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Food transition in the Gulf Cooperation Council Region

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This study investigates (and forecasts) food consumption patterns in the Gulf Cooperation Council (GCC) region from 1961 to 2023. A vector auto-regressive model (VAR) was used to estimate systems of equations of per capita food consumption of major food items, and their trends over time, for the purpose of highlighting changes in the region's dietary patterns. The study area had shown symptoms of diet transition marked by a shift toward consuming more sugar and animal products, and fewer vegetables and cereals. These changes have been accompanied by substantial food waste and an increase in diet-related diseases. The region needs to develop policy programs that combine government action, research, education, and mass media communication programs to raise public awareness about the benefits of diet and exercise, and to promote more healthful eating patterns.

Key words: Diet transition, food consumption, waste, Gulf Cooperation Council (GCC).

INTRODUCTION

Eating patterns worldwide have witnessed a gradual process of "westernization" and evolution, a phenomenon called "food transition." Diets across countries are converging toward one characterized by a greater proportion of added sugar, fats, and animal products, and a lesser proportion of cereals and vegetables. The food chain is becoming increasingly complex with food products that are more processed, sophisticated, and ready-to-eat. A serious related problem is that of food loss and waste.

The Food and Agriculture Organization of the United Nations (FAO, 2012) has argued that food loss represents a significant cost to the world economy, and greatly jeopardizes global food security. Food loss contributes to food price escalation because it decreases market supply. In addition, it results in environmental degradation, as scarce resources are used to produce, process, handle, transport, and dispose wasted food. Thus, decreasing food loss and waste is an important element in mitigating hunger, raising income, and improving food security.

This study investigates (and forecasts) food consumption patterns in the Gulf Cooperation Council region (GCC) for the period 1961 to 2023. Food loss and waste, and diet-related health problems will also be discussed as associated phenomena. The study's main objective is to shed light on changes in diet patterns to induce policy changes to enhance food security and

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human health in the region. A secondary objective is to determine the degree of shortage of data and information regarding a number of variables on this topic; if these gaps were filled, it could facilitate the design and implementation of policies to enhance food systems' sustainability.

This study relies on the concept of "food transition" (also called "nutrition transition"), introduced by Popkin (1993) and Guyomard et al. (2012). Food transition is an overall change in food consumption patterns consisting of two main characteristics: The first is a rise in calorie intake, with proportionally equal increases in all food products. Once caloric saturation is achieved, the second step, called "diet transition," occurs, in which cereal and vegetable consumption decreases, and consumption of sugar, fats, and animal products increases. Developed countries achieved the second step of "food transition" within a century. Most other countries are now following a similar pattern but at a considerably accelerated rate. The duration of food transition has reduced to 20 years in emerging countries and 40 years in developing countries.

METHODOLOGY

This study used the vector Auto-Regressive (VAR) model to estimate systems of equations of per capita consumption of major food items and their trends over time. Linear and quadratic forms were used. Hannan-Quinn (HQIC), Akaike (AIC and AICC), and Schwarz's Bayesian (SBIC) information criteria were determined, and their minimum values were used to indicate the optimum model. Appendix 1 provides the theoretical model, and a summary of estimation results of the system equations. The estimated equations were used to forecast the per capita consumption of each variable for the period 2014 to 2023.

The study used time series data of per capita food consumption of major food items, food loss and waste at distribution and consumption stages, and health indicators related to food intake. FAO (2018) data have been used. Weighted averages have been calculated for the GCC region, weighted according to each country's proportion of the total population. Other sources of data and information used in the study are specified at appropriate places throughout.

Data limitations

The GCC region lacks time series data regarding food consumption and food waste. The FAO statistics database is the only source of data available. Moreover, most of the required food consumption data are not available for Bahrain, Oman, and Qatar in the FAO database. However, the total population of the other GCC countries included in the study accounted for 86% of the region's total population (GCC, 2014). Thus, it is reasonable to generalize this study's results to the entire region.

RESULTS AND DISCUSSION

This section discusses food consumption patterns, food waste, and diet-related health problems prevailing in the GCC states.

Food consumption in the GCC region

Since 1961, the GCC region has experienced a steady increase in food supply and consumption. The huge oil revenues that have been earned since the mid-20th century have enabled the region to maintain high levels of food imports. Per capita food consumption of the different food items will be discussed in detail, as follows.

Consumption of animal products

This group of items has been divided into two sub-groups. This is because one of the VAR model's underlying assumptions is that the number of parameters should not exceed the number of observations.

Group 1: Beef, mutton, poultry, fish and seafood

Table 1 in Appendix 1 provides estimates of the coefficients of current per capita consumption of beef (Y_{1t}), mutton (Y_{2t}), poultry (Y_{3t}), and fish and seafood (Y_{4t}), plus their standard errors, t statistics, and $p\,values$ (all the roots of $|\Phi(L)|=0$). The estimated system of equations (1) is provided below:

$$\underbrace{\begin{bmatrix} Y_{1t} \\ Y_{2t} \\ Y_{3t} \\ Y_{4t} \end{bmatrix}}_{\hat{\mathbf{Y}}_t} = \underbrace{\begin{bmatrix} -1.198 & 0.083 & -0.002 \\ 0.419 & 0.089 & -0.002 \\ -12.688 & 0.375 & 0.000 \\ 1.238 & -0.009 & 0.001 \end{bmatrix} \begin{bmatrix} 1 \\ t \\ t^2 \end{bmatrix}}_{\hat{\psi}\mathbf{Z}_t} + \underbrace{\begin{bmatrix} 0.516 & -0.025 & 0.014 & 0.475 \\ 0.003 & 0.771 & -0.021 & 0.166 \\ -0.435 & 1.604 & 0.439 & 0.786 \\ 0.111 & -0.043 & 0.005 & 0.754 \end{bmatrix} \begin{bmatrix} Y_{1t-1} \\ Y_{2t-1} \\ Y_{3t-1} \\ Y_{4t-1} \end{bmatrix}}_{\hat{\Phi}\mathbf{Y}_{t-1}}, \quad t = 2,3,4,\ldots,54 \qquad (1)$$

The eigenvalues of matrix $\hat{\Phi}(L)$ are $\lambda=(0.886\ 0.601\ 0.601\ 0.404)$. All eigenvalues are less than one, which means that all the roots of $|\hat{\Phi}(L)|=0$ fall outside the unit circle. When considering that the data have a quadratic trend, the time series of per capita consumption of these food items are thus stationary. By comparing the $p\,value$ $(pr>|T^*|)$ with a 0.05 significance level, the independent variables have significant effects on the dependent variables, as follows:

The first equation represents current per capita beef consumption. The quadratic trend term (t^2) has a significant negative effect on current beef consumption, whereas per capita consumption of beef and fish lagged

Table 1. Estimation results of beef, mutton, poultry, fish, and seafood consumption in the GCC region.

Equation	Coefficients	$\hat{\beta}$	$S.E_{\hat{\beta}}$	t	$(pr>\|T^*\|)$	Ind.Var.
	$\beta_{10}=\psi_{10}$	-1.198	1.369	-0.880	0.3861	1
	$\beta_{11}=\psi_{11}$	0.083	0.059	1.410	0.1662	t
	$\beta_{12}=\psi_{12}$	-0.002	0.001	-2.360	0.0228	t^2
Y_{1t} Beef	$\beta_{13}=\phi_{11}$	0.516	0.137	3.760	0.0005	Y_{1t-1}
	$\beta_{14}=\phi_{12}$	-0.025	0.198	-0.130	0.8998	Y_{2t-1}
	$\beta_{15}=\phi_{13}$	0.014	0.048	0.290	0.7721	Y_{3t-1}
	$\beta_{16}=\phi_{14}$	0.475	0.156	3.050	0.0038	Y_{4t-1}
	$\beta_{20}=\psi_{20}$	0.419	0.808	0.520	0.6069	1
	$\beta_{21}=\psi_{21}$	0.089	0.035	2.550	0.0141	t
	$\beta_{22}=\psi_{22}$	-0.002	0.001	-2.810	0.0074	t^2
Y_{2t} Mutton	$\beta_{23}=\phi_{21}$	0.003	0.081	0.040	0.9678	Y_{1t-1}
	$\beta_{24}=\phi_{22}$	0.771	0.117	6.600	0.0001	Y_{2t-1}
	$\beta_{25}=\phi_{23}$	-0.021	0.029	-0.730	0.4706	Y_{3t-1}
	$\beta_{26}=\phi_{24}$	0.166	0.092	1.810	0.0775	Y_{4t-1}
	$\beta_{30}=\psi_{30}$	-12.688	3.483	-3.640	0.0007	1
	$\beta_{31}=\psi_{31}$	0.375	0.150	2.500	0.0161	t
	$\beta_{32}=\psi_{32}$	0.000	0.003	0.130	0.8967	t^2
Y_{3t} Poultry	$\beta_{33}=\phi_{31}$	-0.435	0.349	-1.240	0.2196	Y_{1t-1}
	$\beta_{34}=\phi_{32}$	1.604	0.504	3.180	0.0026	Y_{2t-1}
	$\beta_{35}=\phi_{33}$	0.439	0.123	3.570	0.0009	Y_{3t-1}
	$\beta_{36}=\phi_{34}$	0.786	0.396	1.980	0.0534	Y_{4t-1}
	$\beta_{40}=\psi_{40}$	1.238	1.207	1.030	0.3106	1
	$\beta_{41}=\psi_{41}$	-0.009	0.052	-0.180	0.8617	t
	$\beta_{42}=\psi_{42}$	0.001	0.001	0.850	0.3972	t^2
Y_{4t} Fish and seafood	$\beta_{43}=\phi_{41}$	0.111	0.121	0.910	0.3654	Y_{1t-1}
	$\beta_{44}=\phi_{42}$	-0.043	0.175	-0.250	0.8070	Y_{2t-1}
	$\beta_{45}=\phi_{43}$	0.005	0.043	0.120	0.9057	Y_{3t-1}
	$\beta_{46}=\phi_{44}$	0.754	0.137	5.480	0.0001	Y_{4t-1}

one period $(Y_{1,t-1}, Y_{4,t-1})$ has a significant positive effect on it. Per capita consumption of beef has increased considerably in the study period.

The second equation represents current per capita mutton consumption. The trend (t), and per capita consumption of both mutton and fish lagged one period $(Y_{2,t-1}, Y_{4,t-1})$ have significant positive effects on the current consumption of mutton, whereas the quadratic trend term (t^2) has a negative effect on it. Per capita consumption of mutton meat has increased considerably in the study period.

The third equation represents current per capita poultry

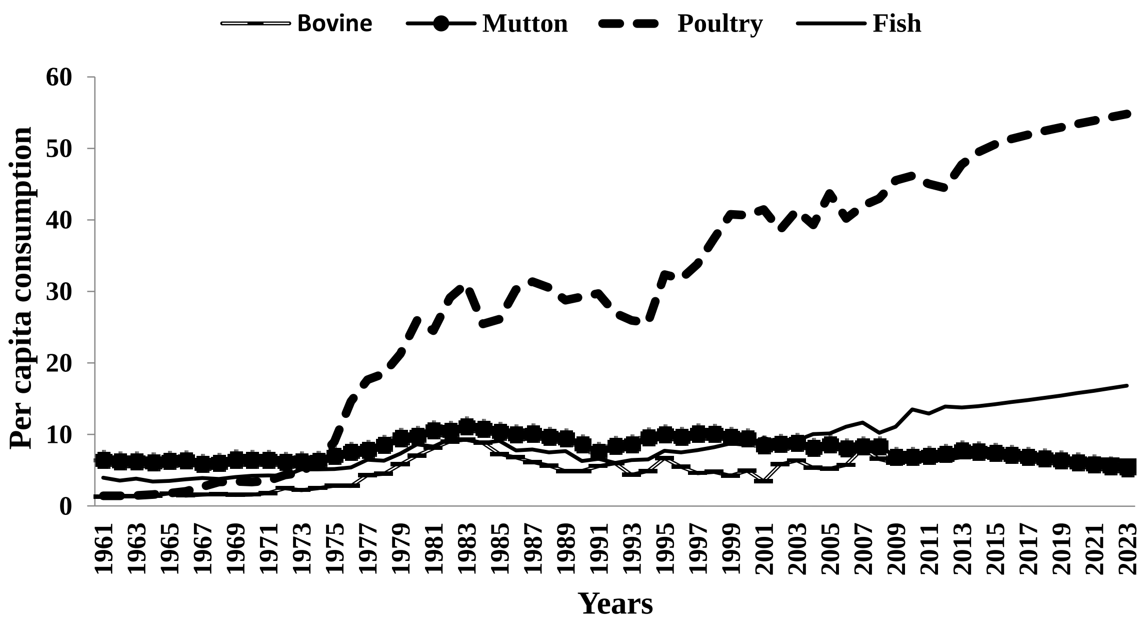

Figure 1. Real and predicted per capita consumption of beef, mutton, poultry, fish, and seafood in the GCC region from 1961 to 2023 (kg/capita/year).
Data source: Food and Agriculture Organization,[1b] and the predicted values: estimated model.

consumption. The constant term has a negative effect on current poultry consumption, whereas the linear trend (t) and per capita consumption of mutton, poultry, and fish lagged one period $(Y_{2,t-1}, Y_{3,t-1}, Y_{4,t-1})$ have significant positive effect on it. Per capita poultry consumption is dramatically increasing over time. From an average of 6.3 kg from 1961 to 1964, it has increased to 45.8 kg from 2009 to 2013. It is expected to reach 54.9 kg in 2023.

The fourth equation represents current per capita consumption of fish and seafood. Per capita fish consumption lagged one period $(Y_{4,t-1})$ has significant positive effect on the current consumption of fish and seafood, whereas the trend did not show a significant effect on it. Per capita consumption of fish and seafood has increased considerably during the study period, and is expected to continue increasing over time. The estimated model (1) is used for predicting the per capita consumption of this group of food items from 2014 to 2023. The predicted, as well as real per capita consumption, of these food items have been plotted in Figure 1.

Group 2: Meat, butter, eggs, and milk

Table 2 in Appendix 1 provides the maximum likelihood estimates of system equations of current per capita food consumption of meat (Y_{1t}), butter (Y_{2t}), eggs (Y_{3t}), and milk (Y_{4t}); the standard errors of these estimates; and t statistics. Per capita meat consumption is the summation of per capita consumption of beef, mutton, poultry, and fish. The estimated system of equations (2) is provided below:

$$\underbrace{\begin{bmatrix} Y_{1t} \\ Y_{2t} \\ Y_{3t} \\ Y_{4t} \end{bmatrix}}_{\mathbf{Y}_t} = \underbrace{\begin{bmatrix} 0.052 & 0.358 \\ 0.286 & 0.003 \\ 0.026 & 0.013 \\ 14.020 & -0.364 \end{bmatrix} \begin{bmatrix} 1 \\ t \end{bmatrix}}_{\boldsymbol{\psi}\mathbf{Z}_t} + \underbrace{\begin{bmatrix} 0.630 & 1.424 & 0.783 & 0.024 \\ -0.009 & 0.342 & -0.004 & 0.013 \\ -0.013 & 0.402 & 0.888 & 0.003 \\ 0.419 & 10.574 & 3.868 & 0.326 \end{bmatrix} \begin{bmatrix} Y_{1t-1} \\ Y_{2t-1} \\ Y_{3t-1} \\ Y_{4t-1} \end{bmatrix}}_{\Phi\Delta\mathbf{Y}_{t-1}}, \quad t = 2,3,4,\ldots,54 \qquad (2)$$

The eigenvalues of matrix $\hat{\Phi}(L)$ are $\lambda = (0.9463,\ 0.6952,\ 0.5394,\ 0.0053)$. All eigenvalues are less than one, which mean that all the roots of $|\hat{\Phi}(L)| = 0$ fall outside the unit circle, and that the time series data of per capita consumption of these items are stationary with linear trends. By comparing $p\ value\ (pr > |T^*|)$ with a 0.05 significance level, the independent variables have shown significant effects on the dependent variables, as follows:

The first equation represents the per capita consumption of meat. The linear trend and meat per capita consumption lagged one period $(Y_{1,t-1})$ has shown a significant positive effect on current meat consumption.

Table 2. Estimates of system equations of current per capita consumption of meat, butter, eggs, and milk in the GCC region.

Equation	**Coefficients**	$\hat{\beta}$	$S.E_{\hat{\beta}}$	t	$(pr>\|T^*\|)$	**Ind. Var.**
	$\beta_{10}=\psi_{10}$	0.052	1.716	0.030	0.976	1
	$\beta_{11}=\psi_{11}$	0.358	0.119	3.020	0.004	t
Y_{1t}	$\beta_{12}=\phi_{11}$	0.630	0.119	5.290	0.000	Y_{1t-1}
Meat	$\beta_{13}=\phi_{12}$	1.424	1.694	0.840	0.405	Y_{2t-1}
	$\beta_{14}=\phi_{13}$	0.783	0.510	1.530	0.132	Y_{3t-1}
	$\beta_{15}=\phi_{14}$	0.024	0.055	0.440	0.659	Y_{4t-1}
	$\beta_{20}=\psi_{20}$	0.286	0.155	1.840	0.072	1
	$\beta_{21}=\psi_{21}$	0.003	0.011	0.310	0.755	t
Y_{2t}	$\beta_{22}=\phi_{21}$	-0.009	0.011	-0.790	0.431	Y_{1t-1}
Butter	$\beta_{23}=\phi_{22}$	0.342	0.154	2.230	0.031	Y_{2t-1}
	$\beta_{24}=\phi_{23}$	-0.004	0.046	-0.100	0.924	Y_{3t-1}
	$\beta_{25}=\phi_{24}$	0.013	0.005	2.530	0.015	Y_{4t-1}
	$\beta_{30}=\psi_{30}$	0.026	0.294	0.090	0.929	1
	$\beta_{31}=\psi_{31}$	0.013	0.020	0.640	0.528	t
Y_{3t}	$\beta_{32}=\phi_{31}$	-0.013	0.020	-0.630	0.530	Y_{1t-1}
Eggs	$\beta_{33}=\phi_{32}$	0.402	0.290	1.390	0.172	Y_{2t-1}
	$\beta_{34}=\phi_{33}$	0.888	0.087	10.180	0.000	Y_{3t-1}
	$\beta_{35}=\phi_{34}$	0.003	0.009	0.330	0.745	Y_{4t-1}
	$\beta_{40}=\psi_{40}$	14.020	4.664	3.010	0.004	1
	$\beta_{41}=\psi_{41}$	-0.364	0.322	-1.130	0.265	t
Y_{4t}	$\beta_{42}=\phi_{41}$	0.419	0.324	1.290	0.202	Y_{1t-1}
Milk	$\beta_{43}=\phi_{42}$	10.574	4.605	2.300	0.026	Y_{2t-1}
	$\beta_{44}=\phi_{43}$	3.868	1.386	2.790	0.008	Y_{3t-1}
	$\beta_{45}=\phi_{44}$	0.326	0.149	2.190	0.034	Y_{4t-1}

Per capita meat consumption is increasing significantly over time.

The second equation represents the per capita consumption of butter. The constant, per consumption lagged one period $(Y_{2,t-1})$, and consumption of milk lagged one period, $(Y_{4,t-1})$ have significant positive effects on current butter consumption, whereas the trend has no significant effect on it. The per capita butter consumption is stable over time.

The third equation represents the per capita egg consumption. Only the lagged one period consumption $(Y_{3,t-1})$ has a significant positive effect on its current per capita consumption, whereas the trend has no significant effect on it. Consumption of eggs per capita is stable over time. The last equation represents the per capita consumption of milk. The constant, per capita consumption of butter lagged one period $(Y_{2,t-1})$, per capita egg consumption lagged one period $(Y_{3,t-1})$, and per capita milk consumption lagged one period $(Y_{4,t-1})$, have significant positive effects on the current per capita consumption of milk. The trend has no significant effect on the current milk consumption, which means that milk consumption is stable over time.

The estimated model (2) has been used to predict per capita consumption of meat, butter, eggs, and milk from 2014 to 2023. The predicted, as well as real per capita consumption of these food items, have been plotted in Figure 2.

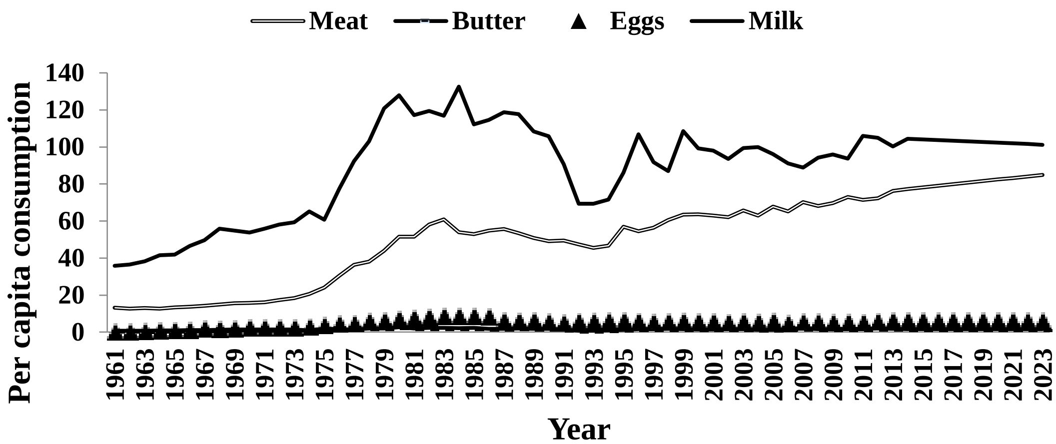

Figure 2. Real and predicted per capita consumption of meat, butter, eggs, and milk in the GCC region from 1961 to 2023 (kg/capita/year)
Data source: Food and Agriculture Organization,[(1b)] and their predicted values: estimated model.

In conclusion, the per capita consumptions of meat, poultry, fish, and seafood all show upward trends. Per capita consumption of poultry has the highest increase over this period. Seafood consumption has also shown an upward trend. The aggregate per capita consumption of all kinds of meat has shown a dramatic increase. From an average of 13.1 kg during 1961 to 1965, it has increased to 59.9 kg from 2005 to 2009, a 357.3% increase. It is expected to continue increasing over time and reach 85 kg by the year 2023. This may represent a symptom of diet transition in the GCC region.

Consumption of food cereals and pulses

This group includes current per capita consumption of cereals (Y_{1t}), pulses (Y_{2t}), rice (Y_{3t}), and wheat (Y_{4t}). Table 3, Appendix 1, provides the estimated system of equations, their standard errors, statistics t, the corresponding $p values$ and all the roots of $|\Phi(L)|=0$. The estimated model (3) is shown below:

$$\underbrace{\begin{bmatrix}\hat{Y}_{1t}\\ \hat{Y}_{2t}\\ \hat{Y}_{3t}\\ \hat{Y}_{4t}\end{bmatrix}}_{\hat{\mathbf{Y}}_t}=\underbrace{\begin{bmatrix}33.01 & 0.717 & -0.004\\ 2.928 & -0.065 & 0.002\\ 9.635 & -0.296 & 0.008\\ 28.771 & 1.401 & -0.017\end{bmatrix}\begin{bmatrix}1\\ t\\ t^2\end{bmatrix}}_{\hat{\psi}\mathbf{Z}_t}+\underbrace{\begin{bmatrix}0.828 & -1.242 & -0.106 & -0.183\\ -0.02 & 0.558 & 0.032 & 0.008\\ -0.046 & -1.254 & 0.901 & 0.082\\ -0.052 & 0.597 & -0.195 & 0.519\end{bmatrix}\begin{bmatrix}\hat{Y}_{1t-1}\\ \hat{Y}_{2t-1}\\ \hat{Y}_{3t-1}\\ \hat{Y}_{4t-1}\end{bmatrix}}_{\hat{\Phi}\Delta\hat{\mathbf{Y}}_{t-1}} \quad t=2,3,4,\ldots,54 \tag{3}$$

The eigenvalues of matrix $\hat{\Phi}(L)$ are $\lambda=(0.9304, 0.6944, 0.6944, 0.4947)$. All eigenvalues are less than one, meaning that all the roots of $|\hat{\Phi}(L)|=0$ fall outside the unit circle. When considering that the data have a quadratic trend, the time series of per capita consumption of all food items are thus stationary. By comparing the $p\ value$ $(pr>|T^*|)$ with a 0.05 significance level, the independent variables have shown significance effects on the dependent variables, as follows:

The first equation represents per capita consumption of cereals. The constant, linear trend (t) and consumption of cereals lagged one period $(Y_{1,t-1})$ have significant positive effects on cereal current consumption.

The second equation represents the per capita consumption of pulses (including beans, lentils, and peas). The constant, quadratic trend, consumption of pulses lagged one period $(Y_{2,t-1})$, and consumption of rice lagged one period $(Y_{3,t-1})$, have significant positive effects on the current consumption of pulses, whereas the linear trend and consumption of cereals lagged one period $(Y_{1,t-1})$ have significant negative effects on it.

The third equation represents the per capita consumption of rice. The quadratic trend, consumption of rice lagged one period $(Y_{3,t-1})$ and consumption of wheat lagged one period $(Y_{4,t-1})$ have significant positive effects on current consumption of rice (Y_{3t}), whereas the linear trend (t) and consumption of pulses lagged one period $(Y_{2,t-1})$ have significant negative effects on it. The last equation represents the current per capita

Table 3. Estimates of system equations of current per capita consumption of cereals, pulse, rice, and wheat in the GCC region.

Equation	Coefficients	$\hat{\beta}$	$S.E_{\hat{\beta}}$	t	$(pr>\|T^*\|)$	Ind.Var.
Y_{1t} Cereals	$\beta_{10}=\psi_{10}$	33.008	15.439	2.140	0.038	1
	$\beta_{11}=\psi_{11}$	0.717	0.406	1.770	0.084	t
	$\beta_{12}=\psi_{12}$	-0.004	0.008	-0.530	0.600	t^2
	$\beta_{13}=\phi_{11}$	0.828	0.100	8.310	0.000	Y_{1t-1}
	$\beta_{14}=\phi_{12}$	-1.242	1.574	-0.790	0.434	Y_{2t-1}
	$\beta_{15}=\phi_{13}$	-0.106	0.224	-0.470	0.638	Y_{3t-1}
	$\beta_{16}=\phi_{14}$	-0.183	0.116	-1.570	0.122	Y_{4t-1}
Y_{2t} Pulses	$\beta_{20}=\psi_{20}$	2.928	1.190	2.460	0.018	1
	$\beta_{21}=\psi_{21}$	-0.065	0.031	-2.080	0.043	t
	$\beta_{22}=\psi_{22}$	0.002	0.001	3.780	0.001	t^2
	$\beta_{23}=\phi_{21}$	-0.020	0.008	-2.550	0.014	Y_{1t-1}
	$\beta_{24}=\phi_{22}$	0.558	0.121	4.600	0.000	Y_{2t-1}
	$\beta_{25}=\phi_{23}$	0.032	0.017	1.830	0.074	Y_{3t-1}
	$\beta_{26}=\phi_{24}$	0.008	0.009	0.940	0.354	Y_{4t-1}
Y_{3t} Rice	$\beta_{30}=\psi_{30}$	9.635	5.913	1.630	0.110	1
	$\beta_{31}=\psi_{31}$	-0.296	0.156	-1.900	0.063	t
	$\beta_{32}=\psi_{32}$	0.008	0.003	2.670	0.010	t^2
	$\beta_{33}=\phi_{31}$	-0.046	0.038	-1.200	0.238	Y_{1t-1}
	$\beta_{34}=\phi_{32}$	-1.254	0.603	-2.080	0.043	Y_{2t-1}
	$\beta_{35}=\phi_{33}$	0.901	0.086	10.510	0.000	Y_{3t-1}
	$\beta_{36}=\phi_{34}$	0.082	0.044	1.850	0.071	Y_{4t-1}
Y_{4t} Wheat	$\beta_{40}=\psi_{40}$	28.771	17.303	1.660	0.103	1
	$\beta_{41}=\psi_{41}$	1.401	0.455	3.080	0.004	t
	$\beta_{42}=\psi_{42}$	-0.017	0.009	-2.000	0.051	t^2
	$\beta_{43}=\phi_{41}$	-0.052	0.112	-0.470	0.641	Y_{1t-1}
	$\beta_{44}=\phi_{42}$	0.597	1.764	0.340	0.737	Y_{2t-1}
	$\beta_{45}=\phi_{43}$	-0.195	0.251	-0.780	0.440	Y_{3t-1}
	$\beta_{46}=\phi_{44}$	0.519	0.130	4.000	0.000	Y_{4t-1}

consumption of wheat. The linear trend and consumption of wheat lagged one period $(Y_{4,t-1})$ have significant positive effects on current consumption of wheat, while the quadratic trend (t^2) has a significant negative effect on it. The estimated model has been used to predict the per capita consumption of cereals, pulses, rice, and wheat from 2014 to 2023. The predicted, as well as real per capita consumption of these food items, have been plotted in Figure 3.

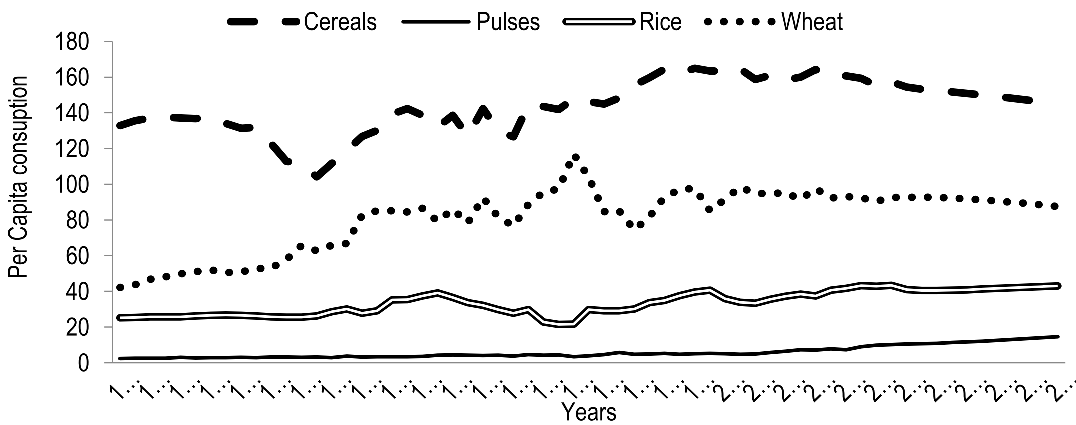

Figure 3. Real and predicted per capita consumption of cereals, pulses, rice, and wheat in the GCC region from 1961 to 2023 (kg/capita/year).
Data source: Food and Agriculture Organization, (1b) and the predicted values: estimated model.

Wheat is the GCC's main food grain, as depicted in Figure 3. Per capita wheat consumption was increasing at a decreasing rate from 1961 to 2002, and then starts decreasing at an increasing rate, and it will continue decreasing over time during the prediction period. This may be another symptom of diet transition in the study area.

Rice is the second-most important food cereal in the GCC region. Its per capita consumption has increased over time during the study period. The grain did not show a sign of diet transition. This may be attributed to the increasing number of expatriates, who accounted for about 40% of the GCC population in 2013, especially Asian people whose main food is rice. Furthermore, most of the expatriates stay for a limited time, whereas newcomers join the population, a matter expected to destabilize the rice diet pattern.

Per capita cereal consumption as an aggregate has been fluctuating over time. It decreased at a decreasing rate from 1961 to 1973, and then started increasing at an increasing rate. An inflection point occurred in 1992 when the growth rate of per capita cereal consumption started to decrease onwards for the rest of the study period. Per capita consumption of food cereals started to decrease in 2007 and is expected to continue decreasing in the projection period. This is another symptom of diet transition in the study area. Consumption of pulses has shown a slight increase over time. However, since 1993, it has been stabilizing at around an average of 5 kg, and is expected to be stable going forward.

Consumption of fruits, vegetables, sugar, and sweeteners

The estimated model of current per capita consumption of fruits (Y_{1t}), vegetables (Y_{2t}), sugar, and sweeteners (Y_{3t}); the standard errors of these estimates; t statistics; corresponding $p values$; and all the roots of $|\Phi(L)|=0$ are given in Table 4 of Appendix 1. The estimated system of equations (4) is provided below:

$$\underset{\hat{\mathbf{Y}}_t}{\begin{bmatrix} Y_{1t} \\ Y_{2t} \\ Y_{3t} \end{bmatrix}} = \underset{\hat{\psi}\mathbf{Z}_t}{\begin{bmatrix} 10.779 & 0.866 & -0.017 \\ 36.398 & 6.544 & -0.126 \\ 2.263 & 0.172 & -0.001 \end{bmatrix} \begin{bmatrix} 1 \\ t \\ t^2 \end{bmatrix}} + \underset{\hat{\Phi}_1 \Delta \mathbf{Y}_{t-1}}{\begin{bmatrix} 1.243 & -0.081 & 0.873 \\ -0.043 & 0.102 & -0.173 \\ 0.064 & 0.002 & 0.814 \end{bmatrix} \begin{bmatrix} Y_{1t-1} \\ Y_{2t-1} \\ Y_{3t-1} \end{bmatrix}} + \underset{\hat{\Phi}_2 \Delta \mathbf{Y}_{t-2}}{\begin{bmatrix} -0.571 & 0.054 & -0.311 \\ -0.194 & -0.200 & 2.250 \\ 0.057 & -0.032 & -0.295 \end{bmatrix} \begin{bmatrix} Y_{1t-2} \\ Y_{2t-2} \\ Y_{3t-2} \end{bmatrix}}, \quad t = 3,4,\ldots,54 \qquad (4)$$

The eigenvalues of matrix $\hat{\Phi}(L)$ are $\lambda = (0.750, 0.750, 0.680, 0.680, 0.543, 0.543)$. All eigenvalues are less than one, which means that all the roots of $|\hat{\Phi}(L)|=0$ fall outside the unit circle. When considering that the data have a quadratic trend, the time series of per capita consumption of these food items are, thus, stationary. By comparing the $p\ value$ $(pr>|T^*|)$ with a 0.05 significance level, the following points regarding the estimated equations can be stated.

The first equation represents current per capita fruit consumption. The constant, fruits consumption lagged one period $(Y_{1,t-1})$ and sugar consumption lagged one period $(Y_{3,t-1})$, have positive significant effects on current fruit consumption, whereas consumption of vegetables lagged one period $(Y_{2,t-1})$ and fruits lagged two periods $(Y_{1,t-2})$ have negative significant effects on it.

The second equation represents current per capita

Table 4. Estimates of system equations of current per capita consumption of fruits, vegetables, and sugar in the GCC region.

Equation	Coefficients	$\hat{\beta}$	$S.E_{\hat{\beta}}$	t	$(pr>\|T^*\|)$	Ind.Var.
Y_{1t} Fruits	$\beta_{10}=\psi_{10}$	10.779	5.157	2.09	0.043	1
	$\beta_{11}=\psi_{11}$	0.866	0.703	1.23	0.225	t
	$\beta_{12}=\psi_{12}$	-0.017	0.012	-1.44	0.158	t^2
	$\beta_{13}=\phi_{111}$	1.243	0.151	8.25	0.000	Y_{1t-1}
	$\beta_{14}=\phi_{112}$	-0.081	0.047	-1.75	0.088	Y_{2t-1}
	$\beta_{15}=\phi_{113}$	0.873	0.481	1.81	0.077	Y_{3t-1}
	$\beta_{16}=\phi_{211}$	-0.571	0.170	-3.36	0.002	Y_{1t-2}
	$\beta_{17}=\phi_{212}$	0.054	0.049	1.11	0.272	Y_{2t-2}
	$\beta_{18}=\phi_{213}$	-0.311	0.422	-0.74	0.465	Y_{3t-2}
Y_{2t} Vegetables	$\beta_{20}=\psi_{20}$	36.398	16.597	2.19	0.034	1
	$\beta_{21}=\psi_{21}$	6.544	2.263	2.89	0.006	t
	$\beta_{22}=\psi_{22}$	-0.126	0.039	-3.24	0.002	t^2
	$\beta_{23}=\phi_{121}$	-0.043	0.485	-0.09	0.930	Y_{1t-1}
	$\beta_{24}=\phi_{122}$	0.102	0.150	0.68	0.499	Y_{2t-1}
	$\beta_{25}=\phi_{123}$	-0.173	1.549	-0.11	0.912	Y_{3t-1}
	$\beta_{26}=\phi_{221}$	-0.194	0.547	-0.36	0.724	Y_{1t-2}
	$\beta_{27}=\phi_{222}$	-0.200	0.157	-1.28	0.208	Y_{2t-2}
	$\beta_{28}=\phi_{223}$	2.250	1.358	1.66	0.105	Y_{3t-2}
Y_{3t} Sugar	$\beta_{30}=\psi_{30}$	2.263	1.435	1.58	0.122	1
	$\beta_{31}=\psi_{31}$	0.172	0.196	0.88	0.384	t
	$\beta_{32}=\psi_{32}$	-0.001	0.003	-0.24	0.814	t^2
	$\beta_{33}=\phi_{131}$	0.064	0.042	1.53	0.133	Y_{1t-1}
	$\beta_{34}=\phi_{132}$	0.002	0.013	0.14	0.888	Y_{2t-1}
	$\beta_{35}=\phi_{133}$	0.814	0.134	6.08	0.000	Y_{3t-1}
	$\beta_{36}=\phi_{231}$	0.057	0.047	1.21	0.234	Y_{1t-2}
	$\beta_{37}=\phi_{232}$	-0.032	0.014	-2.38	0.022	Y_{2t-2}
	$\beta_{38}=\phi_{233}$	-0.295	0.117	-2.51	0.016	Y_{3t-2}

vegetable consumption. The constant parameter and the linear trend (t) have positive significant effects on the current consumption of vegetables (Y_{2t}), whereas the quadratic trend (t^2) has a significant negative effect on it.

The third equation represents current per capita sugar consumption. Per capita consumption of sugar lagged one period $(Y_{3,t-1})$ has a significant positive effect on current sugar consumption, whereas per capita consumption of vegetables lagged two periods $(Y_{2,t-2})$ and per capita consumption of sugar lagged two periods $(Y_{3,t-2})$, have negative significant effects on it. The

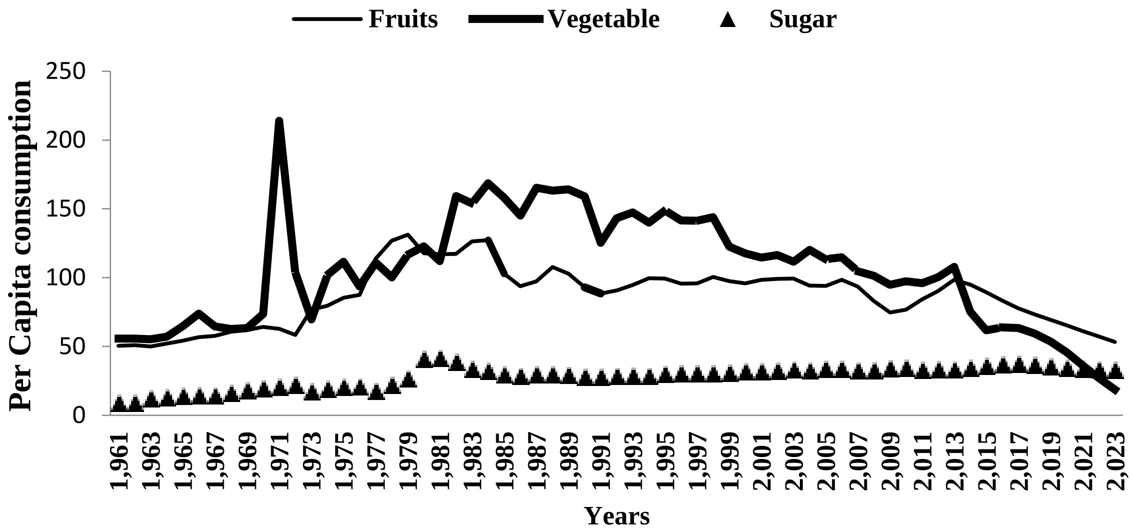

Figure 4. Actual and predicted per capita consumption of fruits, vegetables, sugar, and sweeteners in the GCC region from 1961 to 2023 (kg/per capita/year).
Data source: Food and Agriculture Organization,[1b] and the predicted values: estimated model.

estimated model 4 was used to predict the per capita consumption of these food items from 2014 to 2023. The predicted as well as real per capita consumption patterns since 1995 are plotted in Figure 4.

In 1971, per capita consumption of vegetables showed an unexplained exotic number for Saudi Arabia. The figure shows that the per capita consumption of vegetables and fruits decreased over time since the early 1980s and will continue decreasing in the prediction period. Per capita consumption of sugar and sweeteners has continuously increased over the study period, and are expected to continue increasing in the prediction period. All these trends are signals of a diet transition.

Overall, it is clear that the GCC states have witnessed a diet transition. However, the results of this study could not be compared with those of previous studies due to a lack of similar studies in the region.

Food losses and waste in the GCC region

Food losses refer to a decrease in edible food mass throughout the supply chain that specifically leads to a decrease in food available for human consumption. Food losses and wastes are measured only for products directed at human consumption, excluding feed and parts of products that are inedible. Therefore, food that was originally meant for human consumption but which subsequently was removed from the human food chain is considered a loss or waste even if it is then directed to a non-food use such as feed, bio-energy, and so on (Parfitt et al., 2010).

Food can be lost or wasted in different stages of production (in-farm, post-harvest, packing, and processing), distribution, processing, and final consumption (food service including restaurants, cafeterias, fast food, caterers, and households), or during disposal (composted food wastes, and food wastes dumped in landfills). Food loss that occurs due to retailer and consumer behavior is called “food waste.”

According to the FAO (2012), wastage at the consumer level is typical of food systems in developed countries, while losses from production to the retail level characterize those of developing countries. The exact causes of food losses vary throughout the world, depending on the specific conditions of each country. These conditions include crop production choices and patterns, internal infrastructure and capacity, marketing chains and channels for distribution, as well as consumer purchase and food use practices. Developing countries can incur significant losses at harvest time or when crops are left un-harvested due to lack of effective demand. For the case of food cereals, drying, threshing, and milling can cause huge losses. Regarding perishable fruits and vegetables, approximately half the crop is usually lost due to poor handling and packaging and in transportation.

While many food products are ultimately biodegradable, their non-consumption means that the scarce resources used in their cultivation, production, marketing, and processing are also wasted. Thus, food loss and waste also imply loss of human labor, land, water, fertilizer, and other inputs as well as loss of fuel for transportation, processing, and cold storage. Furthermore, “cleaning up”

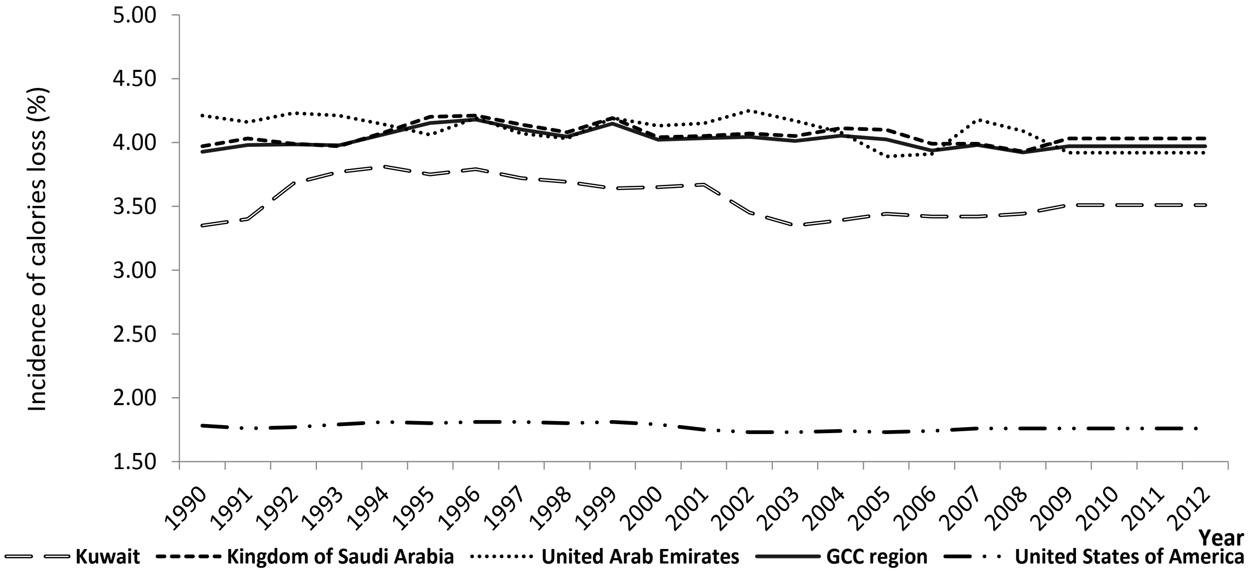

Figure 5. Incidence of caloric losses at retail distribution level in GCC region and USA from 1990 to 2012 (percentage). Data source: The Food and Agriculture Organization (1b)series.

food waste and food packing materials imposes further costs in terms of labor, energy, and environmental contamination.

With reference to the aforementioned literature about food loss and waste, food waste in retail distribution and consumption levels are the most relevant to the GCC region. This is because GCC countries depend mainly on international markets for their food, thus making “in-farm” as well as “post-harvest” and “in packing” losses irrelevant, except for a limited number of food items produced domestically. Thus, the discussion about food wastes in the study area has been confined to the retail distribution and consumption levels.

Food wastes at the retail distribution level

Regarding food waste at the retail distribution level, the FAO (2013) has provided estimates of the incidence of caloric losses for the period 1990 to 2012 (Figure 5). USA food loss data have also been plotted for purposes of comparison. The figure shows a high incidence of food waste in the study area. The United Arab Emirates (UAE) has shown the highest level of food waste from 1990 to 2008, which was then surpassed by the Kingdom of Saudi Arabia (KSA) from 2008 onward. Food waste in the GCC region is very high compared with that of the USA. The average caloric loss in the region during the same period was 2.3 times that of the USA. Kuwait does relatively better in terms of food wastage, when compared with KSA and the UAE.

Food waste at the consumption level

Food waste at the consumption level is caused mainly by consumer purchase and food usage practices, among other reasons. Regarding the study area, the major challenge is the paucity of data and information regarding the exact volume of food wasted in households and food service operations. Only estimates are found for the whole continent of Southeast Asia, which includes the study area. For instance, Gustafson and Otterdijk (2011) have estimated per capita food waste in South/Southeast Asia as falling in the range of 120 to 170 kg/year, whereas in Europe and North-America it is approximately 280 to 300 kg/year.

As a matter of culture in the GCC region, offering plenty of food for family members, guests, and to anyone who might ask for it, is an appreciated social behavior and sign of generosity. Furthermore, the volume of food purchases (and waste) dramatically increases on special occasions, such as the fasting month of Ramadan and other social and religious events. For instance, setting up lavish food tables during Ramadan and Eid festivals, weddings, parties, and informal get-togethers is common. Supermarkets, restaurants, and cafés are renowned for their excessive waste via unsold food items and damaged goods.

Minimizing food waste is a difficult challenge in a culture in which food is so readily thrown away, even though this contradicts the Islamic teaching in the holy Quran, which emphasizes moderation in food consumption; shuns extravagant, wasteful behaviors; and asks Muslims to avoid waste. For instance, one passage states, “Eat and drink, but be not excessive; indeed, He likes not those who commit excess.”

Diet–related health concerns in the GCC region

It is well recognized in the health field that food consumption is closely related to many non-communicable diseases and health problems. These include the following:

(1) Obesity and being overweight, which are related to the quantity and quality of food intake, among other factors
(2) Diabetes: Type II diabetes, the disease’s most common form, is largely related to consuming too much sugar, especially processed and refined versions like high fructose corn syrup and refined flours, plus not enough fresh fruits, vegetables, and whole grains.
(3) Hypertension and dyslipidemia, which are highly linked to the quantity and quality of food intake.
(4) Osteoporosis: Calcium is important for healthy bones, while its deficiency can lead to osteoporosis. Highly refined foods like fast food, junk food, and sodas, deplete the body of vital minerals including calcium.
(5) Cardiovascular disease: High cholesterol levels and clogged arteries often arise from too much stress and saturated fat, and insufficient fiber, omega-fats, or exercise. Women especially are at risk for heart attacks after menopause.
(6) Cancer: A growing volume of research connects diet to many types of cancer. Nitrites in processed meat, artificial colors, sweeteners, preservatives, and pesticides used in producing non-organic crops, can all increase cancer risks.

Regarding the situation in the GCC region, all the aforementioned diseases are common. Obesity and being overweight represent major public health problems in GCC states. According to Alhyas et al. (2011a), the prevalence of overweight in the region is estimated in the range of 25-50%, and obesity is in the range of 13–50%. Importantly, these health problems are increasing over time. The most affected groups are women, children, and the elderly.

In another study, Ng. et al. (2011) have noted that the prevalence of overweight and obesity are astounding particularly in Kuwait, Qatar, KSA, and Bahrain, where between two-thirds and three-quarters of adults and 25-40% of children and adolescents are overweight or obese. The authors have argued that these levels are higher than those found in developed countries, such as the USA, Australia, and the UK.

Regarding hypertension and diabetes, their prevalence rates in the study area are among the highest in the world. According to the International Diabetes Federation (2014), KSA, Kuwait, and Qatar are among the world’s “top ten” countries for diabetes prevalence in 2013, with rates of 24, 23.1, and 22.9%, respectively. The prevalence rates of diabetes were 19% in the UAE, 21.8% in Bahrain, and 14.2% in Oman. People with diabetes are two to six times more likely to develop cardiovascular disease than people without diabetes.

Estimates of hypertension prevalence in the region vary between 6.6 and 33.6%. The UAE and Bahrain have shown the highest hypertension rates. With respect to hyperglycemia and dyslipidemia, their estimated prevalence rate among adults fall in the range of 10-20%, with an upward trend over time. This higher prevalence rate is associated with advancing age and female groups. The estimates for dyslipidemia fall in the range of 2.7-51.9%, with an increasing trend over time (Alhyas et al., 2011b). Regarding cancer prevalence, there is no known study of the prevalence of diet-related cancers among the population of the GCC states (Ng et al., 2011).

CONCLUSION AND RECOMMENDATIONS

The GCC region has shown symptoms of a diet transition marked by a shift toward a more varied diet, with more items of animal origin and containing more added sugar and fat. This is accompanied by substantial food waste and the prevalence of health problems related to such food intake, including being overweight, obesity, diabetes, hypertension, and dyslipidemia. Food waste at the retail level is also substantial. Regarding food waste at the consumption level, the study region lacks sufficient and systematic data and information. Overall, the current situation reflects the need for proper food waste legislation, a thoughtful long-term strategy, and effective mechanisms for its implementation. The region needs to develop a policy program considering food transition, food waste, and diet-related chronic diseases. The program should include a combination of government action, and educational as well as mass media programs, to encourage commitment to dietary guidelines sensitive to traditional and religious concerns, and to raise public awareness regarding diet, exercise, and food waste. Finally, it is important for the GCC region to consider the data shortage regarding food consumption and waste, and to intensify research on the underlying causes of nutrition transition, food wastage, and prevalence of diet-related health problems. Ultimately, this will facilitate the design and implementation of policies that enhance the sustainability of food systems to improve human health in the GCC region.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Alhyas L, McKay A, Balasanthiran A, Majeed A (2011a). Prevalence of overweight, obesity, hyperglycemia, hypertension and dyslipidemia in the Gulf: Systematic review. JRSM Short Reports 2(7):1-16.

Alhyas L, McKay A, Balasanthiran A, Majeed A (2011b). Quality of type 2 diabetes management in the states of the Co-operation Council for the Arab States of the Gulf: A systematic review. PloS One 6(8):e22186.

Food and Agriculture Organization of the United Nations (2012). FAO Statistical Yearbook 2012. Retrieved on 5 April 2013 from FAO website: http://www.fao.org/docrep/015/i2490e/i2490e00.htm.

Food and Agriculture Organization of the United Nations (2018). Retrieved from FAOSTAT databases in 7/April/2018. http://faostat3.fao.org/faostat-gateway/go/to/download/FB/*/E.

Gulf Cooperation Council (GCC) (2014). GCC states: A statistical glance, 4th edition. Statistical Center of the Cooperation Council for the Arab States of the Gulf (2012-2016).

Gustafson J, van Otterdijk R (2011). Global food loss and food wastes: Extent, causes, and prevention. FAO, Rome.

Greene WH (2003). Econometrics Analysis, 5th Ed. New Jersey, 07458, Prentice Hall, Pearson Education International.

Guyomard H, Darcy-Vrillon B, Esnouf C, Marin M, Russel M, Guillou M (2012). Eating patterns and food systems: Critical knowledge requirements for policy design and implementation. Agriculture and Food Security 1(1):13

Hamilton JD (1994). Time Series Analysis. Princeton University Press, Princeton.

International Diabetes Federation (2014). IDF Diabetes Atlas, 6th ed. Retrieved July 8 2014 from IDF website: http://www.diabetesatlas.org/.

Johnson RA, Wichern DW (1992). Applied Multivariate Statistical Analysis, 3rd Ed, Prentice-Hall International Inc.

Lütkepohl H (1991). Introduction to Multiple Time Series Analysis. Springer-Verlag, Berlin.

Ng SW, Zaghloul S, Ali H I, Harrison G, Popkin BM (2011). The prevalence and trends of overweight, obesity and nutrition-related non communicable diseases in the Arabian Gulf States. Obesity Reviews 12(1):1-13.

Parfitt J, Barthel M, McNaughton S (2010). Food waste within food supply chains: quantification and potential for change to 2050. Philosophical Transactions of the Royal Society of London B: Biological Sciences 365(1554):3065-3081.

Pesaran MH, Pesaran B (1997). Working with Micro fit 4.0: An interactive econometric software package (DOS and Windows versions), Oxford University Press, Oxford.

Popkin BM (1993). Nutritional patterns and transitions. Population and Development Review:138-157.

APPENDIX

The *VAR*(*p*) model could be written as follows:

$$VAR(p):\quad \mathbf{Y}_t = \boldsymbol{\psi}\mathbf{Z}_t + \boldsymbol{\gamma}_1\mathbf{Y}_{t-1} + \boldsymbol{\gamma}_2\mathbf{Y}_{t-2} + \ldots + \boldsymbol{\gamma}_p\mathbf{Y}_{t-p} + \boldsymbol{\varepsilon}_t\ ,$$
$$t = p+1, p+2, \ldots, T$$

where $\mathbf{Y}_t = (Y_{1t}, Y_{2t}, \ldots, Y_{nt})'$, $t = p+1, p+2, \ldots, T$ denote a n-dimensional time series vector of the random variables under study, $\mathbf{Z}_t = (1, t, t^2)'$ is a 3×1 vector of determinants, $\boldsymbol{\psi}, \{\boldsymbol{\gamma}_i, i = 1,2,\ldots, p\}$ are $n\times 3, n\times n$ coefficient matrices, and $\boldsymbol{\varepsilon}_t$ is a sequence of $n\times 1$ independent white noise vectors with zero mean and non-singular contemporaneous covariance matrix given by $\boldsymbol{\Sigma}_\varepsilon$. The model is a system of seemingly unrelated regression (*SUR*) equations with independent variables including lagged vectors $\mathbf{Y}_{t-1}, \mathbf{Y}_{t-2}, \ldots, \mathbf{Y}_{t-p}$ and vector of deterministic terms; $\mathbf{Z}_t$. The model is based on the following assumptions ((Lütkepohl ,1991) and (Pesaran and Pesaran ,1997)):

Assumption 1: $E(\boldsymbol{\varepsilon}_t) = \mathbf{0}$, $E(\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_t') = \boldsymbol{\Sigma}_{\boldsymbol{\varepsilon}}$ *for all t, where* $\boldsymbol{\Sigma}_{\boldsymbol{\varepsilon}} = \{\sigma_{ij}^2, i, j = 1,2,\ldots,n\}$ is *a positive definite matrix*, $E(\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_{t'}') = \mathbf{0}$ *for all* $t \neq t'$, *and* $E(\boldsymbol{\varepsilon}_t \mid \mathbf{Z}_t) = 0$.

Assumption 2: *All the roots of* $|\boldsymbol{\gamma}(L)| = |I_n - \sum_{i=1}^{p}\boldsymbol{\gamma}_i L^i| = 0$ *fall outside the unit circle*, *or, all eigenvalues of the* $np\times np$ *companion matrix have modulus less than one*, *and* $\mathbf{I}_n$ is $n\times n$ *identity matrix*.

Assumption 3: $(\mathbf{Y}_{t-1}, \mathbf{Y}_{t-2}, \ldots, \mathbf{Y}_{t-p}, \mathbf{Z}_t)$, $t = p+1, p+2, \ldots, T$ *are not perfectly collinear*.

Given that no restrictions were imposed on parameters of the model, and that assumption 2 holds, the general form of the multivariate linear model could be represented by:

$$\underset{(m\times n)}{\mathbf{Y}} = \underset{(m\times k)}{\mathbf{X}}\ \underset{(k\times n)}{\mathbf{B}} + \underset{(m\times n)}{\mathbf{E}}$$

where $\mathbf{Y} = (\mathbf{Y}_{p+1}, \mathbf{Y}_{p+2}, \ldots, \mathbf{Y}_T)'$, $\mathbf{X} = (\mathbf{X}_{p+1}', \ldots, \mathbf{X}_T')'$, $\mathbf{X}_t = (\mathbf{Z}_t', \mathbf{Y}_{t-1}', \ldots, \mathbf{Y}_{t-p}')$, $\mathbf{B} = (\boldsymbol{\psi}, \boldsymbol{\gamma}_1, \ldots \boldsymbol{\gamma}_p)'$, $\mathbf{E} = (\boldsymbol{\varepsilon}_{p+1}, \boldsymbol{\varepsilon}_2 \ldots, \boldsymbol{\varepsilon}_T)'$, $m = T - p$, and $k = np + 3$. Then coefficient matrix $\mathbf{B}$ can be estimated by using the conditional least squares (LS) method (Johnson and Wichern, 1992) which is:

$$\hat{\mathbf{B}}_{ls} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Y}$$

and this estimation can be used for estimating the covariance matrix of error vector; $\boldsymbol{\Sigma}_\varepsilon$ which given by $\hat{\boldsymbol{\Sigma}}_\varepsilon = \sum_{t=p+1}^{T}\hat{\boldsymbol{\varepsilon}}_t\hat{\boldsymbol{\varepsilon}}_t' / m$, where $\hat{\boldsymbol{\varepsilon}}_t = (\mathbf{Y}_t - \mathbf{X}_t\hat{\mathbf{B}}_{ls})$ is the residual vector. Let $\hat{\boldsymbol{\beta}}_{ls} = vec(\hat{\mathbf{B}}_{ls})$ denotes the operator that stacks the columns of the $(k\times n)$ matrix $\hat{\mathbf{B}}_{ls}$ into a long $(nk\times 1)$ vector. The estimate $\hat{\boldsymbol{\beta}}_{ls}$ is consistent and asymptotically normally distributed with asymptotic covariance matrix; $avar(\hat{\boldsymbol{\beta}}_{ls}) = \hat{\boldsymbol{\Sigma}}_\varepsilon \otimes \left[(\mathbf{X}'\mathbf{X})^{-1}/m\right]$ (Hamilton, 1994) and (Lütkepohl, 1991). From the statistical properties of $\hat{\boldsymbol{\beta}}_{ls}$, all important statistical hypothesis tests as well the predicted values to dependent variables in *VAR*(*p*) model can be performed.

Prediction of dependent variables: with given independent variables matrix; $\tilde{\mathbf{X}}_{T+h|T} = (\mathbf{D}_{T+h}', \tilde{\mathbf{Z}}_{T+h}', \hat{\mathbf{Y}}_{T+h-1|T}', \ldots, \hat{\mathbf{Y}}_{T+h-p|T}')$, the best linear predictor with period of h length; $\mathbf{Y}_{T+h}$ is given by:

$\hat{\mathbf{Y}}_{T+h|T} = \hat{\mathbf{B}}'_{ls}\tilde{\mathbf{X}}'_{T+h|T}$, $h = 0,-1,...,$ *Furthermore*

Where $\mathbf{Z}_{T+h} = (1, T+h, (T+h)^2)$, and $\hat{\mathbf{Y}}_{T+j|T} = \mathbf{Y}_{T+j}$ *for* $j \leq 0$. The mean square error matrix (MSE) of the h -step forecast (Green, 2003) is given by $\hat{\Sigma}(h) = \Sigma(h) + MSE[(\mathbf{B} - \hat{\mathbf{B}}_{ls})'\tilde{\mathbf{X}}'_{T+h|T}]$. In practice, the second term; $MSE[(\mathbf{B} - \hat{\mathbf{B}}_{ls})'\tilde{\mathbf{X}}'_{T+h|T}$ is often ignored and $\hat{\Sigma}(h)$ is computed as:

$$\hat{\Sigma}(h) = \sum_{s=0}^{h-1} \hat{\Lambda}_s \Sigma_\varepsilon \hat{\Lambda}'_s$$

were $\hat{\Lambda}_s = \sum_{j=1}^{s-1} \hat{\Lambda}_{j-1}\hat{\Phi}_j$, $\Lambda_0 = \mathbf{I}_n$, $s = 1,2,..., p$, . Asymptotic $(1-\alpha).100\%$ confidence intervals for the individual elements of $\hat{\mathbf{Y}}_{T+h|T}$ are then computed as:

$$\hat{Y}_{k,T+h|T} - Z_{(1-\alpha/2)}.\hat{\sigma}_k(h) < Y_{k,T+h} < \hat{Y}_{k,T+h|T} + Z_{(1-\alpha/2)}.\hat{\sigma}_k(h)$$

where $Z_{1-\alpha/2}$ is the $(1-\alpha/2)$ quartile of the standard normal distribution, and $\hat{\sigma}_k(h)$ denotes the square root of the k^{th} diagonal element of $\hat{\Sigma}(h)$.