Climate change and food security: Assessing the prospect for Kuwait using an economy-wide model

Ayele U. Gelan[1,*], Giles Atkinson[2]

[1]*Techno-economic Division, Kuwait Institute for Scientific Research (KISR), Kuwait*
[2]*Dept. of Geography & Environment, London School of Economics,London, UK*
[*]*Corresponding author: augelana@gmail.com*

Abstract

This study is concerned with food security effects of global warming in Kuwait. The Intergovernmental Panel on Climate Change (IPCC) approach to monitor impacts of human activities on climate change has essentially remained top-down. Hence, it fallen out of favour among end user communities. In this procedure, the needs of policymakers at national scale have been peripheral. Kuwait's food security is a good illustration of this. The study is implemented by applying a recursive dynamic computable general equilibrium model for Kuwait. The model was calibrated on Kuwaiti data to examine food security impacts of the five Shared Socio-economic Pathways. The simulation results indicate asymmetrical impacts on Kuwait's agriculture and food processing industries. Arid countries would benefit by enhancing national capacities to assess food security implications of global warming scenarios.

Keywords: Arid agriculture; food prices; food security; global warming scenarios; integrated assessment models.

1. Introduction

This study is concerned with food security effects of global warming in Kuwait. Kuwait's food security provides a useful focus to explore the IPCCs global scenarios. Indeed, Kuwaiti authorities would benefit from knowing impacts of exogenous shocks on the status of Kuwait's food security. In the context of global warming scenarios, food security effects are often assessed in terms of global warming either helping or hindering food production depending on biophysical conditions and agro-ecological zones of the country in question (FAO *et al*., 2018). Regional and national targets are often indirectly drawn using assessments by the IAV modelling communities. These often work with high resolution remote sensing and geographical information systems to draw food production implications of global targets set according to IAM projections (Phetheet *et al*., 2021; Uchiyama & Stevenson, *et al.*, 2020, Nebie *et al*.,2021).

Food security in arid countries is often affected by what happens elsewhere. That is, production conditions in food exporting countries and how those changes affect demand and supply relationships for food products and hence food prices in the world market. Integrated Assessment models (IAMs) often work with exceedingly coarse regional groupings, lumping extremely heterogeneous regions into one group (Moss *et al*., 2008). For instance, in some IAM models, the MAF region lumps together the Middle East and Africa (Gütschow, *et al.,* 2020, Happman *et al*., 2019).

The current study is implemented by applying a recursive dynamic CGE model for Kuwait. It examined food security impacts of five IPCC Shared Socio-economic Pathways (SSP). A world food price index (WPI) was constructed and used as an exogenous variable to shock the Kuwaiti national model through its influence on food imports prices.

The remainder of this paper is organized as follows. Section 2 highlights the global scenarios and socio-economic pathways. Section 3 provides an overview of the Kuwaiti recursive dynamic CGE mode. Section 4 discusses simulation results. Section 5 presents concluding remarks.

2. Global climate change scenarios

The IPCC approaches to developing its global climate change scenario have undergone two rounds of revisions. These are briefly discussed in this section.

2.1 The Special Report on Emissions Scenarios (SRES)

The procedure for monitoring GHG emission in scenarios was initially formalized in the Special Report on Emissions Scenarios (SRES) (Nakicenovic *et al.,* 2000). This took a sequential approach, which begins with specifications of scenarios for major drivers and associated CO2 emissions (left hand side of Figure 1). At an early stage, the IPCC was closely coordinating and leading efforts by IAM communities. Population, GDP, and technology assumptions developed in stage 1 and the associated CO2 emissions cascaded down to stage 2, radiative forcing, which denotes increases in temperature and global warming effects.

In stage 3, outputs of stages 1 and 2 are fed into climate change models to undertake projection by global scenarios. The IAV implications of the climate changes are assessed in the final stage of the sequential approach (stage 4).

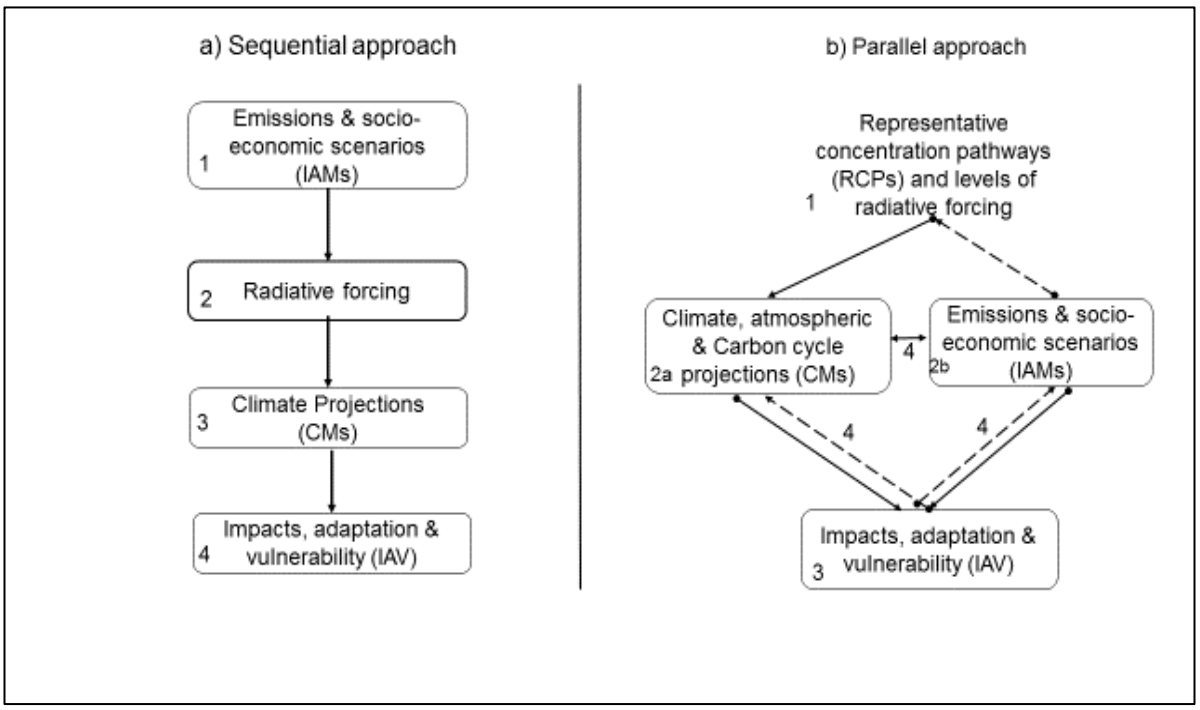

Fig. 1. Approaches to developments of global scenarios. Source: Moss *et al*. (2008**)**.

The sequential approach fell out of favor among many end user communities (in climate change and IAV modelling). Moss *et al.* (2008) discusses the circumstances surrounding a shift to the parallel approach (the right-hand side of Figure 1). Climate modelers were not supposed to start their activities until outputs from the IAMs were released. The IAV communities had to wait for releases from climate change models (CM) results. This led to a shift to the parallel approach, which created room for different end user communities to operate independently (Moss *et al.,* 2008).

While the concerns of the modeling community as one end user group seems to have been addressed through a move to the parallel approach, it seems concerns of policy practitioners have remained unaddressed, subjecting the IAM models to serious criticisms regarding their top-down approach (Gambhir *et al.* 2019, Kebede *et al.* 2018).

2.2 Shared socioeconomic pathways (SSP)

SRES was replaced by a new set of scenarios referred to as Shared Socio-economic Pathways (SSP) (O'Neill *et al.,* 2014). The change was made to recognize the fact that human activities or anthropogenic factors are responsible for not only driving climate change but also facilitating or hindering policy response measures such as mitigation and adaptation strategies (Huppmann *et al*. 2019; IPCC 2019, Riahi *et al.,* 2017; Kristie *et al.,* 2014).

Five distinct SSPs were identified. The ranges in global warming scenarios (expressed in terms of Representative GHGs Concentration Pathways (RCPs) were pretty much as specified in the previous global scenarios (SRES). However, each SSP was separately mapped to the RCPs in different ways. Riahi *et al.* (2017) presents a concise description of the SSP narratives.

- SSP1: Sustainability – taking the green road (low challenges to mitigation and adaptation)
- SSP2: Middle of the road – medium challenges to mitigation and adaptation
- SSP3: Regional rivalry – a rocky road (high challenges to mitigation and adaptation)
- SSP4: Inequality – a road divided (low challenges to mitigation, high challenges to adaptation)
- SSP5: Fossil-fuelled development – taking the highway and economic growth first (high challenges to mitigation, low challenges to adaptation)

The latest IPCC report focused on "greenhouse gas (GHG) fluxes in land-based ecosystems, land use and sustainable land management in relation to climate change adaptation and mitigation, desertification, land degradation and food security" (IPCC, 2019, p. 6).

Kuwait's agricultural activity trends are assumed to follow patterns reflected in the IAM projections for the MAF region to which Kuwait belongs. Since imports constitute the bulk of the country's food supply, Kuwait's food security is greatly influenced by what happens to food prices in the world market. Changes in these food prices depend critically on excess demand for food: balance of changes between demand and supply (production).

3. The Kuwaiti National Model

The global scenarios described in the preceding section were evaluated using an economy-wide national model developed for Kuwait. The model was calibrated on Kuwait's comprehensive socioeconomic database, a Social Accounting Matrix (SAM), which was constructed with 2013 as its base year (Gelan, 2018).

The Kuwaiti model was reformulated to suit the SSP scenarios on Kuwait's food security. Given the SSP scenarios long-term projections, the impacts can be evaluated using a recursive dynamic CGE model that corresponds to IPPC SSP scenarios run from 2010 to 2100. The shock applied to the model was related to long-term food price scenarios in the world market corresponding to each SSP.

The food price effects of imbalances between demand and production were captured by altering relationships in the food import functions in the model, specifically the relationships between food prices in domestic and world markets.

$$PM_{C,T} = pwm_{C,T}\left(1 + tm_{C,T}\right) * EXR_T + \sum_{CT} PQ_{CT,T}\, icm_{CT,C,T} \quad (1)$$

Where

Subscripts:

C, CT: commodities and trade services respectively

T: time

Parameters:

tm: import tariffs

pwm: world market price of imports

icm: trade margins

Variables

PM: domestic prices of imports

EXR: exchange rate

PQ: composite price of commodities

Equation 1 represents import price formation, whereby domestic sales price of imported food products are given as a function of world market price, import tariffs, exchange rate, and domestic trade margins.

The standard import function displayed in Equation 1 was reformulated to suit the purpose of this study:

$$PM_{C,S,T} = pwm_{C,S,T}WPI_{C,S,T} * \left(1 + tm_{C,S,T}\right) * EXR_{S,T} + \sum_{CT} PQ_{CT,S,T}\, icm_{CT,C,S,T} \quad (2)$$

Equation 2 differs from equation 1 in two respects. First, the introduction of an additional subscript, S denoting scenarios, and the world price index (WPI), which is multiplied by the world market price (pwm). If the value of WPI is greater than 1, then the value of PM will increase: i.e. domestic sales prices of imported food will rise, and vice versa.

Increases in prices of imported food items affect the relationships between demand for domestic products and imported products. The expected change in this relationship is given in equation 3.

$$\frac{QM_{C,T}}{QD_{C,T}} = \left(\frac{PD_{C,T}}{PM_{C,T}} \frac{\delta q_{C,T}}{(1-\delta q_{C,T})}\right)^{\frac{1}{1+\rho q_C}} \quad (3)$$

Where
Parameter
δq: share of domestic products in total demand
$\rho q = (1/\sigma q) - 1$: where σq is elasticity of substitution in the commodity demand function
Variables
QD, PD: quantity and price of domestic products
QM, PM: quantity and price of imports

When WPI > 1, then the value of PM increases in equation 2. This enters the import demand function in equation 3. If PM increases, then PD/PM falls, and hence QM/QD falls too. If SSP scenarios cause world market prices to rise, this is bound to encourage local primary production, but discourages local food processing.

4. Simulation experiments

4.1 Constructing the long term World food Price Index (WPI)

IPCC's IAM have not yet produced price projections by SSPs. Hence, it was necessary to derive world market price indices (WPI) using indirect methods from food demand and production relationships presented in the long-term projection by SSPs on crop production and demand relationships, separately for World and the MAF region. The projections were obtained from the SSP database (Riahi *et al.,* 2017). The SSP projections were made from 2005 to 2100. Given the base year of the Kuwaiti SAM was 2013, it was necessary to drop 2005 and adopt 2010 as a base year, which is closer to 2013. In order to show the position of the Middle East and Africa region relative the world average, the projected figures were converted to indices as changes from the 2010 baseline year scenario.

The most relevant factor in determining world market price trends is imbalance between demand and supply. Table 1 presents gaps between demand for crops and supply of crops at global scales. Having decided demand and supply imbalance as a suitable variable to serve as proxy to calculate WPI, then we turn our attention to describing methods used to calculate the indices by SSPs. This is derived by using the following relationship:

$$WPI0_{C,S,T} = \frac{Log(D_{C,S,T})}{Log(P_{C,S,T})} \quad (4)$$

Where
Subscripts
C: Food products
S: scenarios, SSP1… SSP
T: denotes decades, 2010, 2020,…,2100.
Variables
WPI0: World price index derived from excess demand function
D: Demand for crops

P: Production of crops

Two food product categories were considered. The first was primary agricultural products. In the baseline database, agricultural activities are aggregated into a single industry producing a composite agricultural product: "primary agricultural product". The second was processed food, which comes from the food-processing branch of manufacturing. Food security is affected by what happens to production conditions of these two branches of Kuwait's domestic food sectors, which in turn are firmly linked to food prices in the world market.

Table 1. World market price indices (WPI) by SSP (2010 = 100)

	2010	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
SSP1	1.0000	0.8595	0.9646	1.0016	1.0518	1.1173	1.1826	1.2568	1.3363	1.4214
SSP2	1.0000	0.8609	0.9773	1.0378	1.0947	1.1616	1.2319	1.3047	1.3834	1.4670
SSP3	1.0000	0.8624	0.9687	1.0031	1.0748	1.1452	1.2181	1.2943	1.3727	1.4561
SSP4	1.0000	0.8597	0.9708	1.0569	1.1224	1.1893	1.2642	1.3425	1.4239	1.5090
SSP5	1.0000	0.8607	0.9748	1.0756	1.1501	1.2188	1.2945	1.3745	1.4612	1.5539

Source: Derived by the authors based on information obtained from Riahi *et al.* (2017); FAO (2018).

The world market food price indices (WPI0) were derived from SSP projections of excess demands for crop. However, the indices may not necessarily reflect the level of price changes. For this reason, WPI0 would need to be adjusted so that the indices come closer to prices changes reported in the literature. First, price changes compiled from various studies varied from 3% to 84%, but the extent of price changes implied by WPI0 fell short of these figures. Second, in its publication entitled "The future of food and agriculture – Alternative pathways to 2050", FAO (2018) reported price increase scenarios. The FAO projections were used to adjust and upscale the WPI0. The adjusted figures are reported in Table 1.

The simulation experiments were conducted by running a recursive dynamic model 50 times (S x T), five scenarios (SSP1 to SSP5) and years in decades (2010 to 2100). It is important to note WPI takes a value of unity for the "base" for 2010.

4.2 Results and discussion

4.2.1 Domestic prices of food products

The SSP projections discussed below typically undertake long-term scenario analysis. Accordingly, Figure 2 displays imported food prices on the vertical axis and years in decades on the horizontal axis. This indicated drops in food prices in the near term, up to 2030, implying excess supply over demand and hence declines in prices of crops in the world market. However, supply will fall short of demand beyond 2030 and the gaps would get wider for the subsequent decades.

In Figure 2 SSP5 depicted the highest of all the scenarios for the period beyond 2030. In Equation 2, WPI entered the import price function, multiplying the exogenous world prices of imported food products (pwm). The differences in prices of imported food products reflects the

WPI value reported in Table 1 and the translations of those values to domestic import prices of food displayed in equation 2. All SSP scenarios show sharp increases in prices of imported food products. SSP5 projects a nearly 4.5-fold increase from the 2010 level while in the SSP1, the sustainability scenario is expected to lead to nearly 2.5-fold increase in imported food prices. The other scenarios fall in between these extremes.

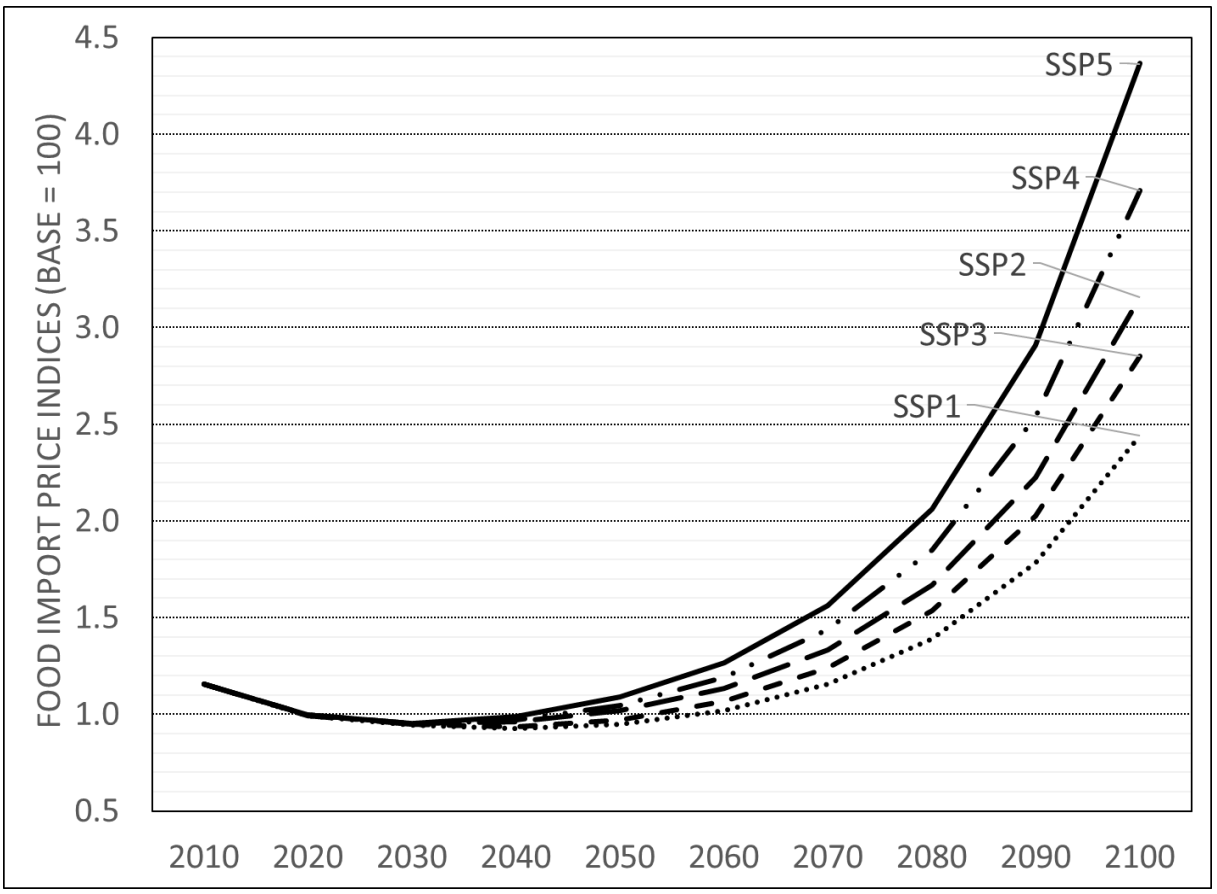

Fig. 2. Import price effects

The differences in import price scenarios reflect underlying assumptions adopted in constructing the SSP scenarios. SSP1 and SSP5 portray two sharply contrasting features. The world population growth assumptions for SSP1 and SSP5 are similar, but GDP growth scenarios do sharply contrast. SSP5 (economic growth first scenario) projects global GDP nearly three times to that reported under SSP1 (sustainability scenario). SSP5 is characterized by high material intensity and waste both in production and consumption, while the opposite is true with SSP1.

4.3 Aggregate food production effects

The domestic output index reported in Figure 3 is the weighted average of primary and processed food products. The differently shaded SSP5 comes closest to what would be Kuwait's status quo scenario: i.e. fossil fuel-based growth, the current trajectory.

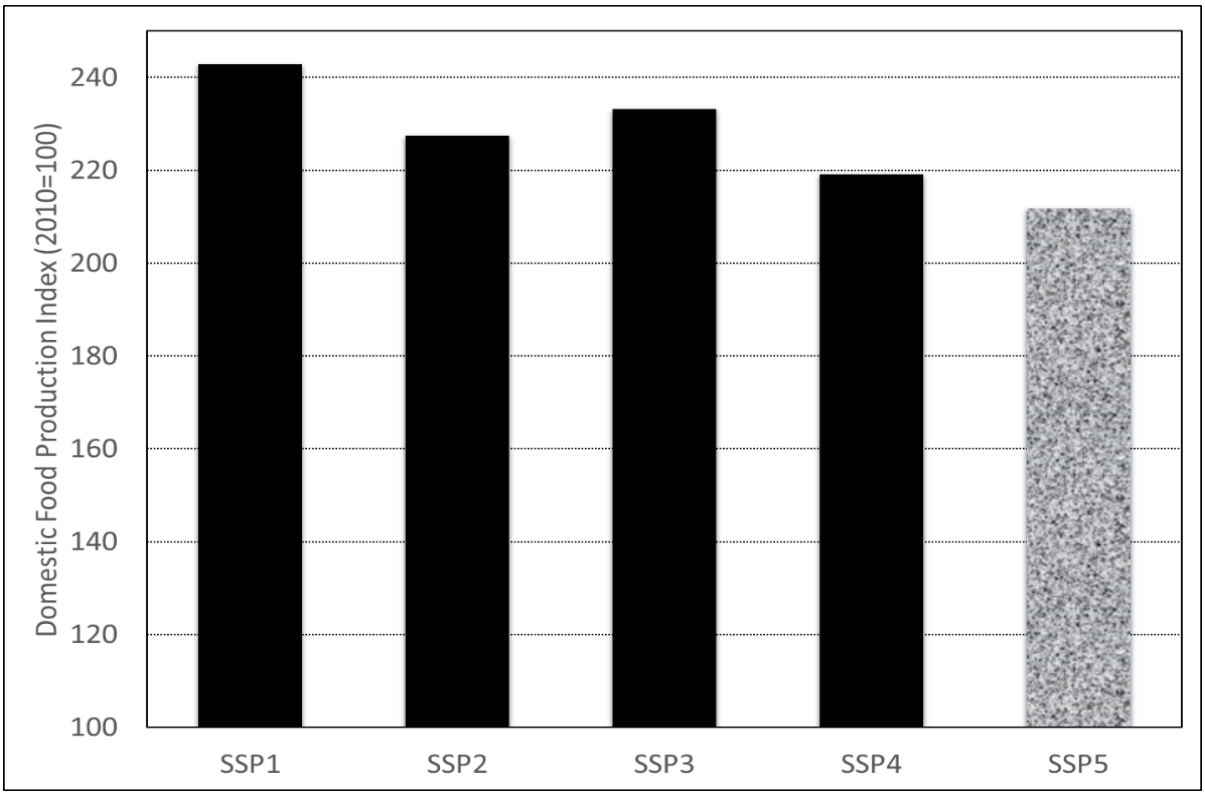

Fig. 3. Aggregate domestic food production effects

Domestic food production effects contrast with changes in prices of food products in the world market. The possibility of expanding Kuwait's primary agricultural production is severely constrained by biophysical conditions. However, within the limits set by the country's arid natural environment, there have been expansions of farming activities, historically, aided by substantial government support. Therefore, the model was specified considering these realities.

SSP5 has the highest import price increases and hence it yields the lowest domestic food output increase. The output of processed or manufactured food has much larger weight in Kuwait's domestic food production. Increases in imported food prices hurt food processing, since the bulk of Kuwait's food processors import inputs. This gives the lowest domestic food production level in the SSP5 scenario. Given it yielded the lowest price increase, SSP1 caused the largest increase in processed food production, because it offers cheaper imported inputs for the domestic industries. Kuwait's domestic food production is likely to be higher in SSP5 than all other SSPs. Under all conditions of global warming and related socioeconomic pathways, Kuwait is likely to increase domestic food production, mostly domestic food processing relying on imported inputs.

4.3.1 Disaggregated food production effects

Figure 4 disaggregates the domestic food production effects already reported in Figure 3 into primary and processed food counterparts. Given its greater weight in the composition of domestic food production, the pattern of changes across the scenarios for the processed food remained much as in Figure 3, the highest increase in SSP1 and the lowest in SSP5.

Disaggregation highlights interesting insights for the primary agricultural production effects. Importantly, it reveals contrasting fortunes for primary and secondary food production systems. Higher import prices have contractionary effects on food processing resulting in an increase in the cost of production, given the bulk of intermediate inputs are imported (e.g. cereals for flour-mills, even powder milk for dairy processing plants, etc.).

An increase in world market prices for primary farm products means domestic production of primary products become more competitive. This creates favorable conditions for primary agricultural production; a positive influence on Kuwait's food production system. Given we considered SSP5 to be closer to the status quo, the global warming and socioeconomic pathways means limited prospects to expand Kuwait's primary agricultural production.

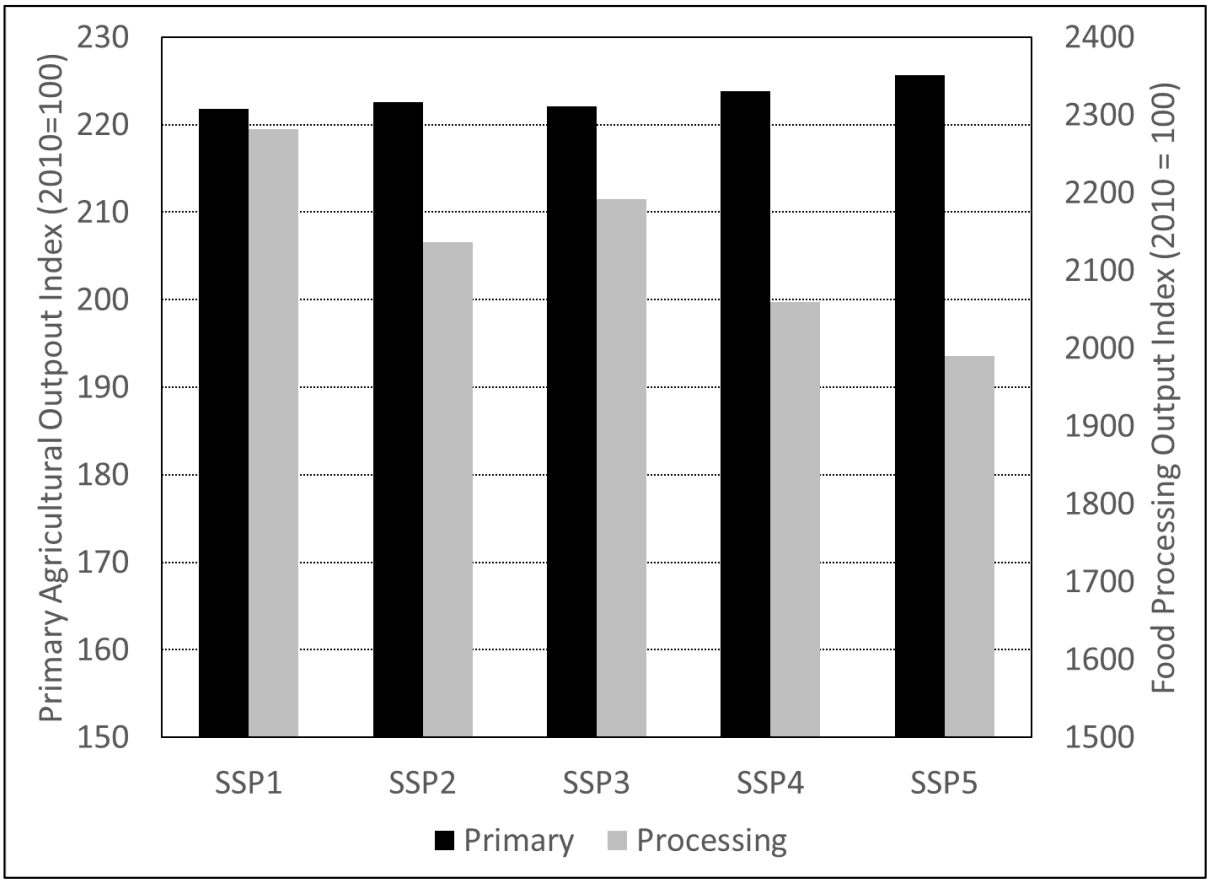

Fig. 4. Primary and processed food production effects

Broadening the scope of analysis is likely to reveal constrained outcomes for primary food production in Kuwait. First, it is likely that existing generous government subsidies are not sustained, particularly due to falling oil revenues and government budget constraints. Second, increasing GHG emission controls means the Kuwaiti farms will not be allowed to utilize energy at the current rate. Finally, water scarcity is likely to worsen. The simulation results displayed in Figure 3 regarding primary agricultural output are thus likely to represent a conservative estimate. Primary agricultural output is unlikely to increase even at the rate displayed in SSP1.

4.3.2 Food import effects

The food production results discussed in the preceding sections were presented with domestic food production and its long-term dynamics. However, overall food supply consists of domestic production and imports. Except for differences across the SSP scenarios with regard to domestic food production (primary plus processed), ultimately Kuwait is bound to rely on imports to feed its rapidly growing population.

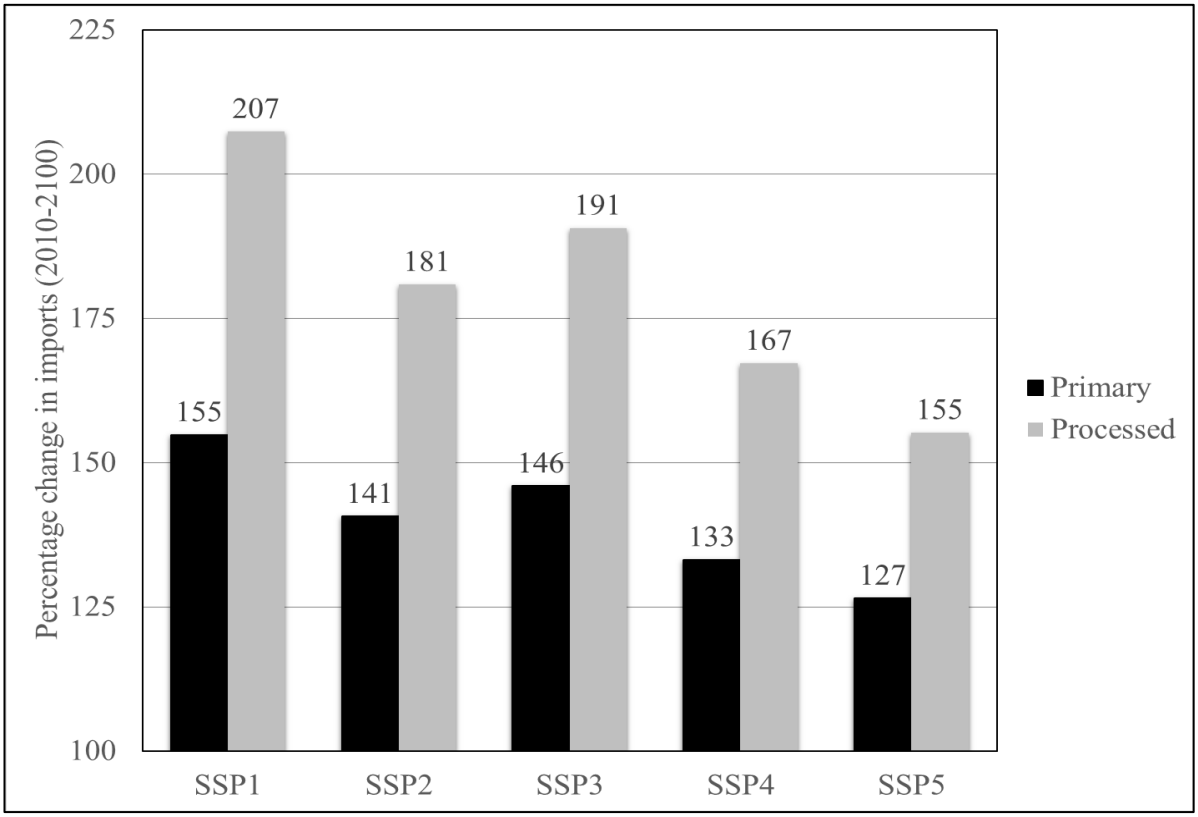

Fig. 5. Primary and processed food import effects

Figure 5 presents percentage changes in the level of food imports between the initial and final periods, 2010 and 2100. A rise in primary food imports is projected from 127% (SSP5) to 155% (SSP1). The corresponding percentage increases for processed food would be 155% and 207% respectively. These results are likely to represent conservative estimate of Kuwait's future food imports. The results reported in this study hinge on projected world market prices. If food prices increase by larger proportions, causing food import increases to be much higher than the results reported.

5. Conclusions

Food price variability in the world market have always been a major source of concern for Kuwaiti policymakers. Securing its food supply hinges on production conditions in food exporting countries. Adverse exogenous shocks at global scale can cause deterioration in Kuwait's food security. Sudden shocks like COVID-19 have disrupted global trade in a relatively short span of time. Climate change is a different category of adverse shock. Here

changes occur slowly but steadily over a long-term horizon. While ad hoc and one-off shocks like COVID-19 can be reversed, long-term shocks would prove to be long-lasting and not easily reversible.

In this simulation experiment, WPI increases varied from over 4.5 and 2.5 times in SSP5 and SSP1, respectively. In the IPCC scenario, SSP5 is associated with "economic growth first", fossil fuel and material intensity in both production and consumption. However, SSP1 was associated with "green growth", most favorable to sustainability. This implies the worst scenario would be the projection of WPI in the business as usual scenario. In other words, Kuwait would expect to pay less for food imports with alternative SSP scenarios than if the current trend continued in the long-term.

The experiments were conducted by classifying domestic food production into primary agricultural production and food processing manufacturing sectors. In aggregate, Kuwait is expected to produce more food domestically with the alternative sustainability scenario. However, the increase in domestic production is expected to come more from food processing and adding value to the food value chain. SSP1 offered a relatively cheaper food import scenario, with cheaper intermediate inputs of primary food products. Cheaper primary agricultural products mean less favorable conditions for local primary producers. SSP5 has already been favoring local agricultural production, which survived by not only large subsidies but also rising food prices in the world market. SSP5 simply projects the current situation into the longer time horizon.

Inevitably, Kuwait will continue to import food, both primary and secondary. The food import-value index rose by just over 200, double the current level. These results are likely to represent conservative estimates of Kuwait's future food imports. The results reported depend on projected world market prices, and results reported are likely to be conservative especially if food prices increase by larger proportions. Sensitivity analysis of the results obtained to the key parameters was not conducted in this study. This emanates from the relatively wide scope of the study ranged from simulation experiments to report. The above drawback will be addressed in subsequent research.

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