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The Impact of Logistics on Four Dimensions of Food Security in Developing Countries

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Abstract

With zero hunger in the heart of the Food Agriculture Organization (FAO), FAO's end goal is to ensure that all people always have physical and economic access to sufficient and nutritious food. However, the number of hungry people in the world can be considered as relatively high and the path to reach the level called "enough" food or "perfect" food security still has a long way to go. Considering the complicated nature of food security, this study aims to investigate the impact of logistic performance on food security in 51 developing countries covering the period 2010–2016, under 4 unique dimensions of food security. Applying the generalized method of moments (GMM), the results provide supportive evidence that the level of food security tends to be improving in countries with a higher level of logistic performance. Similarly, it is observed that every dimension of food security, namely food availability, accessibility, utilization, and stability, can be improved with better logistics. Therefore, the overall result suggests that policymakers should improve the level of logistic performance, which is generally far below that in developed countries, so that it can form the fundamental ground toward alleviating hunger and improving the food supply.

Keywords Logistic performance · Food security · Panel data analysis

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Introduction

Zero hunger is one of the pillars of the Sustainable Development Goals (SDGs)[1]. Nonetheless, many parts of the world are still seriously struggling with this issue. As mentioned by the United Nations, several indicators show that this issue is far from being solved. The first fact is that 821 million people were undernourished in 2017, with sub-Saharan Africa maintaining its status quo to be the region with the highest prevalence of hunger of 23.2 percent in 2017, an increase of 2.5 percent relative to 2014 (FAO, 2017, 2018). Moreover, 149 million or 22 percent of children less than 5 years of age were chronically undernourished in 2018. According to the 2019 Global Hunger Index (GHI) by von Grebmer et al. (2018), countries that fall under serious, alarming, and extremely alarming levels of hunger are mainly in African regions, India, and some of the Association of Southeast Asian Nations (ASEAN) countries. Although Latin America, Russia, and East Asia regions generally fall under a low hunger index, the detailed history still shares some frightening issues of increasing index, as shown in Table 1.[2] In South America, apart from Uruguay, Guyana and Bolivia have shown a remarkable improvement in the hunger index but are still under the moderate category. Venezuela, on the other hand, suffers a serious setback when the hunger index is worsening almost double in a decade.

In contrast to North America, the South American region shows consistent improvement in the hunger index in all 6 countries. However, Guatemala and Haiti are still at a serious rate. Europe is generally treated as a region with a low hunger problem, as described by the low hunger index in both years, but currently worsening and the index is close to a serious level.

Meanwhile, Fiji which is the only country in the Oceania region has a similar situation to Georgia in that its hunger index is gradually worsening, albeit still within a low category. For Asia, with more countries on the list, various situations can be observed. Firstly, Yemen is still in the worst scenario of the alarming category, accompanied by 10 countries under the serious category. Secondly, some countries like Lebanon and Malaysia recorded a declining trend in the hunger index, while Turkmenistan, Vietnam, the Philippines, Afghanistan, and Sri Lanka do not show a significant improvement in the hunger index. Accordingly, the rising hunger levels have been becoming one of the targets under Sustainable Development Goals (SDG) of the United Nations, which bring into sharp focus on the theme of food insecurity, which emphasizes the uncertainty and limited availability of nutrition and safe foods or disability to acquire acceptable foods for active and healthy life (Dwyer & Drewnowski, 2017). Food security continues to be a major global challenge even though 72 developing countries out of 129 countries have reached the hunger target of the Millennium Development Goals (MDGs) of the United Nations (United Nations, 2018).

[1] Even refugee camps and refugees can easily be reached if logistic facilities are well in place. Hence, no one can be denied getting sufficient food.

[2] The index is scaled as low ($GHI \leq 9.9$), moderate ($10.0 \leq GHI \leq 19.9$), serious ($20.0 \leq GHI \leq 34.9$), alarming ($35.0 \leq GHI \leq 49.9$), and extreme hunger ($GHI \geq 50.0$).

Table 1 Hunger index of selected countries

	2010	2019	Change		2010	2019	Change
North America				**Asia**			
Jamaica	9.7	8.2	−1.5	Lebanon	8.0	11.6	3.6
Trinidad and Tobago	12.7	9.1	−3.6	Turkmenistan	15.0	11.8	−3.2
Honduras	14.8	12.9	−1.9	Malaysia	11.9	13.1	1.2
Nicaragua	16.2	13.3	−2.9	Vietnam	18.8	15.3	−3.5
Guatemala	22.0	20.6	−1.4	Sri Lanka	18.0	17.1	−0.9
Haiti	48.8	34.7	−14.1	Iraq	23.8	18.7	−5.1
Europe				Myanmar	25.9	19.8	−6.1
Georgia	8.4	9.2	0.8	Indonesia	24.9	20.1	−4.8
Oceania				Philippines	20.5	20.1	−0.4
Fiji	8.6	8.9	0.3	Nepal	24.5	20.8	−3.7
Latin America and The Caribbean				Laos	30.5	25.7	−4.8
Argentina	5.9	5.4	−0.5	Bangladesh	30.3	25.8	−4.5
Brazil	5.4	5.3	1.0	North Korea	30.9	27.7	−3.2
Costa Rica	5.0	<5		Pakistan	35.9	28.5	−7.4
Ecuador	13.2	11.3	−1.9	India	32.0	30.3	−1.7
Uruguay	5.4	<5		Afghanistan	34.3	33.8	−0.5
Guyana	16.0	12.6	−3.4	East Timor	42.3	34.5	−7.8
Bolivia	21.6	15.4	−6.2	Yemen	34.5	45.9	11.4
Venezuela	8.4	16.9	8.5	China	10.0	6.5	−3.5
				Cambodia	27.6	22.8	−4.8
Sub-Saharan Africa							
The Central African Republic	42.0	53.6	11.6	Kenya	27.6	25.2	−2.4
Madagascar	36.2	41.5	5.3	Namibia	30.6	24.9	−5.7
Zimbabwe	35.8	34.4	−1.4	Botswana	28.1	23.6	−4.5
Rwanda	32.4	29.1	−3.3	Nigeria	29.9	27.9	−2.0
Swaziland	26.5	20.9	−5.6	Angola	38.6	29.8	−8.8
Malawi	31.1	23.0	−8.1	Uganda	30.8	30.6	−0.2
Ethiopia	37.4	28.9	−8.5	Lesotho	26.2	23.2	−3.0
Tanzania	34.1	28.6	−5.3				

Source: von Grebmer et al. (2018)

Several factors are cited as critical to food security problems such as rapid population growth (Brown, 1981; Hanjra & Qureshi, 2010), size of arable land (Li et al., 2018; Smith, 2013), and climate change (Rasul & Sharma, 2016; Shresha & Aryal, 2011). Nevertheless, the complexity of delivering sufficient food to the world's population shows why food security poses a significant challenge for developing countries. Food security is highly linked to logistic activities, which refer to both inward and outward flows of food from the farm to the end-user.[3] Broadly speaking,

[3] As well as flow of input to the farmers either from domestic or foreign suppliers.

inefficiencies in logistics can disrupt all segments of the food supply chain, including farm production, food processing, transportation, and people's food consumption, resulting in increased hunger and food insecurity. Similarly, the Shahin (2020) suggests that improving the efficiency of the supply chain is a way of feeding the 800 million hungry people on Earth. In this case, if a country takes this challenge seriously, the government may need to pay more attention to the role of logistics in improving food security. With improvement in logistic performance, we can expect that food, especially nutritious food, can be supplied to the needy in other districts or countries at a cheaper price in a more consistent manner.

Given the fact that food security is an abstract term and consists of several dimensions such as food availability (i.e., a supply of total food), food utilization (i.e., supply of healthy food), food accessibility (i.e., cheap price-led affordability), and food stability (i.e., consistent supply), it is interesting to also examine the role of logistics on each of the dimensions suggested by FAO (2018). Although every country in the world is improving its logistic condition to be favorable to businesses, the score profile of the logistic performance index has shown limited dissimilarity between 2007 and 2014 for 160 countries investigated (Arvis et al., 2018).[4] Therefore, the question of whether logistics improvements will affect food security arises. To confirm this hypothesis, this study examines the implication of logistic improvement on food security in developing countries, with a special interest in its implication on each dimension of food security; 51 countries have been utilized as a sample for a period between 2010 and 2016 using the regression analysis of GMM. In doing so, the paper contributes to existing research on the logistics-trade nexus by shedding new empirical light on the importance of logistical accomplishments in enhancing food security, particularly its separate dimensions, namely food availability, food accessibility, food utilization, and food stability.

The rest of the paper is structured as follows. The "Literature Review" section reviews the literature of past studies, and the "Methodology" section presents the research methodology, including model specification and the estimation strategy. The empirical results are reported in the "Result" section, and finally, the "Conclusion" section concludes the article.

Literature Review

The pioneering work in this field, which links food security and population growth, can be traced back to Malthus (1798). The Malthusian theory identifies that food shortages exist due to the presence of too many people compared to the amount of food supply and thus exacerbated long-run food insecurity (Malthus, 1798). The

[4] In other word, each developing country has tried hard to improve their logistic condition and resulted in more or less similar co-movement as compared to developed countries. Only after 2016 that the gap between developed countries and developing countries' logistic performance has widened.

population tends to grow at a much faster rate than human substances, such as foods and products based on agriculture. Accordingly, empirical studies by Ehrlich et al. (1993), Gilland (2002), Faisal and Parveen (2004), Godfray et al. (2010), Schneider et al. (2011), Tian et al. (2016), and Hall et al. (2017) reveal that population growth hurts food security. A substantial increase in population results in an increase in water demand for consumption and land use for housing, which in turn reduces agricultural production. Continuous reduction in crop production will cause people to suffer from food shortages and thus pose a serious threat to food security. Overall, the result shows that more population significantly decreases the food supply and thus can play a role in addressing food security problems. Hence, this study can synthesize from past studies that population growth negatively affects food security.

Arable land is another important variable that can affect food security. In keeping with the original Malthus, neo-Malthusians only add to the classical Malthus theory that in addition to population size, the land is also set as an important basis for food security. This implies that more land significantly increases the food crops and thus can play a role in addressing food security problems. This hypothesis has been confirmed empirically by Arnell et al. (2004), Schneider et al. (2011), Negash and Swinnen (2013), Mahmood et al. (2016), Meyfroidt (2018), Zhang et al. (2018), and Delvaux and Paloma (2018). Arnell et al. (2004), Schneider et al. (2011), Negash and Swinnen (2013), Meyfroidt (2018), Zhang et al. (2018), and Delvaux and Paloma (2018) explain that the improvement of agricultural production depends on arable land while it is impossible to secure food production without this attribute. Therefore, land as a static resource plays an essential role and foundation in the production of crops as well as making more food available for a growing population. In sum, this study discovers that arable lands are the key to maintaining and achieving food security.

The role of environmental quality in food production can be considered as one of the basic economic principles. Theoretically, the theory of Food Availability Decline (FAD) proposes that food insecurity is primarily caused by a decline in food availability that leads to insufficient food to feed the growing population. The theory strongly emphasizes the supply side failure as the source of the problem. Due to that, the FAD indicates that food production is vulnerable to environmental degradation. Empirically, Faisal and Parveen (2004), Droogers (2004), Gregory et al. (2005), Hanjra and Qureshi (2010), Codjoe and Owusu (2011), Sarr (2012), Rasul and Sharma (2016), Connolly-Boutin and Smit (2016), and Hall et al. (2017) find that environmental degradation has a significant negative impact on food security. Climate change is expected to increase temperature, thereby reducing crop yield and production in the short and long term. Codjoe and Owusu (2011) and Sarr (2012) also recognize that flooding is destroying growing seasons, leading to crop loss, low yields, and reduced food availability. Overall, it suggests that environmental degradation poses significant threats to food security due to changes in crop productivity and food supply.

Food Entitlement Decline (FED) theory focuses on the set of alternative commodity bundles that a person can command in a society using the totality of rights and opportunities that he or she faces. Simply, FED theory is more concerned about access to food or demand sides of food security which is far more important than food availability. Thus, food demand or consumption is determined by several variables such as income inequality (Masters et al., 2013; Otsuka, 2013) and price (Campbell et al., 2016; Koizumi, 2015). Meanwhile, empirical studies such as Hanjra and Qureshi (2010), Otsuka (2013), Masters et al. (2013), Koizumi (2015), Campbell et al. (2016), Grzelak (2017), and Elmes (2018) shift the focus on the role of income inequality and its implication on food security. According to Otsuka (2013), Masters et al. (2013), Swinnen (2015), Koizumi (2015), Campbell et al. (2016), and Elmes (2018), income inequality intensifies food insecurity by perpetuating poverty and widening the inequalities in terms of affordability to get food. Unequal distribution of income remains an issue of concern because poor households would not have enough money to purchase nutritious food relative to those who are rich, but small. Hence, this implies that a higher level of inequality weakens the accessibility of households to consume sufficient food.

Aside from income inequality, food price also affects food security. Koizumi (2015) and Campbell et al. (2016) show that food prices can be an important element in whether people can get enough food to conduct an active life, given their fixed low income. Higher food prices may threaten food consumption by the poorest people who are not regularly getting enough food, especially nutritious food. In this case, household purchasing power is constrained by food prices, particularly in developing countries. As a result, this study predicts that there is a negative relationship between the price and food supply.

Over the last few decades, studies related to logistic performance have generally emphasized that logistic performance is one of the major factors contributing to economic growth through increased employment opportunities, national income, and attracting international investment. Given the importance of logistic performance, several studies such as Hobbs and Young (2000), Aghazadeh (2004), Hsiao et al. (2010), Zhang and Li (2012), Siddh et al. (2017), La Scalia et al. (2017), Sharma and Parhi (2017), and Mittal et al. (2018) emphasize the significant influence of logistic management on food supply. From the findings of the previous studies, improvement in logistics management has a positive impact on the food supply of a country because it improves the effectiveness and efficiency of the food supply chain. According to the Food and Agriculture Organization (FOA), during production, handling, and storage, much food loss occurs. In that way, the recent studies which examine the linkage between logistics and food supply show significant progress in the reduction of post-harvest losses from field to local storage by improving the performance of logistics in terms of handling, storage, distribution, and transport. Overall, most of the past studies discuss the importance of logistics on food supply from a global perspective, while relatively limited analysis is available in developing countries. Also, no empirical analysis has emerged from past studies as the existing literature is classified as a case study, focus group, and descriptive.

Methodology

The food security model can be based on three theories mentioned in "Literature Review." In other words, food security (*FS*) can be formulated as a function of three theories as follows.

$$FS = f(MALTHUS, FAD, FED) \tag{1}$$

where *MALTHUS* refers to the Malthus theory. Hence, the food security function can then be expended after taking into account the proxies for each theory as discussed in the "Literature Review" section to be as follows:

$$lnFS_{it} = \alpha + \beta_1 lnPOP_{it} + \beta_2 lnAL_{it} + \beta_3 lnED_{it} + \beta_4 lnIE_{it} + \beta_4 lnPRI_{it} + \varepsilon_{it} \tag{2}$$

where *FS, POP, ED, IE, PRI,* and ε represent food security, population growth, environmental degradation, income inequality, food price, and the error term, respectively. The subscript i refers to cross-section and t refers to time series. The prefix "*ln*" represents the normal logarithm. Based on the objective of this study, the core variable logistic performance (*LPI*) is added to examine the implication of logistic performance on food security across developing countries. The final estimating model will then be

$$lnFS_{it} = \alpha + \beta_1 lnPOP_{it} + \beta_2 lnAL_{it} + \beta_3 lnED_{it} + \beta_4 lnIE_{it} + \beta_4 lnPRI_{it} + \beta_4 lnLPI_{it} + \varepsilon_{it} \tag{3}$$

Given the panel nature of our data, we adopted the panel data analysis which consisted of pooled, fixed-effect, and random-effect models. Note that, in the first place, all of the observations are pooled in the regression model with the assumption that all of the countries are homogenous. To relax the assumption, the fixed-effect model is the solution. In the fixed-effect model, the intercept may differ across the subjects, and the intercept does or does not vary over time, which is known as time-variant or time-invariant (Gujarati & Porter, 2009). However, the fixed-effect model is expensive in terms of the degree of freedom if there are several cross-sectional units. As a solution, we resorted to the random-effect model. In the random-effect model, the individual error components are not correlated with each other and are not correlated with the cross-section and time-series units. Therefore, the difference between the fixed-effect and random-effect is that each cross-sectional unit has a fixed intercept value in all cross-sectional units.

Although we adopted standard panel models to estimate Eq. (3), we also estimated Eq. (3) by using the generalized method of moments (GMM) estimator. GMM estimation is applied to control for the potential endogeneity of all the explanatory variables. This estimation is referred to the work of Arellano and Bond (1991), but they, in fact, popularized the work of Holtz-Eakin et al. (1988). Following Arellano and Bond (1991), the difference GMM estimator transforms Eq. (3) into a first difference to eliminate the country-specific effect and use lagged levels of regressors as instruments to eliminate simultaneity bias. Nevertheless, the difference GMM estimator led to incorrect inferences if the explanatory variables are persistent, and the lagged levels of the variables become weak instruments (Arellano & Bover, 1995). In this case, System GMM undertakes the first difference GMM by combining the level and difference equations (Blundell & Bond, 1998). The lagged differences of the regressors are then used as additional instruments for a level equation. Moreover, the consistency of the GMM estimator depends on two specification tests, namely Hansen and serial correlation (or autocorrelation) tests. In the Hansen test of over-identifying restriction, failure to reject the null hypothesis would imply that the

Table 2 List of variables, definition, and sources

Variables	Definition/measurement	Sources
lnPOP	Annual population growth rates	World Bank (2018)
lnED	Carbon dioxide emissions in metric tons per capita	World Bank (2018)
lnAL	Land area in the percentage of the total land	World Bank (2018)
lnLPI	Index of logistics performance	World Bank (2018)
lnPRI	Food price index	FAOSTAT (2018)
lnIE	Income inequality in the GINI index	OECD (2018)
lnFS	Food security dimensions where $lnFS_{AVA}$, $lnFS_{ACC}$, $lnFS_{UTI}$, $lnFS_{STA}$ stand for food availability, food accessibility, food utilization and food stability, respectively	FAOSTAT (2018)

instruments are valid, and the model is correctly specified. Serial correlation tests the null hypotheses of no first-order serial correlation and no second-order serial correlation in the residuals of the first-differenced equation. Rejection of the null of the absence of first-order serial correlation $AR(1)$ and failure to reject the absence of second-order serial correlation $AR(2)$ will validate and conclude that the models are correctly specified (Ibrahim & Law, 2014).

Data

On the measurement of the food security index, this study constructs the index based on the average of four components or dimensions of food security by FAO, namely the index of food availability, food accessibility, food utilization, and food stability. Besides that, logistic performance is measured as a logistic performance index (*LPI*), expressed in the index number.[5] We use a panel of 51 developing countries over the period 2010–2016. The present study uses various data sources to obtain the datasets on dependent and independent variables, as summarized in Table 2.

Result

Before proceeding to estimate the panel data technique, this study starts the analysis by examining the descriptive and correlation analysis (see Table 3). According to the descriptive statistics, the mean for food security (*lnFS*) of a group of developing

[5] The LPI is a comprehensive index created to help countries identify trade logistics performance challenges and opportunities. The LPI assesses the performance of countries in the six areas identified below and is an equally weighted average of these six components, such as (1) the efficiency of customs and border clearance, (2) the quality of trade and transport infrastructure, (3) the ease of arranging competitively priced shipment, (4) the competence and quality of logistics services, (5) the ability to track and trace consignments, and (6) the frequency with which shipments each consignees within scheduled or expected delivery times into a single aggregate measure (Martí et al., 2014; World Bank, 2018). Methodology, LPI is based on a worldwide survey of multinational freight forwarders and the main express carriers. The LPI survey1 was designed and is implemented by the World Bank International Trade and Transport Departments, with the support of Finland's Turku School of Economics (TSE). The World Bank conducts the LPI survey every two years.

Table 3 Summary of variables

Variable	*lnFS*	*lnFS$_{AVA}$*	*lnFS$_{ACC}$*	*lnFS$_{UTI}$*	*lnFS$_{STA}$*	*lnPOP*	*lnAL*	*lnED*	*lnIE*	*lnPRI*	*lnLPI*
Mean	43.43	51.68	29.79	69.16	23.10	1.21	19.02	90.63	39.89	174.30	*3.48*
Std. dev	4.37	7.65	23.27	11.90	11.39	1.06	16.38	13.70	39.89	112.60	*1.06*
Min	34.33	35.27	32.40	34.92	23.09	−1.19	0.07	2.28	39.89	38.49	*1.72*
Max	61.95	74.51	99.26	85.83	54.70	3.72	62.18	99.86	39.89	788.68	*3.75*
lnFS	***1.00***										
lnFS$_{AVA}$	0.09	1.00									
lnFS$_{ACC}$	0.26	0.28	1.00								
lnFS$_{UTI}$	0.18	0.17	0.23	1.00							
lnFS$_{STA}$	0.36	0.34	0.44	0.26	1.00						
lnPOP	−0.04	−0.32	−0.28	−0.50	−0.09	1.00					
lnAL	0.06	0.05	0.04	0.08	0.03	−0.19	1.00				
lnED	−0.06	−0.27	0.30	−0.20	−0.13	0.27	0.14	1.00			
lnIE	−0.02	0.25	−0.24	0.08	0.14	−0.01	0.07	−0.09	1.00		
lnPRI	−0.04	0.04	−0.10	−0.05	−0.05	−0.08	0.27	−0.10	−0.19	1.00	
lnLPI	−0.15	−0.18	0.14	−0.04	−0.06	0.05	−0.17	−0.06	0.05	0.02	1.00

countries is recorded as 51.68 percent. The maximum *lnFS* is 74.51 percent and could be represented by the case of Thailand in 2016, whereas the lowest food security is observed at 35.27 percent and potentially refers to Sudan in 2011. The mean value of the *lnPOP* for the developing countries during the same period is only at 1.21 percent, while the maximum *lnPOP* is 3.72 percent in the year 2016 (for Sudan). For arable land, the maximum value of 62.18 percent and minimum value of 0.07 percent are recorded in 2016 (for Ukraine) and 2015 (for Belarus), respectively. The mean and maximum value of the logistic performance index is recorded as 3.48 percent and 3.75 percent. Looking at the standard deviation, the statistics state that food price has the greatest variation and is followed by income inequality and environmental degradation. Besides, Table 3 also displays the results of the correlation matrix for the independent and dependent variables. The correlation between food security and population growth, environmental degradation, income inequality, and food price are negative and consistent with the studies of Tian et al. (2016), Connolly-Boutin and Smit (2016), Campbell et al. (2016), Elmes (2018), and Hall et al. (2017). However, the logistic performance index demonstrates a positive correlation with food security and failed to be in line with the previous studies by Siddh et al. (2017), La Scalia et al. (2017), Sharma and Parhi (2017), and Mittal et al. (2018).

The result of the static panel analysis, like the pooled, fixed-effect (FEM), and random-effect (REM) models, is shown in Table 4. As observed in Table 4, the Breusch-Pagan test is applied to choose the best model between the pooled regression and random-effect models. Hence, the *p-value* is significant at one percent and implies that the random-effect model is more favorable than the pooled regression. Then, we run the *F*-statistic (poolability) test to compare the pooled regression and the fixed-effect models. The result accepted the alternative hypothesis and concluded that the preferred model is the fixed-effect model. Finally, the choice between

Table 4 Regression analysis – full sample [$DV = lnFS$]

	Pooled	FEM	REM
C	0.501*** [2.82]	0.928*** [9.12]	0.362*** [2.92]
lnPOP	−0.095*** [−2.75]	−0.079*** [−2.53]	−0.102*** [−2.46]
lnAL	0.044*** [2.93]	0.134** [2.29]	0.243** [2.24]
lnED	−0.082*** [−3.20]	−0.084*** [−3.41]	−0.684** [−2.21]
lnIE	−0.017*** [−2.45]	−0.017* [−1.69]	−0.014* [−1.96]
lnPRI	−0.077*** [−2.93]	−0.020* [−1.84]	−0.098* [-2.03]
lnLPI	0.156*** [2.79]	0.027** [2.23]	0.049*** [3.12]
		Model criteria	
Adj-R^2	0.545	0.518	0.640
F-stat (overall)	142.42*** (0.00)	25.94*** (0.00)	142.66*** (0.00)
LM test	735.15*** (0.00)	-	-
F-stat (poolability)	-	58.61*** (0.00)	-
Hausman test	-	-	35.97*** (0.00)

Figures in "[]" stand for *t*-statistic, and figures in "()" stand for *p*-value. Adj-R^2 is adjusted R^2. The variables are in logarithmic form

*Significance at the 10% level; **Significance at the 5% level; ***Significance at the 1% level

the fixed- and random-effect models is tested by using the Hausman test. As the *p*-value of the χ^2 is less than one percent, the Hausman test does not accept the null hypothesis and concludes that the fixed-effect is the superior model over the random-effect model. Thus, the fixed-effect is the appropriate model over the pooled and random-effect models.

Several observations from the results can be derived. First, this study observes that population growth has a significant negative impact on food security. For instance, the population growth coefficient of 0.059 suggests that every one percent increase in population is associated with an average decrease in food security by 0.079 percent. Arable land has a significant positive impact on food production. The estimated value of the coefficient on arable land implies that a 1 percent increase in arable land will increase the food supply in developing countries by 0.134 percent. The result also validates the findings of Schneider et al. (2011), Negash and Swinnen (2013), Meyfroidt (2018), Zhang et al. (2018), and Delvaux and Paloma (2018). By increasing the availability of land to farmers, they have a high potential for high food production. With respect to environmental quality, the results in Table 3 demonstrate that environmental quality has a significant negative impact on food security, which is supported by past studies (Godber & Wall, 2014). The environmental quality coefficient of −0.084 suggests that every 1 percent decrease in the quality of the environment is associated with an average decline in food security by 0.084 percent. To the extent that food production is decreased by worsening environmental quality, harmed the capability of countries producing enough food to feed everyone.

Meanwhile, this study finds that a higher level of income inequality decreases the level of food security. In other words, a 1 percent increase in income inequality is associated with a −0.017 percent fall in food security. This outcome is in line with Otsuka (2013), Masters et al. (2013), Swinnen (2015), Koizumi (2015), Campbell et al. (2016), and Elmes (2018), who show income inequality worsens food insecurity by exacerbating poverty and widening access disparities. In addition, food price remains the primary constraint to global food supplies. Increases in food prices tend to lower the purchasing power of households and ultimately reduce people's access to sufficient, safe, and nutritious food (Swinnen, 2015). For instance, the food price coefficient of −0.020 suggests that every 1 percent increase in food price is associated with an average decrease in food security by 0.020 percent.

Moving on to the core variable, it is found that logistic performance is statistically significant at one percent and positively affects food security. The logistic performance coefficient of 0.027 suggests that every 1 percent increase in logistic performance is associated with an average increase in food security by 0.027 percent. The estimated positive sign of logistic performance is close to the one reported by Siddh et al. (2017), La Scalia et al. (2017), Sharma and Parhi (2017), and Mittal et al. (2018). Thus, this highlights that better logistic performance promotes a sizeable increase in food security in developing countries.

Robustness Check

However, the results of the above OLS-based random-effect model may suffer a bias due to endogeneity. This study observes a sign of endogeneity issue by the fact that the independent variables can also influence other explanatory variables. For instance, *lnGDP* and *lnIE* might be having bidirectional causality and hence result in an endogeneity problem. *lnIE* is a critical factor of *lnGDP*, while *lnGDP* itself is considered being a powerful force for reducing income inequality. In economics, a Kuznets curve displays that income per capita increases the income inequality rises until the peak level and started to drop once the income level moves further beyond the threshold level (Kuznets, 1955). Empirically, Shahbaz (2010), Shin (2012), Tiwari et al. (2013), Rose and Viju (2014), and Batabyal and Chowdhury (2015) confirm the hypothesis of an inverted *u*-shaped relationship between income and income inequality. These studies, in short, suggest that there is a possibility of bidirectional causality between *ln*GDP and income inequality.

Therefore, this paper continues the analysis by applying the robustness test of the dynamic panel generalized method of moments (GMM) technique. Table 5 reports the result of GMM estimation for Eq. (3) in one step and two steps, where

Table 5 Regression analysis using GMM [DV: *lnLFS*]

	One step		**Two steps**	
	DIFF-GMM	SYS-GMM	DIFF-GMM	SYS-GMM
$lnL\ FS_{t-1}$	0.238*** [3.26]	0.993*** [5.66]	0.264*** [3.43]	0.984*** [6.14]
lnPOP	−0.008 [1.42]	0.067** [2.15]	−0.002* [−1.91]	−0.084** [−2.25]
lnAL	0.060 [1.50]	0.003*** [2.47]	0.084*** [2.75]	0.003* [1.83]
lnED	−0.003* [−1.77]	−0.002 [−1.64]	−0.005* [−1.76]	−0.085** [−2.21]
lnIE	−0.038* [−1.75]	−0.011* [−1.90]	−0.011*** [−2.20]	−0.009* [−1.96]
lnPRI	−0.085* [−2.01]	−0.014** [−2.24]	−0.021*** [2.38]	−0.001* [1.79]
lnLPI	0.035*** [2.30]	0.002** [2.14]	0.030*** [2.81]	0.023*** [2.35]
	Model criteria			
Hansen	0.273	0.954	0.273	0.350
AR(1)	0.065*	0.086*	0.009***	0.035**
AR(2)	0.318	0.170	0.811	0.128
Dif-Sar	-	0.793	-	0.922
#instruments	33	39	33	39
#country	41	41	41	41

Figures in "[]" stand for *t*-statistic. The values of the Hansen and AR tests stand for the *p*-value

*Significance at the 10% level; **Significance at the 5% level; ***Significance at the 1% level

both analyses remain largely similar across estimations. The Hansen test fails to reject the null hypothesis of no over-identifying restrictions and recommended that we have a valid model of specification. Subsequently, serial correlation statistics reject the null of no first-order autocorrelation for AR (1), while it fails to reject the null of no second-order autocorrelation for AR (2). Besides that, the *p*-value of scalar-statistic in the GMM approach is used to compare the DIF-GMM and SYS-GMM and confirms the validity of the SYS-GMM where it is failure to reject the null hypothesis of the validity of the level moment conditions (Blundell & Bond, 1998). Hence, this study utilizes the SYS-GMM estimator and can be confident that SYS-GMM achieves greater efficiency than DIF-GMM for the model.

More essentially, the finding of the GMM approach also provides another support for the findings of the static panel estimation where population growth, arable land, environmental quality, and income inequality are statistically significant. At this stage, the analysis receives more confidence to conclude that arable land tends to increase the level of food security in developing countries.

Meanwhile, the coefficients of *lnPOP*, *lnEQ*, and *lnIE* have a statically significant negative impact on *FS* in both models. Mainly, this study finds support for the hypothesis that logistics has a statistically significant and positive impact on food security. It advocates that every 1 percent increase in the performance of logistics is associated with an average increase in food supply by 0.023 percent.

For further analysis, we perform a robustness check for the individual of all four dimensions of food security, namely availability (FS_{AVA}), accessibility (FS_{ACC}), utilization (FS_{UTI}), and stability (FS_{STA}). The empirical results are reported in Table 6. As shown in Table 6, the notable similar findings show that population growth, arable land, environmental degradation, income inequality, and food price are statistically significant determinants of food supply throughout all models. In respect of logistic performance, it is found that these variables have a significant positive impact on food security for all dimensions. The findings solidly support the earlier conclusion that a country's food security status tends to be better for a country with a higher level of logistic performance.

Furthermore, this paper also examines the dynamic impact of innovation (Global Innovation Index, GII) in further improving the impact of logistics on food security. We report only the results for system GMM estimation in Table 7 using the same econometric approaches. Concerning the interaction term of (*lnLPI**lnGII*), we get a positive sign suggesting that the impact of logistic performance on food security can further increase with the improvement in the country's level of innovation. Developing logistic innovation with several technologies tends to play a role in addressing concerns related to the four dimensions of food security. Digital innovations can enable logistics operators to promote efficiency and lower cost (Frank et al., 2019; Holl & Mariotti, 2021; Parola et al., 2021; Schaefer & Cheung, 2018; Wollschlaeger et al., 2017). This can significantly assist help farmers in making more precise resource management decisions and potentially reduce scale economies in agriculture, making small-scale producers more competitive. Besides, logistics innovation is an effective means of assisting suppliers in dealing with unexpected issues and risks. Smart packaging, for example, using innovative technologies, processes, and services, can decrease food damage during shipping, online tracking, and tracing can give accurate and timely information while reducing the risk of food delivery delays (Frank et al., 2019; Schaefer & Cheung, 2018; Wollschlaeger et al., 2017). Adopting digital technology for storage, refrigeration, logistic, and handling such as dehulling technologies, nanotechnology, green logistic, and wireless sensor networks (WSN) reduce the cost of connecting sellers and buyers with disparities in access to knowledge and market, making food more affordable and accessible to people, particularly those with lower incomes (UNCTAD, 2018).

Discussion

This section explains the empirical findings in greater depth and detail. It is commendable to declare that population growth, arable land, environmental quality, income inequality, and food price are statistically significant determinants of food

Table 6 Regression analysis of dimensional [DV: *lnFS*]

	$lnFS_{AVA}$		$lnFS_{ACC}$		$lnFS_{UTI}$		$lnFS_{STA}$	
	DIFF-GMM	SYS-GMM	DIFF-GMM	SYS-GMM	DIFF-GMM	SYS-GMM	DIFF-GMM	SYS-GMM
$lnFS_{t-1}$	0.476*** [4.57]	1.002*** [8.44]	0.947*** [6.26]	1.003*** [5.09]	0.631*** [6.50]	0.985*** [4.61]	0.850 [3.86]	0.963*** [7.43]
lnLPOP	0.006 [1.71]	−0.002*** [−1.90]	−0.047 [1.57]	0.008 [1.60]	−0.008*** [−4.55]	−0.001*** [−3.55]	−0.032*** [−2.62]	−0.004*** [−3.18]
lnAL	0.015*** [2.57]	0.033* [2.06]	0.007*** [3.37]	0.014* [1.94]	0.010*** [2.38]	0.003* [1.85]	0.058* [1.84]	0.042* [1.79]
lnED	−0.001* [−1.84]	−0.084*** [−3.26]	−0.009*** [−5.16]	−0.002*** [−2.52]	−0.015*** [−4.40]	−0.073** [−2.22]	−0.041*** [−2.69]	−0.022*** [−1.82]
lnIE	−0.006** [−2.21]	−0.026*** [−2.76]	−0.003*** [−3.39]	−0.057* [−1.87]	−0.018*** [−4.76]	−0.015* [−1.85]	−0.083*** [−3.33]	−0.046*** [−2.55]
lnPRI	−0.002* [−1.90]	−0.003* [−1.96]	−0.094** [−2.25]	−0.016** [−2.17]	−0.035*** [6.38]	−0.003*** [−4.70]	−0.302*** [5.00]	−0.063*** [−3.10]
lnLPI	0.009* [1.86]	0.006*** [2.55]	0.077* [1.95]	0.021* [1.87]	0.022*** [3.18]	0.011*** [2.61]	0.032** [2.26]	0.003*** [3.03]
	Model criteria							
Hansen	0.457	0.686	0.758	0.659	0.522	0.376	0.435	0.865
AR(1)	0.014**	0.005***	0.050**	0.041**	0.010**	0.082*	0.041**	0.046*
AR(2)	0.169	0.136	0.284	0.286	0.125	0.385	0.503	0.236
Dif-Sar	-	0.875	-	0.981	-	0.995	-	0.867
#instruments	33	35	33	35	33	29	27	30
#Country	41	41	41	41	41	41	41	41

Figures in "[]" stand for *t*- statistics. The values of the Hansen and AR tests stand for the *p*-value. The model is estimated using the two-step model with robust estimation

*Significance at the 10% level; **Significance at the 5% level; ***Significance at the 1% level

Table 7 Regression results for innovation variable [DV = lnFS]

	lnLFS		***$lnFS_{AVA}$***		***$lnFS_{ACC}$***		***$lnFS_{UTI}$***		***$lnFS_{STA}$***	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
$lnFS_{t-1}$	3.06*** [3.39]	5.62** [2.28]	6.05*** [3.39]	7.37*** [3.33]	2.78*** [6.30]	5.04*** [2.91]	4.28*** [3.15]	4.19*** [2.65]	3.39*** [5.03]	3.18*** [2.55]
lnPOP	−0.77*** [−3.89]	−1.98*** [−2.47]	−0.20*** [−3.19]	−0.91*** [−2.82]	−0.83* [−2.01]	−0.26** [−2.18]	−0.47* [−1.93]	−0.91*** [−2.47]	−0.47** [−2.30]	−0.84** [−2.33]
lnAL	0.84*** [3.79]	1.05** [2.27]	0.24*** [3.36]	0.73*** [4.68]	0.15* [2.07]	0.34** [2.31]	0.11* [1.84]	0.54* [1.93]	0.57* [2.08]	0.37** [2.14]
lnED	−0.51*** [−3.32]	−0.21* [−1.95]	−0.05*** [−4.33]	−0.15** [−2.22]	−0.24*** [−4.49]	−0.27*** [−2.70]	−0.06*** [−3.13]	−0.08*** [2.66]	−0.07* [−1.96]	−0.29** [−2.11]
lnIE	−0.35*** [−4.80]	−0.68*** [−4.57]	−1.03*** [−2.60]	−0.05*** [−2.74]	−0.07* [−1.92]	−0.02*** [−3.23]	−0.12** [−2.34]	−0.21*** [−3.16]	−0.27*** [−3.26]	−0.07* [−1.95]
lnPRI	−0.62** [−2.29]	−0.24* [−2.08]	−0.86*** [−3.92]	−0.78** [−2.19]	−0.32*** [−3.36]	−0.41*** [−4.87]	−0.73*** [−3.00]	−0.16*** [−2.91]	−0.30*** [−4.16]	−0.16*** [−3.35]
lnGII	0.85*** [3.31]	1.09*** [3.54]	0.29*** [2.72]	0.60*** [2.73]	0.47* [2.03]	0.18*** [2.48]	0.62*** [2.89]	0.78*** [3.20]	0.29*** [3.12]	0.51* [1.97]
lnLPI	0.06*** [2.96]	0.05** [2.16]	0.03* [1.85]	0.06*** [3.31]	0.09*** [2.87]	0.04** [2.17]	0.08* [2.05]	−0.07** [2.21]	0.10* [2.06]	0.14* [2.09]
*lnLP*lnGII*	-	0.24*** [2.79]	-	0.66*** [3.47]	-	0.46*** [2.54]	-	0.85*** [2.98]	-	0.60*** [2.72]
	Model criteria									
Hansen	0.45	0.74	0.78	0.56	0.83	0.53	0.71	0.64	0.77	0.49
AR(1)	0.01**	0.05*	0.00***	0.07*	0.02**	0.02**	0.08*	0.01**	0.03**	0.07*
AR(2)	0.16	0.41	0.23	0.44	0.30	0.41	0.23	0.32	0.19	0.29
Dif-Sar	0.92	0.98	0.95	0.76	0.82	0.62	0.87	0.61	0.97	0.92

Table 7 (Continued)

	Model criteria									
#instruments	33	33	33	33	33	33	33	33	33	33
#Country	41	41	41	41	41	41	41	41	41	41

Figures in "[]" stand for *t*- statistics. The values of the Hansen and AR tests stand for the *p*-value. The model is estimated using the two-step model with robust estimation. GII stands for Global Innovation Index (a) without interaction and (b) with interaction

*Significance at the 10% level; **Significance at the 5% level; ***Significance at the 1% level supply throughout all models. Concerning population growth, the regression results support Malthusian theory's claims that population growth is the most basic determinant of food security. An increasing number of people have not been able to keep up with the level of food production, which typically results in chronic food insecurity (Ehrlich et al., 1993; Gilland, 2002; Godber & Wall, 2014; Hall et al., 2017). Consequently, this raises the challenge to food production and distribution systems in meeting human and nutritional needs. The result also validates the food availability decline (FAD) theory that the level of the food supply is determined by environmental quality. For example, higher temperatures are expected as environmental quality deteriorates, reducing crop yield and crop production in the short and long term. This then leads to insufficient food to feed the growing population, thus resulting in a deteriorated level of food security in developing countries. In addition, the result derived from the income inequalities and food price supports the Food Entitlement Decline (FED). Increased income disparities and food prices reduce food accessibility and utilization, raising the risk of chronic food insecurity in developing countries.

As expected, improvement in logistics performances may help address the food security challenges throughout all stages of food supply chains, particularly during production, handling, and storage. Logistics which allow the free movement of goods and people are recognized as a key element in achieving food security, involving a sequence of food processes ranging from agriculture, processing, and distributing to ultimate usage. Besides that, the cold chain distribution center is one of the most effective cold chain logistics links, providing equipment for receiving, storing, and sorting a large number of perishable food products from a large number of suppliers for respective grocery stores. The use of refrigerated containers has helped in particular since they represent over 50% of the world's total cooled cargo transported. It is, therefore, crucial to look at the logistic performance to prevent food losses and strengthen food security.

This fact suggests that improvement in the logistic performance increases food supply by reducing costs in the food system. This is because efficient transportation, warehousing, and inventory management are essential drivers of cost. This is particularly true for small farmers managing their crops' movement from farm to market, which is much easier and cheaper. Consequently, it reduces food prices in developing countries, which in turn would result in increased food accessibility. Improvement in the aspect of warehouse logistics operations will help to store sufficient and large quantities of food, especially in the case of emergencies. Thereby, the food that is available and accessible should be affordable to the poorest people. Moreover, an improvement in the logistic performance also enhances the ability of farmers and producers to provide buyers with detailed information about production methods and sourcing. This will eventually help in enhancing people's ability to absorb nutrients and healthy foods (Blasbalg et al., 2011; Kuai & Zhao, 2017; Maas et al., 2012; Widener & Shannon, 2014). These studies argue that less affordability of healthy foods affects people's decisions about acquiring and utilizing foods, resulting in less consumption of foods high in health-promoting nutrients that are available. In such cases, decreasing the accessibility and utilization of healthier food items adversely affects nutrient intake and diet quality and increases the risk of various forms of malnutrition. In Nigeria, for example, a lack of access to and consumption of food containing nutrients, such as energy, protein, fat, minerals, and vitamins, leads to malnutrition and illness-related illnesses, which can result in serious health problems like heart disease, osteoporosis, stunting, wasting, and underweight (Mekonnen et al., 2021).

On the effect of logistic performances on all dimensions of food security, the coefficients demonstrate that logistics are positively associated with food availability. This indicates that better logistic performance in countries will lead to increased food availability in terms of quantities and qualities of food that are either locally produced or supplied by imports, accessibility by improving food distribution, utilization in terms of food quality and safety throughout the supply chain activities of transport and stability by stabilizing the other three dimensions. Logistics can make the supply of raw materials such as feedstock and primary commodities easier and faster. Higher logistical performance in terms of transport infrastructure development and transit time reductions may further encourage the movement to food industries of the commodities produced by farming, farming, fisheries, and breeding. Raw materials are one of the main components in food production, which speeds up the process of food production and eventually increases the availability of adequate quantities of food. Besides, logistics performance also highly influences the international trade of food, significantly represented by the import of food and food aid. This increases the inflow of food to the country and thus helps to increase the country's food availability. In addition, an improvement in logistics performance is expected to positively affect food accessibility by improving food supply and distribution in developing countries. Maintaining logistics efficiency in transportation infrastructure, customs clearance process, quality of logistics, and trade tend to ensure a reliable and consistent food supply, making food more accessible to everyone. Increased logistics performance will also have a positive impact on food utilization. The empirical estimates indicate that food utilization is positively impacted by logistic performance. Ensuring food safety and quality is the main requirement element when it comes to appropriate food utilization. Effective and efficient logistics management can help ensure foodstuffs are supplied and sold in the best quality, especially foodstuffs such as refrigerated items or fresh foods, and reduce transit time to reduce the risk of damage and contamination in food. This can help to ensure that the hygiene and cleanliness standards of food are maintained and, subsequently, the utilization of healthy and nutritious food can be made possible. For the dimension of food stability, this study shows that logistics contribute to the increase in food stability. Higher logistics level performance tends to increase the food supply chains' sustainability, leading to an increase in food production (availability), food distribution (accessibility), and consumption levels (utilization). Hence, this, in turn, may cause the status of food security of those developing countries better off.

Policy Implication

By the objectives of this study, several policy implications are emerging from our analysis. Policymakers need to look at the improvement of logistic performance as a tool for improving the food security of a country. Firstly, to improve logistic performance, policymakers need to ensure that infrastructure such as roads, railroads, and ports are maintained in good condition as well as expanded to remote areas so that food accessibility can be improved. Ultimately, this will lead to efficient flow and storage of foods from the point of origin to the point of consumption to meet people's requirements. Secondly, given the low return from logistic improvement with regard to food security, other aspects of logistics that may reverse that positive outcome should be monitored. Among the sources of negative side effects of logistics could be pollution generated by logistics and the higher cost of handling logistic services. Thirdly, the governments in developing countries need to design a policy or strategy that can increase the affordability level of people in remote areas who are generally poor. Improvement in logistic infrastructure such as land roads if not accompanied by improvement in affordability of these people may not lead to better food security among the poor.

Conclusion

This paper focuses on providing insights into the neglected role of logistic performance on food security in developing countries over the period 2010–2016. The relationship between logistic performance and food security has been proven by applying the static panel methodology. More importantly, it is noted that logistics has a statistically significant positive effect on food security. This indicates that as the performance of logistics improves, the probability of accessing food increases. In conclusion, the findings of this study display that the significant improvement in logistic performance could contribute to the increment in food security and may allow households and individuals to be food secure at all times.

One of the limitations of this study is to do with the lack of data might be causing the findings and conclusion to be treated more cautiously. As we know, the data only runs from 2010 and 2016, where the time frame is considered to be short and does not show the real scenario of developing economies in the long run. Moreover, this study examined only a group of selected developing countries that mixed varieties of the region and income groups. Based on World Bank (2018), the data are only available for 52 developing countries among 139 countries. Thus, the findings of these studies might be inconsistent for all the developing countries, even though it visibly explores the total picture of environmental degradation in respect of poverty. Thus, future studies may expand his analysis on a country-specific level to identify more precise implications at the country-specific level once published long-term time series data on measures of the logistic variables becomes available.

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