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Economic and Environmental Impacts of Dietary Changes in Iran: An Input-Output Analysis

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ABSTRACT

Iran's simple and environmentally extended commodity by commodity input-output (IO) model was used to determine the impacts of dietary changes on the Iranian economy and on the environmental load. The original model is based on the status-quo diet and was modified to include the World Health Organization (WHO), the World Cancer Research Fund (WCRF) and Mediterranean alternative dietary scenarios. A range of impacts occurred depending upon the relative changes in food items. The direction of changes was similar in the three alternative scenarios. The greatest and smallest impact occurred in the WHO and the Mediterranean scenarios respectively. Total changes in output in WHO, WCRF and Mediterranean dietary scenarios were calculated to be 7010.1, 4802.8 and 3330.8 billion Rials respectively. The outputs of rice, vegetables, fruit, bread and macaroni decreased, but those of live and other animal products increased. The output of non-food commodities and services increased as well. The environmental load increased for three dietary scenarios in comparison with the status-quo diet. The greatest and smallest environmental load occurred in WHO and Mediterranean dietary scenarios respectively. Thus, although dietary changes can have positive effects on economic output, in order to avoid negative environmental effects, it is necessary to consider strategies such as applying capabilities, particularly natural resources in an optimal healthy and environmentally diet, planning for improving forest covering and green space simultaneously with increasing economic activities and using indirect incentives, such as taxes and insurance, for promoting sustainable and healthy foods and reducing greenhouse gas emissions.

Keywords: Simple and environmentally extended input-output models, environmental impact, dietary changes, Iran
JEL Classification: C67, Q54

1 Introduction

Throughout the world a nutritional transition is taking place, where people are shifting towards more affluent food consumption patterns (FAO, 2003; Grigg, 1995; Gerbens-Leenes et al., 2010; Popkin, 2002). In some countries, this transition is based on changes in available resources and purchasing power, leading to long-term changes in dietary patterns (Ivanova et al., 2006). In Asian countries, rapid economic growth, urbanization and globalization are leading to a dramatic shift of Asian diets away from staples and increasingly towards livestock and dairy products, vegetables and fruit, and fats and oils (Pingali, 2006).

Accordingly, dietary habits have the potential to change economic and environmental impacts as well. According to the literature, environmentally extended input-output models (EEIO) have been typically developed to analyze environmental impacts (Tukker et al., 2009; Nijdam et al., 2005; Leatherman, 1994). The findings of these studies are that over 70 % of the life-cycle environmental impacts from final consumption expenditures are related to food consumption, mobility and housing/energy use. Tukker et al. (2009) introduced three alternative dietary scenarios. Scenario 1 is an optimal diet and follows the WHO dietary recommendations. The second scenario is based on the

WCRF, following a diet with a higher reduction in meat intake (WCRF, 2007). The third scenario is a

Mediterranean diet. This diet can be described as the dietary pattern found in olive-growing areas of the Mediterranean basin, in the late 1950s and early 1960s, when the consequences of World War II were overcome, but the fast-food culture had not reached the area yet (Trichopoulou, 2001).The main difference among these scenarios is related to the share of vegetable and animal products.

Based on the findings of Duchin (2005), a shift from affluent consumption patterns towards the Mediterranean diet pattern has a favorable impact on the environment and health. Wolf et al. (2011) investigated the environmental and economic impacts of dietary changes in Europe by comparing three alternative scenarios developed by Tukker et al. (2009) with the current diet. They concluded that final consumption of food products figures amongst the strongest contributors to a negative environment in Europe, production of beef and pork at the agricultural level, being the main part of the food supply chain, responsible for the environmental load. They concluded that food expenditure for a diet based on the WHO recommendation slightly increased, leading to a reduced consumption of non-food products. In the scenarios that take into account WCRF recommendations and the Mediterranean diet, decreasing expenditures for food products cause a slight increase in non-food products. The production of cattle and meat products decreased in all scenarios compared with the base, whereas the production of poultry and miscellaneous livestock increased in the WHO diet and decreased in other dietary scenarios. Accordingly, feed grain products decreased, whereas food grain production, vegetable and fruit consumption increased. The environmental loads for all impact categories except eco-toxicity decreased in the scenarios introduced compared with the current diet.

In Iran, nutritional transition is taking place within the context of a rapid demographic change, urbanization and social development, but in absence of steady and significant economic growth (Ghassemi, et al., 2002). Per capita daily energy increased from 1772 Kcal in 1961 to 3044 Kcal in 2007. Share of per capita daily energy supplied by cereals declined from about 60.3 percent in 1961 to 50.6 percent in 2007. Share of the daily protein supply through animal products increased from 26.48 in 1961 to 28.49 percent in 2007. Per capita consumption of most foodstuffs such as meat, dairy products, vegetables and fruit has increased over the past decades. Per capita consumption of vegetables and fruit increased from 57.8 and 41.1 kg in 1961 to 193.7 and 158 kg in 2007 respectively and that of milk and meat increased from 51.9 and 14.5 kg in 1961 to 70.5 and 30.4 kg in 2005 respectively (FAO, 1961, 2005 and 2007). In Iran, food supply for providing energy and abdominal fullness is sufficient, but in terms of nutrients, cellular fullness, diversity, quality and food safety, there are many deficiencies. Comparing the current food consumption pattern with an optimal healthy diet show that consumption of cereals and sugar should be reduced, while consumption of dairy products, fruits and vegetables should be increased (Kimiagar et al., 2004).

Until now, the environmental impact of the food consumption pattern have not been investigated in Iran, but based on the available data, it can be inferred that there is a high potential for climate change, worsening the situation. In recent decades, per capita energy consumption increased from 650 kg in 1970 to 2,438 kg in 2005 based on kg of oil equivalent. The compound annual average growth rate of energy per capita consumption was 3.85 percent in this period. Among consumer energy sectors, the residential, commercial and the public sectors have the largest carbon dioxide emissions after the powerhouse sector (Energy balance sheet, 2008). Also, CO2 emission per capita increased from 2 tons in 1960 to 7 tons in 2005. The compound annual average growth rate of CO2 emissions has been 3.64 percent in that period (http://ddp-ext.worldbank.org). Perhaps this subject is one of the most important reasons for higher temperatures and climate change in Iran in recent years.

It is expected that the nutritional transition that has occurred in Iran will generate economic and environmental impacts. Although the status-quo dietary scenario in Iran is to some extent different from the scenarios explained, the nutritional transition show signs of convergence towards general recommendations of these scenarios. With respect to these scenarios, food consumption patterns in different areas change, leading to changes in final consumer demand for food products and also changes in food and other commodities and services outputs. This paper aims at determining the economic and environmental impacts (climate change) of dietary changes from the status-quo to the WHO, WCRF and Mediterranean dietary scenarios, and it includes a simulation for Iran based on the Iranian Health Institute reports (Iranian nutrition and food technology research institute, 2004). For this purpose, we start by explaining the status-quo diet and by calculating the changes that are relevant in alternative dietary scenarios. Next, the integrated changes for the food group of the scenarios simulated are calculated and the compositions of diets per scenario in IO items are translated. The results regarding the relationship between final demand for commodities and services and their outputs in the IO model are then presented and the environmental loads for climate change (CO_2, CH_4, N_2O) in the dietary scenarios defined are evaluated. Lastly, the conclusions are described. The method in our study is a commodity by commodity approach in input- output models.

2 Methods and Data

2.1 The Commodity by Commodity Approach in Input-Output Models

Input-output analysis provides a framework for describing the relationship among economic sectors, commodities and final demands. It also opens up a path for studying the effects of consumption on environment (Leontief, 1974). In an ordinary input-output model, the relationship among output vector (X), the transactions matrix ($Z_{n\times n}$) and final demand (F) is represented by the following expression:

$$X= ZI +F \qquad (1)$$

the technical coefficients, $A=[a_{ij}]$, are defined as:

$$A = Z \hat{X}^{-1} \qquad (2)$$

in which superscript ^ represents digitalization (arranging the elements of output vector in the main diagonal).

In the commodity by industry approach, the inter-industry transactions matrix, Z, is replaced initially by the Use matrix, $U_{m\times n}=[u_{ij}]$, where u_{ij} is the purchase value of commodity i by industry j, and the technical coefficients $B=[b_{ij}]$ are defined as:

$$B = U \hat{X}^{-1} \qquad (3)$$

in which column j represents the value of inputs of each commodity per million Rials (the Iranian currency, approximately 1USD= 12500 Rials) of industry j′ s output, and the Make matrix, showing how industries make commodities, denoted by V. An element of V, v_{ij}, shows the value of the output of commodity j that is produced by industry i (Miller and Blair, 2009).

Table 1 shows a presentation of commodity by industry and industry by commodity framework in Iran. The 1999-2000 Iranian input- output tables are published at detail level, of 119 commodities and 54 industries (Central Bank of Iran, 2005). In the table, $U_{119\times 54}$ is Use matrix, $E_{119\times 1}$ is final demand vector for commodities, $Q_{119\times 1}$ is total output vector for commodities, $V_{54\times 119}$ is Make matrix, $F_{119\times 1}$ is final demand vector for industries, $X_{54\times 1}$ is total output vector for industries, M′ is imports vector, and

Table 1.
The general structure of Commodity- Industry and Industry – Commodity for Iranian economy in 1999-2000

		Commodities	Industries	Final demand	Totals
		1 2.................................. 119	1 2 58		
Commodities	1		u_{11}, u_{12}, u_{13}, ... $u_{1\times54}$	e_1	q_1
	2		u_{21}, u_{22}, u_{23},.................. $u_{2\times54}$	e_2	q_2
	.		. . . .	.	.
	.		. . . .	.	.
	.		. . . .	.	.
	119		$u_{119\times1}, u_{119\times2}, u_{119\times3}$,…. $u_{119\times54}$	e_{119}	q_{119}
Industries	1	v_{11}, v_{12}, v_{13}, . . $v_{1\times119}$		f_1	x_1
	2	v_{21}, v_{22}, v_{23},. . $v_{2\times119}$		f_2	x_2
	.	. . . .		f_3	.
	.	. . . .		.	.
	.	. .		.	.
	.	. . . .		.	.
	54	$v_{54\times1}, v_{54\times2}, v_{54\times3}$, . . $v_{54\times119}$		f_{54}	x_{54}
Import/ Value added		m_1, m_2, m_3,................ m_{119}	r_1, r_2, r_3, ... r_{54}		
Totals		q_1, q_2, q_3, ... q_{119}	x_1, x_2, x_3, ... x_{54}		

the R′ vector is the commodities value added for industries output.

Considering the objectives of this study and a greater emphasis on food and agricultural products, the commodities and industries accounts in the Make and Use tables are aggregated in 44×44 commodity by industry according to central products classification(CPC,1993) and international standard classification of economic activities (ISIC, 1993). The method of calculating a commodity by commodity total requirements matrix that connects commodity final demand to commodity output based on Table 1, is presented in appendix A.

2.2 Input–output analysis and environmental impacts

We quantify the environmental impact intensities of goods and services by using the methods of Nijdam et al., (2005) and Kerkhof et al., (2009), by which the direct and indirect environmental impacts related to the Dutch consumption of goods and services are quantified. The direct environmental load occurs during use of the product by the consumer and the indirect environmental load occurs before the product or service has been purchased, or after it has been collected for waste treatment. The indirect load is important for most environmental impact categories. Only road noise is mostly associated with direct environmental load (Nijdam et al., 2005). In accordance with these studies, we evaluated the indirect environmental load of greenhouse gases (CO_2, CH_4 , N_2O) for climate change impact in Iran and then compared dietary scenarios for this impact.

The environmental impact intensities are determined by means of environmentally extended input-output analysis (EEIOA). EEIOA relates environmental impact intensities to monetary flows in the IO table. To get the emission intensities of commodities, em, first the total emission intensities of sectors are calculated with IO analysis. In accordance with Nijdam et al., (2005) and Kerkhof et al., (2009), the supply coefficient matrix of Iranian IO tables is used to convert the emission intensities of sectors to emission intensities of commodities and services. It is a matter of presentation that we express this as a post-multiplication of the Leontief inverse with the supply coefficient matrix (Wier et al., 2005; Kerkhof et al., 2008; Kerkhof et al., 2009). Accordingly, the emission intensities of commodities and services are calculated using the following equation:

$$em_p = d(I - A_{(i\times i)})^{-1}V \qquad (4)$$

where em_p is a vector containing the emission intensities of commodities groups (kg emission equivalent per million Rial of commodities value); d, row vector of environmental load intensities per sector; $(I - A_{(i\times i)})^{-1}$, the 44×44 Leontief inverse matrix of Iran with $A_{i\times i}$ ($A_{i\times i}$ = DB where D and B are defined previously in the text and appendix A respectively) as a 44 × 44 matrix of input –output coefficients based on inter-sectoral commodity flows, and I, an identity matrix. The environmental load intensities of sectors, d, were calculated based on the GHHs emission inventory of Iran in 2000, and the share of energy consumption in these sectors. V is an aggregated 44 × 44 matrix with supply coefficients describing the supply of 44 sectors to 44 product groups purchased by consumers. Supply coefficients are expressed as supply of a sector to one product group per total supply to that particular product group.

Following Kherkhof et al., (2009) we assumed the imports are produced with technologies similar to those in Iran, implying that emission intensities of imports are equal to the Iran emission intensities of similar products.

2.3 Diet scenarios and environmental impacts

Within the context nutritional transition, food pattern reform is necessary in order to get an optimal diet from environmental and nutritional perspectives. The recommendations by the WHO and the Iranian Health Institute imply the need of increasing consumption of milk, vegetables and fruits (WHO, 2002; Iranian nutrition and food technology research institute, 2004). Also, the WCRF recommends the intake of meat products, in particular red meat, to be in low quantities, i.e. less than 300 g/week, whereas fruit and vegetables as well as carbohydrate-rich food, such as bread, are recommended as part of the daily diet (WCRF, 2007). The Mediterranean diet is plant-centered; it differs from other diets in that it is lower in red meat and dairy products and higher in fruit and vegetables (Keys, 1995). Dietary recommendations and characteristics are formulated for foods, food-based dietary guidelines, (for example, more fruit and vegetables) as well as nutrients (for example, energy percentage of fat intake less than 35 and saturated fat intake less than 10). Such recommendations are issued by international organizations, such as WHO (WHO, 2002), WCRF, the American Institute for Cancer Research (WCRF and the American Institute for Cancer Research, 2007) and nutritionists. The 2003 food balance sheets of Mediterranean countries confirmed the Mediterranean food pattern and further distinguished from the rest of Europe with respect to the low sugar intake, a higher intake of pulses and a low intake of animal fat (Tukker et al., 2009). Nowadays, these recommendations are based on prevention of nutritional deficiencies on the one hand, but also aim at reducing chronic diseases and obesity on the other. As mentioned before Tukker et al., (2009) introduced these dietary scenarios. A summary of the characteristics of these scenarios is given in Table 2. These characteristics are translated into dietary scenarios.The improved dietary pattern took the existing diet as a starting point and may be regarded as a more feasible and less drastic choice for alternative diets. The simulation was performed for each defined scenario using a spreadsheet. The principle was to change the share of food groups into the recommended direction (see Table 3 for Scenarios 1, 2 and 3), without changing the overall energy intake. Care was also taken that protein intake was maintained between 11 and 12 energy percent. To achieve this condition, substitutions were made with favorable foods such as dairy products (to compensate for energy and protein) and vegetable oils (to compensate, if necessary, for meat and animal fat). Dairy products were increased, as their consumption is low in comparison with recommended diets and they are also important for providing calcium and other nutrients.

Table 2.
Alternative dietary scenarios characteristics

Scenarios / Characteristics	Scenario1	Scenario2	Scenario3
Dietary recommendation source	WHO Recommendation	WCRF Recommendation	Mediterranean diet (confirmed by the 2003 food balance sheets data of Mediterranean countries)
Nutrient content	Energy content (kcal) 3044 Protein intake 86.4	Energy content (kcal) 3044 Protein intake 86.4	Energy content (kcal) 3044 Protein intake 86.4
Food composition	Slightly less meat, more fish, more fruit and vegetables	Less meat, more fish, more fruit and vegetables	Less milk, less meat, significantly more fish, more fruit and vegetables

Source: Tukker et al., 2009. Environmental impacts of diet changes in the EU, EUR 23783 EN, European Commission, Joint Research Center, Institute for Prospective Technological Studies. 2- FAO, 2007. Food balance sheet data for Iran 1961-2007.

Similar to Tukker et al., (2009), to analyze the environmental impacts of alternative diets, it is assumed that dietary patterns in Iran are represented by the existing expenditure on food as incorporated in the IO tables for 1999-2000 in vector E_0. The three alternative diets are represented as relative deviations to current expenditure for individual food products in vector E_0, resulting in vectors E_1, E_2 and E_3. Total environmental emissions associated with the final demand of commodities in each diet

(E_i), and also total outputs to satisfy this final demand (Q_i), are possible by pre-multiplying the vector of emission intensities of commodities (em_p) per Q_i, i.e.

$$S_i = em_p (I - A_{(c \times c)})^{-1} E_i \ , \qquad i = 0,1,2,3 \qquad (5)$$

Where S_i is total environmental emission related to each diet and $A_{c\times c}$ ($A_{c\times c}$ = BD) is a 44×44 matrix of input – output coefficients. The change in environmental load (ΔS_i) could be determined by multiplying (ΔQ_i) into em_p

2.4 Data sources and steps of research

The study relies on available data from organizations such as the Food and Agricultural Organization (FAO), the Central Bank, Ministry of Energy and Environmental Organization of Iran as follows:

1- Food balance sheets (FBSs), assembled by the Food and Agricultural Organization of the United Nations (FAO) from national statistics on production, imports and export of ingredients and primary agricultural foods. FBSs estimate the amount of food available per capita per year and produce derived information, such as energy, fat and protein availability per capita per day. These data are available for Iran from 1960 to 2007. The detailed classification of commodities at the level of primary agricultural products could reasonably be translated into IO categories. As a first step of research based on the Iranian FBSs data, availability of food categories (capita/day) in the year 2007 (the last year for which these data were available) was calculated as a status-quo diet. Then relative changes of alternative dietary scenarios (% weight) to the status-quo were calculated based on the dietary scenarios characteristics and recommendations.

2- IO tables: The IO tables were obtained from the Iranian system of National Accounts (Central Bank of Iran, 2005). The Make and Use tables contain 119 commodities in 54 industries and are expressed in base and purchase prices. These tables are aggregated in 44× 44 commodity by industry tables based on the CPC and ISIC classifications. Aggregation of the accounts was done in such a way that the changes in the output and environmental load related to final demand of dietary scenarios could be evaluated. The second step of research is the aggregation of IO tables considering the objectives of the study.

3- Evaluating direct changes in food use and total changes of commodities and services output in the three dietary scenarios relative to the status-quo requires a link between the FBS food groups and the IO categories. This correspondence was established by a bridge matrix. In this matrix, food items with respect to their shares in the IO tables are associated to a FBS food group. The third step of research is establishing the bridge matrix and calculating direct changes in food use and total changes of commodities and services output of the dietary scenarios relative to the status-quo.

4- The Greenhouse Gases (GHG_s) (CO_2, N_2O and CH_4) emissions data for all sectors in the year 2000 have been obtained from the Iranian documents and reports of the Environmental Organization. For preparing these data, the 1996 IPCC (Intergovernmental Panel on Climate Change) Revised Guidelines and default emission factors were used (Iran second National Communication to the United Nations Framework Convention on Climate Change, 2010). The energy sector is the most important sector in the emission inventory of greenhouse gases in Iran (%77 in overall GHGs emission).

5- The energy data have been obtained from the annual Iranian energy balance sheet report for the years 1999-2000. The environmental load intensities of all subsectors were calculated based on the GHHs emission inventory and the share of energy consumption in these subsectors with IO analysis. Based on the methodology the supply coefficient matrix of Iranian IO tables is used to convert the emission intensities of sectors to emission intensities of commodities and services. Lastly, total environmental load related to each diet and its related output is calculated.

3 Results

The results of the status-quo diet and the corresponding changes in alternative scenarios are presented in Table 3. As shown, many changes may occur if the existing dietary pattern shifts toward each of the dietary patterns described. The most important changes are decreasing the weight percentage of cereals (-26.36 to -17.47), fruit (-36.24 to -5) and vegetables (-26.61 to -6.47), and increasing the weight percentage of vegetable oil (49.25 to 115.56), oil crops (280.5 to 584.9), meat (188.45 to 228.18) and milk (174.62 to 263.96). With respect to the cultural and economic conditions, the changes in dietary patterns generally occur gradually and over a period of several years. Therefore, in this study, it is assumed that the dietary changes took place over a ten-year-period.

Table 3.
Food availability capita/ day and relative changes according to simulated scenarios

Commodities based on Food balance sheet (FBS) categories	Status-quo		Relative changes to status-quo (% weight)		
	Energy %	Gram/day	Scenario 1 (WHO)	Scenario 2 (WCRF)	Scenario 3 (Mediterranean)
Cereals - Excluding Beer (Total)	50.31	502.47	-26.36	-26.26	-17.47
Starchy Roots (Total)	3.45	147.12	15.99	15.99	26.39
Sugar and Sweeteners (Total)	8.52	78.90	12.55	12.55	9.31
Pulses (Total)	2.16	19.73	-74.65	1.9	-29.53
Tree nuts (Total)	1.32	14.52	-38.2	70.90	27.06
Oil crops (Total)	0.13	1.64	432.70	280.50	584.90
Vegetable Oils (Total)	7.30	26.58	49.25	104.85	115.56
Vegetables (Total)	3.45	530.68	-6.47	-26.61	-16.98
Fruits - Excluding Wine (Total)	7.05	432.88	-36.24	-17.11	-5
Meat (Total)	4.61	90.14	228.18	188.45	188.45
Red meat	2.46	35.62	348.79	160.30	63.91
Poultry Meat	2.18	53.70	14.70	14.70	23.52
Animal Fats (including butter)	2.26	10.14	-34.4	-34.4	-23.15
Milk - Excluding Butter (Total)	2.88	181.10	263.96	263.96	174.62
Eggs (Total)	0.97	21.92	57.11	57.11	27.65
Fish, Seafood (Total)	0.47	19.45	204.40	204.40	366.75
Other foods*	0.50	-	-	-	-

Source: Tukker et al., 2009. Environmental impacts of diet changes in the EU,EUR 23783 EN, European Commission, Joint Research Center, Institute for Prospective Technological Studies. 2- FAO, 2007. Food balance sheet data for Iran 2007. 3. Authors' estimates.

Evaluating the effects of dietary changes on the economy requires a link between the FBS food groups and the IO categories. This correspondence for some food groups, which is presented in the Table 4, was established by a bridge matrix and was established for those IO categories related to foodstuffs. This matrix presents food items with respect to their shares in the IO tables associated to an FBS food group. Furthermore, it was made at the level of the main FBS food groups. For example, the IO items such as types of flour and other products, types of bread and other bakery products (including

bread cookies), wheat, rice and other cereals related to the FBS group cereals with a weight based on the status-quo consumption situation and according to the IO data. In other words, the weights of all IO categories that contribute to one FBS main category (e.g. cereals) amount to 1.

Also, Table 4 presents the integrated change for some food groups of the scenarios simulated and translates the composition of diets per scenario in IO items. The results indicate that the direct effects of dietary changes in the three scenarios described are similar in comparison with the status-quo. In all three scenarios, consumption of rice, wheat, other cereals, vegetables, fruit, flour, bread and macaroni decreases, and consumption of oilseeds, meat, milk and sugar increases. The reductions in rice consumption are 79.6, 79.6 and 53 billion Rials respectively in the WHO, WCRF and Mediterranean dietary scenarios. These figures found to be 12.3, 12.3 and 8.2 billion Rials for various types of flour and 18.9, 17.9 and 11.9 billion Rials for breads. Reduction in wheat consumption is low and about 0.2 billion Rials for scenarios WHO and WCRF and 0.1 billion Rials for Mediterranean scenario. The corresponding figures for vegetables and fruits are remarkable and fluctuate among the scenarios. Whilst the reduction in vegetables consumption varies from 507.8 billion Rials to 212.8 and 136 billion Rials, those of fruits are found to be 363.6, 171.8 and 50.2 billion Rials respectively in the WHO, WCRF and Mediterranean dietary scenarios

Increase in red meat (live animals and other animal products, red meat and meat products based on IO categories) consumption are 2855.5, 1312.3 and 559.2 billion Rials in the WHO, WCRF and Mediterranean dietary scenarios respectively. These figures are found to be 1616.8, 1616.8 and 1069.3 billion Rials for dairy products and137.8, 137.8 and 247.2 billion Rials for fish and seafood and 80, 80, and 127.9 billion Rials for chicken meat in the respective scenarios. The bridge matrix for corresponding between all FBS

1- Other foods include stimulants, spices, offal and miscellaneous. Since the main FBS food groups are considered, relative changes in these categories from status-quo to the scenarios mentioned are not calculated.

food categories and IO categories, as well as direct changes in food use relative to status-quo in all scenarios and linked to IO categories are presented in appendix B.1.

Table 4.

Direct changes in food use relative to status-quo in the three dietary scenarios and linked to IO categories

IO Categories	FBS items	Direct relative changes (Billion Rials)		
		Scenario 1 (ΔE_1)	Scenario 2 (ΔE_2)	Scenario 3 (ΔE_3)
Wheat	Cereals	-0.2	-0.2	-0.1
Rice	Cereals	-79.6	-79.6	-53.0
Other cereals	Cereals	-5.2	-5.2	-3.5
Vegetables; kitchen garden and other crops	Vegetables	-507.8	-212.8	-136.0
Fruit	Fruit	-363.6	-171.8	-50.2
Oilseeds	Oil crops	34.1	22.1	46.0
Live animals and other animal products	Red meat	893.4	410.6	163.7
Fish and other fishing products	Fish and seafood	137.8	137.8	247.2
Red meat and meat products	Red meat	1962.1	901.7	359.5
Chicken meat	Chicken meat	80.0	80.0	127.9
Animal and vegetable oils and fats	Vegetable oils/ Animals fat	95.6	133.0	166.7
Dairy products	Milk	1616.8	1616.8	1069.3
Types of flour and other products from milled grains	Cereals	-12.3	-12.3	-8.2
Types of bread and other bakery products (including bread cookies)	Cereals	-18.0	-17.9	-11.9
Sugar	Sugar and sweeteners	28.5	28.5	21.1

Source: Central bank of Iran, data available at www.fao.org and authors' estimates

Total output changes of some commodities and services (ΔQi) and corresponding changes in final demand (Ei) of each dietary scenario are presented in Table 5. The results show that total outputs of commodities such as wheat and other cereals increase, despite the direct reduction in their outputs. The reason, beyond this, is the use of these commodities in non-food cases, and also the increasing output in other subsectors (e.g. livestock). The total amount of wheat output increases in

Mediterranean, WCRF and WHO scenarios are 101.6, 144.6 and 163.8 billion Rials respectively. The total effect of dietary changes for commodities such as rice, vegetables, fruit, flour, bread and macaroni, is similar to their direct effect and their reduced output. Also, the outputs of commodities such as meat and dairy products increase as a result of dietary changes in their output. The increases in total output are found to be 493.4, 990.6 and 2053.1 billion Rials for meats (red and chicken) and 1074.4, 1624.3 and 1625.9 billion Rials for dairy products respectively in Mediterranean, WCRF and WHO scenarios.

The impact of dietary changes for non-food commodities and services is often increasing output, i.e. dietary changes cause the needs for these commodities to increase. For example, increasing the total output are 78.5, 52.7 and 37.4 billion Rials for oil products and 114.1, 80.7 and 71.3 billion Rials for nonmetallic products in the WHO, WCRF and Mediterranean dietary scenarios respectively. Also increasing in the outputs of services such as transportation, wholesale and retail services is remarkable. The increase in the total output of transportation services in the WHO, WCRF and Mediterranean dietary scenarios are 267.2, 210 and 147.3 billion Rials respectively. These figures are found to be 114.1, 80.7 and 71.3 billion Rials for wholesale and retail services. Total changes in output of all commodities and services in the WHO, WCRF and Mediterranean dietary scenarios are respectively 7010.1, 4802.8 and 3330.8

billion Rials. Generally, the greatest change occurs in the WHO scenario, and the smallest in the Mediterranean scenario. The changes in outputs of all commodities and services relative to status-quo are presented in appendix B.2.

Table 5.
The effects of dietary changes on some commodities and services output (Q) for IO categories

IO Categories	Total changes relative to status-quo (Billion Rials)		
	ΔQ_1	ΔQ_2	ΔQ_3
Wheat	163.8	144.6	101.6
Rice	-79.2	-79.5	-52.8
Other cereals	241.1	118.5	59.4
Vegetables; kitchen garden and other crops	-507.2	-210.1	-133.7
Fruit	-350.8	-160.0	-42.0
Red meat and meat products	1972.4	910.1	365.1
Chicken meat	80.7	80.6	128.3
Dairy products	1625.9	1624.3	1074.4
Types of flour and other products from milled grains	182.9	166.3	118.4
Types of bread and other bakery products (including bread cookies)	-17.7	-17.7	-11.7
Types of macaroni and other similar products from flour	-1.1	-1.1	-0.7
Oil products	78.5	52.7	37.4
Nonmetallic products	114.1	80.7	71.3
Wholesale and retail services	230.5	167.4	116.3
Transport services	267.2	210.0	147.3
Total output changes of all commodities and services	7010.1	4802.8	3330.8

Source: Calculated based on available at www.fao.org and Iran Input – Output data tables

The emission intensities of some commodities and services calculated based on the equation (4) are presented in Table (6). The findings show that the emission intensity in the transportation services,

Table 6.
Emission intensities (em_p) for some commodities and services

Title of commodities and services	em_p (ton per Million Rials)
Wheat	0.46
Rice	0.57
Live animals and other animal products	0.84
Fish and other fishing products	0.86
Crude petroleum and natural gas; Ores and mineral products	1.56
Meat and meat products	0.49
Animal and vegetable oils and fats	0.74
Dairy products	0.71
Oil products	1.55
Non metallic products	1.22
Electricity , gas and water	1.72
Construction	1.18
Transportation services	1.87

Source: 1. Iran' s second communication to UNFCCC, 2010/ Prepared by the Department of Environment, National Climate Change office with the cooperation of the United Nations Development Programme (UNDP).
2. Iran Input – Output data tables. 3. Energy balance for years 1999-2000.

crude petroleum and natural gas, ores and mineral products; electricity, gas and water; petroleum products and construction sectors is more than food, agriculture and services sectors

In the agricultural sector, the emission intensity in the livestock subsector is higher than that in the farming and gardening subsectors. For example, the emission intensities of commodities and services such as transportation services; electricity, gas and water; crude petroleum, natural gas, ores and mineral products; oil products; nonmetallic products and construction are 1.87, 1.72, 1.56, 1.55, 1.22 and 1.18 ton per million Rials respectively. In the agricultural sector, the emission intensities for live animals and other animal products, rice and wheat are 0.84, 0.57 and 0.46 ton per million Rials respectively. In the food industry sector the emission intensities for animal and vegetable oils and fats, dairy products and meat are 0.74, 0.71 and 0.49 ton per million Rials respectively. The emission intensities for all commodities and services calculated based on equation (4) are presented in appendix B.3.

Total changes in environmental load (ΔS_i) by specifying changes in the commodity's output (ΔQ_i) related to the final demand of each dietary scenario (E_i) have been calculated based on equation (5) and are shown in Table (7). The results show that the WHO and Mediterranean diets have, respectively, the highest (3.2) and the lowest (1.6) environmental load. This means that a shift from the current diet to alternative diets increase the environmental pressure. The reason is that, in the alternative scenarios, mainly the share of meat and dairy products consumption increased in comparison with the current diet.

Table 7.
Total changes in environmental load of alternative dietary scenarios

	WHO (ΔS_1)	WCRF (ΔS_2)	Mediterranean (ΔS_3)
Total changes in environmental load (ΔS)	3.20	2.2	1.60

Source: calculations of research

4 Conclusions

In recent decades dietary changes have taken place in Iran, where people are shifting towards a higher consumption of animal products (FAO, food balance sheets, 1961-2007; Gerbens-Leenes et al., 2010; Ghassemi et al., 2002). If the status-quo dietary pattern shifts towards WHO, WCRF and Mediterranean dietary patterns, relatively large changes are expected in the status-quo food items. Changes in dietary patterns cause other changes in commodities and services output as well as in environmental load. In this study, simple and environmentally extended input – output commodity by commodity models were used to analyze the economic and environmental impacts of dietary changes in Iran.

Our findings showed that a shift from the current diet to alternative diets increases both the economic output and the environmental pressure. The reason for the increasing environmental pressure is that mainly the share of meat and dairy products increases in the alternative scenarios. The direction of changes is similar in the three alternative dietary scenarios. The greatest and smallest impacts occur in the WHO and Mediterranean scenarios respectively. Total changes in output in WHO, WCRF and Mediterranean dietary scenarios are 7010.10, 4802.8 and 3330.8 billion Rials respectively. While the outputs of rice, vegetables, fruit, types of bread and macaroni decrease, those of live and other animal products (dairy products, types of meat) increase. In non-food commodities and services, the outputs of all categories increase. Total changes in environmental load in WHO, WCRF and Mediterranean dietary scenarios are 3.2, 2.2 and 1.8 million ton CO2 equivalent respectively. So, although dietary changes can have positive effects on economic output, it has negative environmental impact.

Compared to the Mediterranean dietary pattern, shifting Iranian dietary patterns towards WHO and WCRF has a greater positive effect on economic output and also more negative impact on the environment. Therefore, in selecting an optimal diet, capabilities particularly natural resources should be used in such a way so that we could have more economic output with less negative environmental impact. Considering the fact that the use of natural resources in Iran, as in many other developing countries is a large, planning for acquiring the Mediterranean dietary pattern seems to be a suitable selection for the Iranian economy in the current conditions.

Considering that some species of plants in Iran have a high potential for carbon sequestration and CO2 reduction in the atmosphere (Mesbah, 2009), improving forest covering and green space simultaneously with increasing economic activities should be considered by policy makers and planner.

Emissions intensity for various commodities and services has a wide diversity. Therefore, in order to increase economic activities for producing food commodities and services, the policy makers should utilize instruments such as taxes and insurance for acquiring an optimal healthy and environmentally diet. For non-food commodities and services, these instruments should be implemented for encouraging investment in controlling and reducing greenhouse gas emissions.

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Appendix A: Explanations of commodity by commodity approach in input – output models

From the data in the Make matrix (V), the total output of any industry (x_i) is found by summing over all commodities produced by that industry based on producer prices. These totals are the row sums of V, or in the matrix form:

$$X=VI \quad (1)$$

Similarly, total output of any commodity (q_j) can be found by summing over all industries that produce the commodity. These totals are the column sums of V, or in the matrix form:

$$Q = (V') I \quad (2)$$

Alternatively, from the Use matrix in Table 1,

$$Q = UI+E \quad (3)$$

In the original input-output, the model combining equations 1 and 2 gives:

$$X = AX+F \quad (4)$$

and the operational form of the model becomes

$$X= (I-A)^{-1}F = LF \quad (5)$$

The driving force is the exogenous vector of final demand for industry outputs. In conjunction with the Leontief inverse (total requirements) matrix, $(I-A)^{-1}$, the industry outputs necessary to sustain the final demand could be determined.

The commodity–industry approach uses equations, $B = U\hat{X}^{-1}$ and $Q=UI+E$. Substituting equation, $B = U\hat{X}^{-1}$, into equation, Q = UI+E, gives

$$Q = BX+E \quad (6)$$

Since equation 6 contains commodity outputs (Q) and industry output (X), one cannot generate the total requirements matrix as equation 5 (Miller and Blair, 2009).

One solution for this problem is to use the data in the Make matrix and find an expression to transform industry outputs, X, to commodity outputs, Q, or alternatively, to transform commodity outputs (and commodity final demand, E) to industry terms.

Define $d_{ij}= v_{ij}/q_j$, so that d_{ij} denotes the fraction of total commodity j output that was produced by industry *i*. Forming a matrix of these commodity output proportions, $D_{n\times m} = [d_{ij}]$, we have

$$D = V\hat{Q}^{-1} \quad (7)$$

and defining $c_{ij} = v_{ij}/x_i$, so that c_{ij} denotes the fraction of total industry i output that is in the form of commodity j. Defining V′ as the supply matrix with commodity by industry dimensions, the matrix of these industries is found as:

$$C = V'\hat{X}^{-1} \quad (8)$$

The results in equations 7 and 8, in conjunction with equations 1 and 2, provide two alternative linear transformations between commodity and industry outputs. Using equation 7,

$$D = V\hat{Q}^{-1} \Longrightarrow D\hat{Q} = V \Longrightarrow D\hat{Q}I = VI$$

and from equation 1:

$$DQ = X \Longrightarrow Q = D^{-1}X \quad \text{or} \quad X-DQ = 0 \quad (9)$$

From equations 6 and 9 two matrix equations in X and Q; and in portioned matrix form can be presented as:

$$\begin{bmatrix} I & -D \\ -B & I \end{bmatrix} \begin{bmatrix} X \\ Q \end{bmatrix} = \begin{bmatrix} 0 \\ E \end{bmatrix} \quad (10)$$

Solving equation 10, for the commodities output gives the commodities by commodities requirement matrix (the central block in commodity by commodity input- output model). Using D, one solution to the presence of both X and Q in equation 6 is provided by equation 9. By substituting DQ for X in equation 6, we have

$$Q = B\,(DQ) + E = (BD)\,Q + E$$

from which

$$Q = (I-BD)^{-1}E \Longrightarrow Q = (I-A_{c\times c})^{-1}E \qquad (11)$$

The inverse on the right-hand side, which is called a commodity by commodity total requirements matrix, connects commodity final demand to commodity output. This total requirement matrix has the same structure as the Leontief inverse in the original input-output model (Miller and Blair, 2009). Now we are able to predict change in a commodity's output (ΔQ_i) by specifying changes in final demand (ΔE_i) related to each dietary scenario. Formally, the predictive form is given as follows:

$$\Delta Q_i = (I - A_{c\times c})^{-1} \Delta E_i \qquad i = 1,2,3 \qquad (12)$$

Appendix B.1: Bridge matrix for corresponding between all FBS food categories and IO categories (Columns 1 and 2), and direct changes in food use relative to status-quo

IO Categories	FBS items	Direct relative changes (Billion Rials)		
		Scenario 1 (ΔE_1)	Scenario 2 (ΔE_2)	Scenario 3 (ΔE_3)
Wheat	Cereals	-0.2	-0.2	-0.1
Rice	Cereals	-79.6	-79.6	-53.0
Other cereals	Cereals	-5.2	-5.2	-3.5
Vegetables; kitchen garden and other crops	Vegetables	-52.0	-212.8	-136.0
Fruit	Fruit	-363.6	-171.8	-50.2
Oilseeds	Oil crops	34.1	22.1	46.0
Beverages and spices products	Beverages	-	-	-
Live animals and other animal products	Red meat	893.4	410.6	163.7
Fish and other fishing products	Fish and seafood	137.8	137.8	247.2
Red meat and meat products	Red meat	1962.1	901.7	359.5
Chicken meat	Chicken meat	80.0	80.0	127.9
Fish and seafood products from Aquatics	Fish / seafood	15.0	15.0	26.9
Prepared and preserved vegetables	Vegetables	0.0	-0.2	-0.1
Fruit and vegetable juices	Fruit/ Vegetables	-0.8	-0.9	-0.5
Prepared and preserved fruits	Fruit	0.0	0.0	0.0
Animal and vegetable oils and fats	Vegetable oils/ Animals fat	95.6	133.0	166.7
Dairy products	Milk	1616.8	1616.8	1069.3
Types of flour and other products from milled grains	Cereals	-12.3	-12.3	-8.2
Types of starch and starchy products	Starchy Roots	1.4	1.4	2.3
Types of bread and other bakery products (including bread cookies)	Cereals	-18.0	-17.9	-11.9
Sugar	Sugar and sweeteners	28.5	28.5	21.1
Cocoa, chocolate and sweets	Sugar and sweeteners	6.9	6.9	5.1
Types of macaroni and other similar products from flour	Cereals	-1.1	-1.1	-0.7
Other food products	-	-	-	-

Source: Central bank of Iran, data available at www.fao.org and authors' estimates

Appendix B.2: Effects of dietary changes on commodities and services output (Q) for IO categories

IO Categories	Total changes relative to status-quo (Billion Rials)		
	ΔQ 1	*ΔQ 2*	*ΔQ 3*
Wheat	163.8	144.6	101.6
Rice	-79.2	-79.5	-52.8
Other cereals	241.1	118.5	59.4
Vegetables; kitchen garden and other crops	-48.4	-210.1	-133.7
Fruit	-350.8	-160.0	-42.0
Oilseeds	67.2	52.3	67.3
Living plants, cut flowers and flower buds; flower seeds and fruit seeds, vegetable seeds	170.2	84.8	44.6
Beverages and spice products	7.5	6.8	4.8
Tobacco, not processed	0.0	0.0	0.0
Sugar beet and sugarcane	37.3	34.1	23.9
Live animals and other animal products	1056.3	524.6	235.6
Forestry	3.6	3.0	3.3
Fish and other fish products	159.0	158.1	273.2
Crude petroleum and natural gas; Ores and mineral products	32.8	23.4	18.0
Red meat and meat products	1972.4	910.1	365.1
Chicken meat	80.7	80.6	128.3
Fish and seafood products from Aquatics	38.6	26.9	32.9
Prepared and preserved vegetables	0.0	-0.1	-0.1
Fruit and vegetable juices	2.7	2.3	1.8
Prepared and preserved fruits	0.4	0.3	0.2
Animal and vegetable oils and fats	224.3	250.5	249.3
Dairy products	1625.9	1624.3	1074.4
Types of flour and other products from milled grains	182.9	166.3	118.4
Types of starch and starchy products	2.3	2.2	2.9
Animal and poultry feeds	139.9	69.3	34.6
Types of bread and other bakery products (including bread cookies)	-17.7	-17.7	-11.7
Sugar	89.4	75.2	51.6
Cocoa, chocolate and sweets	8.1	8.0	5.9
Types of macaroni and other similar products from flour	-1.1	-1.1	-0.7
Other food products	5.0	4.7	4.9
Types of beverages	0.4	0.3	0.2
Types of cigarettes and other tobacco products	0.1	0.1	0.1
Textiles, clothing and leather products	26.0	23.2	24.0
Wood and paper products	45.4	39.5	28.9
Oil products	78.5	52.7	37.4
non metallic products	114.1	80.7	71.3
Metallic products	49.9	43.9	35.8
Machinery and equipment	47.2	40.2	31.8
Electricity , gas and water	51.4	29.2	25.4
Construction	24.1	19.4	13.0
Wholesale and retail services	230.5	167.4	116.3
Transport services	267.2	210.0	147.3
financial and other business services	209.8	154.7	108.4
other services	51.5	39.1	29.8
Total output changes	7010.1	4802.8	3330.8

Source: Calculated based on available at www.fao.org and Iran Input – Output data tables

Appendix B.3: Emission intensities (em_p) for all commodities and services categories

	Title of commodities and services	emp (ton per Million Rials)
1	Wheat	0.46
2	Rice	0.57
3	Other cereals	0.46
4	Vegetables, kitchen garden and other crops	0.46
5	Fruit	0.46
6	Oilseeds	0.46
7	Live plants, branches and flower buds; seed of flowers, fruits and vegetables; and other raw plant materials	0.46
8	Beverages and spice products	0.48
9	Tobacco, not processed	0.46
10	Sugar beet and sugarcane	0.48
11	Live animals and other animal products	0.84
12	Forestry	0.67
13	Fish and other fishing products	0.86
14	Crude petroleum and natural gas; Ores and mineral products	1.56
15	Red meat and meat products	0.49
16	Chicken meat	0.49
17	Fish and seafood products from Aquatics	0.49
18	Prepared and preserved vegetables	0.49
19	Fruit and vegetable juices	0.49
20	Prepared and preserved fruits	0.49
21	Animal and vegetable oils and fats	0.74
22	Dairy products	0.71
23	Types of flour and other products from milled grains	0.3
24	Types of starch and starchy products	0.35
25	Animal and poultry feeds	0.32
26	Types of bread and other bakery products (including bread cookies)	0.32
27	Sugar	0.39
28	Cocoa, chocolate and sweets	0.53
29	Types of macaroni and other similar products from flour	0.39
30	Other food products	0.39
31	Types of beverages	0.39
32	Types of cigarettes and other tobacco products	0.38
33	Textiles, clothing and leather products	0.38
34	Wood and paper products	0.33
35	Oil products	1.55
36	Non metallic products	1.22
37	Metallic products	1.1
38	Machinery and equipment	1.05
39	Electricity , gas and water	1.72
40	Construction	1.18
41	Wholesale and retail services; repair	0.63
42	Transportation services	1.87
43	Financial and other business services	0.63
44	Other services	0.63

Source: 1. Iran' s second communication to UNFCCC, 2010/ Prepared by the Department of Environment, National Climate Change office with the cooperation of the United Nations Development Programme (UNDP). 2. Iran Input – Output data tables. 3. Energy balance for years 1999-2000.