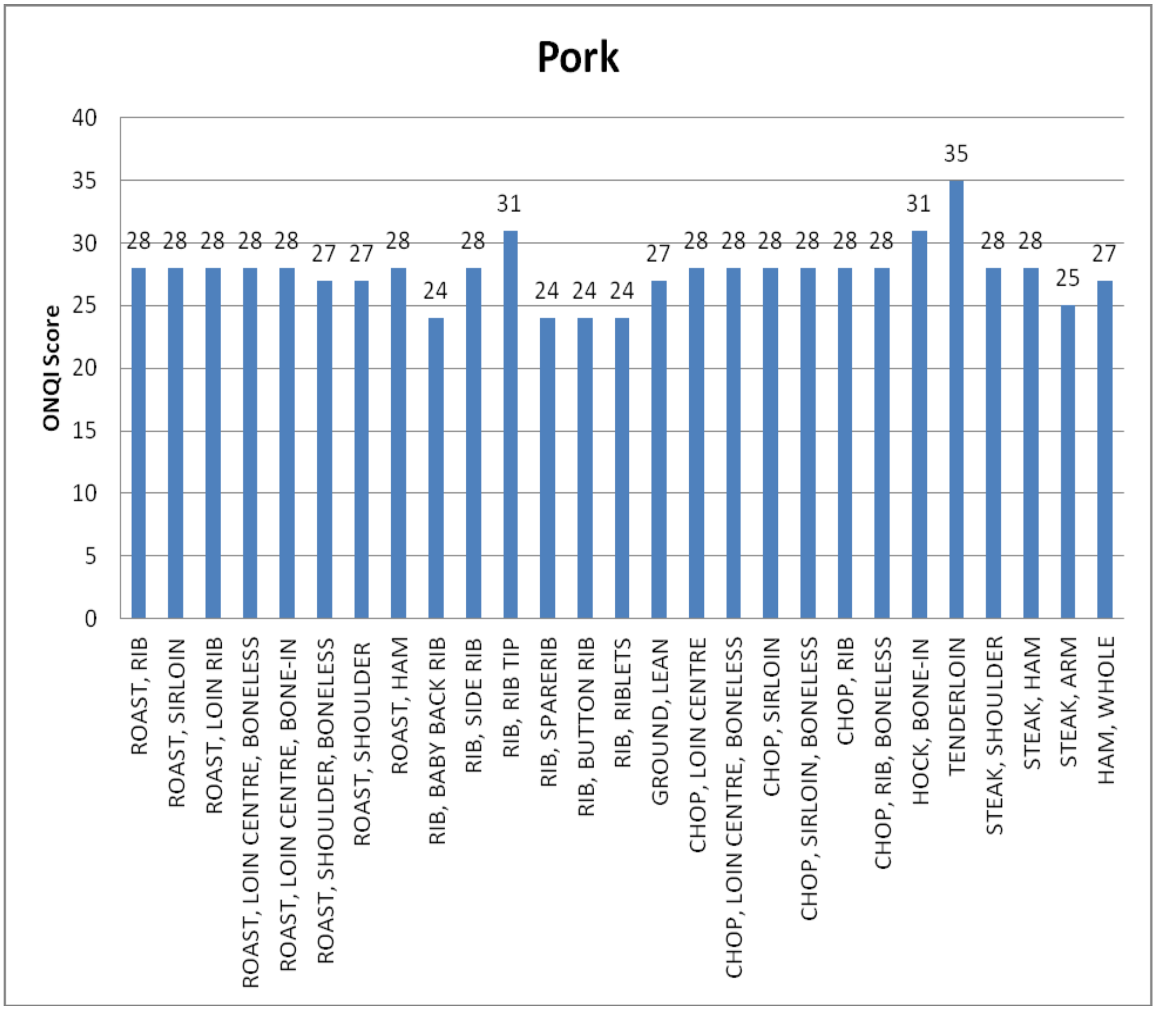

Figure 9 The ONQI scores in the pork group. (Data Source: NuVal LLC, 2012[3])

In Figure 9, the ONQI scores of these pork parts are quite consistent and they vary from 24 to 35. It is obvious that tenderloin has the highest ONQI score of 35, followed by pork rib tip with an ONQI score of 31. Baby back rib, sparerib, button rib and riblets have the lowest of ONQI score of 24, followed by arm steak with an ONQI score of 25, and then boneless and skinless shoulder roast, shoulder roast, lean ground and whole ham with an ONQI score of 27. The rest of the pork parts have the same ONQI score of 28. Due to the similar levels of ONQI scores for each part, it is not a big difference in choosing which product to eat. Due to the low levels of ONQI scores of pork parts, consumers should limit the amount of intake of pork.

Figure 10 shows the ONQI scores of beef parts.

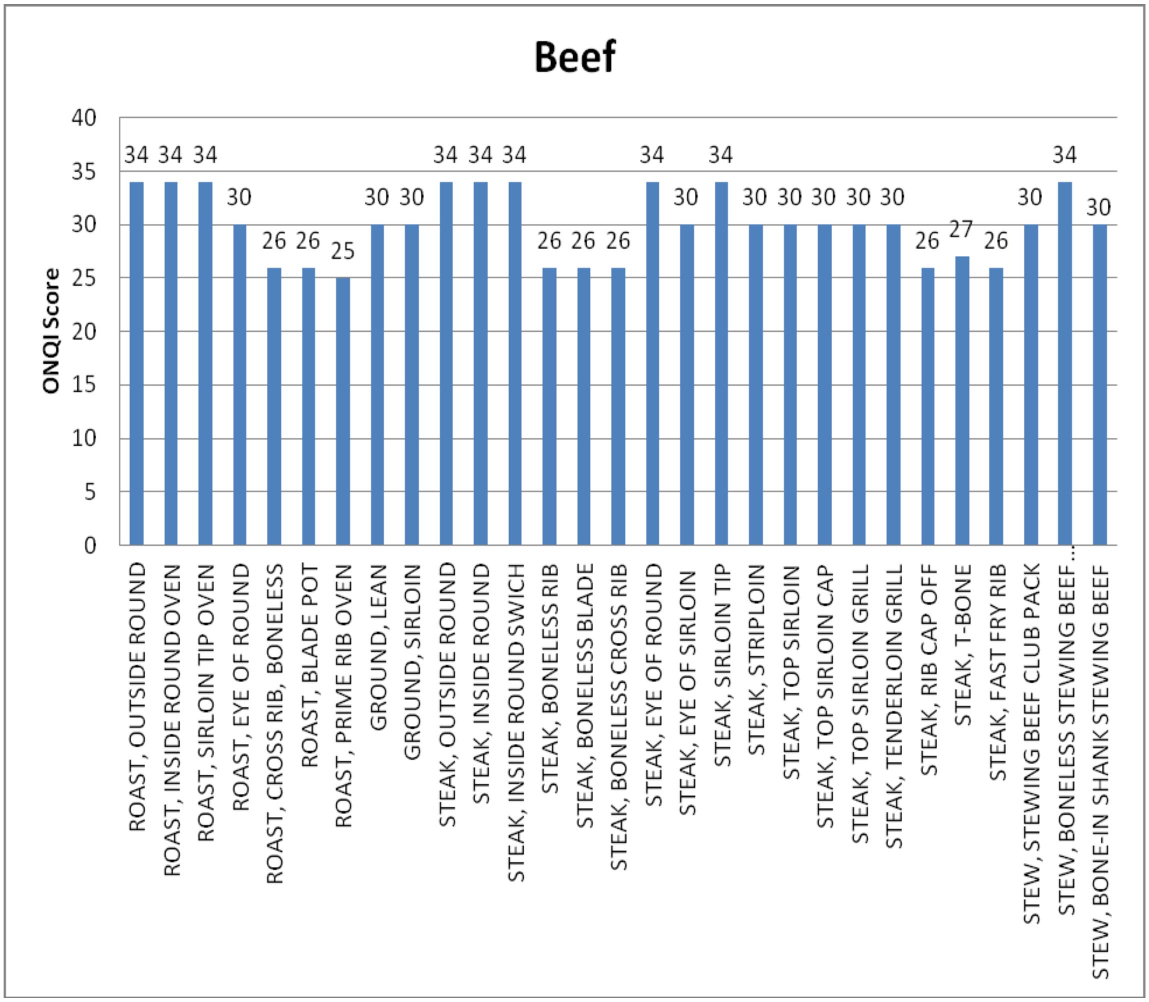

Figure 10 The ONQI scores in the beef group. (Data Source: NuVal LLC, 2012[3])

From Figure 10, the different parts of beef have quite similar ONQI scores which vary from 25 to 34. It is visible that prime rib oven roast has the lowest ONQI score of 25, followed by boneless cross rib roast, blade pot roast, boneless rib steak, boneless blade steak, boneless cross rib steak, rib cap off steak and fast fry rib steak with the same ONQI score of 26, and then T-bone steak with an ONQI score of 27. There are several parts with a higher ONQI score of 30; that is, eye of round roast, lean ground, sirloin ground, eye of sirloin steak, striploin steak, top sirloin steak, top sirloin cap steak, top sirloin grill, tenderloin grill steak, stewing beef club pack and bone-in shank stewing beef. The rest of the beef parts have the highest ONQI score of 34. Since all these parts have relatively low ONQI scores, it is not suggested to consume too much beef.

5.2 Comparisons between Groups

Figure 11 shows the plots between ONQI scores and carbon footprints of foods.

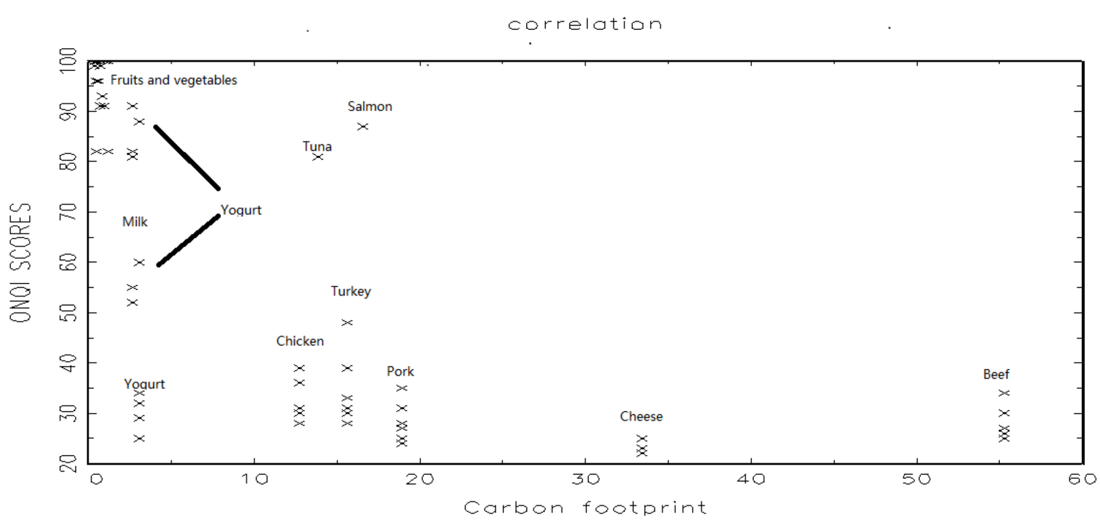

Figure 11 Correlation between ONQI scores and carbon footprints of foods. (Data Source: NuVal LLC, 2012[3] and CleanMetrics Corp, 2011)

In Figure 11, fruits and vegetables have the highest levels of ONQI scores of more than 80, followed by seafood such as tuna and salmon. Therefore, fruits and vegetables and seafood should be recommended for consumers' health. In addition, milk is also quite high in ONQI score but lower than fruits and vegetables and seafood. It ranges from 52 to 91. Unfortunately, meat, such as chicken, turkey, pork and beef, has relatively lower

ONQI levels, so it is not really healthy to eat them. The ONQI scores of meat are less than 50. Moreover, cheese also has a quite low level ONQI score with less than 25. However, the ONQI scores for yogurt vary dramatically from 25 to 88.

From Figure 11, it is clear that beef has the highest level of carbon footprint with 55.32 kg of CO_2e per pound, followed by cheese with a carbon footprint of 33.45 kg of CO_2e per pound. The carbon footprint for another three types of meat (turkey, chicken and pork) is quite smaller, which ranges from 12.72 to 18.92 kg of CO_2e per pound. The carbon footprints for the seafood are relatively similar to those for chicken, turkey and pork and they vary from 13.88 to 16.59 kg of CO_2e per pound. Fruits and vegetables, milk and yogurt have quite low levels of carbon footprint (with less than 10 kg of Co_2e per pound), especially fruits and vegetables which have only around 1 kg of CO_2e per pound. Therefore, it is environmentally friendly to eat more fruits and vegetables and eat less meat and seafood.

In Figure 11, consistent relationships between ONQI scores and carbon footprints were found for fruits and vegetables, milk and yogurt. The higher the ONQI score of the food, the lower is the carbon footprint. However, even though the relationships for meat, poultry and cheese are the same, it is obvious that the slope is truly smaller. They all have low levels of ONQI scores, but are high in carbon footprint levels. That is, as the carbon footprints of meat, poultry and cheese increase, the ONQI scores will only decrease slightly. Therefore, it can be found that the plots look like a hockey stick. In the study, the carbon footprint of pork will be treated as a critical point. This is because there is a steeper slope when the carbon footprint level of food is smaller than that of pork and there is a flatter slope when carbon footprint is larger than that of pork. Consequently, a dummy variable, D will be created. That is, if D is equal to 1, the carbon footprint of the food product is larger than or equal to18.92 CO_2e/lb (pork), 0 otherwise.

5.3 Regression Results

Table 1 shows the results of the Hedonics model (Regression 1) and the potential implications for food labeling (Regression 2).

Table 1 Regression Results of the Hedonics model (Regression 1) and the potential implications for food labeling (Regression 2)

	Regression 1	**Regression 2**
	Regressand	
Regressors	ln(P)	ln(ONQI)
Constant	-1.011 (-1.33)	4.096*** (38.93)
D	0.263 (0.56)	-1.088*** (-4.31)
ln(P)	-	0.195*** (3.20)
ln(ONQI)	0.550*** (3.20)	-
ln(CF)	0.530*** (6.87)	-0.372*** (-9.11)
ln(CF)*D	-0.146 (-1.03)	0.338*** (4.44)

Note: The values in brackets are t-values. (* p<0.1, ** p<0.05, ***p<0.01)
P, ONQI and CF stand for price, Overall Nutritional Quality Index score and carbon footprint of foods. D is a dummy variable, which is equal to 1 if the carbon footprint is larger than or equal to18.92 kg of CO_2e/lb (pork), 0 otherwise. All variables are in natural logarithm except the dummy variable (D).

As can be seen from Table 1, in Regression 1 (Hedonics Model) where the natural logarithm of price is regressand, it is shown that, given the food carbon footprint, there is a positive relationship between price and healthiness of foods. That is to say, the healthier foods are more expensive. This would be bad for poor consumers because they cannot afford the healthier foods. This result can be used to explain why poor people have worse health outcomes. Wagstaff (2002) found that poor people tend to have worse health outcomes than better-off people. This is reasonable because better-off people can afford healthier food so they have better health outcomes. However, Cash et al (2007) found there was a significant positive relationship between income and percent of obesity. In other words, rich people are more likely to be obese (unhealthy). In this case, the results of this study cannot be used to explain this. On the contrary, it could be explained by that rich people's time is more valuable and they spent much of it on work, so they do not have much time to spend on exercise. This is why rich people are more likely to be obese. Besides, it has been found that there is a statistically significant positive relationship between price and environmental impacts of foods. That is, the higher the carbon footprint, the higher the price is. This implies higher priced foods have a larger environmental impact. It is good for the environment because the higher price will lead to the decrease of demand of a food product and finally lead to the declined impact on the environment.[4]

From Regression 2 where the natural logarithm of ONQI is regressand, given the price, there is no trade-off between ONQI score and carbon footprint of foods. That is, there is a negative relationship between healthiness and environmental impacts of foods. It is good for consumers because consumers are not conflicted when making decisions about choosing healthier foods or environmentally friendly foods. In that case, consumers can choose healthier foods without worrying about their environmental impacts because

[4] This thesis does not analyze the nutritional value and carbon footprint of junk food. However, poor people may buy more junk food because it is cheap.

healthier foods have lower environmental impacts. In addition, it is obvious that whether the food carbon footprint is larger than or equal to 18.92 (that is, the dummy variable D is equal to 1) or not, there is no trade-off relationship between healthiness and environmental impacts of foods. However, when the carbon footprint is larger than or equal to 18.92, the healthiness and environmental impacts are nearly independent because the increase in the carbon footprint will lead to nearly zero decrease of the ONQI score. On the other hand, for any carbon footprint, there is a statistically significant positive relationship between price and healthiness of foods, which is consistent with the results obtained from Hedonics. In other words, the healthier foods are more expensive. It is bad for poor consumers because it is hard for them to have access to the healthier foods. In this situation, it will be recessive if the government imposes a tax on unhealthier foods because the poor consumers still cannot afford healthier foods but now they also cannot afford unhealthier foods, due to the tax. Regressions 1 and 2 indicate that a diet that is high in fruits and vegetables and low in animal proteins is healthier for consumers and smaller in its carbon footprint.

As mentioned above, regarding the natural logarithm of price or ONQI score as a dependent variable, the relationships among health, environment and the price of food are consistent. That is, the correlations among ONQI score, carbon footprint and the price of food are the same in these two regressions. However, the statistics, such as the coefficients, t-values and variances, are not invariant to which variable is chosen as regressand and which variables are chosen as regressors. For example, the coefficients in those two regressions are different because they have different dependent variables (price and ONQI score).

5.4 DISTORTIONS IN FOOD LABELING BY USING AGGREGATE CARBON FOOTPRINT

The relationship between health (ONQI score) and environment (carbon footprint) of food we found in this study may help consumers make choices between health and environment of food across groups. However, we could not empirically determine within group substitutions. That is, we could not empirically explore the relationship among health, environment and the price of food within a food group. This is because the food carbon footprint may be associated with a food item that is one of many joint products. For example, there are 29 types of food products in the beef category (as can be seen from Figure 10) and they all have their own ONQI scores and prices; however, they have only one identical carbon footprint of 55.32kg CO_2e per pound. However, a carbon footprint cannot be associated with each product described in Figure 10, except on an arbitrary base. Each of the 29 products can be derived from a single animal. Moreover, a single animal will produce additional products not listed in Figure 10, a cow or steer will produce leather and pet food, for example. The carbon footprint really is associated with a single animal, not with each product the animal produces. Any allocation of a carbon footprint over a set of joint products will be arbitrary just as any allocation of joint costs over products jointly produced is arbitrary. The fact, that a carbon footprint can be regarded as an external cost, does not change its status as a joint cost. Since we cannot run a regression with a variable that is constant all the time, we cannot explain the substitutions within a group by using statistical methods.

In the theoretical perspective, the use of the aggregate food carbon footprint for labeling may lead to distortions. The carbon footprint label is supposed to provide consumers information about the impacts of the food on the environment. However, in fact, the aggregate carbon footprint may not reflect the food environmental impact accurately. Thus, it may lead to distortions by using the aggregate carbon footprint as labels. The distortions could be explained by considering beef as an example.

Table 2 shows some examples of the dressed weights of several beef products from the short loin of an animal.

Table 2 Examples of the dressed weights of some beef products from the short loin of an animal

Beef Products	Dressed Weight(lbs)
Ground Beef	22.7
Tenderloin Steak	6.8
T-Bone	9.8
Fat and Bone	26.5

(Data source: GourmetSleuth, 2000-2012)

The beef products have only one identical carbon footprint of 55.32kg CO_2e per pound. Put simply, the impact of one pound of one type of beef product on the environment is identical to that of one pound of any other type of beef product. However, this is misleading. For example, as we can see from Table 2, there are approximately 6.8 lbs of tenderloin steak and 22.7 lbs of ground beef in the short loin for one animal, respectively. It is obvious that the weight of ground beef is about three times than that of tenderloin steak. Since there are only 6.8 lbs of tenderloin steak in one animal, if consumers want one more pound of tenderloin steak, the producers may have to slaughter one more animal to get it. Slaughtering one more animal means that more carbon footprint will be produced. On the contrary, the producers may not have to slaughter one more animal if the consumers need one more pound of ground beef this is because there are more than three times pounds of ground beef than tenderloin steak in one animal. In this case, the impact of one more pound of tenderloin steak on the environment may not be identical to the impact of one more pound of ground beef. This is because the producers may have to slaughter one more animal to get another pound of tenderloin steak and they may not need to slaughter another animal to obtain another pound of ground beef. This result is not consistent with the carbon footprint theory, which arbitrarily allocates a carbon footprint over joint produced products. An allocation that shows all beef products have the same carbon footprint is only one of many arbitrary allocations. This is why we say there could be distortions in food labeling by using the aggregate carbon footprint. By using the aggregate carbon footprint labels, consumers may think what they are doing is environmentally friendly; however, it may not be accurate in fact. Hence, the aggregate carbon footprint may only work when the constant numbers of animals are slaughtered for both tenderloin steak and ground beef. Even then, tenderloin steak and ground beef are joint products. We could just as easily increase the carbon footprint assigned to tenderloin steak and reduce the carbon footprint assigned to ground beef by exactly offsetting amounts. Any allocation is arbitrary.

CHAPTER 6 CONCLUSION

There is no trade-off relationship between the two potential health (ONQI score) and environmental (carbon footprint) labels across groups. That is, there is a negative relationship between healthiness and environmental impacts of foods. In addition, there is little relationship between healthiness and environmental impacts of foods when there is high level of carbon footprint. That is, the increase of carbon footprint will lead to a slight decrease (nearly zero) of ONQI score. The negative relationship implies there is a complementary and not competitive relationship between the healthiness of food and its impact on the environment. It is good for consumers because they are not conflicted when making decisions about choosing healthier foods or environmentally friendly foods. Hence, there is the potential to use both ONQI score and carbon footprint for labeling to help consumers make reasonable choices.

In addition, it is found that there is a positive relationship between price and ONQI score (healthiness) of foods. That is to say, healthier foods are more expensive. Therefore, in order to access healthier foods, it is necessary for consumers to eat more expensive food. It is difficult for poor consumers because they cannot afford to have access to healthier food. This could explain why poorer consumers are less healthy than richer consumers (Wagstaff, 2002), and why taxing food would disproportionately impact the health of the poor (Smed et al., 2005). It is, of course, possible that poor consumers are purchasing cheap, processed food, which we have not considered here. Soft drinks are less expensive than skim milk and soft drinks also have almost no nutritional value.

Moreover, a positive relationship between price and carbon footprint is found. This implies higher priced foods have a larger environmental impact. This is environmentally friendly because the high price of a food product will result in the decrease of its demand. For this, the producers could produce less amount of this product. Finally, it may decrease the impact on the environment. A diet based on a relatively high consumption of fruit and vegetables and relatively low consumption of animal proteins is both healthier and more environmentally friendly.

However, there may be distortions in food labeling by using the aggregate carbon footprint. Thus, the carbon footprint as an environmental label is not recommended. There are two reasons for this conclusion. First, the carbon footprint only measures the environmental impact that is related to global warming and it does not measure other environmental impacts. Second, when the carbon footprint is applied to jointly produced foods, it makes an arbitrary allocation of the carbon footprint among these foods.

Finally, the aggregate nature of the carbon footprint precluded a more comprehensive analysis of the relationship between the healthiness of food and its environmental impact. This aggregation is not a problem for the ONQI since it has been applied to 40,000 different food products. When the carbon footprint is arbitrarily allocated over joint products, it produces misleading results. Better insight might be obtained by assigning a carbon footprint to a set of joint products instead of arbitrarily allocating it among the joint products.

There are some limitations in this project. There may exist simultaneous and causal problems in the statistical analysis of this project. Also, better insight might be obtained by assigning a carbon footprint to a set of joint products instead of arbitrarily allocating the carbon footprint to products in the jointly produced set. For example, any assignment of a carbon footprint to beef products is arbitrary because all beef products are jointly produced from a single animal. Suppose we accept an allocation that assigns an equal carbon footprint to each of the many beef products that come from a single animal. This also means that a carbon footprint of zero has arbitrarily been assigned to pet food and leather.

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APPENDIX A Four Main Food Categories

The four main categories of foods are considered in this project.

1) **Fruit and vegetables:**

Fruit: oranges, peaches, strawberries, apples, bananas and grapes
Vegetables: broccoli, cabbage, carrots, lettuce-iceberg, potatoes, and tomatoes.

2) **Meat and Poultry:**

Chicken: CHICKEN, WHOLE, CHILLED
CHICKEN, WHOLE, FILLETS REMOVED, BONELINESS AND SKINNESS
CHICKEN BREAST
CHICKEN BREAST, SKINLESS
CHICKEN THIGH, BONELESS AND SKINLESS
CHICKEN LEG, BONE-IN AND SKIN-IN
CHICKEN WING, BONE-IN AND SKIN-IN
CHICKEN WING, TIPS REMOVED, BONE-IN AND SKIN-IN
CHICKEN DRUMSTICKS, BONE-IN AND SKIN-IN
CHICKEN GIBLETS
Turkey: TURKEY, WHOLE, FRESH
TURKEY, WHOLE, CHILLED
TURKEY, WHOLE, FILLETS REMOVED, BONELESS AND SKINLESS
TURKEY BREAST
TURKEY BREAST, SKINLESS
TURKEY WING, BONE-IN AND SKIN-IN
TURKEY DRUMSTICKS, BONE-IN ANS SKIN-IN
TURKEY THIGH
TURKEY THIGH, SKINLESS AND BONELESS
Pork: PORK, ROAST, RIB
PORK, ROAST, SIRLOIN
PORK, ROAST, LOIN RIB
PORK, ROAST, LOIN VENTRE, BONELESS
PORK, ROAST, LOIN CENTRE, BONE-IN
PORK, ROAST, SHOULDER, BONELESS
PORK ROAST, SHOULDER
PORK, ROAST, HAM
PORK, RIB, BABY BACK RIB
PORK, RIB, SIDE RIB
PORK, RIB TIP
PORK, RIB, SPARERIB
PORK, RIB, BUTTON RIB
PORK, RIB, RIBLETS
PORK, GROUND, LEAN
PORK, CHOP, LOIN CENTRE

PORK, CHOP, LOIN CENTRE, BONELESS
PORK, CHOP, SIRLOIN
PORK, CHOP, SIRLOIN, BONELESS
PORK, CHOP, RIB
PORK, CHOP, RIB, BONELESS
PORK, HOCK, BONE-IN
PORK, TENDERLOIN
PORK, STEAK, SHOULDER
PORK, STEAK, HAM
PORK, STEAK, ARM
PORK, HAM, WHOLE

Beef: BEEF, ROAST, OUTSIDE ROUND
BEEF, ROAST, INSIDE, ROUND OVEN
BEEF, ROAST, SIRLOIN TIP OVEN
BEEF, ROAST, EYE OF ROUND
BEEF, ROAST, CROSS RIB, BONELESS
BEEF, ROAST, BLADE POT
BEEF, ROAST, PRIME RIB OVEN
BEEF, GROUND, LEAN
BEEF, GROUND, SIRLOIN
BEEF, STEAK, OUTSIDE ROUND
BEEF, STEAK, INSIDE ROUND
BEEF, STEAK, INSIDE ROUND SWICH
BEEF, STEAK, BONELESS RIB
BEEF, STEAK, BONELESS BLADE
BEEF, STEAK, BONELESS CROSS RIB
BEEF, STEAK, EYE OF ROUND
BEEF, STEAK, EYE OF SIRLOIN
BEEF, STEAK, SIRLOIN TIP
BEEF, STEAK, STRIPLOIN
BEEF, STEAK, TOP SIRLOIN
BEEF, STEAK, TOP SIRLOIN CAP
BEEF, STEAK, TOP SIRLOIN GRILL
BEEF, STEAK, TENDERLOIN GRILL
BEEF, STEAK, RIB CAP OFF
BEEF, STEAK, T-BONE
BEEF, STEAK, FAST FRY RIB
BEEF, STEW, STEWING BEEF CLUB PACK
BEEF, STEW, BONELESS STEWING BEEF CUBES
BEEF, STEW, BONE-IN SHANK STEWING BEEF

Egg: REGULAR WHITE AND BROWN EGGDS, NOT FOR OMEGA-3 EGGS

3)Fish and shellfish

SALMON, TUNA & SHRIMP

4)Dairy:

Milk: WHOLE MILK
SKIM MILK

REDUCED FAT (2%) MILK
REDUCED FAT (1%) MILK
REDUCED FAT (0.5%) MILK

Yogurt: 99% FAT FREE STRAWBERRY YOGURT VITAMIN A, D & CALCUIM
FATFREE RED RASPBERRY YOGURTVITAMIN A&D1/3FEWER CALORIES THAN THE LEADING LOW FAT YOGURT
GREEK YOGURT, NON FAT YOGURT, EXOTIC FIG
LOW FAT YOGURT MOUSSE VITAMIN A&D
GREEK YOGURT, NON FAT YOGURT, PEACH
GREEK YOGURT, GREEK-STYLE, PLAIN

Cheese: MEDIUM CHEDDAR
SWISS CHEESE
MOZZARELLA CHEESE