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Impacts of climate change on food security and agriculture sector in Malaysia

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Abstract This study attempts to analyze the short- and long-run impacts of the probable change in rainfall and temperature simultaneously on food availability and access to food issues, as the two dimensions of food security, in Malaysia. It uses an integrated method comprising of a stochastic method and a computable general equilibrium model using the latest (2010) input–output table published in 2015. The stochastic method, which relates to the Monte Carlo simulation, provides the probable changes in rainfall and temperature patterns and their probability of occurrence based on historical data of rainfall and temperature and crop productivity. It was found that, simultaneous variation of rainfall and temperature, in both the short- and long-run, contracts the economic performance of Malaysia. Findings also show the negative impact of rainfall–temperature variability, in both time periods, on food availability and access to food due to a reduction in the supply of agricultural products, a commodity inflation pressure and a reduction in household income. Moreover, results suggest that the climate variability shocks lead to a reduction in the consumption and welfare of all household groups, particularly in rural areas.

Keywords Climate change factors · Rainfall and temperature variation · Monte Carlo simulation · Risk analysis · Food availability · Access to food · CGE

This paper investigates the impacts of rainfall and temperature variation on food security and agriculture sector in Malaysia. The novelty of this paper is simultaneous analysis of both rainfall and temperature on the agriculture sector and food security in Malaysia. Another is that it can show the readers the short- and the long-run impacts of this shock on food security in Malaysian community which did not attention in the previous literature.

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1 Introduction

In the early stages of industrialization, countries without any attention to environment destroyed it dramatically. Finally, they found that they must attention to environment seriously. In recent decades, climate change and its impacts on economic and the livelihood of people have become the major issues for scientists and policymakers in all around the world. Climate change directly influences agriculture sector most seriously compared to other economic sectors. Therefore, this sector is the most vulnerable to climate change, particularly in the tropical area like Malaysia. Climate change affects agriculture sector through decreasing its production, increasing food insecurity and by changing sea level can affect the supply chain of this sector (Vaghefi et al. 2011; Zainal et al. 2012). Branca et al. (2013) believe that sustainable land management practices, as a substantial component of food security, can increase crop productivity. Brown and Funk (2008) stated that food insecurity increases by climate change. All four dimensions of food security, i.e., food availability, access to food, food utilization and food supply, influence negatively from changes in climate (Schmidhuber and Tubiello 2007). Moreover, food system, which encompasses the above first three dimensions of food security, also stresses by climate change and other agents of environmental change (Gregory et al. 2005). Nevertheless, a national food security strategy, which is able to identify the mechanisms, institutions and resources of the country, is necessary to protect the society from climate change factors (Stamoulis and Zezza 2003).

Climate change has different impacts on economic and livelihood of communities. For example, over and lower levels of precipitation and temperature influence agriculture sector more seriously and destroy crop yields significantly. Thus, they lead to food insecurity and increase the limitation on food availability for societies, especially for poor people in developing countries. On the other hand, climate change by decreasing the production of agriculture sectors decreases the income of economic factors resulting in a decrease in the purchasing power of workers to buy foods and other necessity goods, which declines access to food in the society.

As Malaysia is located in a wet weather, its crops significantly are sensitive to the normal precipitation and temperature while the impacts on agriculture differ from one crop to the other. Therefore, changes in rainfall and temperature pattern could affect yields directly. As discussed by Rahim (2014), climate change factors, such as a rise in temperature and changes in rainfall pattern, affect Malaysia's yield directly or indirectly through fastening the spread of fungus and diseases in the agriculture sector. However, Schlenkera and Roberts (2009) highlighted that normal temperature is necessary for yield growth and increases its production, while higher ranges of temperature decrease it sharply. The areas such as the northern Peninsular Malaysia and the coasts of Sabah and Sarawak are the most vulnerable to these problems. For example, Alam et al. (2014) and Zainal et al. (2014) addressed that both temperature and rainfall affect the production of paddy most seriously. Moreover, Zainal et al. (2012) found that the agricultural production in Peninsular, Sabah and Sarawak lose between 37RM and 48RM per hectare by an increase in temperature and precipitation.

Rahim (2014) also showed that if the weather for a long time faces with the lower and higher levels of rainfall, they are harmful to crops and jeopardize the security of food supply. However, farmers can solve low levels of rainfall through irrigation, but they cannot control high rainfalls, and at the end of the crop cycle, they cause destructive damages on output and lead to serious damages to crops (Alam et al. 2011). Therefore, the rainfall and temperature times are very important during an agricultural outcome cycle not only in Malaysia but also for all around the world.

In 1996 World Food Summit, the food availability and access to food, as considered above, introduced as the two main dimensions of the concept of food security (FAO 1996).[1] As Malaysia's agricultural crops and food security heavily influenced by the variation of climate factors, this paper by applying an integrated approach (computable general equilibrium (CGE) model is integrated with a stochastic analysis) and based on predicted values of rainfall–temperature captured by the risk analysis, attempts to answer the following questions. What is the short- and long-run probably changes in productivity of major agricultural products and their probability of occurrence caused by simultaneous variability in rainfall and temperature? Hence, what is the short- and long-run impact of such changes on food availability and access to food and on the entire economy of Malaysia? Therefore, it is possible to suggest two main and testable hypotheses. The first is that simultaneous change in rainfall and temperature decreases the productivity of major agricultural products in Malaysia. Second, the variation in precipitation–temperature declines food availability and access to food in the country. It should be noted that the rainfall and temperature patterns mean the trend variation of these variables.

The rest of the study is organized as follows. Section 2 provides an overview of the Malaysia's economy and agriculture sector. Section 3 describes methodology and data of the study. Section 4 shows the estimation of the stochastic equations. A discussion on the results of the CGE model is provided in Sects. 5 and 6 concludes the results.

2 Agriculture sector in Malaysia

This section reviews agriculture sector and some aspects of food security in Malaysia, but before that, it is necessary to discuss overall Malaysian economy. In 2015, the preliminary Malaysia's real GDP was 1062.8 RM billion by a growth rate of 5%. The main contributor to real GDP was service sector by 53.53% followed by manufacturing (22.98%), mining and quarrying (8.95%), agriculture (8.85%) and construction (4.39%). In this year, total export and imports of goods and services were 774.7 RM billion and 683.5 RM billion accounted to an annual growth rate of 0.6 and 1.2%, respectively. Malaysian households consumed about 556.6 RM billion and invested about 179.3 RM billion in this year (EPU 2016).

The agriculture sector plays an important role in economic development of Malaysia. Before industrialization, this sector was the major contributor to Malaysian economy in the production of agricultural products for domestic consumption and providing foreign exchange. While the agriculture does not have a very significant share in gross domestic products (GDP), it employs a high proportion of the labor force and an important source of income for Malaysian households, particularly in rural areas. In 2014, this sector employed about 1.7 million people or 12.3% of the total Malaysia employment. While the share of agriculture to Malaysia GDP has declined over time, in 2015, its contribution to the GDP increased and was about 8.9%. The production of palm oil increased from 60.6 million tons in 2005 to 72.7 million tons in 2014. The production of rubber, on the other hand, has

[1] "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit 1996). This definition encompasses four dimensions of food security namely, Food availability, Food access, Utilization of food and Stability of food supplies.

declined by 18.07% during 2005–2014 (Fig. 1). This shows that the investment on palm oil has increased significantly, and resources from rubber and other agricultural sectors have moved to this sector.

The main aim of farming and producing of agricultural products is food security. One of the development stages, as happened in developed countries, is independence in the production of some strategic agricultural products such as rice and wheat. Malaysia is not an exception in this context, and the government and agricultural policymakers have attempted to increase the production of agricultural products to achieve this goal. One of the policies that implemented in Malaysia for this purpose is the national agro-food policy (NAP4) (2011–2020). This policy was introduced to achieving sustainable production of foods for food security and safety goal (KADA 2011).

However, Malaysia is a net importer of foods as the production cost of the agricultural products is high resulting in a lower comparative advantage in the production of food items (Fig. 1). This situation leads to lower production of foods and larger share of cash crops. Accordingly, the government is supporting the main food items, such as rice, through paying subsidies and controlling their prices.

3 Methodology

We first estimate the scenarios (rainfall–temperature predictions) according a risk analysis, which is based on the Monte Carlo method. Then, we use the outcomes of the risk analysis, as inputs, in the general equilibrium model to analyze the short- and long-run simultaneous impacts of the change in rainfall and temperature on food availability and access to food and on entire economy of Malaysia.

3.1 Stochastic method

In order to estimate the risk analysis, following Sassi and Cardaci (2013) study we first define a parametric model to find out the simultaneous impacts of rainfall and temperature on the productivity of different crops as follows[2]:

$$X_{it} = \alpha_1 \mathrm{TEMRF}_t + \alpha_2 \mathrm{TEMRF}_t^2 + \alpha_3 T_t + \varepsilon_t \tag{1}$$

where X_i represents the productivity of crop i (i = paddy, food crops, palm oil and rubber,) at time t. Yield is declared in kg per hectare, TEMRF is the multiplication of rainfall (millimeter) and temperature (degree Celsius) variables, as there is an interdependency between rainfall and temperature (Cong and Brady 2012; Wen and Sidik 2011). The parameters $\boldsymbol{\alpha_1}$, $\boldsymbol{\alpha_2}$ and $\boldsymbol{\alpha_3}$ are the coefficients of the model that will be estimated; T is the time trend and $\boldsymbol{\varepsilon}$ is the random error term. The crops productivity and rainfall and temperature data for estimating Eq. 1 gathered from the department of statistics. All variables are time series data from 1980 to 2014 period. Figure 2 represents the trends of rainfall, temperature and crops production per hectare in Malaysia during 2000–2014.

We assign a probability distribution function (PDF) to each of the input stochastic independent variables. After a number of steps (such as calculating the model output many times, choosing randomly new values for each input, saving the outputs), a probability distribution value generate for the output values (see Hayse (2000) for details).

[2] Choosing the parametric model was based on primary assessments of results, testing alternative samples (linear, log–log, and log-linear) and other functional forms.

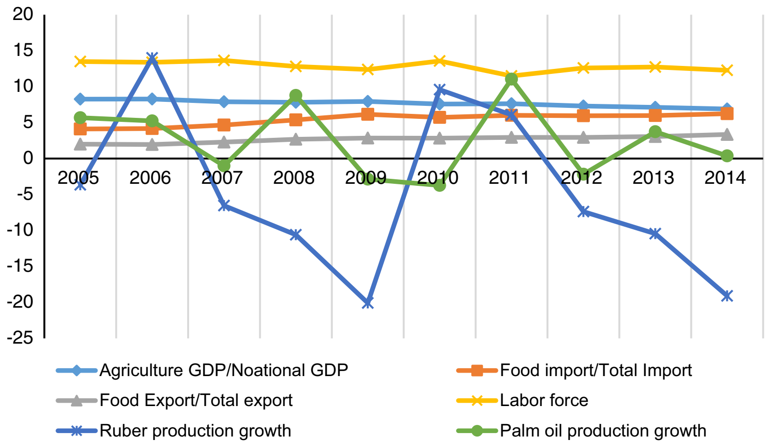

Fig. 1 GDP and other agricultural indicators. *Source*: Author's calculation based on Department of Statistics databases

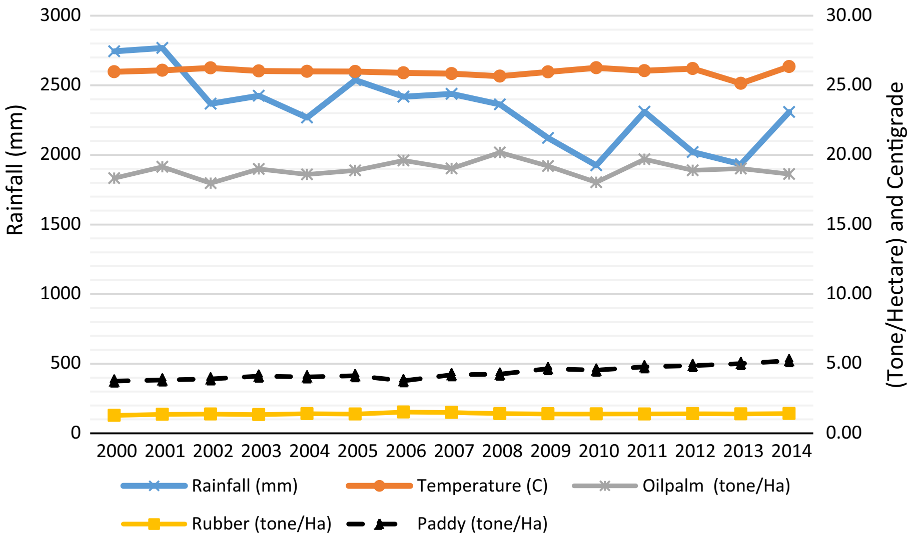

Fig. 2 Trends of rainfall, temperature and crops production in Malaysia during 2000–2014

We expect that the sign of the first variable (TEMRF) is positive and the second variable ($TEMRF^2$) is negative, as normal rainfall and temperature are useful for yield crops and over and lower levels of both are harm for crop production. Previous studies also argued a positive and negative relationship between crop productivity and rainfall–temperature and its square value, respectively (Eboh et al. 2012; Teklu et al. (1991); Hatfield and Prueger 2015; Schlenkera and Roberts 2009).

The probable values of rainfall–temperature and its square are represented by a probability density function (PDF) with the lower bound equals to zero and the upper bound limited but unknown. Zero is due to this fact that the minimum level of rainfall is zero, and as Malaysian historical data of temperature shows the minimum degree of temperature is upper than zero. For the upper bound, there are over rainfall and temperature that have limited ranges, but we do not know how much they are, such as a flood. The distribution function is selected based on a number of statistical tests, the Chi-squared statistic (C–S), the Anderson–Darling statistic (A–D), the Kolmogorov–Simirnov statistic (K–S) and other statistics, which measure the goodness-of-fit of rainfall–temperature and its square value with the selected PDF.

After choosing PDF, it and its square values will substitute to TEMRF and TEMRF^2, respectively, and 5000 iterations used for estimating the stochastic model of each crop. Based on $F(x_i) = Prob(X_i \leq x_i)$, three values are obtained from the output of each stochastic model (for detail see Sassi and Cardaci 2013). They make reference to the predicted mean, upper and lower bound values. Their changes, with respect to the figures in 2014, represent the average, the best and the worst scenario, respectively, those scenarios that simulated by the CGE model. The upper and lower bound values make references to a 90% confidence interval for the random variable to take on a value included among them.

3.2 CGE model

The paper uses a static CGE model with a specific focus on analyzing the Malaysian economic features. This is a multi-sectoral, economy-wide model consists of linear and nonlinear equations explaining the transaction from each sector/commodity to the other sectors/commodities in a Social Accounting Matrix (SAM). Particularly, the main data source of the current CGE study is the 2010 input–output (I–O) table and other socioeconomics data, which collected from the department of statistics Malaysia, to construct the SAM. The 2010 input–output table consists of 124 sectors that for the current study are aggregated into 15 sectors, listed in Tables 6, 7, 8, 9, 10, 11, 12 and 13. Household and labor are disaggregated into urban and rural categories. Despite two labor categories, the factors of production are also including capital and land.

The production function, which is the supply side of the model, determines the producer's demand for intermediate inputs and value added (factors of production are labor, land and capital). Total domestic output X_i is given as follows:

$$X_i = \alpha_i^x \left(\beta_i^x . \mathrm{INT}_i^{-\rho_i^x} + \left(1 - \beta_i^x\right) . \mathrm{VA}_i^{-\rho_i^x} \right)^{-\frac{1}{\rho_i^x}} \tag{2}$$

where α_i^x is the shift parameter, INT_i represents the intermediate inputs in sector i; VA_i is the value-added input in sector i, which includes labor, capital and land inputs; and β_i^x denotes the share parameter of the production function. The structure of the CGE model is illustrated in Fig. 3.

The stochastic component represented by rainfall–temperature influences the value-added function. Therefore, following Sassi and Cardaci (2012), Karaky (2002), Harris and Robinson (2001), Arndt et al. (2011), Sassi and Cardaci (2013) and Seung and Ianelli (2016), the value-added equation provided by the CGE model is modified as follows:

$$\mathrm{VA}_i = \mathrm{temr\ f}_i^s . \alpha_i^v \left(\sum_f \beta_i^v \mathrm{FDSC}_{i,f}^{-\rho_i^v} \right)^{-\frac{1}{\rho_i^v}} \tag{3}$$

where $\mathrm{FDSC}_{i,f}$ is the quantity demanded of factor f from sector i; α_i^v and β_i^v are the shift and the share parameters of the value-added function, respectively; temrf_i^s is the parameter representing the shock to agricultural products (i = paddy, food crops, palm oil, rubber)

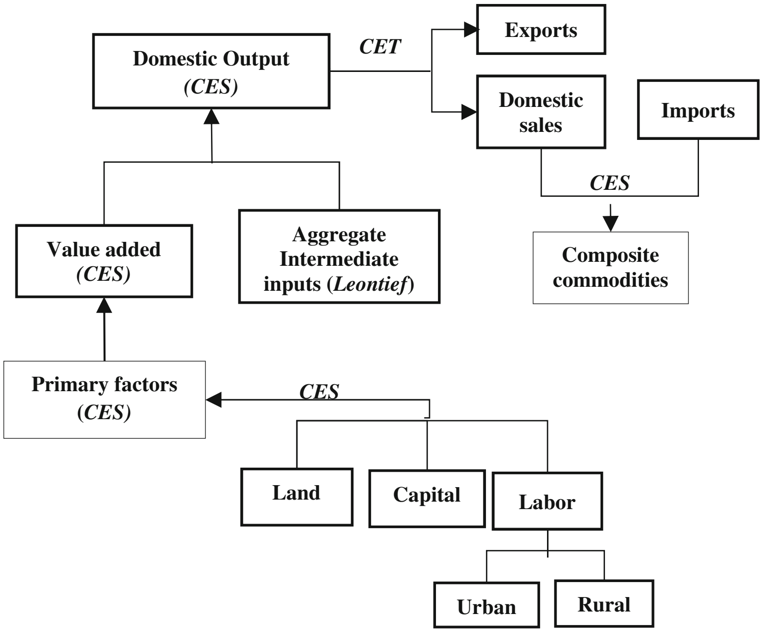

Fig. 3 Structure of the CGE model

for the three scenarios (s = average scenario, best scenario, worst scenario) in the baseline run, which the values of temrf_i^s is $0 < \text{temrf}_i^s < 1$.

Profit maximization is an assumption for the firms that they can produce either a single- or multi-products by implementing some different inputs.

The literature on applying CGE models for analyzing policy and external shocks is strong in Malaysia. For example, Ahluwalia and Lysy (1979) investigated the impacts of demand management policies on Malaysian welfare. Solaymani and Shokrinia (2016) investigated the impacts of tariff reform on emissions of air pollutants and the economy of Malaysia. For recent studies on applying CGE models in this country, refer to Solaymani et al. (2014, 2015), Solaymani and Kari (2014) and Solaymani (2015, 2017a, b) studies.

3.3 Model closure

At the final aspect of the definition of a CGE model, modelers use model closures to impose a number of restrictions on the model to achieve macroeconomic consistency. These closures can be captured in the current account balance, the savings-investment balance, and the government balance.

In the investment-saving closure, the marginal propensity to save is fixed and savings is a flexible variable. This implies saving to adjust as investment varies. Furthermore, in the government expenditure closure, government saving is an endogenous variable, whereas government transfer and consumption are exogenous. Finally, in the current account balance, the real exchange rate is a fixed variable while the constraints let the foreign saving to be a flexible variable. In the short run, both capital and land, as factors of production, are fixed and only labor is sectorally mobile. Therefore, capital cannot adjust overt time and there is no new investment. However, in the long run, all factors of production are sectorally mobile and can adjust over time.

4 Calculations

4.1 The parametric model

In this section, we estimate Eq. 1 through an Ordinary Last Square (OLS) method for all four commodities that discussed above. The estimated results for palm oil are presented as follows:

$$\begin{gathered} Q_{\text{palmoil},t} = 5.7086 * \text{TEMRF}_t - 0.0005 * \text{TEMRF}_t^2 + 34.1388 * T_t + \varepsilon_t \\ (0.2497)(0.0004)(18.9874) \\ F(3,32) = 4316.29, \quad \text{Prob} > F = 0.000; \quad \text{Adj}R^2 = 0.9973 \end{gathered} \tag{4}$$

The trend variable is not statistically significant for other commodities, namely food crops, paddy and rubber. In risk analysis, as it is necessary to consider only the model input coefficients that significantly explain the phenomena investigated, we only use those input coefficients in the stochastic model of food crops, rubber and paddy that are statistically significant. Their estimates are as follows:

$$\begin{gathered} Q_{\text{rubber},t} = 0.4335 * \text{TEMRF}_t - 0.00003 * \text{TEMRF}_t^2 + \varepsilon_t \\ (0.0633)(0.00001) \\ F(2,33) = 515.32, \quad \text{Prob} > F = 0.000; \quad \text{Adj}\,R^2 = 0.9671 \end{gathered} \tag{5}$$

$$\begin{gathered} Q_{\text{paddy},t} = 0.2148 * \text{TEMRF}_t - 0.00002 * \text{TEMRF}_t^2 + \varepsilon_t \\ (0.0049)(0.000001) \\ F(2,33) = 21587.39, \quad \text{Prob} > F = 0.000; \quad \text{Adj}\,R^2 = 0.9992 \end{gathered} \tag{6}$$

$$\begin{gathered} Q_{\text{foodcrops},t} = 0.1385 * \text{TEMRF}_t - 0.0001 * \text{TEMRF}_t^2 + \varepsilon_t \\ (0.0033)(0.000001) \\ F(2,33) = 20224.04, \quad \text{Prob} > F = 0.000; \quad \text{Adj}\,R^2 = 0.9991 \end{gathered} \tag{7}$$

In all estimated equations, the coefficients are statistically significant and show the expected signs. The figures in parentheses are standard errors. Palm oil productivity is the most sensitive to rainfall–temperature, followed by that of rubber. In comparison with other crops, food crop is the most tolerant to drought.

The sign of the estimated coefficients suggests that all the productivity of three crops influence negatively from the simultaneous change in precipitation and temperature. Finally, in the palm oil model, the last variable is the trend that is statistically significant and has a positive impact on palm oil productivity.

As the variables introduced in Eq. 1 have different units, it is necessary to check the robustness of them by performing a sensitivity analysis. The sensitivity analyses calculated using non-dimensionalizing the dependent and independent variables. To obtain non-dimensionalizing, the data of crops productivity, rainfall and its square are expressed as a percentage of their maximum values. Table 1 reports the results of non-dimensional regression.

The results of non-dimensional regression support the outcomes of the normal estimation of Eq. 1 as illustrated in Table 1.

Table 1 Results of non-dimensional regression for sensitivity analysis. *Source*: Author's calculation

Variables	TEMRF	$TEMRF^2$	Time	Statistics
$Q_{Palm\ oil}$	2.2127 (0.0969)	−1.3570 (0.1206)	0.15590 (0.0899)	F(3, 32) = 4412.52 Adj R^2 = 0.9974
Q_{Rubber}	2.1971 (0.3328)	−1.3468 (0.3967)	–	F(2, 33) = 514.31 Adj R^2 = 0.9670
Q_{Paddy}	2.3836 (0.0531)	−1.4860 (0.0633)	–	F(2, 33) = 22975.22 Adj R^2 = 0.9992
$Q_{Food\ crops}$	2.384055 (0.0549)	−1.4874 (0.0654)	–	F(2, 33) = 21451.38 Adj R^2 = 0.9992

(…) shows standard errors

Table 2 PD functions and statistical tests for TEMRF

Functions	BIC	AIC	C-S	K-S	A-D
RiskBetaGeneral (25.398, 11.181, 0, 9283.8)	563.9288	567.5456	3.6	0.1279	0.5445
RiskPert (0, 7406.3, 7950.6)	576.8099	579.5456	18.8	0.1971	2.1181
RiskTriang (0, 7258.5, 8124.7)	598.4501	601.1858	30.4	0.466	10.4643
RiskUniform (0, 8165.1)	632.6553	634.0894	51.6	0.642	20.1758

(…,…,…) are the parameters of the functions

4.2 The stochastic model

In order to derive the stochastic model from the above equations, we substitute a probability density function into the Millimeter-Celsius of rainfall–temperature and its square value as explanatory variables. Table 2 reports the probability distribution functions, their arguments (in parenthesis) and the values of their statistical test. As observed from Table 3, all the statistical tests for the RiskBetaGeneral function have the lowest value and fit the historical data of rainfall–temperature.[3] Then, we substitute this distribution function [RiskBetaGeneral (25.398, 11.181, 0, 9283.8)] into the TEMRF (rainfall–temperature value) and the $TEMRF^2$ (rainfall–temperature square value). The variable T also takes the number 36 that is the number of observations plus one.

Table 3 summarizes the output of the stochastic model for each crop. The output is represented in terms of a probability distribution function with the indication of the mean value and the bounds corresponding to a 90% probability.

These values are used for calculating the scenarios simulation in the CGE model. The scenarios measure the change between each of the values in Table 3 and their 2014 corresponding value. Therefore, according to the reference values and their corresponding 2014 values, the mean value is used for defining the average scenario, the upper bound value for defining the best scenario and the lower bound value is used for defining the

[3] The *Akaike information criterion* (*AIC*), the Bayesian information criterion (*BIC*) and other statistical tests (*C-S*, *K-S* and *A-D*) are criterions for model selection among a finite set of models, and the model with the lowest AIC, BIC and others is preferred. For each of these statistics, the smaller the value, the better the fit (Palisade Corporation 2010).

Table 3 Outputs of the stochastic models. *Source*: Author's calculation

	Rubber	Palm oil	Paddy	Food crops
Mean value	1533.22	19,109.61	543.85	472.39
Upper bound	1566.02	19,333.5	576.74	479.56
Lower bound	1201.79	16,228.44	389.29	326.03

Table 4 Shocks and scenarios. *Source*: Author's calculation

	Scenarios				Shocks[a]			
	Rubber	Palm oil	Paddy	Food crops	Rubber	Palm oil	Paddy	Food crops
Baseline (mean value)	−0.1086	−0.0737	−0.1994	−0.1212	0.8914	0.9263	0.8006	0.8788
Best (upper bound)	−0.0895	−0.0628	−0.1509	−0.1079	0.9105	0.9372	0.8491	0.8921
Worst (lower bound)	−0.3013	−0.2434	−0.3169	−0.3935	0.6987	0.7566	0.6831	0.6065

[a] Shock means the value of a parameter in the CGE model (temrf_i^s in the current study as presented in Eq. (3) that changes from its baseline-run value

worst scenario. Table 4 shows the shocks (by the scenario in the benchmark values) that are computed on the basis of $\text{temrf}_i^s = 1 + \text{temrain}_i^s$.

As observed from the results of the CGE simulations, with a 90% probability for happening the impacts, the extreme values of this confidence interval are the best and the worst scenarios.

In addition to the above agricultural products that the shocks are imposed on them, we used the food crops scenario as a base for other agricultural products in the model, since it has the lowest impact from rainfall–temperature variation. This happened due to data limitation on the productivity of other agricultural products. Therefore, in the CGE model, all ten agriculture sectors influence from rainfall–temperature variability.

5 Results and discussion

5.1 Macroeconomic impacts

The short- and long-run analyses of the production accounts show a typical feature of the Malaysian economy. This highlights that all simulations primarily affect paddy and other crop accounts significantly.

Previous studies highlighted that changes in economic growth are partially depended on climate change factors, such as rainfall and temperature, in Malaysia and other countries around the world (Sassi and Cardaci 2013; Zhai and Zhuang 2009). As Table 5 illustrates, the macroeconomic impacts of the scenarios simulated in this paper show that, in the short run, the economic performance of Malaysia with a 90% probability, in real terms, changes between −1.51 and −7.38% while, in the long run, changes between −1.09 and −5.23%. Hence, results show a negative change in Malaysia's GDP in both time periods. This shows that the negative impact of a change in climate factors declines over time. This reduction is

Table 5 Aggregate results of selected national accounts

Variables	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Real GDP	−7.38	−1.86	−1.51	−5.23	−1.29	−1.09
Nominal GDP	−13.30	−3.45	−2.72	−8.60	−2.11	−1.75
Investment	−11.30	−1.63	−1.12	−9.48	−0.64	−0.35
Government revenue	−10.41	−2.47	−2.03	−8.08	−1.97	−1.66
Exports	−9.89	−2.59	−2.07	−5.94	−1.56	−1.32
Imports	−9.11	−2.16	−1.73	−6.16	−1.29	−1.08
Private consumption	−6.56	−1.68	−1.43	−5.94	−1.57	−1.38
Rural consumption	−6.60	−1.56	−1.32	−6.13	−1.43	−1.25
Urban consumption	−6.29	−1.48	−1.27	−5.89	−1.39	−1.21
Rural welfare	−20.84	−4.85	−4.12	−19.09	−4.37	−3.81
Urban welfare	−17.28	−4.01	−3.41	−15.94	−3.68	−3.21

the consequence of a decline in private consumption and the trade flows in both time periods. The gross domestic product of Malaysia, in the short run, influences less when we investigate the impact of rainfall variation on Malaysian performance that is between −0.67 and −2.27%.

In the short run, the aggregate private consumption, in this context, declines between 1.43 and 6.56%. However, in the long run, with a 90% probability, the aggregate private consumption decreases between 1.38 and 5.94%. While rainfall–temperature fluctuation, in both time periods, leads to a decrease in trade flows, the magnitude of the impacts in export is greater than the import. Zhai and Zhuang (2009) found that a fluctuation in rainfall in the Southeast Asian region decreases the export of these countries between 0 and −1.7% and decreases their imports between −0.3 and −2.7%.

In the short run, real investment with a 90% probability decreases between 1.12 and 11.30%, as government savings and private savings decline, which are related to the reduction in prices due to simultaneous change in rainfall and temperature (see Tables 10, 11). In the long run, the magnitude of the impacts on investment is less than the short run.

In both the short- and long-run, the rural households, in general, experienced greater falls in their income and consumption than the urban households, while the consumption of the rural household, compared to the urban household, declines more in those crops that harm from rainfall–temperature fluctuation. The earlier, in this context, happened due to a decline in their labor wages resulting in a decline in their income. Therefore, with a 90% probability, in the short run, the welfare of urban household decreases within 3.41–17.28% and for rural household falls between 4.129 and 20.84%. However, the magnitudes of the long-run impacts of the shocks on the welfare of both household groups are initially smaller than the short-run impacts.

The increase in export of other activities, such as crude oil and financial and insurance activities relates to the decrease in domestic prices of these accounts as illustrated in Table 6, but the magnitudes are lower in the long run.

Table 6 Changes in exports of all commodities

Sectors[a]	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Paddy	−80.04	−64.83	−50.79	−39.28	−23.72	−17.76
Food crops	−58.86	−19.80	−18.36	−61.04	−22.89	−21.11
Vegetables	−59.59	−19.72	−18.21	−84.22	−40.67	−37.98
Fruits	−54.36	−18.32	−16.94	−68.56	−25.37	−23.36
Rubber	−34.73	−13.29	−10.87	−65.24	−38.11	−33.27
Pal moil	−36.08	−10.98	−9.55	−21.96	−5.61	−4.72
Livestock	−41.74	−12.80	−11.70	−46.58	−14.57	−13.36
Forestry and logging	−41.05	−11.88	−10.86	−32.55	−9.01	−8.16
Fish	−40.28	−12.27	−11.23	−44.76	−14.15	−12.99
Other agriculture	−55.32	−17.92	−16.56	−47.05	−15.73	−14.41
Crude oil, natural gas and mining	7.78	2.07	1.66	1.94	0.52	0.45
Industrials	−13.08	−3.32	−2.63	−6.77	−1.44	−1.19
Transportation and communication	0.25	−0.08	−0.05	1.52	0.38	0.32
Financial	3.06	0.53	0.44	0.89	−0.09	−0.09
Other services	0.25	0.02	0.03	0.45	0.39	0.35

[a] As this study uses commodity-by-commodity table of 2010 I–O, the terms commodity or sector have the same meaning in this study

5.2 Agricultural impacts

Insufficient rainfall and temperature regularly lead to food insecurity in all over the globe as also argued by Milan and Ruano (2014) and Generoso (2015). Therefore, rainfall–temperature variability that is driven from three scenarios simulated in this paper has a negative impact on food security in Malaysia.

We can distinguish the results of our CGE model for the agriculture sector in two dimensions. The first is commodity availability and the other is access to commodity in both the short- and long-run. The commodity availability means the quantity of the commodity that is available from domestic supply and imports (both together provide composite commodities) according to their domestic prices.

Table 7 shows the impacts of three scenarios on the quantity of composite commodities (i.e., domestic produced commodities plus imported commodities), which shows the availability of commodities in the domestic market. As observed, in both the short- and long-run, all commodities and services influenced negatively from all scenarios. It means that the availability of all goods declined in all scenarios mainly from the worst scenario.

The top three commodities that strongly affected directly by the shocks, in the short run, are fruits, vegetables and livestock commodities. Indeed, in this time period, for fruits, there is a 90% probability for the reduction to be included between −10.07 and −36.77%, while for vegetables the intensity of the shocks is within −8.06 and −31.64% and for livestock is between −6.20 and −25.34%. Similarly, in the long run, these commodities still are the top three commodities but with greater magnitudes. This is due to the long time reduction in the domestic supply of these commodities (Table 8). It shows that, in the long

Table 7 Changes in quantity of composite commodities

Sectors	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Paddy	−13.57	−4.10	−3.24	−7.20	−1.76	−1.42
Food crops	−21.77	−5.93	−5.18	−18.41	−5.42	−4.86
Vegetables	−31.64	−8.91	−8.06	−48.68	−17.97	−16.54
Fruits	−36.77	−11.04	−10.07	−46.91	−14.88	−13.57
Rubber	−12.71	−3.21	−2.55	−7.30	−1.73	−1.44
Palm oil	−12.37	−3.11	−2.47	−6.69	−1.39	−1.14
Livestock	−25.34	−6.94	−6.20	−27.13	−7.49	−6.78
Forestry and logging	−16.29	−4.37	−3.70	−10.37	−2.55	−2.22
Fish	−23.62	−6.55	−5.86	−25.08	−7.14	−6.48
Other agriculture	−23.72	−6.94	−6.19	−18.69	−5.46	−4.91
Crude oil, natural gas and mining	−12.08	−3.05	−2.42	−6.48	−1.37	−1.13
Industrials	−10.22	−2.49	−2.00	−6.51	−1.39	−1.16
Transportation and communication	−6.34	−1.58	−1.27	−3.91	−0.89	−0.75
Financial	−3.82	−1.03	−0.83	−3.50	−1.12	−0.95
Other services	−4.91	−1.08	−0.86	−3.48	−0.55	−0.44

Table 8 Changes in quantity of domestic supply

Sectors	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Paddy	−18.81	−8.45	−6.41	−9.22	−3.08	−2.39
Food crops	−35.27	−11.25	−10.24	−33.84	−12.08	−11.08
Vegetables	−41.50	−12.88	−11.79	−60.93	−26.12	−24.26
Fruits	−38.91	−11.94	−10.92	−49.55	−16.16	−14.78
Rubber	−31.29	−11.83	−9.68	−53.13	−31.98	−28.07
Palm oil	−14.66	−3.84	−3.13	−8.14	−1.78	−1.48
Livestock	−28.41	−8.04	−7.23	−31.06	−8.93	−8.11
Forestry and logging	−21.97	−6.19	−5.44	−15.52	−4.12	−3.67
Fish	−26.41	−7.52	−6.78	−28.74	−8.48	−7.72
Other agriculture	−31.21	−10.03	−9.12	−25.68	−8.36	−7.61
Crude oil, natural gas and mining	−1.75	−0.54	−0.43	−2.30	−0.46	−0.37
Industrials	−12.67	−3.20	−2.54	−6.73	−1.43	−1.18
Transportation and communication	−3.18	−0.87	−0.69	−1.31	−0.29	−0.24
Financial	−3.08	−0.87	−0.69	−3.04	−1.01	−0.86
Other services	−3.70	−0.83	−0.65	−2.56	−0.33	−0.26

run, the country cannot improve the economic situation of these sectors that have harmed from climate change factors even by applying adaptation policies. It is assumed that, in the long run, the government in order to protect those sectors that influenced negatively from climate change may use adaptation policies as this is the main responsibility and general role of the government in an economy. The agriculture sector may adapt through development in technologies, government programs, management of the farm, financial and farm production practices (Smit and Skinner 2002). In addition to fruits, vegetables and livestock, another commodity that has this condition is fish.

Inversely, among all agricultural commodities, in both time periods, the palm oil commodity followed by rubber and forestry experienced the lowest impact from the shocks. This may be partially due to lower exposure to rainfall and temperature, as their productions mostly depend on normal precipitation and temperature.

Furthermore, in the short run, with a 90% probability the quantities of food crops, the main source of food commodities, declined between −5.18 and −21.77%, and in the long run declined between 4.86 and 18.41%. This shows that in both the short- and long-run, the rainfall–temperature variability influences the availability of food commodities as well as other sources of food commodities such as vegetables, livestock and fish commodities. This finding is in line with the Alam et al. (2013) study arguing that Malaysia rainfall fluctuation between −30 and +30% reduces crop production and leads to drought in many areas. Therefore, the cultivation of some crops such as rubber, palm oil and cocoa becomes impossible. This finding is also consistent with the Felix and Romuald (2014) study arguing that rainfall variability affects food security most directly through the food supply.

As composite commodities are components of imports and domestic sales, the decline in composite commodities can be found mainly in the decline in domestic supply and its shortage can be compensated by imports. Therefore, the rainfall–temperature variability decreases the domestic supply of all commodities, in both the short- and long-run, mainly those agricultural commodities that significantly affected by it, such as vegetable, fruits and food crops (Table 8). As highlighted above, in the long run, some agriculture sectors, such as vegetable, fruits, livestock and fishing, cannot adapt themselves to the shocks to anticipate the adverse effects of climate change, as well as other agriculture sectors can.

However, the decline in composite commodities is not compensated by the rise in commodity imported (Table 9). Therefore, Table 9 shows that, in both the short- and long-run, the import of the majority of commodities does not counterbalance the reduction in domestic supply.

As observed, in both the short- and long-run, the exception here is mainly for paddy, food crops, palm oil, rubber, forestry and logging, and other agricultural commodities. This happened due to the dramatic rise in prices of domestic products (Table 10), which is combined with the elasticity of substitution with domestic demand, leads to buying them from the international market.

Alam et al. (2012) highlighted that the country depends highly on rice, as the main staple food, to imports (about 10–35%) from other countries, particularly those are the neighbor to Malaysia.

In the short run, the results of high domestic prices represented in Table 10 show the greatest variability among the three scenarios within paddy which is between 123.9 and 479.4%, while, in the long run, the magnitude of the shocks on this commodity is significantly small and is between 24.01 and 65.63%. Furthermore, in both the short- and long-run, the domestic price of all agricultural commodities, particularly other agriculture, food crops, forestry, palm oil and vegetables, increased because of the shocks. The intensity of the short-run change of these commodities with a 90% probability to be

Table 9 Changes in quantity of imported goods

Sectors	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Paddy	178.43	112.40	64.86	29.44	19.75	13.57
Food crops	26.17	5.75	5.81	41.57	9.88	9.15
Vegetables	−8.48	−2.40	−2.00	0.46	−1.96	−1.74
Fruits	−16.24	−4.29	−3.73	−16.40	−4.71	−4.20
Rubber	1.33	2.34	1.95	56.88	24.93	20.56
Palm oil	20.81	5.51	5.19	11.77	3.03	2.57
Livestock	−9.65	−2.21	−1.78	−7.60	−1.75	−1.47
Forestry and logging	16.11	3.04	3.35	16.72	3.75	3.54
Fish	−12.53	−3.28	−2.81	−11.55	−3.16	−2.79
Other agriculture	21.20	3.46	3.55	17.59	4.14	3.89
Crude oil, natural gas and mining	−25.37	−7.03	−5.63	−12.82	−2.88	−2.40
Industrials	−9.61	−2.32	−1.87	−6.46	−1.38	−1.15
Transportation and communication	−9.98	−2.45	−1.98	−6.95	−1.62	−1.37
Financial	−9.82	−2.46	−1.99	−7.43	−2.07	−1.76
Other services	−8.62	−1.91	−1.53	−6.34	−1.26	−1.04

Table 10 Changes in domestic demand price of all commodities

Sectors	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Paddy	479.43	231.64	123.88	65.63	35.08	24.01
Food crops	101.46	18.87	17.59	123.99	24.77	22.50
Vegetables	66.69	12.99	11.96	217.99	36.88	33.33
Fruits	54.30	11.99	11.12	101.10	19.06	17.28
Rubber	36.91	12.57	10.08	193.40	65.15	52.57
Palm oil	78.37	16.71	14.71	38.61	8.29	6.93
Livestock	36.82	8.53	7.90	47.91	10.51	9.62
Forestry and logging	85.19	15.28	14.40	64.63	12.67	11.52
Fish	37.45	8.47	7.84	48.03	10.56	9.68
Other agriculture	171.27	26.05	24.11	122.10	23.58	21.39
Crude oil, natural gas and mining	−30.76	−8.91	−7.18	−14.48	−3.38	−2.84
Industrials	3.99	1.03	0.78	0.34	0.06	0.03
Transportation and communication	−10.20	−2.37	−1.93	−8.35	−1.99	−1.68
Financial	−12.50	−2.97	−2.42	−8.25	−1.98	−1.67
Other services	−8.85	−1.93	−1.56	−6.75	−1.64	−1.38

included between 24.1 and 171.3% for other agriculture, within 17.6–101.5% for food crops, between 14.4 and 85.2% for forestry and between 14.7 and 78.4% for palm oil, are marked enough to stimulate a shift from domestic supply of these commodities toward imports.

In view of the foregoing, we can conclude that simultaneous variability in rainfall and temperature, in both the short- and long-run, declined food availability in Malaysia, since the quantities of composite food commodities (such as food crops, vegetables, fruits and fish) decreased and their imports could not significantly counterbalance the reduction in domestic supply. Therefore, in both time periods, based on this context (90% probability), the agriculture sector losses from the change in rainfall–temperature pattern in Malaysia. In conclusion, the simultaneous change in rainfall and temperature leads to a decline in the production of food commodities. This, consequently, increases the domestic prices of these commodities resulting in an increase in their import by the government or private to compensate the shortage of their supply in the domestic market.

The rainfall–temperature variability also affects access to food. This subject implies the ability of the household to buy foods according to their incomes and level of market prices of domestic commodities. It means that how much is the purchasing power of the households to buying foods. The sources of household income can be from primary factors, public and private transfers.

The simultaneous change in rainfall and temperature is a factor of food insecurity (through food supply reduction) in developing countries. It also influences food prices, and the adverse effect of this shock is high for countries that are vulnerable to food price shocks (Felix and Romuald 2014; Rademacher-Schulz et al. 2012).

In both the short- and long-run, besides the decline in food availability that combines with an increase in the sales prices of all agricultural commodities, such as paddy, food crops, vegetables, palm oil and other agricultural products (Table 10), the rainfall–temperature volatility increases composite prices of these commodities in the domestic market but with different magnitudes (Table 11).

In the short run, these prices dramatically affected by the shocks with an expected change of paddy prices included between 114.1 and 431.83% and, in the long run, increased between 22.41 and 60.88%. In this condition, consumers are the most vulnerable group that their consumption and welfare decline significantly from high food prices.

The income of rural and urban household, in the context of 90% probability, decreases on average between 1.99 and 11.1%, in the short run, as their labor wages decrease between 1.65 and 8.34%. However, in the long run, their incomes decrease between 2.04 and 10.9% because their wages decrease between 1.65 and 8.34%. Tables 12 and 13 report the short- and long-run responses of household consumption to a change in commodity prices resulted from the simultaneous changes in rainfall and temperature. As observed, in both the short- and long-run, demand for the majority of commodities by all household groups decreased. The short-run exception is for mining and crude oil that high composite commodity prices lead to an increase in their consumption while the long-run results show a decrease in the consumption of these commodities. This may happen due to a significant decline in the domestic price of these commodities in the short run.

In both the short- and long-run, the rural household, compared to the urban household, experienced the greatest decline in their consumption from the majority of agricultural commodities.

In both time periods, demand for paddy and other agricultural commodities followed by food crops, forestry, fish, fruits and livestock show the highest reduction for both household types, particularly for rural household. The urban household is the most affected by

Table 11 Changes in price of all composite commodities

Sectors	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Paddy	431.83	211.39	114.10	60.88	32.69	22.41
Food crops	81.74	15.75	14.70	99.14	20.61	18.74
Vegetables	51.71	10.36	9.54	161.05	29.01	26.26
Fruits	49.42	11.02	10.22	91.31	17.48	15.85
Rubber	28.22	9.73	7.82	140.35	49.19	39.91
Palm oil	70.77	15.25	13.44	35.10	7.58	6.34
Livestock	31.32	7.34	6.80	40.38	8.99	8.24
Forestry and logging	72.52	13.25	12.49	55.28	11.00	10.00
Fish	31.15	7.11	6.59	39.36	8.76	8.03
Other agriculture	152.43	23.58	21.83	109.15	21.35	19.38
Crude oil, natural gas and mining	−27.95	−8.05	−6.48	−13.09	−3.05	−2.56
Industrials	1.35	0.35	0.27	0.12	0.02	0.01
Transportation and communication	−7.62	−1.76	−1.44	−6.23	−1.48	−1.25
Financial	−12.09	−2.87	−2.34	−7.98	−1.92	−1.62
Other services	−7.66	−1.66	−1.34	−5.84	−1.42	−1.19

Table 12 Changes in quantity of consumed commodities for rural households

Sectors	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Paddy	−25.36	−20.69	−16.44	−14.61	−8.29	−6.34
Food crops	−16.77	−5.29	−4.86	−17.53	−6.13	−5.61
Vegetables	−14.20	−4.09	−3.68	−20.44	−7.67	−7.05
Fruits	−13.96	−4.24	−3.84	−17.03	−5.50	−5.01
Rubber	00.00	00.00	00.00	00.00	00.00	00.00
Palm oil	00.00	00.00	00.00	00.00	00.00	00.00
Livestock	−15.20	−4.34	−3.89	−16.93	−4.93	−4.46
Forestry and logging	−16.08	−4.75	−4.37	−14.05	−4.08	−3.69
Fish	−15.40	−4.34	−3.88	−17.18	−4.97	−4.50
Other agriculture	−21.27	−7.12	−6.58	−18.86	−6.53	−5.97
Crude oil, natural gas and mining	3.04	1.06	0.79	−1.64	−0.35	−0.32
Industrials	−6.46	−1.53	−1.27	−5.36	−1.25	−1.07
Transportation and communication	−4.75	−1.04	−0.88	−4.20	−0.92	−0.80
Financial	−3.57	−0.73	−0.63	−3.97	−0.85	−0.74
Other services	−5.95	−1.35	−1.14	−5.43	−1.19	−1.03

Table 13 Changes in quantity of consumed commodities for urban households

Sectors	Percentage change from base-run values					
	Short run			Long run		
	Worst scenario	Average scenario	Best scenario	Worst scenario	Average scenario	Best scenario
Paddy	−21.61	−17.57	−13.99	−12.84	−7.14	−5.49
Food crops	−14.66	−4.65	−4.26	−15.22	−5.33	−4.87
Vegetables	−12.57	−3.65	−3.28	−17.59	−6.62	−6.09
Fruits	−12.38	−3.77	−3.41	−14.81	−4.80	−4.37
Rubber	00.00	00.00	00.00	00.00	00.00	00.00
Palm oil	00.00	00.00	00.00	00.00	00.00	00.00
Livestock	−13.97	−4.00	−3.57	−15.45	−4.49	−4.06
Forestry and logging	−14.10	−4.20	−3.85	−12.39	−3.61	−3.26
Fish	−14.17	−4.00	−3.57	−15.73	−4.55	−4.11
Other agriculture	−18.39	−6.22	−5.73	−16.38	−5.69	−5.20
Crude oil, natural gas and mining	1.37	0.67	0.48	−2.28	−0.47	−0.42
Industrials	−6.31	−1.50	−1.25	−5.31	−1.23	−1.06
Transportation and communication	−5.12	−1.13	−0.96	−4.53	−0.99	−0.86
Financial	−4.30	−0.90	−0.77	−4.47	−0.95	−0.83
Other services	−6.54	−1.48	−1.26	−5.93	−1.29	−1.12

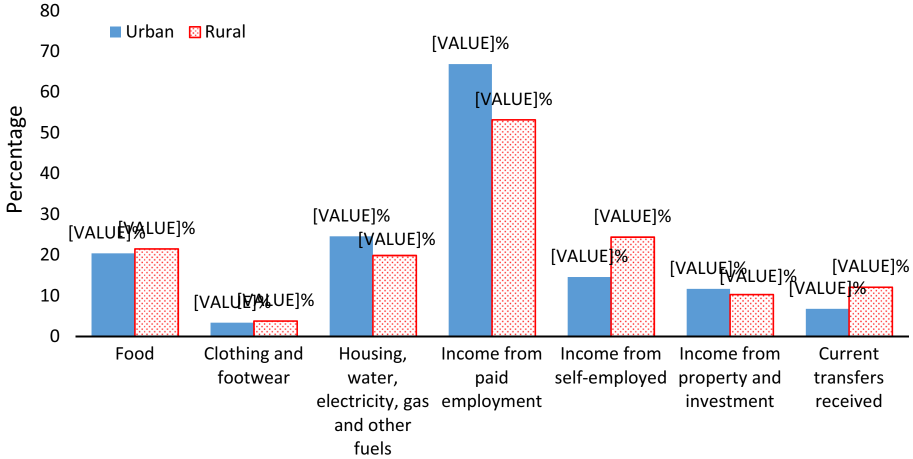

Fig. 4 Share of commodity consumption and income sources by household, 2014. *Source*: Author's calculation based on Department of Statistics databases

the shocks simulated on the side of transport and services demand, followed by rural households.

In both time periods, an important fact regards food crops is that the impact of the shocks on food security of all household groups, particularly the rural household, is even more severe considering that this commodity is a staple food and that, for this household category, represents more than 20% of their total demand[4] (Fig. 4).

From the above results, we can conclude that rainfall–temperature variation declines Malaysian income and increases domestic prices of composite goods, in both the short- and long-run, resulting in a decline in access to food in the country. The consumption of all agricultural commodities for both household types strongly is affected by the shocks, especially in rural areas.

6 Conclusions

This paper analyzed the short- and long-run responses of different rainfall–temperature scenarios on the major sources of Malaysia food availability, such as food crops, vegetables, fruits, livestock, fish and household access to food using an integrated CGE model, which integrates a stochastic model with a CGE model. The results of the parametric model show a direct correlation between change in rainfall–temperature and the productivity of agricultural products whose intensity declines over time. This shows that normal rainfall and temperature increase the productivity of agricultural products and excessive precipitation and temperature hamper agricultural output. Accordingly, this evidence confirms the first hypothesis of the study. Therefore, as the results of the CGE model indicated, a dramatic decline in both food availability and access to food, in both the short- and long-run, will accrue when the agriculture sector harms from abnormal changes in environmental situations.

The decline in availability of food is due to a substantial decline in the quantities of agricultural commodities available in the domestic market. In the Malaysia case, this situation is happening due to a reduction in cereals import and export incentives.

The access to food, instead, is worsened due to a decrease in household income and the inflationary pressure of the major agricultural products. Both household groups negatively affected by the simulated climate change shocks. However, the greatest impact is on the rural households because they spend a high share of their budget on food, more than 21% of the total. Accordingly, the above results confirmed the second hypothesis of the study that the simultaneous changes in rainfall and temperature decline food availability and access to food in Malaysia.

The simultaneous change in rainfall and temperature declines the wage rates of rural and urban workers resulting in a decrease in the income of rural and urban households. The shocks increase significantly the domestic prices of agricultural commodities and decrease the income of both household groups, particularly the rural household. Therefore, with the 90% confidence interval, rural consumption declines between 1.32 and 6.60% and urban household consumption decreases between 1.27 and 6.29% resulting in more decline in the welfare of rural household in comparison with the urban household. This is the net impact of the climate change shocks on the two main household groups in Malaysia.

The CGE model, on the other hand, provides this possibility to trace the impact of the rainfall–temperature shocks on the main macroeconomic causalities and food security in the Malaysian economy. The country, especially the agriculture sector, in both the short- and long-run, influences negatively from the shocks but the magnitude of the impacts is low in the long run. In both time periods, the predicted declines in GDP, private

[4] Which include rice, bread and other cereals, meat, fish and seafood, milk, cheese and eggs, oils and fats, fruits and vegetables.

consumption, government revenue due to the fall in taxes, export and import of commodities under the simulated scenarios are the main response of the Malaysian economy to these shocks.

Finally, in the long run, we found that some of the agricultural products could not adapt themselves to climate change. These products are fruits, livestock, vegetables and fish. Therefore, we clearly suggest that the Malaysian policymakers pay more attention to improving the government current climate change policy on the agriculture sector, particularly in these agricultural products. We also recommend crop insurance programs for both the short- and long-run to diminish the risk of farming. In both the short- and long-run, farmer awareness and training programs regarding adaptation to climate change are also necessary. In the long run, it is recommended to develop agricultural technologies, as an important adaptation policy, to cope with climate change issues. Government supports on agriculture sector, such as subsidy on fertilizers, seeds and other financial supports, can help the farmers to increase their products to protect the society from food insecurity.

In fact, the strong interconnections among climate change, food insecurity and poverty suggest coordination of policies in these areas. Based on these results, the development of plant varieties tolerant to high variation in precipitation pattern is suggested to eliminate the negative impacts on agricultural products in both the short- and long-run.

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