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Responsiveness of food security to macroeconomic variables: The cases of Maldives, Mauritius and Seychelles

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ABSTRACT: This paper investigates into the major macroeconomic variables influencing food security at national level in three Indian Ocean Small Island Developing States (SIDS): Maldives, Mauritius and Seychelles. Food stability – a measure of food security responsiveness – is estimated within the framework of cointegration and error correction model (ECM) to differentiate the short run and long run elasticities. There is evidence that food security co-moves with the explanatory variables in our model in the long run. The results unveil the importance of trade openness, investment in the agriculture sector, domestic food production (measured in terms of quantity, quality and variety) and structural transformation in enhancing food stability. In contrast, economic growth measured by GDP per capita worsens food security in Maldives and Mauritius in the long run. The ECM results suggest that changes in food security brought about by its determinants are cancelled out fastest in the Maldives; suggesting serious difficulties in securing a more sustainable food security strategy. The results of this study generate policy recommendations, which can also be adapted to the context of other SIDS.

Keywords: Error Correction Model, food security, Maldives, Mauritius, Seychelles, SIDS

Introduction

Globally, half of all Small Island Developing States (SIDS) import over 80 percent of their food requirements (FAO, 2016). This high dependency on food imports raises their vulnerability to external shocks by adversely affecting incentives for longer-term investments in the agriculture sector, and exposes them to the triple burden of malnutrition: chronic mal/under-nutrition, vitamin and mineral deficiencies, obesity and related non-communicable diseases (NCDs) associated with consuming highly processed imported foods rich in sugars, fats and salt and a transition away from local/traditional nutritive diets (UNICEF, 2020). It is widely recognized that food and nutrition security is crucial for human dignity, the very foundation of human rights and is linked to economic stability, long-term health, women's empowerment and the environment (Ayala and Meier, 2017). Achieving food security is crucial in achieving various Sustainable Development Goals (SDGs) such as SDG2 – Zero

Hunger, SDG3 – Good Health and Well-Being, SDG12 – Responsible Consumption and Production, SDG14 – Life Below Water, and SDG15 – Life on Land (United Nations, 2022).

Different theories and models have attempted to identify and explain the main factors influencing food security at the *national* level. For instance, in the inceptive theories of Malthus (1798) and Boserup (1975), population growth is proposed as the main determinant of food security. For Malthus, higher population growth would negatively impact food availability; while Boserup argued that people would adapt to population pressure by intensifying agricultural production through investment in labour practices such as multi-cropping. Empirically, various studies (e.g. Oke, 2015; Wahab, Applanaidu and Bakar, 2014, 2015; Kopnova and Rodionova, 2017; Oguntegbe et al., 2018; Osabohien, Afolabi and Godwin, 2018; Pawlak and Kołodziejczak, 2020) reflect the Malthusian perspective on population growth and food security sustainability. Other variables – such as arable land, equipment, infrastructure, technology and transfer of knowledge – are assumed to contribute to improving agricultural productivity. (Oke, 2015; Kopnova and Rodionova, 2017; Pawlak and Kołodziejczak, 2020; World Bank, 2021).

From an economic perspective, authors like Bullock and Firebaugh (1990); Firebaugh and Beck (1994) and Bouet and Laborde(2017) have stretched the connotations of the modernisation and economic dependency theories to the food security dilemma: they have posited economic growth and international economic interconnectedness (captured mainly by trade and foreign direct investment) as important factors impacting on food security. To illustrate, on the one hand, the modernisation theory postulates that, the more an economy grows, the more it can spend on food production, food supply and therefore, on food security. On the other hand, the core argument of the economic dependency theory is that the global economic system functions to promote the interests of economically powerful countries, at the expense of periphery countries, resulting in underdevelopment and worsened food insecurity in the latter countries. The application of the modernization theory reveals ambiguous results, with some declaring that economic growth increases the adoption of high-tech agricultural equipment and better yielding soils, making investment in agriculture a tool to enhance food security (Breisinger et al. 2012; Adom, 2014; Manap and Ismail, 2019; Pawlak and Kołodziejczak, 2020). In contrast, others (e.g. Smith and Meade, 2019) argue that economic growth has no or negative effects on food security, particularly in middle-income countries. Economic growth accompanied by environmental degradation exacerbate soil loss, deforestation and pest incidence; which in turn result in yield decline and food insecurity. Moreover, income growth may not contribute to food security due to an unequal distribution of income (Aziz et al., 2021).

The relationship between trade openness and food security has been long debated (e.g. FAO, 2003; McCorriston et al., 2013; Díaz-Bonilla, 2015b). Most claim that trade and trade openness lead to hunger (Madeley, 2000); while a few others opine that a thorough liberalization of global agricultural trade would enhance food security (Griswold, 1999; Mihalache-O'keef and Li, 2001; Hutchet-Bourdon and Zitouna, 2015; Santangelo, 2018). Furthermore, a few scholars (Slimane et al., 2015; Fleming, 2019) find FDI enhancing food security; but this positive relationship prevails as long as FDI from the agriculture sector spills over to non-agriculture sectors, or the FDI has been generated by investors from developed countries.

Structural transformation through its four main features – falling share of agriculture in economic output and employment; rising share of urban economic activity in industry and modern services; migration of rural workers to urban settings; and demographic transition in birth and death rates that collectively lead to spurts in population growth – has a prominent

impact on food security (Timmer, 2009a). Moreover, studies have analysed the impact of other macroeconomic and monetary factors on food security. For example, inflation, on its own, is a risk to food security: it affects production and consumption by influencing food price levels in different countries (Woertz et al. 2008; Coleman-Jensen and Gregory, 2014; International Dietary Data Expansion Project, 2015; Snell, 2022). While it can quell purchasing or consumption powers – that is, the demand side – it can equally boost supply (Adom, 2014), especially as producers and suppliers get more money by selling food at soaring prices. This signifies that inflation may have a non-linear relationship with food security. Nonetheless, inflation can also occur in energy prices. When crude oil prices rise, the cost of transportation and agricultural chemical and fertilizer products also rise, which in turn spike production and food prices. Rising food prices in turn can unsettle domestic food production (Kargbo, 2005). Rising interest rates as well can be a risk to food security. On the supply side, agricultural credits become unattractive and costs of production and producer food prices rise. Lower interest rates, on the demand side, imply that the opportunity cost for holding stocks declines. In both cases, availability of food and access to it are threatened, simultaneously affecting food security. The only study cited in Adom (2014) which found no link between interest rate and agricultural product prices is that of Lombardi et al. (2010). The impact of exchange rate on prices of agricultural commodities is also empirically established. When the exchange rate rises, at the expense of the depreciating local currency, food availability is affected in three ways. First, the country with the weaker currency has a floppier capacity to import food or resources to produce food. Second, when resources invested in agricultural production are bought at higher prices, costs of production increase, so do the prices of agricultural and food outputs. More costly agricultural inputs may also discourage production, causing it to fall, again affecting the availability and supply of food stock. Third, domestic inflation occurs as a consequence of rising exchange rates and this affects households' incomes, albeit at different degrees (Adom, 2014).

Against the above backdrop, this paper contributes to the existing literature in the following ways. To start with, most of the studies on the determinants of food insecurity have taken a microlevel perspective and investigate individual's and households' ability to tackle food insecurity. As pointed out by Ecker et al., (2011) even though food security at household level is crucial, it does not capture the necessary conditions to sustain adequate nutrition. In 2011, the United Nations acknowledged that development goals related to nutrition must be achieved at the national level beyond the household level. This paper therefore explores the macroeconomic determinants of food security at the national level in three Indian Ocean SIDS: Maldives, Mauritius and Seychelles.

The second contribution is in terms of the context under study. Given food security is a multi-dimensional phenomenon, its analysis tends to be context-dependent and to the best of our knowledge till date no study has focussed on the determinants of food security at the national level in the Indian Ocean SIDS. Such a study is particularly important in the context of the three Indian Ocean SIDS because of their specific characteristics: i) they are net food importers; ii) they provide good examples of the special characteristics of SIDS: smallness, remoteness and high vulnerability to the impacts of climate change and natural calamities; iv) their tourism sector represents a major pillar of their respective economies; v) no such study has been conducted previously using the three countries as context and iv) the impacts of the Covid-19 pandemic are rolling back gains that these economies have made in attaining the SDGs directly or indirectly related to food security. Hence, the results from this research should provide new insights, inform government policy and concerned stakeholders, and provide some takeaways for other SIDS. Thirdly, in terms of methodology, the gap in the literature is bridged by adopting an ECM, which provides information on both the short run and long run responses

of national food security to changes in its macroeconomic determinants. The latter model also provides useful insights regarding the speed of adjustment back to long-run equilibrium and thus is a useful tool for sustainable food security strategy.

Specifically, the objectives of this study are to: (a) provide an overview of the status of food security in the three Indian Ocean SIDS, using a range of measures and dimensions; (b) determine whether the explanatory variables used in the model are exogenous, using the Durbin score, Wu-Hausman test and the Jarque-Bera test; (c) investigate whether there is a long-run relationship between the macro variables and food security; and (d) propose policy recommendations based on the findings.

Contextual analysis

This section provides a synopsis of the three SIDS as well as focusses on the pillars of food security and their associated dimensions/measures. A summary of the impacts of Covid-19 on food security in the three islands is also provided.

Overview of the three island states

Maldives, Mauritius and Seychelles are three small and remote island states, which, despite development challenges associated with their size and remoteness, have made impressive advances. They are known as the pearls of the Indian Ocean with almost no extreme poverty (at the $3.20/day international line, World Bank, 2020). Maldives and Mauritius are classified as upper middle-income countries whilst Seychelles is a high-income economy (World Bank, 2021). Their economies are also very open to world trade, with exports and imports making up 79% of Mauritius' GDP, 75% of Seychelles' GDP and 118% of Maldives' GDP in 2020.[1]

In terms of food security, Maldives, Mauritius and Seychelles are all net food importers and thus rely considerably on external food sources to meet their domestic food needs. In Maldives, the total arable land area is around 2,800-3000ha and agricultural production is largely concentrated on horticultural crop with vegetables and tropical fruits such as chili, local-kale, watermelon, egg-plant, papaya, sweet potato cassava, taro and banana.[2] The agricultural production systems tend to be conventional and include substantial agrochemical and pesticide usage. For instance, FAO (2018) figures suggest that the use of nitrogen fertilizer in Maldives has increased by over 700 tonnes between 2005 and 2014. Yet, with the exception of poultry and cattle ventures, livestock breeding is limited (MoFA, 2018). More interestingly, 100% of the supply of rice, sugar and flour, which are the staple foods in Maldives, are imported from five countries: none of them is grown domestically. This reveals the high degree of vulnerability that Maldives faces in both economic access and physical access. This is so, since first to buy the staple goods, it needs foreign currency which in turn largely depends on the performance of the tourism sector which is the main economic pillar; and second, physical access – that is transport – highly depends on foreign shipping lines. The ongoing Covid-19 pandemic has exacerbated the country's food access vulnerability.

Mauritius on its part, imports above 77% of its staples, which include wheat flour, rice, milk, meat, and temperate fruits, and the country has an overall food self-sufficiency ratio of below 30%. (International Trade Administration, 2021).[3] Food crop production is dominated by small-scale farming. Other than sugar, tea is its only other agri-food export (which is marginal). Such a high dependence on external food supply channels imperils the country to

[1] https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS
[2] FAO. 2012. Maldives Country Programming Framework, 2013–2017. Colombo.
[3] https://www.stopfakes.gov/article?id=Mauritius-Agricultural-Sectors

the international food trade volatilities, in addition to the worsening effects of global food price hikes. The consequence is endangered food stability and security. Besides, local production is also hampered by frequent natural disasters such as hurricanes and droughts as Mauritius is ranked among the top 10% of countries most exposed to natural disasters (Tsakok, 2021).[4] Moreover, changes in consumption patterns have led to amplified environmental issues and reliance on chemical inputs at the field level. The livestock sector in Mauritius is dominated by poultry (broiler chicken and eggs) for which self-sufficiency has been achieved since a few decades. As regard to fisheries, it accounts to about 4% of GDP and contributes to food security and poverty reduction mainly through artisanal fisheries.

An archipelago of 115 islands, Seychelles has scarce agricultural land and food production is limited by a lack of arable land and extreme rainfall patterns and natural calamities like tropical storms, floods and droughts. The agricultural sector is presently a highly fragmented industry with 640 registered farmers and an estimated 5,000 backyard gardeners that account for around 15% of market share. Like in the case of Maldives and Mauritius, its staple food rice is imported. The two traditional export crops, copra (dried coconut meat from which an oil is produced) and cinnamon have dwindled significantly due to high cost of production and competition from low-cost producers on the international market.[5] Livestock production includes goat, pig and chicken and the country is self-sufficient in poultry meat. In Seychelles artisanal fishery plays a meaningful role in food security, employment and revenue earnings. It is exclusively practised by Seychellois small-scale fishers targeting mainly demersal and semi-pelagic species.[6]

Deep dive into the pillars of food security and their associated dimensions

Food security is attained in a circumstance when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which sustains their dietary needs and food preferences for an active and healthy life (FAO, 1996 cited in Najeeb, 2020). At the same time, as per FAO's definition (FAO, 1996), food security has four main pillars namely food availability, food accessibility, food utilization and stability. For food security to prevail, it is believed that all four components have to be sufficiently present. With this in mind, this sub-section will dive into each of these four pillars of food security and their associated dimensions[7] as well as also shed light on one additional food security index widely used by researchers (O'Hagen, 1975; Josling, 1975; Porkka et al., 2013; Liguni, 2018), that is, food self-sufficiency, which is measured as {[production/(production + imports - exports)]*100}, by FAO.

The first pillar food availability is captured by two dimensions: average dietary energy supply adequacy and average value of food production. As demonstrated in Figure 1a in terms of the average value of food production, Mauritius and Seychelles are at par whilst Maldives lags behind. Mauritius leads in terms of average dietary energy supply adequacy.. The statistics also unveil that a the three countries have progressed over the years in terms of GDP per capita, which in turn has improved their food accessibility index. The Covid-19 pandemic impacts are visible from Figure 1b since from 2019 food accessibility experienced a drastic plunge.

[4] https://www.policycenter.ma/sites/default/files/2021-12/PB_37-21_Tsakok.pdf
[5] https://en.wikipedia.org/wiki/Agriculture_in_Seychelles
[6] https://www.rural21.com/english/opinion-corner/detail/article/we-have-nothing-to-hide-but-everything-to-share.html?no_cache=1
[7] Only those dimensions on which data is available for all the three countries are considered.

Figure 1a: Food Availability

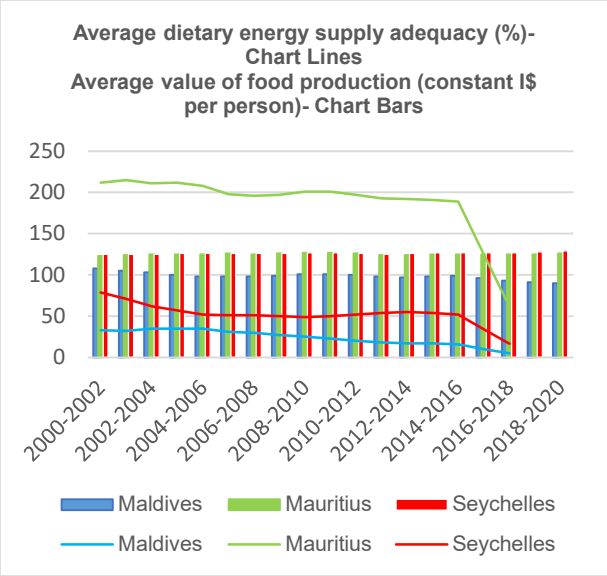
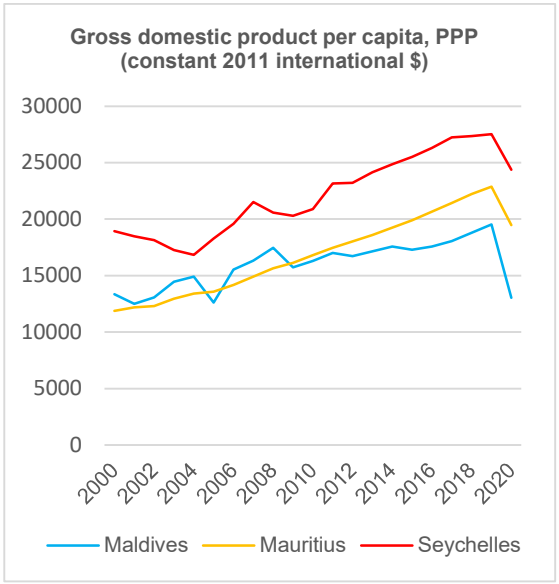


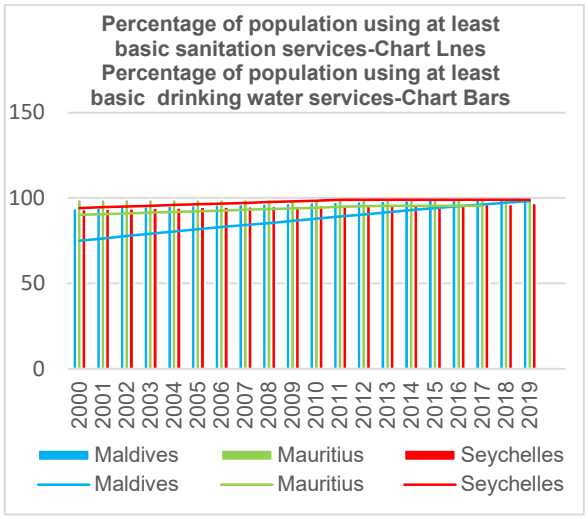
Figure 1b: Food Accessibility

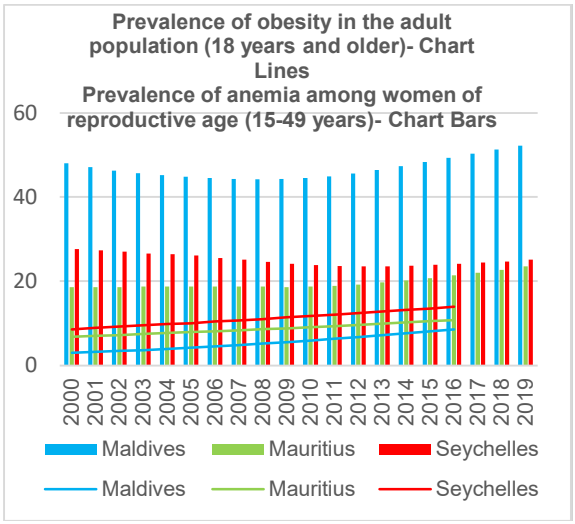


Source: FAO Food Security Statistics

Coming to the third pillar, food utilisation, Figures 2a and 2b illustrate four dimensions which capture it, namely: percentage of population using at least basic sanitation services, percentage of population using at basic drinking water services, prevalence of obesity in the adult population and prevalence of anaemia among women of reproductive age. In Maldives, Seychelles and Mauritius, almost 100% of the population has access to both basic drinking water and sanitation services. Obesity among adults proves to be an issue in both Seychelles and Mauritius and comparatively less worrying in Maldives (though the latter is displaying a rising trend, implying that in the future obesity can turn out to be a matter of concern for Maldives as well). As these islands have moved up the ladder of income classification, they have also experienced substantial changes in dietary and lifestyle patterns. Conventional diets made up of fresh fish, root crops, breadfruit and local fruits and vegetables have been progressively swapped by imported, often highly processed foods such as refined white rice, flour, instant noodles, canned foods, fatty low-grade meats and soft drinks with a high sugar content. Increased reliance on imported foods rather than traditional foods coupled with ease of global food trade and access to low-cost nutrient-poor foods are rendering these already vulnerable small islands states nutritionally insecure. For instance, a look at the statistics on the prevalence of anaemia among women of reproductive age unveils that in Maldives the bar of 50% has been surpassed.

Figure 2a and Figure 2b: Food utilisation



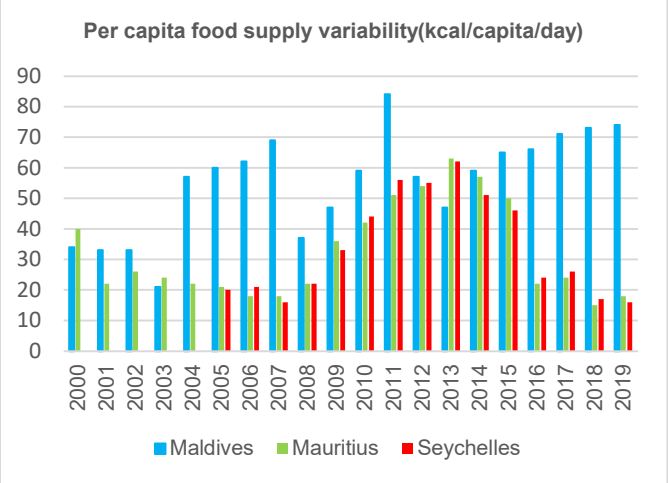


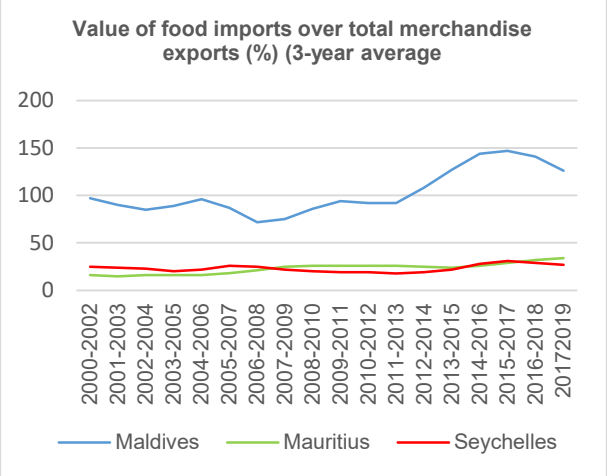
Source: FAO Food Security Statistics

Food stability, the fourth dimension of food security refers to the ability to obtain food over time and ability to acquire food even in times of economic, climate and or health crisis. According to FAO, there are six measures for the stability dimension, but based on data availability and for ease of comparison, we are considering only two of them as displayed in Figures 3a and 3b. Data on per capita food supply variability, one of its measures, shows that though all the three countries demonstrate some degree of vulnerability in this measure, Maldives is the one with the highest volatility. This high volatility is also reflected in its high food price volatility. The excessive variability in food supply in Maldives may result from a mixture of factors like instability in production, trade, consumption and storage as well as government policies such as taxes and subsidies, trade restrictions, stockholding and public distribution. [8] Moreover, it should be noted that secured all year access to affordable food for these India Ocean Islands is challenged by their poor integration in i) regional and global trade channels(as they rely on a few distant partners for their basic food supplies) and ii) in global values chains. Using the second measure of food stability, value of food imports over total merchandise exports- it can be noted that again among the three economies Maldives faces the highest food insecurity. Figure 3b displays that from 2011 onwards the latter has been spending more on imports than it has earned in merchandise exports (the measure being >100%) thereby illustrating the inadequacy of foreign exchange reserves (mainly earned from tourism) to pay for food imports.[9]

[8] https://unctad.org/fr/node/33192
[9] Seychelles' data on per capita food supply availability is available from 2005.

Figure 3a and Figure 3b: Food stability





Source: FAO Food Security Statistics

A glimpse at our self-sufficiency ratio from Table 1 exposes again the same scenario revealed by the majority of the food security measures discussed above, that is Maldives being the most food insecure country among the three, followed by Seychelles and then Mauritius. Both Maldives and Seychelles rely 100% on imports for their wheat, rice and milk supplies, whilst in the case of poultry meat, local production meets around one quarter of the domestic demand. Mauritius is the only country, which is almost self-sufficient in poultry meat.

Table 1: Self-Sufficiency ratio (%).

YEAR	MALDIVES		MAURITIUS		SEYCHELLES	
	Milk	Poultry Meat	Milk	Poultry Meat	Milk	Poultry Meat
2010	0	14	18	98	0	33
2011	0	13	21	98	0	25
2012	0	22	23	98	0	0
2013	0	17	21	96	0	0
2014	0	18	19	96	0	0
2015	0	15	21	96	0	25
2016	0	20	15	96	0	0
2017	0	14	15	96	0	25
2018	0	7	12	94	0	25
2019	0	21	12	93	0	25

Sources: Author's calculation using FAO Food Balance Data.

Covid-19 impacts

The already fragile food system of the three island economies has been further challenged by the Covid-19 pandemic. Closed borders, national lockdowns, and the restricted air and sea traffic have had tremendous negative impacts on food supply chains, which in turn have triggered food price hikes. At the same time, trade disruptions have rendered accessibility to imported agricultural inputs such as fertilizers, crop protection products, equipment and seeds from different parts of the world, more difficult. Such market and trade disturbances have raised costs of production and/or cause decline in crop yields. Movement controls at national level have also led to labour unavailability resulting in lower productivity and supply of food

not meeting local demands. For instance in Maldives, given its high dependency on food imports, the government chartered international flights to Thailand, UAE and Sri Lanka to obviate food shortages and citizens were urged to restart farming practices and were proposed guaranteed purchase of yields at predetermined prices. Alongside, the value of fish exports fell by 46% in March 2020 in annual terms. In the case of Seychelles, fishing vessels catching fresh tuna for export to Europe and US markets came to a standstill in the absence of affordable air cargo. Moreover, the cost of imported inputs in the livestock industry increased by approximately 30% following the deprecation of the domestic currency against the Euro and the US Dollar following the Covid-19 pandemic. In Mauritius, there was significant loss of vegetables and fruits resulting from restricted mobility of farmers to irrigate their crops. Regarding the fisheries sector, artisanal fisheries, which are critical for food security on the island as well as serve the tourism sector, were badly affected by Covid-19 crisis mainly during the national lockdown in March 2020. [10]

Yet the pandemic has also unlocked some avenues for new opportunities. For example in Seychelles new prospects emerged in terms of processing fish into value-added products such as fish cakes, fish balls and fish sausages either for the local market or as potentially new export products. In Mauritius, with limited access to imported fertilizers and pesticides agro-ecological practices such as organic farming, use of natural fertilizers and herbal pesticides were promoted in farms, which in turn benefited the natural ecosystem and ensured financial inflow to farmers. Steps were also taken to recycle livestock manure and other faecal materials as agricultural inputs. The project family farming revived to some extent the interests of the young generation in farming and this was a major step towards sustainable farming and food security given the ageing farmers population in the island state.[11]

Methodology

To assess the determinants of food security, this paper uses food stability, more precisely value of food imports as a % of total merchandise exports, as a proxy of food security. This is due to few data points[12] on other pillars of food security which will not fit a time series model. In addition, according to Clapp (2015), Civin and Smutka (2020) and the Food Security Information and Knowledge Sharing System (2021), this indicator captures the vulnerability of an economy to food imports and the level to which the reserves of foreign exchange can afford these imports. Value of food imports as a % of total merchandise exports is then viewed as appropriate to measure the contributors and risks to food stability and thus, to food security. Hence, the dependent variable is value of food imports as a % of total merchandise exports. The inclusion of the explanatory and control variables in our model is guided by existing literature (see Table 3) as well as the contexts under consideration. Yet it must be noted that, given the dependent variable is already currency-laden, our model does not include the exchange rate as one of the explanatory variables even though prescribed as on in the reviewed studies above.

Thus, our econometric model is:

$$\ln Y_t = \beta_0 + \beta_1 \ln gdpcap_t + \beta_2 \ln gdfcfagri_t + \beta_3 \ln tradeopen_t + \beta_4 \ln prodindex_t + \beta_5 \ln sharenonagri_t + U_t \quad (1)$$

The variables in the above equation (1) and data sources are presented in Table 3.

[10] https://www.cffacape.org/news-blog/after-being-stranded-for-months-due-to-covid-19-pandemic-mauritian-artisanal-fishers-are-now-stuck-between-polluted-waters-and-insufficient-financial-support

[11] https://www.theclimakers.org/fr/mauritius-nature-based-solutions-to-cope-with-climate-change-and-covid-19/

[12] Example for food availability and food utilization we have only 17 and 18 data points respectively.

Table 3: Variables' Definition, Measure, Justification and Data Sources.

Variable	Definition	Measure	Justification for of inclusion	Data Source
lnY	Food security captured by food stability	Ln Value of food imports as a % of total value of merchandise exports	Dependent variable	Calculated by author using FAO data
Lnshare-nonagri[13]	Non-Agriculture share in GDP	Ln Non-Agriculture Value Added as a % share in GDP	Timmer (2009a)- to capture the effect of structural adjustment	Calculated by author using World Bank data
lngdpcap	Gross domestic capital per capita	Ln GDP per capita	Modernization Theory	World Development Indicators
lngdfcfagri	Share of investment in agriculture	Ln Gross Fixed Capital Formation of Agriculture as a share of Total Gross Fixed Capital Formation	Breisinger et al. (2012); Adom (2014); Manap and Ismail (2019); Pawlak and Kołodziejczak, (2020)	World Bank
lntradeopen	Trade openness an indicator of the degree to which the country is open to trade and the adoption of new food production practices and technologies.	Ln Trade share in GDP[14]	Economic Dependence Theory	World Bank
lnprodindex	Food Production Index which is a composite one, capturing agricultural productivity, climate effects, domestic production quantity and crop diversification and quality of the produce.	Ln Food Production Index	Oke (2015); Kopnova and Rodionova (2017); Pawlak and Kołodziejczak (2020)	FAO
U	Error term			

The time series regression for each country is run using data for the period 1988-2020. For the purpose of generating output for analysis, the statistical software STATA has been used. It must be noted that originally our econometric model also included other independent variables mentioned in the literature review like population size, inflation rate, interest rate, share of agriculture in employment and arable land. However, due to their high collinearity with other explanatory variables and/or because their inclusion significantly affected the goodness of fit, we have dropped them from the equation. The multicollinearity test of the

[13] Our first best proxy for structural change is productivity gap between agriculture and non-agriculture sector but due to the absence of data on productivity at sector level for Seychelles, we are using non-agriculture share in GDP as a measure of structural transformation.

[14] A priori, we would have preferred to use a more complete index of trade openness, like the trade freedom score which is based on two inputs: (i) the trade-weighted average tariff rate; and (ii) non-tariff barriers (NTBs). However, due lack of data on this score to run a proper time series, we have used the more common trade openness measure.

retained independent variables shows variance inflation factor (vif) values less 10, in the case of all the three countries. The low degree of multicollinearity reduces the chance of an over-fitting model. This also makes it easier to interpret the regression output as the coefficients are less sensitive to small changes that may arise in the model. Table 4 summarizes the variables for all three SIDS under study.

Table 4: Summary of variables.

Variable	Obs	Mean	Std. dev.	Min	Max
MALDIVES					
Lny	33	4.12	0.50	2.98	5.01
Lngdpcap	33	8.15	0.83	6.69	9.26
Lngdfcfagri	33	0.09	0.20	-0.43	0.51
Lntradeopen	33	5.06	0.07	4.77	5.13
Lnprodindex	33	4.90	0.19	4.58	5.19
Lnsharenonagri	33	4.54	0.01	4.52	4.56
MAURITIUS					
Lny	33	3.32	0.44	2.56	4.07
Lngdpcap	33	8.57	0.53	7.62	9.32
Lngdfcfagri	33	1.19	0.35	0.66	1.87
Lntradeopen	33	4.75	0.13	4.37	4.92
Lnprodindex	33	4.61	0.07	4.42	4.76
Lnsharenonagri	33	4.54	0.03	4.49	4.58
SEYCHELLES					
Lny	33	4.03	0.37	2.88	4.60
Lngdpcap	33	9.13	0.39	8.33	9.69
Lngdfcfagri	33	-0.67	0.25	-1.18	-0.03
Lntradeopen	33	4.86	0.51	3.97	5.42
Lnprodindex	33	4.86	0.20	4.52	5.21
Lnsharenonagri	33	4.57	0.01	4.56	4.59

Moreover, given the definition of food security in the econometric model, that is share of food imports in total merchandise exports, there was a need to account for the endogeneity of the explanatory variables. Having endogenous regressors in the model would cause the ordinary Least Squares estimators to fail. For the endogeneity test, the Durbin score and Wu-Hausman test have been applied. Given their respective p values were >0.05, we do not reject the null hypothesis that the explanatory variables of our model are exogenous. At the same time, evidence from the Jarque-Bera test of each variable confirms a p-value greater than 5%; hence, the variables are normally distributed. Consequently, we can proceed with Ordinary Least Square (OLS) estimation.

Another important test for time series data is to ensure that the variables are stationary. To meet this objective the Dickey-Fuller (DF) and Philip-Perron (PP) unit root tests have been used. Given that the p-values are < 0.05 at first difference for all the listed variables, it can be said that all them are stationary at first difference and hence are integrated of order 1, for Maldives, Mauritius and Seychelles.

Given all our variables achieve stationarity after first difference, the regression model (1) becomes:

$$\ln\Delta Y_t = \lambda_0 + \lambda_1 \Delta\text{lngdpcap}_t + \lambda_2 \Delta\text{lngdfcfagri}_t + \lambda_3 \Delta\text{lntradeopen}_t + \lambda_4 \Delta\text{lnprodindex}_t + \lambda_5 \Delta\text{lnsharenonagri}_t + \Delta U_t \quad (2)$$

However, equation (2) provides information only about the short-run relationship between the variables and ΔY is bound to give us no information about the long-run behaviour

of the model. To solve this issue of lack of information about long-run relationships the concept of cointegration and the ECM are used.

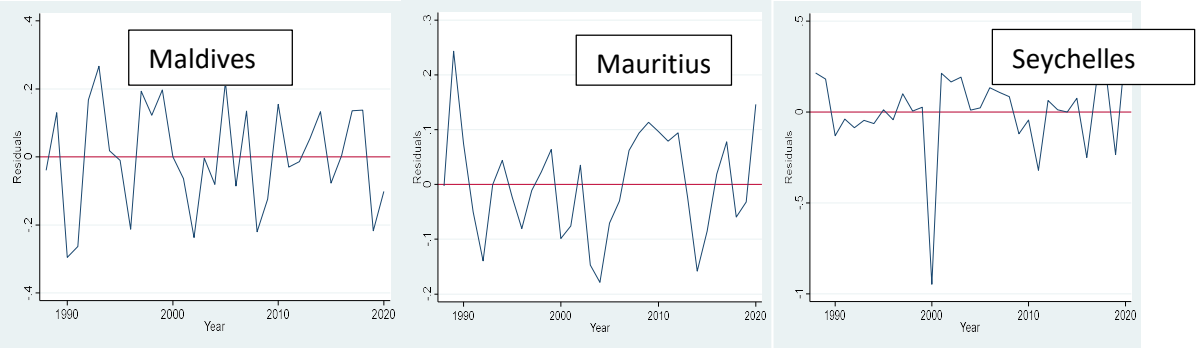
Test for cointegration

Given all our variables are integrated of order 1, the next step is to test for cointegration that is whether there is a correlation between our dependent and the independent variables in the long term. For this we apply the two steps of the Engle-Granger test which estimates the cointegrating regression and test the residuals from the cointegration regression for unit roots. The results of the Engle-Granger tests are depicted in Table 5 and it can be noted that since the calculated test statistic > critical value at 5% (in absolute terms), it can be deduced that the error terms from the cointegrating regressions are white noise. The visual plots of the residuals against time for the three countries in Figure 5 also reiterate the results of the Engle-Granger test.

Table 5: Engle-Granger test for cointegration.

Maldives N (1st step) =33 N(test) = 32			**Mauritius** N (1st step) =33 N(test) = 32			**Seychelles** N (1st step) =33 N(test) = 32		
	Test Statistic	5% Critical Value		Test Statistic	5% Critical Value		Test Statistic	5% Critical Value
Z(t)	-5.549	-5.051	Z(t)	-4.179	-3.791	Z(t)	-6.436	-2.80

Figure 5: Plots of residuals from cointegrating regressions.



Since the results from the Engle-Granger test as well as the plots of the residuals confirm that our variables are cointegrated, we can express the relationship between the dependent and independent variables with an ECM specification as:

$$\ln\Delta Y_t = \theta_0 + \theta_1 \Delta\text{lngdpcap}_t + \theta_2 \Delta\text{lngdfcfagri}_t + \theta_3 \Delta\text{lntradeopen}_t + \theta_4 \Delta\text{lnprodindex}_t + \theta_5 \Delta\text{lnsharenonagri}_t - \pi\hat{U}_{t-1} + \varepsilon_t \quad (3)$$

Equation (3) now includes both long-run and short-run information, where the θs represent the impact multiplier (the short-run effect) that measure the immediate impact a change in the explanatory variables will have on a change in food stability. On the other hand, π is the feedback effect, or the adjustment effect, and shows how much of the disequilibrium is being corrected – that is the extent to which any disequilibrium in the previous period affects any adjustment in $\ln Y_t$. In equation (3) all the variables are stationary, including the estimated residuals $\hat{U}$ and hence OLS should perform well.

Discussion of results

This section of the paper discusses the results from the long-run equations (OLS) as well as the short-run equations (ECM). Table 6 summaries the findings of the regressions for the three economies.

Table 6: Results of short-run and long-run equations.

	Maldives		Mauritius		Seychelles	
Short–Run Estimates	Coefficients	P >| t |	Coefficients	P >| t |	Coefficients	P >| t |
Δlngdpcap	.452	.240	.302	.130	-.068	.857
Δlngdfcfagri	.340	.511	-.024	.684	.176*	.035
Δlntradeopen	-1.155	.771	-.625*	.045	-1.367*	.000
Δlnprodindex	-.785*	.012	-.356*	.004	.476	.218
Δlnsharenonagri	2.226	4.24	.456	.840	7.249	.470
Cons	.264*	.015	.017	.397	-1.181	.602
$\hat{U}_{t-1}$ (Error Correction Term)	-.748*	.000	-.390*	.049	-.021*	.000
No. of Observations	32		32		32	
F (6, 25)	5.10		4.53		14.54	
Prob>F	0.015		0.000		0.000	
Shapiro-Wilk W test	1.495		0.600		2.466	
Prob>z	0.201		0.856		0.030	
Portmanteau statistic	18.045		28.223		8.170	
Prob>chi2(14)	0.205		0.123		0.880	
Long-Run Estimates	Coefficients	P >| t |	Coefficients	P >| t |	Coefficients	P >| t |
lngdpcap	.374*	.000	.754*	.000	.267	.369
lngdfcfagri	.214	.268	-.024	.714	.372*	.025
lntradeopen	-1.646*	.009	-.857*	.009	-1.712*	.001
lnprodindex	-.836*	.003	.239*	.047	-.0339	.920
lnsharenonagri	5.841	.181	-.407*	.049	7.796	.511
Cons	-13.061	.489	10.316	.160	-30.187	.572
No. of Observations	33		33		33	
F (5, 27)	50.42		107.85		9.07	
Prob>F	0.000		0.000		0.000	
Adjusted-R^2	0.8033		0.9323		0.7268	

Note: The * denotes the statistical significance of the coefficients.

Given the p-values of the F-test of overall significance <0.05 for all the three countries in both the short-run and long-run equations, the statistical evidence suggests that our regression models fit the data. At the same time, the p-values of both the Shapiro-Wilk W test and the Portmanteau statistic are <0.05, thereby denoting that the residuals are normally distributed as well as white noise. Before interpreting the results it must be noted that since our dependent variable (share of food imports in total merchandise exports) is negatively related to food stability and hence food security, thus any variable which leads to its increase infers a fall in food security. At the same time, all variables are in natural logarithms and as such their associated coefficients refer to elasticities. Furthermore, the negative and statistically significant coefficients of the error correction terms ($\hat{U}$t-1) in all the three short-run equations imply that the series do not drift too far apart and convergence is achieved in the long-run. For example, in the case of Maldives a coefficient of -0.748 implies that the speed of adjustment is around 74.8% annually. In other words, this means that whenever there is a change in the explanatory variables, the dependent variable will deviate from its long run equilibrium value. The value -0.748 indicates that its takes one year in order to eliminate 74.8% of this deviation in the case of Maldives. For Mauritius and Seychelles, annually 39% and 21% of the deviation is eliminated, respectively. The high speed of adjustment back to long-run equilibrium in the

case of Maldives implies that it is relatively more difficult to ensure a sustainable food security approach in the island compared to Mauritius and Seychelles. Acknowledging that the situation has further worsened with the outbreak of the pandemic, in 2020 the government established the Agro-National Corporation Pvt Ltd, a state owned enterprise. Its aim is geared towards: i) expediting an efficient supply chain for local agricultural products; ii) working on an import substitution policy that will reduce imports of certain locally produced crops by 50% in the medium term and ii) boosting local production, facilitating value-addition in the agriculture sector, and exploring overseas markets for local agricultural exports in the long-run.

Estimates from the short-run equations reveal that the factors that statistically influence food stability in at least one of the countries are food production index, trade-openness and the share of investment in agriculture. For instance, in Maldives the elasticity of food security with respect to food production is 0.785 whilst in Mauritius the responsiveness of food stability to food production is slightly lower at 0.356. Consistent with our results, Gohar and Cashman, (2015) also found that lack of agricultural land and insufficient water resources are the most frequently causes for a lack of food security. In the same line of thought Misselhorn and Hendriks (2017), using data from Malaysia and Costa Rica stated that productivity enhancement resulting from high-yielding varieties and cropping intensity proved to be vital in enhancing food availability. The positive responsiveness of food security to food production in the two island states suggests that, if governments want to enhance food security in the short-run, they should geared efforts towards raising agricultural productivity, domestic production quantity, crop diversification as well as quality of produce. Examples of initiatives in this respect are visible from Table 2, in both countries, such as the actions under the National Fisheries and Agricultural Policy 2019-2029 of Maldives or the measures mentioned under the Mauritian Strategic Plan (2016 - 2020) for the Food Crop, Livestock and Forestry Sectors. Yet, whether such actions/measures will attain their target depends on the efficiency and effectiveness of their implementation process. There is much room for improvement if food stability is to be enhanced through higher productivity, diversification and quality of produce in these islands. One lesson that can be learnt from the world leader in agriculture productivity, Luxembourg[15], is that higher productivity and quality of produce could be achieved through mechanization, recourse to innovation, introduction of numerous new production methods[16] and techniques and a focus on organic agriculture.

Another important driver of food security in Mauritius and Seychelles proved to be trade openness, with a higher impact in Seychelles (elasticity of -1.367) compared to -0.625 in Mauritius. This result supports the findings of Dithmer and Abdulai (2017) and Fusco, Coluccia and De Leo (2020) as well as the World Trade Organisation (WTO, 2022) view that trade openness compensates for the shortages of the domestic food supply. In addition, using Kang's (2015) result of a u-shaped relationship between trade openness and food security, the significant positive coefficient of the variable Δlntradeopen signals that in both Mauritius and Seychelles trade openness has already reached a threshold where it can improve the status of food security. In these island states, where domestic fluctuations in food supply are frequent, trade seemed to have acted as an excellent buffer. However, it must be noted that our measure of trade openness is not a complete measure. Given it does not take into account nontariff barriers and tends to overestimate openness particularly in small economies, the results should be treated with caution. The next crucial factor positively impacting food security in the short-run, more specifically in Seychelles is the share of investment in agriculture captured by

[15] Agriculture value added per worker was 55,631 in 2019 (constant 2015 US$) whilst that of Maldives and Mauritius were 11849 and 11655, respectively.
[16] https://ma.gouvernement.lu/en/le-ministere.html

Δlngdfcfagri. The positive impact of agricultural investment on food security in general has been noted by Breisinger et al. (2012), Adom (2014) and Manap and Ismail (2019). Yet, as argued by Pawlak and Kołodziejczak (2020), for domestic investment to generate food security and in this case more stability, it should firstly target new research, technologies and logistics, particularly improving agricultural infrastructure, which can yield more and better harvests. Secondly, it should be properly planned before being carried out to avoid wastages and inefficiencies. Hence the low coefficient (-0.176) of Δlngdfcfagri indicates that the responsiveness of food security to investment in the agriculture sector is still quite inelastic and attempts should be made at making such investments more conducive to food security.

Coming to the long-run results, the same variables as in the short-run equations appear to be statistically significant: namely, trade openness, local food production index, and share of investment in agriculture. One interesting finding from the long-run estimates is that a rise is GDP per capita worsens food instability and hence food insecurity in all three island states, though with statistical significance only in Maldives and Mauritius. This goes against the prediction of the modernization theory but supported by the study of Holleman and Conti (2020). They claimed that although many middle income countries register positive economic growths, income inequality still persists and undermines the positive effects that economic growth may have on food security. The negative relationship between income per capita and food security in our results can be partly explained by the fact that since both economies are serviced-based (Maldives to a greater degree), a rise in GDP will not necessarily be associated with an increase in merchandise trade, though it will most probably inflate the food import bill and thus adversely impact food stability (share of food import in total merchandise exports). If another measure of food security was used maybe the results would have been different. Another noteworthy result in the long-run is that the coefficients of the variable trade openness are higher than in the short-run and statistically significant for the three islands states. This can be justified because in the long-run trade openness might impact on food security indirectly through different channels. For instance, Bennet (1954) Jaffe et al. (2011) argue that trade openness promotes exports for abundant products in a country, including low-skilled workers (in some developing countries) that will generate employment opportunities and raise workers' incomes. Such a process can play a crucial role in lessening poverty and raising food security. It is equally vital to record that the share of investment in agriculture is only statistically significant in boosting for stability in Seychelles in both the short-run and long –run. This can be substantiated by the fact that is the only island in or study, which implemented an agriculture investment plan at the national level, known as the Seychelles National Agricultural Investment Plan (SNAIP). The plan was developed and launched in 2012 and sought to harmonize, consolidate and accelerate the implementation of the country's agriculture and food security and nutrition related policies and strategies in the period 2015 to 2020. Food stability proved to have responded positively to the structural transformation that took place in the Mauritian economy as the elasticity of the former with respect to structural change is 0.407 with a p-value of 0.049 in the long-run. The main channel through which this positive elasticity arises is higher productivity in the agriculture sector following structural transformation. This result can be noted only in the case of Mauritius as it is the country, which has known the highest extent of structural transformation[17] compared to Maldives and Seychelles.

[17] A key reason for Mauritius' impressive economic performance has been its ability to transform itself from a largely monocrop sugar economy to a diversified manufacturing and services-oriented economy, and reap large productivity gains (IMF, 2019).

Conclusion and policy recommendations

Food security has been a hot discussion topic among academics, stakeholders and policymakers for many years. This research contributes to the existing literature by focusing on Indian Ocean SIDS which tend to be net food importers and where the impacts of Covid-19 pandemic have confirmed the importance of maintaining food stability and food security. Using the FAO indicator of the stability dimension in food security – i.e., the value of food imports as a share of total merchandise exports – results suggest that the common macro variables which tend to enhance food stability in the short and long-run are trade openness and food production index: these capture domestic production quantity, crop diversification and quality of produce. Only in Seychelles has the share of investment in agriculture statistically improved food security in both the short and long run. The findings also indicate that, in the long-run, economic growth measured by GDP per capita worsens food instability in Maldives and Mauritius. Policy making in any country should be based on its own conditions; yet given the three SIDS we have chosen exhibit characteristics typical of small island economies, the results of this study can inspire policy initiatives that may also be applied to other SIDS. Hence, in light of these findings, some recommendations to policymakers interested in improving the national food security status either in the short-run, long-run or in both instances follow below.

First efforts in the short run should be directed towards expanding domestic crop production quantity, quality and variety and enhancing trade openness. Raising the food production index can be achieved through the use of equipment which are not only sophisticated but are motorized as well. For instance, the Comprehensive Africa Agriculture Development Programme (CAADP) platform, along with many policymakers and scholars, recognizes the importance of agricultural mechanization in promoting food security. Some extent of mechanization is visible in the islands (example introduction of aquaponics in Mauritius) but much remains to be done. Alongside the implementation of mechanized agriculture targeting a large number of farms depend on complementary measures such as access to institutional credit, government extension support services, training of farmers. In SIDS which are prone to natural calamities like drought policymakers should assist farmers through subsidies that can enable them to acquire irrigation system equipment to enhance water management in combating drought and the unbalancing of rainfall patterns.

Mechanizing agriculture and food production also requires investing into the right technologies, infrastructures and expertise and tapping into new food production potentials. There is a growing tendency towards processed and preserved food consumption among the population of these three islands. For example, Maldives, Mauritius and Seychelles do have production potential in tomatoes, fish and eggs, yet, they import preserved forms of the two former food items. Investing into storage and preservation of food items is one way to ensure food stability over longer periods, in scenarios of normality as well as the new normal which may come up. Egg is a well-appreciated food in the countries and yet, the poultry farms do not have sophisticated equipment which cater for egg production from incubation to egg collection. The SIDS could invest this production potential and tap into the canning of eggs, among other food items like their exotic fresh fruits and vegetables. However, the success of new production prospects also depend on consumers' willingness to transit to new products and diet habits. For instance, Luxembourg has advanced towards sustainable food security by focusing on three shifts: a diet shift led by citizens to reduce land/CO_2 footprint; a bio-functional shift led by politicians to prioritize resources; and a cultivation shift led by farmers to maximize sequestration[18]. Additionally, nutrient-rich local food production can be promoted by environmentally friendly agriculture such as zero tillage practices and the use of organic

[18] https://luxembourgintransition.lu/wp-content/uploads/2021/06/2phase_2001-komprimiert.pdf

pesticides. Regional projects like 'AfriCultuReS' meant to assist decision-making in the realm of food security by supporting integrated agricultural monitoring and early warning systems, can be valuable to SIDS which may lack the capacity to embark on such projects alone.

Coming to positive association between trade openness and our measure of food security, the policy recommendations glide towards the following measures. First there is a need to continue implementing strong trade policies and food safety technical rules that abide by the relevant rules of the WTO. Examples can include the reduction of oppressive and complex trade regulations and raising awareness about food safety standards. Second there is also a call for developing the infrastructure of food safety and sanitary and phytosanitary, in order to capitalize on the beneficial effects of trade openness on food security. Third, SIDS need to be more pre-emptive in integrating into key global and regional cooperative platforms to secure more external assistance for enhancing their food security status. And fourth, the influential impact of structural transformation in heightening food stability in the long-run in Mauritius, signal the need for SIDS to diversify their economic base by moving up the value chain to boost competitiveness and spur private investment in the agriculture sector.

Besides, in view of the unfavourable impacts of Covid-19, it would be wise for the island economies to come up with and implement a contingency plan. This plan, enforced by legislation, should define and elaborate the procedures and steps that the country has to follow in times of food crises, for example, in case some country cannot operate its food supply chain. Building on lessons, such as wars, pandemics and other restrictions, the contingency plan will help stakeholders identify threats to food stability, inasmuch to food security and prepare itself and respond to the crisis. One example would be to plant crops and grow livestock in advance, especially those which take longer to mature.[19] Another example would be finding substitutes for food items which may become scarce, unavailable or inaccessible. The plan needs to recognize the type of input needed for its implementation: technology, labour force, logistics.

In spite of its interesting findings, this study has some limitations. First: constrained by data availability, our analysis uses only food stability as a measure of food security. However, there is a wide array of indicators representing each of food security's four pillars in the FAOSTAT. Thus, future studies should construct an indicator system to assess each of the four pillars of food security, and based on which, more comprehensive results can be obtained. Second: based on comparison and by referring to the practice of previous studies, the share of trade over GDP has been used here to measure trade openness. Tariffs, non-tariff barriers and free trade agreements (FTAs) are also used as instruments for trade openness: further analysis of these alternative variables' impact on food security is merited.

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[19] For example, if a potato takes three months to reach harvest time, planters should plant another round of potatoes within those three months so that, when the first crop is at the market, a second crop is reaching harvest time.

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