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Climate Change and Agricultural Trade in Iran: A Dynamic Input-Output Analysis

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Abstract

In recent decades, the significance of the issue of climate change has escalated due to its intensified impacts, potentially diminishing or halting economic growth, particularly in developing countries and vulnerable sectors such as agriculture. Climate change may be considered the most important and complex human challenge. Among the economic effects, trade variables have been examined inadequately. Accordingly, the focus of this study is to investigate the impact of climate change on the export and import of agricultural products in Iran over a forty-year horizon, which was carried out using a dynamic input-output model. This study uses scenarios of temperature anomaly to examine the impact of climate change on different sectors of Iran's economy. The findings indicate that climate change has a significant impact on the growth of both exports and imports of agricultural products. Under normal conditions without climate change, the average annual growth rate of agricultural product imports is 2.7 percent. However, this rate decreases to 1-1.8 percent when different climate change scenarios are taken into account. Regarding the exports, the corresponding value is 2.75 percent, expected to be reduced to 0.55-1.8 percent. In addition, it was found that agricultural trade will be dominated by cereals import. Also, the total trade of the Iranian economy will change in favor of non-agricultural commodities.

Keywords: Agricultural trade, Climate change, Input-output

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Introduction

Climate change is the most important and complex human challenge (Hoegh-Guldberg, & Bruno, 2010) because it not only has extensive climatic effects, but it will also have significant economic effects (Dell *et al*., 2014; Burke *et al*., 2015). The impact of climate change is multidimensional and not limited to specific regions. However, the main consequence is natural and economic damage (Liu *et al*., 2020), which is directly reflected in economic variables (Farajzadeh *et al*., 2022).

While scientists focused on the reasons and ecological consequences of climate change, economists' concerns centered on the relationship between economics and climate change. Several studies on the role of climate change on the economy began in the 1990s (Tol, 2009). Over the recent decades, with the intensification of the effects of climate change, the importance of this issue has increased because it may decrease or halt economic growth, especially, in developing countries (Piontek *et al*., 2019). A wide range of studies emphasize that a three-degree increase in temperature in different regions may reduce GDP by 5-35 percent, and the highest damages are related to developing countries located in ecologically sensitive areas (Fankhauser & Tol, 2005; Piontek *et al*., 2019; Swiss Re Institute, 2021). Other economic variables such as welfare level, consumption, and price level are also affected by climate change (Farajzadeh *et al*., 2022). The effects of climate change on economic sectors are also different. The agricultural sector holds significant importance due to its heavy reliance on climatic factors. Despite the neglect of climate change effects on the trade of agricultural products, numerous studies have examined the impact of climate change on agricultural output.

One of the main variables studied in this context is the total production of the economy, which has been examined at the sectoral (Vatankhah *et al*., 2020; Manuel *et al*., 2021) and economy-wide levels (Piontek *et al*., 2019; Dalagnol *et al*., 2022). These studies predict a decrease in total production (output) by up to 40 percent. However, other variables are also expected to be affected by climate change accordingly including trade. Most studies related to trade and climate change have focused on the role of free trade in mitigating the effects of climate change (Balogh & Attila Jámbor, 2020). Among the sectors of the economy, the agricultural sector, due to its high importance in food security and its greater vulnerability to climate change, is the focus of empirical works (Pakmehr *et al*., 2020). Accordingly, a significant body of literature related to trade has focused on the effects of trade liberalization of agricultural products on the damages caused by climate change and environmental performance. Some of these studies confirm the reduction of climate change damages caused by liberalization (Weinzettel & Wood, 2018; Walters *et al*., 2017), and others have seen liberalization ineffective or even destructive (Bourgeon and Ollivier 2012; Dang & Konar, 2018; Antonelli *et al*., 2017; Balogh & Attila Jámbor, 2020; Alavi & Mohammadi, 2023). However, to the best of our knowledge, none of the studies in this field have paid attention to the effects of climate change on the export and import of agricultural products.

Iran, as a developing country in an ecologically sensitive area, has always been the focus of climate change and economics researchers. Iran is classified as a dry, and semi-arid region with average rainfall of 250 mm that is less than a third of the global average (Malakootikhah & Farajzadeh, 2020). Also, studies on temperature and precipitation indicate a decrease of 2.1 mm of precipitation and an increase of 0.02 degrees Celsius in recent years (Abbasi *et al*., 2019). The results of the studies conducted in Iran show that the added value of the agriculture sector, productivity, and the production will decrease significantly due to the destructive effects of climate change. Mosavi *et al*. (2020) predicted a 19-26 percent decrease in the added value of the agriculture sector by 2090. Also, Ghaffari Esmaeili *et al*. (2019) confirmed the reduction of agricultural economic variables, including production, consumption, investment, and export, by around 4.5, 5, 4.5, and 14.8 percent, respectively, by 2030.

The above discussion shows that the effects of climate change on the agriculture sector in Iran are significant. Given Iran's sensitive climate conditions, the trade of agricultural products has become increasingly crucial for the country. A substantial portion of agricultural product consumption in Iran relies on imports. For instance, approximately 40 percent of sugar and barley consumption is sourced through imports. Iran's dependence on more basic products such as corn and oilseeds may amount to approximately 80 percent (FAO, 2023). On the other hand, Iran is known as a significant exporter of some products, such as saffron and pistachios. The exports of Iran's agricultural products in 2021 was around USD 2.47 billion, and its share is approximately 3 percent of Iran's total export. The imports of raw agricultural products in 2021 was over USD 13.9 billion, which amounts to 18 percent of the total imports (FAO, 2023; World Bank, 2022).

Most climate change's studies examining the agricultural activities are experimental based studies at regional level, and interactions between activities are not considered. Therefore, it is necessary to use models that consider inter-sectoral and comprehensive interactions, such as Computable General Equilibrium (CGE) and Input-Output (IO). In addition to the CGE model that has been widely used in this field, a more detailed look at the economics of climate change can be made possible with IO models. To the best of our knowledge, empirical works using IO models have a consistent framework and provide a high resolution of economic sectors and structural economic composition (Donati *et al.*, 2020) but are not a well-established approach to the dynamic nature of climate change. Therefore, one of the goals of the present study is to develop a dynamic IO model to investigate the effects of climate change.

The focus of this study is to investigate the effects of climate change on the amount of export and import of agricultural products of Iran in a forty-year horizon, which was carried out using a dynamic IO model. The main concern of the current research is to examine the amount of damage caused by climate change on the trade of Iran's agriculture sector. In this study, the effects of climate change in the form of several temperature change shocks are investigated. The IO model offers the advantage of enabling a comprehensive examination of various sectors within the economy, including agricultural activities. The remainder of this paper unfolds as follows :The second section reviews relevant literature and illustrates the contribution of the present study to the existing body of knowledge. Section three elaborates on the quantitative simulation tools developed. Subsequently, the simulation results are deliberated upon. Lastly, in section five, the conclusion and policy implications are delineated.

Method and data

The analytical tool to examine the effects of climate change on the import and export of agricultural activities is an IO model which will be described in the following section. In the modeling framework, climate change effects are related to I-O via damage function.

Input-Output model

The input-output model is based on the interrelationships between production and consumption and imported products in activities or production sectors. In the IO framework, the total demand for output consists of intermediate and final demand, which, in terms of value, is equal to the payments made to the output producers. The primary step in building an IO model is to divide the economic activities into production sectors and measure the flow between sectors in monetary values. Given that the economy consists of N sectors, the total output of production sector i, X_i is divided into final demand, F_i , and intermediate demand, Z_{ij} , which is the demand of sector j from industry i ; thus, the corresponding equation is written as follows (Miller & Blair, 2009; Liu *et al.*, 2020):

$$X_i = \sum_{j=1}^{N} Z_{ij} + F_i \qquad (1)$$

where X_i is the total product, Z_{ij} is intermediate or interindustry demand, and F_i is the final demand. Final demand includes private and public sector consumption, export and import amount, and other items of final demand. Eq. 1 indicates that the total output or the total supply of sector i is equal to total demand for the sector products, including its own demand. The matrix arrangement of the Eq. 1 is presented as follows. Also, Z_{ij} is related to total output using equation (2):

$$Z_{ij} = a_{ij}X_j \quad (2)$$

which, a_{ij} is known as technical coefficients (Miller & Blair, 2009; Liu *et al.*, 2020).

$$\begin{bmatrix} X_1 \\ \vdots \\ X_N \end{bmatrix} = \begin{bmatrix} Z_{11} & \cdots & Z_{1N} \\ \vdots & \ddots & \vdots \\ Z_{N1} & \cdots & Z_{NN} \end{bmatrix} + \begin{bmatrix} F_1 \\ \vdots \\ F_N \end{bmatrix} \quad (3)$$

The F matrix, which represents the final demand, includes consumer purchases (C), purchases for investment (I), government purchases (G), and net exports (E) (Miller & Blair, 2009).

There are different modeling approaches in IO-based models. The current study applies the supply-side IO model for two reasons. First, climate changes affect the output through three channels, including value-added inputs, as illustrated in the literature (Tsigaris & Wood, 2019; Tol, 2009). Second, as a novel empirical examination, it develops a dynamic modeling approach in which the growth in productivity and endowment of labor and capital accumulation are the primary features (Aroche Reyes & Marquez Mendoza, 2021; Jabilles & et al., 2019).

Analogue to Eq. (2), the payments segment (value-added) (V) has also been added. Payments segment in supply-side representation is divided into, labor payments (L), capital payments (K), and depreciation (D) as follows:

$$\begin{bmatrix} X_1 \\ \vdots \\ X_N \end{bmatrix} = \begin{bmatrix} Z_{11} & \cdots & Z_{N1} \\ \vdots & \ddots & \vdots \\ Z_{1N} & \cdots & Z_{NN} \end{bmatrix} + \begin{bmatrix} V_1 \\ \vdots \\ V_N \end{bmatrix} \quad (4)$$

The matrix arrangement in Eq. (4) can be presented as follows:

$$X = B'X + V \quad (5)$$

where the value of Z_{ij} and X_i is specified in Eq. (3). Matrix B is the allocation coefficient, which is defined as the ratio of the demand of sector j from sector i (Z_{ij}) to the total production of section i (X_i). Matrix B is defined as follows (Miller & Blair, 2009; Galbusera & Giannopoulos, 2018):

$$b_{ij} = Z_{ij}/X_i \quad (6)$$

In relation (5), V is the matrix of the payment segments. Therefore, the total demand (X) is equal to:

$$X = (I - B')^{-1}V \quad (7)$$

Equation (7) shows that any change in the payment to value-added factors will affect the X matrix and then the Z matrix. Regarding Eq. 1, the final demand block, including the net export, may be as follows:

$$F_i = X_i - \sum_{j=1}^{N} Z_{ij} \quad (8)$$

Also, similar to Eq. 2, the matrix form is Eq. 9:

$$\begin{bmatrix} F_1 \\ \vdots \\ F_N \end{bmatrix} = \begin{bmatrix} X_1 \\ \vdots \\ X_N \end{bmatrix} - \begin{bmatrix} Z_{11} & \cdots & Z_{1N} \\ \vdots & \ddots & \vdots \\ Z_{N1} & \cdots & Z_{NN} \end{bmatrix} \quad (9)$$

where, the final demand includes N components, including net export.

In the dynamic model, the yearly evolution of fixed capital influences the total output by affecting the income derived from capital returns. Consequently, the equation governing the movement of fixed capital should be calculated using Equation 10. This equation presents the fixed capital of the following period, which is the sum of the current period investment and fixed capital discounted for depreciation. The related equations are Eqs. 10-12 (Miller & Blair, 2009):

$$K_{t+1} = (1 - \delta_t)K_t + I_t^n \quad (10)$$

$$I_t^n = S_t \quad (11)$$

$$S_t = Q_t - C_t \quad (12)$$

where I_t^n, S_t , and K_t represent investment, total savings, and total physical capital in the period (t). Q stands for total income and C

indicates consumption. δ[1] is depreciation measured as a fixed percentage of the total physical capital. For year $t+1$, the income obtained from capital stock is calculated based on a fixed amount of income for each unit of capital. Similarly, the time path motion of labor productivity (A) is presented by Eq. (13), in which the rate of annual labor productivity growth (g_A) is considered exogenous and fixed (following Eq. 13).

$$A_{t+1} = (1+ g_A)A_t \quad (13)$$

where, labor productivity is grown yearly at a fixed rate of 1 percent, as applied by the related literature for the Iranian economy (AlShehabi, 2013; Gharibnavaz & Waschik, 2015; Farajzadeh, 2018).

Climate change effects

Climate effects block is related to the I-O via damage function. This includes three channels of interrelationship. Climate change may damage output directly, known as the output level effect. Other channels are capital stock depreciation, and loss in productivity growth (Tsigaris & Wood, 2019) which affect output indirectly. Damage function (D) is defined as a convex function related to the temperature anomaly (T_t) relative to the pre-industrial level (Weitzman, 2012; Dietz & Stern, 2015):

$$D_t = 1 - \frac{1}{(1+\pi_1 T_t+\pi_2 T_t^2+\pi_3 T_t^{6.754})} \quad (14)$$

In the standard damage function from the DICE model[2], for the temperature anomaly of 2-3 ºC (N-damages), π_3=0. As presented by Eq. 15, the damage function is incorporated into the production function (Weitzman, 2012; Dietz & Stern, 2015, Farajzadeh *et al.*, 2022):

$$X_t^N = (1-D_t^x) f_{(Z_{1N}, \,\ldots,\, Z_{NN}, F_N)} \quad (15)$$

where D_t^x is the damage factor for the output level component in time t defined by Eq. 16 (Dietz & Stern, 2015):

$$D_t^x = 1 - \frac{(1-D_t)}{(1-D_t^K - D_t^A)} \quad (16)$$

D_t^K and D_t^A are other components of the damages related to capital stock and labor productivity, respectively, which are quantified as follows (Dietz & Stern, 2015):

$$D_t^K = f^K D_t \quad (17)$$

$$D_t^A = f^A D_t \quad (18)$$

f^K and f^A are allocated values of 0.3 and 0.05, respectively (Dietz & Stern, 2015). Accordingly, the corresponding motion equations of the value-added factors adjusted for climatic effects are presented in Eq. 19 and 20 (Farajzadeh *et al.*, 2022):

$$A_{t+1} = (1-D_t^A)(1+ g_A)A_t \quad (19)$$

$$K_{t+1} = (1-D_t^K)(1-\delta_k)K_t + I_t^n \quad (20)$$

The effects of climate change $(D_t^A \text{ and } D_t^K)$ are not expected to be the same for different sectors. It is worth noting that there is a widely held view that climate change is expected to affect the agricultural sector more significantly than the telecommunications sector, that are less dependent on climatic variables.

Now, we may rewrite the above-mentioned equations incorporating the climate effects. Thus, the corresponding to Eq. (7) will be presented as Eq. (21):

$$X_{t+1} = (1-D_t^x)\,(I-B_t')^{-1}V_t \quad (21)$$

Eq. (21) indicates that under the climate change effect, part of the total output will be lost in the next period due to the damage caused by climate change as D_t^x is allocated a value between zero and one.

Scenario setting

The BAU (Business as Usual) condition ignores the effects of climate change. This study uses scenarios of temperature anomaly (temperature increase shock) to examine the impact of climate change on different sectors of Iran's economy. The first scenario is the warming tendency under the Representative Concentration Pathway (RCP) model, i.e., RCP 2.6 (1.5–2 degrees Celsius Global Mean Temperature Increase). Other scenarios are

1 - The effective rate of depreciation applied in the modeling is 3.95 percent every year (Farajzadeh *et al.*, 2022)

2 - Dynamic Integrated model of Climate and the Economy (the DICE model) attempts to use the tools of modern economics to determine an efficient strategy for coping with the threat of global warming (Nordhaus, 1992).

RCP4.5 (2.5 – 3 degrees Celsius Global Mean Temperature Increase), RCP6 (3 – 3.5 degrees Celsius Global Mean Temperature Increase), and RCP8.5 (5 degrees Celsius Global Mean Temperature Increase). The scenarios for the damage function used in the present study are W-damage and DS-damage. After analyzing climate change in the form of scenarios, the results of each scenario on Iran's economy are studied in the form of the IO model. SSP1-1.9 W is considered to have the least damage, and the most damage is related to the SSP5-DS scenario.

Data

The primary data applied for this study includes Iran's IO table published by the Central Bank of Iran (2016). Another primary data is the damage caused by climate change, which for non-agricultural activities, was mainly obtained from Farajzadeh *et al.* (2022). For agricultural activities, the Iranian Environmental Organization (2021) provides the data for the current production damages. Also, the damages to agricultural natural resources were calculated based on data presented by the UNFCCC report (2017). The data issued in the Iranian literature (Dalir *et al*., 2021; Malakootikhah & Farajzadeh, 2020) was used to calculate the damages to the forestry sector. Other variables including labor productivity growth and physical capital depreciation, were extracted from Farajzadeh *et al*. (2022). Temperature anomaly and projection average temperature based on CMIP6 by 2060 were obtained from the World Bank Climate Change Knowledge Portal (CCKP, 2022).

Results

In this study, the results of changes in the volume of imports and exports due to climate change with other conditions being constant, are given under different scenarios. Fig. 1 shows the temperature time path under different scenarios. The highest temperature increase in the early years is associated with the SSP1-1.9 scenario, but the SSP5-8.5 scenario predicts the most severe temperature increase. The annual average temperature of Iran until 2060 is predicted to be higher than 21°C, which is 2.5°C higher than the current average. The lowest temperature anomaly is more than 0.5°C, which is expected to happen under SSP1-1.9.

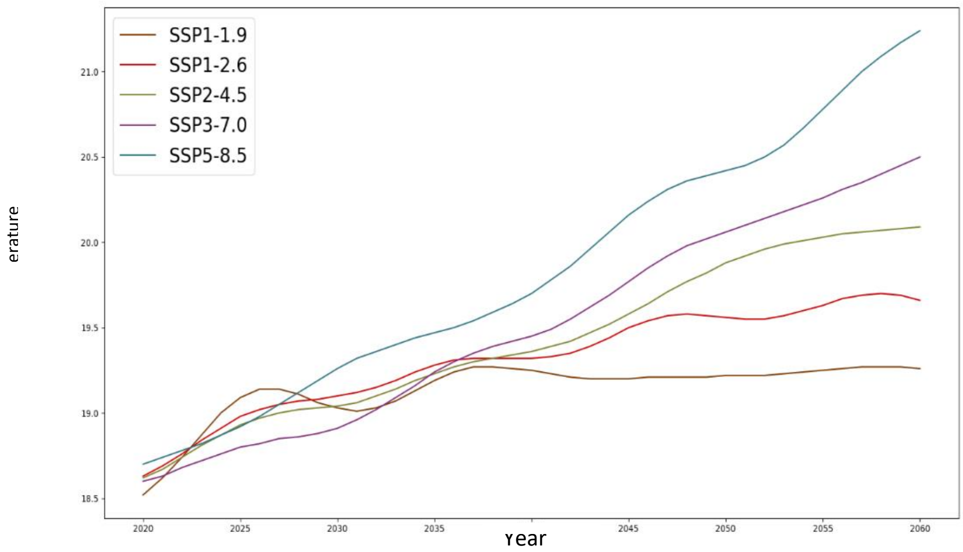

Figure 1- Temperature time path under different scenarios

The alterations in exports and imports resulting from the impacts of climate change stem from three key factors: labor productivity, capital, and final output. Figs. 2 and 3 show the combination of damage from these channels. Fig. 2 shows the decomposition of damages on the import of total agricultural products. In all scenarios, output damage has the most significant contribution, and the lowest contribution is related to labor productivity damage. Output channel accounts for around 39 percent of output damage under SSP1-2.6 and it increases to more than 41 percent under SSP 3 and SSP5. The corresponding values for productivity damage range 26-28.5 percent, while the capital damage channel will be allocated 32-34 percent. In terms of damage share, the W-scenarios contribute slightly more to output damage compared to the DS scenarios, although the difference is minimal. Conversely, higher temperature anomaly scenarios are associated with greater shares of output damage and reduced contributions from productivity sources. These results suggest that in scenarios with more stringent temperature increase levels, the most immediate impact of damage (output damage) plays a more significant role.

Figure 2- Contribution of damaging channels to import

Fig. 3 shows the decomposition of damage sources for the export of agricultural products. Here, as in import, a larger share belongs to output damage, while compared to import, output damage is more significant. In other words, the level or direct effects will be more determinant in the export of agricultural commodities. In the SSP1-2.6 DS-scenario, the labor productivity damage share is 22 percent, and the output damage share is 49 percent, and under the SSP5 DS-scenario, the corresponding values are 21 percent and 48 percent, respectively, which shows a slight change in share values. Contrary to import results, for export, the W and DS scenarios results illustrate more differences. For instance, regarding the W-scenarios, the share of output damage ranges from 40 percent to 49 percent and the corresponding range for labor productivity damage is from 28 percent to 22 percent. In addition, it is worth noting that, to a great extent, in terms of damage share, there is a trade-off between productivity and direct effect of damage (output damage) while the damage share of capital remains with slight variations. This may arise from the fact that under marginal conditions of production, the role of rival inputs is more than productivity growth.

Figure 3- Contribution of damaging channels to export

Fig. 4 and Table 1 show changes in the volume of imports of agricultural products. BAU shows that the annual growth of total agricultural imports is 2.73 percent per year on average. Among the agricultural sectors, livestock has the highest import growth, with an annual growth of 2.8 percent, and forestry has the lowest growth, around 2.65 percent. In other words, under the current situation, there is an insignificant difference among the agricultural sectors, and the time path shows an increasing trend for all sectors.

As shown in the first column (Table 1), around 31 percent of imports are allocated to livestock, followed by cereals with a contribution of more than 25 percent. In other words, the livestock industry and the cereals that contribute to providing protein food item are responsible for more than 56 percent. Rice and oilseeds account for 19.5 and 14 percent, respectively.

Contrary to the ever-increasing trend under BAU, with the application of climate change scenarios, a significant divergence is observed.

Cereals, rice, fishery, and aquaculture exhibit lower susceptibility to climate change across all climatic scenarios, with their overall trend closely aligning with the business as usual (BAU) scenario. In contrast, other sectors experience substantial impacts from climate change, with import trends significantly declining compared to BAU. Particularly notable is the decreasing trend observed in sectors such as oilseeds and sugar beet. The average growth of imports of the total agricultural sector, compared to the BAU, decreases for all scenarios. This reduction is 0.95 percent for the optimistic scenario and 1.7 percent for the pessimistic scenario per year (Table 1 and Fig. 4). The total output at the economy-wide level and the decrease in disposable income are responsible for these changes.

Among the agricultural sub-sectors, the decline in oilseed imports is more pronounced compared to other products. In the SSP5-DS scenario, the average change in the import of this product is -2.49 percent. Conversely, the reduction in cereal imports is comparatively less significant. Additionally, it's noteworthy that the amount of cereal imports decreases with the mitigation of damage across different scenarios. The cereals import trend, even under the most restricting scenario, remains above 2 percent, ranging from 2.05 to 2.30 percent. Regarding the current population increase of 1.24 percent (Statistical Center of Iran, 2022), this figure shows an increase in per capita consumption, which is in accordance with expectations since the current consumption of Iranian households is not high enough. Regarding import growth, cereals are followed by fishing and aquaculture products. The above range for these sectors is 1.7-2.05 and 1.5-1.9 percent, respectively. These ranges are higher than those of aggregate agriculture.

The import fluctuations for other agriculture and livestock, which constitute a substantial portion of agricultural output, exceed 1 percent in all scenarios except for SSP5. Regarding production interrelationships, there is a close association between livestock and cereals. Higher import growth of creels, which is accompanied by lower import growth of livestock output, may indicate that the domestic output of livestock produced by imported cereals provides higher output, requiring lower levels of import of livestock products. In all scenarios, cereals import grows over 2 percent, while the corresponding value for livestock is mostly less than 1.5 percentOverall, the changes in agricultural imports tend to favor cereals and aquaculture products, while other crops, particularly those utilized as intermediate inputs in food processing activities, are projected to experience declines in imports. In order to provide a comparison, in the last row of Table 1, the import value and the changes in non-agricultural import are also presented. Under all climatic scenarios, the import growth of non-agricultural commodities is higher than that of agricultural ones. The import growth of agricultural commodities is almost less than 1.5 percent while for non-agricultural one is around 1.9-2 percent. It is also worth noting that the value of the current imports of agriculture is less than 7 percent of total imports, and under climatic scenarios, this value will be dampened.

As is shown in Table 1, climatic scenarios are examined under two options of the damage function, i.e., W-damage and DS damage. It seems that the effect of damage option is more significant under higher temperature anomalies compared to the lower ones. For example, under SSP1-1.9, the import growth of agriculture in W and DS options are 1.61 and 1.60, and the corresponding values for scenario SSP5 are 1.12 and 1.03. The same implication is observed for non-agriculture as well. In terms of the extent of the effects, there are substantial differences between sectors.

Table 1- Import growth under different scenarios

	Base Year (10^ 6 Billion Rls.)	BAU	SSP5-DS	SSP5-W	SSP3-7.0 D	SSP2-4.5 D	SSP1-2.6 D	SSP3-7.0 W	SSP2-4.5 W	SSP 1-2.6 W	SSP 1-1.9 W
Agriculture	185.2	2.73	1.03	1.12	1.33	1.45	1.60	1.36	1.46	1.61	1.78
Wheat	2.4	2.72	0.13	0.19	0.81	1.08	1.40	0.83	1.09	1.41	1.69
Rice	36.1	2.71	1.48	1.56	1.70	1.76	1.81	1.72	1.77	1.81	1.86
Cereal	47.8	2.73	2.18	2.29	2.17	2.14	2.09	2.20	2.15	2.09	2.05
Oilseeds	26.0	2.73	-2.49	-2.44	-1.29	-0.72	0.07	-1.27	-0.71	0.07	0.95
Sugar beet	0.2	2.72	-1.51	-1.45	-0.45	-0.43	0.66	-0.42	-0.42	0.66	1.30
Livestock	57.3	2.80	0.62	0.71	1.17	1.36	1.59	1.19	1.37	1.60	1.81
Forestry	9.5	2.65	-0.29	-0.28	0.15	0.35	0.65	0.16	0.35	0.65	0.98
Fishing and aquaculture	0.2	2.73	1.72	1.84	1.91	1.96	2.00	1.94	1.97	2.00	2.04
Other Agriculture	5.6	2.74	0.34	0.41	0.99	1.24	1.53	1.02	1.25	1.53	1.79
Non-Agriculture	2589.8	2.73	1.67	1.85	1.91	1.96	2.00	1.95	1.97	2.00	2.04

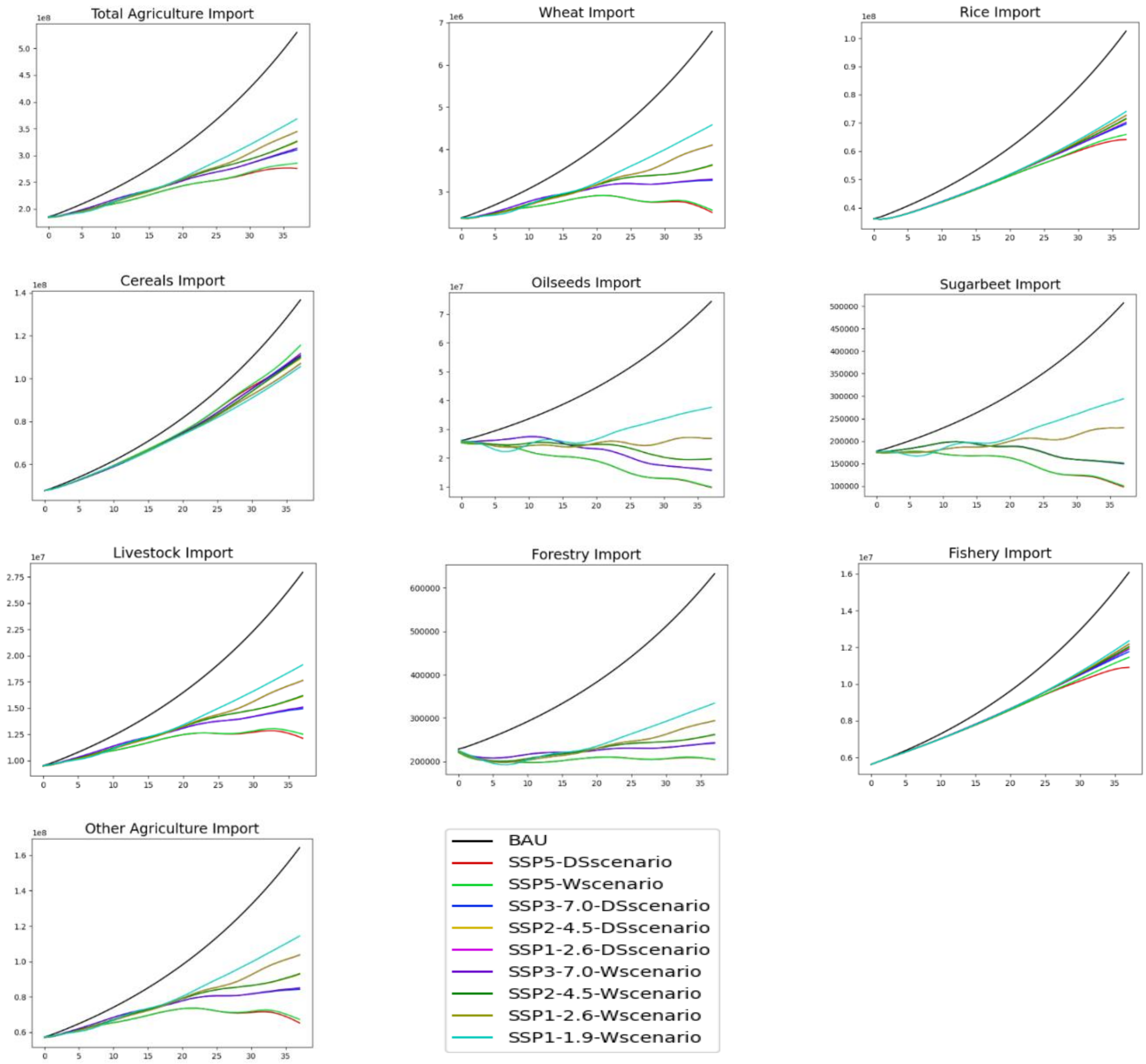

Figure 4- Time path of imports under different scenarios

X-axis indicates time horizon and Y-axis shows corresponding values in Rials multiplied by exponents

In terms of exports, agricultural activities account for only around 3 percent. It is worth noting that energy-related commodities account for most of Iranian exports. Livestock products account for more than two-thirds of agricultural exports, followed by forestry, contributing to 22 percent of agricultural exports. Around 9 percent of agricultural export is also allocated to other agricultural products that are mainly horticultural products.

Table 2 and Fig. 5 show the status of agricultural export growth. In the base year, the total export volume of agricultural products is less than half of the import, but the annual growth rate of exports in BAU conditions is estimated to be 2.75 percent on average. Among the subsections, livestock has the highest export growth, with an annual growth of 2.8 percent. On the other hand, the export of wheat, rice, oilseeds, and sugar beets is zero. In general, the export trend of the agricultural sector is increasing under different scenarios; however, it is less substantial compared to the increasing import trend, and only under the SSP1- 1.9 W scenario, the annual growth trend of exports exceeds imports.

Partially, the growth trend of cereals, and fishery and aquaculture exports show the lowest damage, so the growth trend of cereals exports will not be less than 2 percent per year under any of the scenarios. However, it should be noted that the amount of grain exports in the base year is slight. Regarding aquaculture, the amount of export is three times the amount of import in the base year, and the annual growth rate of its export is between 1.7 and 2.04 under different scenarios.

Since Iran does not export wheat, rice, oilseeds, and sugar beet, the export change for these products is zero. When considering the export of other goods, forestry exhibits the lowest rate of export growth at 2.65 percent per year. Intriguingly, this sector also experiences the highest damage from climate change. Under the most restricting scenario, the annual growth rate of forestry exports is -0.29 percent, and under the most optimistic scenario it is 0.98 percent, which is significantly lower than other sectors.

Climate change will reduce non-agricultural exports growth since its current annual growth of 2.7 percent is lower than those under climatic scenarios. However, the corresponding value for agricultural export is lower. Under the BAU, the export growth is around 2.7 percent for both agricultural and non-agricultural commodities; however, climate change cut the growth by half for most scenarios. This indicates that under climate change, export composition is expected to be more inclined toward non-agricultural commodities.

Table 2- Export growth under different scenarios

Sections Scenarios	Base Year (10^ 6 Billion Rls.)	BAU	SSP5-DS	SSP5-W	SSP 3-7.0 D	SSP 2-4.5 D	SSP1-2.6 D	SSP3-7.0 W	SSP2-4.5 W	SSP1-2.6 W	SSP1-1.9 W
Agriculture	90.7	2.75	0.56	0.64	1.12	1.34	1.59	1.15	1.35	1.59	1.81
Wheat	0.0	0	0	0	0	0	0	0	0	0	0
Rice	0.0	0	0	0	0	0	0	0	0	0	0
Cereals	0.3	2.73	2.18	2.29	2.17	2.14	2.09	2.20	2.15	2.09	2.05
Oilseeds	0.0	0	0	0	0	0	0	0	0	0	0
Sugar beet	0.0	0	0	0	0	0	0	0	0	0	0
Livestock	61.7	2.80	0.62	0.71	1.17	1.36	1.59	1.19	1.37	1.60	1.81
Forestry	20.1	2.65	-0.29	-0.28	0.15	0.35	0.65	0.16	0.35	0.65	0.98
Fishing and aquaculture	0.6	2.73	1.72	1.84	1.91	1.96	2.00	1.94	1.97	2.00	2.04
Other Agriculture	7.9	2.74	0.34	0.41	0.99	1.24	1.53	1.02	1.25	1.53	1.79
Non-Agriculture	3250.6	2.73	1.67	1.85	1.91	1.96	2.00	1.95	1.97	2.00	2.04

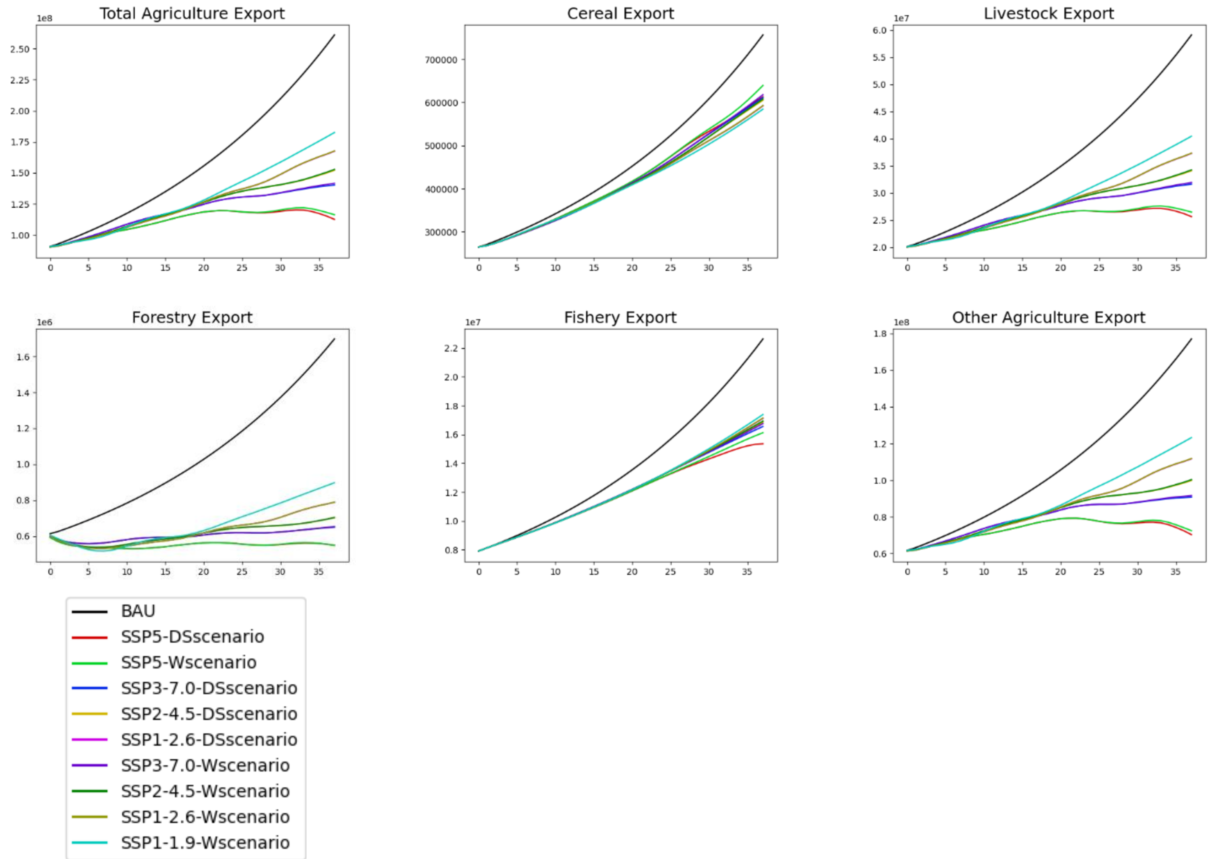

Figure 5- Time path of exports

X-axis indicates time horizon and Y-axis shows corresponding values in Rials multiplied by exponents

To analyze the import and export of agricultural commodities collectively, the trade balance is evaluated. Regarding net exports, agricultural commodities can be divided into two groups. As depicted in Fig. 6, the import of wheat, rice, grains, oilseeds, and sugar beet products notably exceeds their exports, leading to a negative trade balance for these items. Consequently, the overall export of the agricultural sector is lower than its import. The interesting point is that climate change leads to a higher trade balance in this category since it induces a more significant reduction in their import compared to their export. Especially in the last decade of the simulation horizon, improvement in trade balance tends to increase significantly. Among the sectors, oilseeds and sugar beet, for some scenarios, approaches to positive net export values. Export of livestock, forestry, aquaculture, and other products in the base year is more than their import, and the trade balance is positive. For this group, also, climate change dampens the net export potential. Especially for forestry, climate change wears out the potential. This is due to significant damage to natural resources in this sector.

Conclusion

Agricultural trade in Iran is remarkably subjected to trade barriers like tariffs or non-price barriers such as quotas. In addition, the prohibitive sanctions have also restricted trade, including agricultural trade. There is evidence supporting the positive effect of economy-wide trade liberalization (Farajzadeh *et al.*, 2017) and agricultural free trade (Farajzadeh *et al.*, 2012; Zolanvari Shirazy & Farajzadeh, 2023). This implicitly may indicate that there is potential in the Iranian economy, including agriculture, to benefit from free trade. However, climate change, especially at the higher temperature anomalies, harms the possibility of enjoying the advantages.

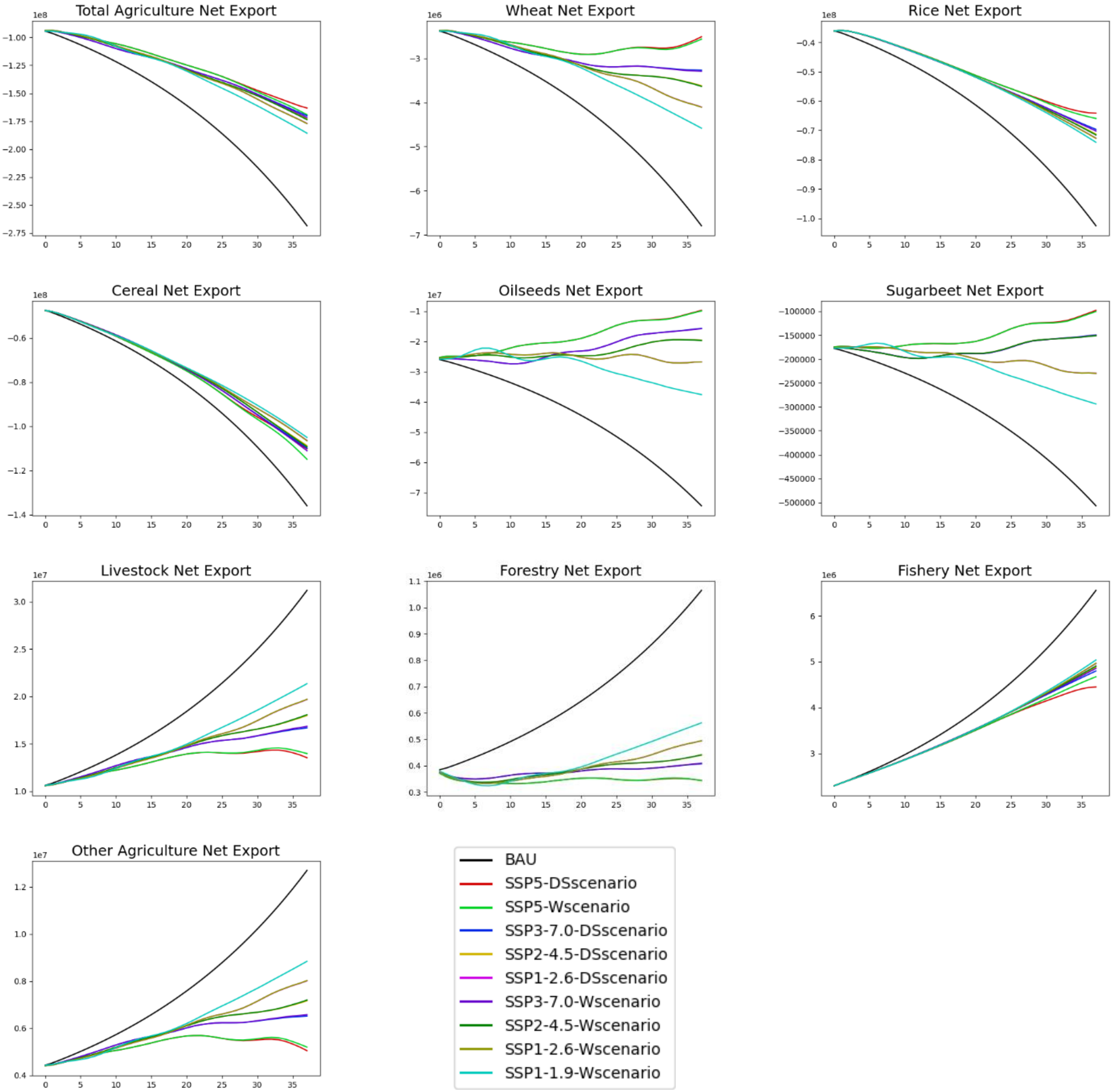

Figure 6- Time path of trade balance (net export)

X-axis indicates time horizon and Y-axis shows corresponding values in Rials multiplied by exponents

Based on this, active participation in trade, especially in the less climate vulnerable sectors, partially offsets the negative impact of climate change on production, capital and labor productivity, and further improves the economy's capacity for more trade in climate vulnerable sectors. However, there is a difference between the channels of damage and different measures to dampen the adverse effects. Damage to output level may be more complicated, while two other channels, i.e., productivity and capital damage, sound more straightforward. Developing measures to increase the capital resistance against depreciation and technologies enhancing labor’s ability to perform under severe conditions should be considered. However, especially for export, around half of the damages are carried out through output level damage indicating significant damage to output.

Climate change is anticipated to alter the trade composition both at the economy-wide level and within agricultural sectors at the national level. Non-agricultural trade is projected to expand relatively, while at the sectoral level, cereals, livestock, and forestry are expected to play a more prominent role in trade compared to other activities. Total net export of agriculture is expected to be improved via, to a great extent, a reduction in import; however, this should be addressed more deeply since output expansion of water-intensive products such as cereals will be difficult. During the years 1988 to 2017, Iran's average rainfall decreased by 2.1 mm, and on the other hand, the average temperature increased by 0.025 degrees Celsius (Abbasi *et al.*, 2019). Since Iran is located in an arid and semi-arid region, this decreases in rainfall and increase in temperature, which will continue in the coming years, will have wide-ranging effects on the production of water-intensive products. Therefore, the cultivation of less water-intensive crops can highlight the importance of the role of Iran's agricultural sector in trade.

The current situation of the Iranian economy, including agricultural, is characterized by government dominance in policy adoption, leading to limited advantages from a market-based economy. Thus, significant reform will be expected in the agricultural sector. Climate change will put pressure on agricultural trade; however, there is a wide held view that agriculture may benefit from these reforms (Zolanvari Shirazy & Farajzadeh, 2023). Therefore, it is recommended to proceed with the reforms along with the climate change occurrence.

Although agricultural trade and especially its export may be dampened based on the current situation of the Iranian economy as depicted by the IO table of 2016, there is some evidence that may provide more chances for agricultural export expansion. For example, adopting environmental restrictions may grant agricultural exports because of its less energy and emission intensity especially if it is accompanied by higher efficiency in natural resources use (Jebli & Youssef, 2017; Baker *et al.*, 2018; Dang & Konar, 2018).

Overall, as outlined in the literature, there exists substantial potential for agricultural trade, particularly agricultural exports. However, climate change poses a threat to this potential, necessitating the implementation of policies and actions to mitigate the damages caused by climate change. Trade liberalization and the reduction of export barriers can serve as crucial measures in alleviating the effects of climate change on agricultural trade. A possible extension for the current study that other empirical studies may investigate is the climate change effect under trade liberalization. Iranian agricultural trade will be significantly important in both exports and imports. As far as export is concerned, the necessity of expanding non-oil export revenues assigns a high priority to agricultural export.

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تغییر اقلیم و تجارت کشاورزی در ایران: تحلیل داده-ستانده پویا

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چکیده

در دهه‌های اخیر با تشدید پیامدهای تغییر اقلیم، اهمیت این موضوع فزونی یافته است. زیرا ممکن است این پدیده در کشورهای درحال توسعه و به‌ویژه در مورد فعالیت‌های کشاورزی، موجب کاهش رشد اقتصادی یا توقف آن شود. می‌توان تغییر اقلیم را مهم‌ترین و پیچیده‌ترین چالش فعلی جامعه بشری تلقی نمود. در همین راستا مطالعه حاضر کوشیده است پیامدهای تغییر اقلیم را در حوزه صادرات و واردات محصولات کشاورزی در طی یک افق ۴۰ ساله و با استفاده از مدل داده-ستانده پویا ارزیابی کند. تغییر اقلیم به‌صورت سطوح مختلفی از ناهنجاری دما منظور و پیامدهای آن در بخش‌های مختلف اقتصاد ارزیابی شد. یافته‌ها نشان داد تغییر اقلیم رشد صادرات و واردات بخش کشاورزی را بشدت تحت تأثیر قرار می‌دهد. متوسط رشد سالانه واردات کالاهای کشاورزی در شرایط بدون تغییر اقلیم ۲/۷ درصد است، در حالی‌که در شرایط تغییر اقلیم و تحت سناریوهای مختلف افزایش دما به ۱/۸-۱ درصد کاهش می‌یابد. مقادیر متناظر برای صادرات کشاورزی به‌ترتیب ۲/۷۵ و ۱/۸-۰/۵۵ درصد است. افزون بر این، مشخص گردید در شرایط تغییر اقلیم بخش مهمی از تجارت کشاورزی را واردات غلات تشکیل می‌دهد. هم‌چنین نتایج نشان داد تجارت کل اقتصاد ایران به سمت کالاهای غیرکشاورزی بیش‌تر متمایل خواهد شد.

واژه‌های کلیدی: تجارت کشاورزی، تغییر اقلیم، داده-ستانده

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