Does Trade Facilitation Contribute to Food Security? A Panel Data Analysis in Sub-Saharan Africa

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Abstract

Food insecurity remains a serious and global concern that continues to escalate due to various factors, including the COVID-19 pandemic and the Ukraine crisis, which have exposed structural vulnerabilities of developing economies, particularly in African countries. This paper analyses the contribution of trade facilitation through physical infrastructure, Information and Communication Technology (ICT), business environment as well as border, and transport efficiency to food security in Sub-Saharan Africa (SSA). The analysis uses a sample of 36 SSA countries from 2005 to 2019 and adopts the fixed effects and the two stage least square methods. Results show that improvement in trade facilitation enhances food security in SSA. This effect is evident in the composite food security and in two dimensions (access and utilization) of food security. Similarly, trade facilitation indicators, namely business environment and ICT are the most promising in SSA's fight against food insecurity. Moreover, the results show also that countries with low rural population experienced positive effects of facilitating trade than countries with high rural population. The results highlight the need for improving regulatory environment as well as simplifying and harmonizing trade procedures to enhance food security in SSA.

Keywords: Trade facilitation, food security, two-stage least squares, Sub-Saharan Africa.

Jel Classification: F13; F14; Q18.

1. Introduction

Food insecurity remains a serious and global concern that continues to escalate due to many factors such as the COVID-19 pandemic as well as conflicts like the Ukraine crisis (Food and Agricultural Organization of the United Nations (FAO), 2020; Campi et al., 2021; Nchanji and Lutomia, 2021; World Bank (WB), 2023). Indeed, the COVID-19 pandemic and the Ukraine crisis have exposed structural vulnerabilities of developing economies, particularly in African countries, and underlined the need for national policymakers, international and regional institutions, and the academic community to explore methods to build economies that are more resilient and immune to future shocks (Gnangnon, 2021). According to FAO (2022), Sub-Saharan Africa (SSA) and Asia are the two regions in the world most affected by food insecurity. Statistics also show that in 2021, approximately 425 million people in Asia and 278 million people in Africa which represent 9.1 and 20.2 percent of their respective population were food insecure (FAO, 2022b). The situation is more critical in the different sub-regions of the continent. In fact, according to the World Bank (2023), up to 67 million people in eastern and southern Africa continue to experience acute food insecurity, including famine while West and Central Africa people (28.9 million people precisely) still depend on emergency food assistance.

Currently, one of the world's key priorities is to attain food security. Food security is broadly defined as ‘a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life’ (FAO, 2003; McGuire, 2013). This definition underlines the multidimensional nature of food security encompassing availability, access, utilization and stability (Dithmer and Abdulai, 2017).

It is in that context that the United Nations Conference on Trade and Development (UNCTAD) and the United Nations Economic Commission for Africa (ECA) and other international organizations, have been advocating for strengthening productive capacities and competitivity in developing countries, and particularly in Africa with a view to promoting structural transformation of economies and sustainable growth and development. Moreover, FAO, International Fund for Agricultural Development (IFAD), and World Food Programme (WFP) recommend increasing public expenditure to enable investments in agriculture and hence increase agricultural productivity, encourage diversification, and ensure the production of nutritious foods (McGuire, 2015).

African countries and institutions are placing great emphasis on strengthening trade integration through the effective implementation of the African Continental Free Trade Area (AfCFTA) agreement among the factors for promoting structural transformation and ensure food security in Africa (African Development Bank Group, 2021). To this end, among strategies for the effective implementation of the AfCFTA, countries, international and regional institutions are placing particular emphasis on Trade Facilitation[1] (TF). Trade facilitation has become an important part of the current debate on trade liberalization policy. It was at the heart of the World Trade Organization (WTO) negotiating agenda since 2004. In a narrow sense, TF is defining as the simplification and harmonization of international trade procedures, with trade procedures being the activities, practices, and formalities involved in the collection, presentation, communication, and processing of data necessary for the movement of goods in international trade (World Trade Organization (WTO), 2015). Broadly, for Portugal-Perez and Wilson (2012), TF refers to any policy measures aimed at reducing trade costs.

Many countries have recognized the importance of trade policy in contributing to the growth of the international market with the aim to eradicate poverty as well as improve the availability of food (Anderson, 2010; Olper et al., 2018). The tariffs and non-tariffs barriers reduction through trade openness and trade facilitation respectively plays a crucial role in ensuring the continuity of supply, as it allows countries in the most suitable areas to produce food and to move it to countries with limited food supplies. Thus, supply and demand are smoothed out, price fluctuations are reduced, resulting in an increase in the quantity and variety of products available to the local population, thereby ensuring a good level of food security (FAO, 2000 ; Dithmer and Abdulai, 2017). Moreover, according to Dithmer and Abdulai (2017), through imports and trade facilitation measures, each country can decide to obtain the food resources it needs at a less cost than if it produced them domestically. Furthermore, facilitating trade allows access to larger markets and production specializations which give the opportunity to benefit from economies of scale, technological transfers, and knowledge spillovers (FAO, 2006; Wacziarg and Welch, 2008). In spite of these studies, Díaz-Bonilla and Ron, (2010) point out that various factors affecting the relationship make it difficult to determine whether the international trade has a positive or negative impact on food security.

Enhancing food security has been the subject of intense work recently in empirical literature. Such studies include for example the effects of environmental and energy factors (Blom et al., 2022 ; Candelise et al., 2021 ; Subramaniam et al., 2019),

[1] The Appendix 4 of AfCFTA is advocating to trade facilitation.

income and income distribution (Haddad et al., 2003 ; Soriano an Garrido, 2016 ; Arndt et al., 2020), agricultural land acquisition (Mechiche-Alami et al., 2021), armed conflict (Mottaleb et al., 2022), welfare changes (Nechifor et al., 2021), institutional quality (Soko et al., 2023), trade openness and international trade (Kang, 2015 ; Dithmer and Abdulai, 2017 ; Fusco et al., 2020 ; Assoumou-Ella and Eba-Nguema, 2019) on food security. However, studies so far have ignored the role of trade facilitation in maintaining food security. Most of the empirical studies on the effectiveness of TF reforms have generally focused on countries' export performance in terms of export volumes (Wilson et al., 2003; Portugal-Perez and Wilson, 2012; Moïsé and Sorescu, 2013 ; Seck, 2016 ; 2017 ; Odebiyi and Alege, 2019) or sometimes, in terms of export diversity (Lee and Kim, 2012 ; Feenstra and Ma, 2014 ; Beverelli et al., 2015). It has been found that TF has contributed significantly to the increase in exports at the intensive and extensive margins of countries (Beverelli et al., 2015). While such an increase in exports can contribute to economic growth, recent evolution on the global economy with the consequences of the COVID-19 pandemic and Ukraine crisis point to the need on ways to overcome external shocks. In light of this context:

The main objective of this paper is to analyze the contribution of trade facilitation to food security in Sub-Saharan Africa. Specifically, we seek to:

- analyze this contribution on aggregate food security as well as on its four dimensions.
- analyze which aspect of trade facilitation is more important to achieve food security in SSA.

Compared to the existing literature, this study makes contributions at several levels. The contributions are threefold. First, we analyze the contribution of trade facilitation on food security in Sub-Saharan Africa. To the best of our knowledge, this is the first study that quantitatively link trade facilitation and food security in SSA. Indeed, we focus on SSA because, Sub-Saharan Africa experiences the worst effects of food insecurity (Soko et al., 2023) coupled with inefficient trade procedures (Sakyi et al., 2018). Second, in this paper, the aim is not only to analyze the contribution of trade facilitation reforms on food security, but also to determine in which dimensions of food security TF is more critical in SSA. Taking all the dimensions of food security will help in terms of policy implications. Third, we analyze the contribution of trade facilitation on food security using the broader set of trade facilitation. The broader set of TF helps to use various indicators and take into account the characteristics of trade costs in Africa (OECD-WTO, 2016).

The rest of this paper is organized as follows: Section 2 presents the stylized facts on trade facilitation and food security while Section 3 presents the conceptual

framework of the study. Section 4 outlines our methodology. In Section 5, we present the results and conclude with policy implications in Section 6.

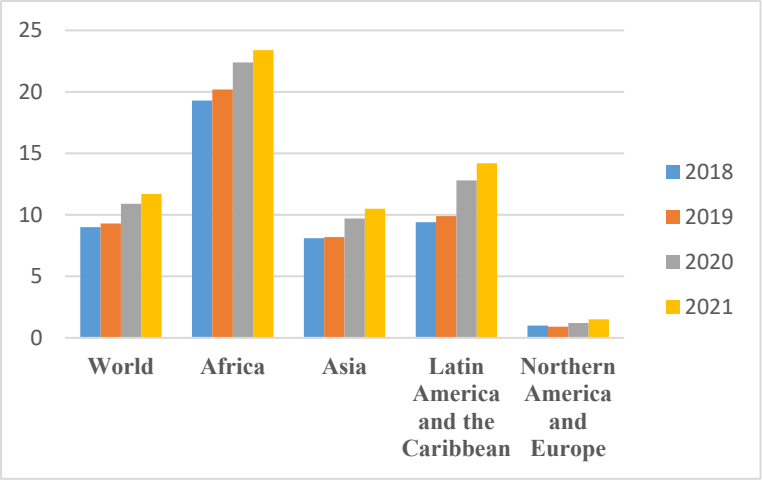
2. Stylized Facts on Trade Facilitation and Food Security

We present in this section some facts related to trade facilitation as well as food security in Africa.

Figure 1 below shows a comparative analysis of food insecurity in the world. The figure shows that Africa is the region that is most affected by food insecurity in the world. Indeed, from this Figure, three conclusions can be drawn. Firstly, food insecurity in Africa is above the average of the world. Secondly, the continent shows a consistent upward trend with around 20 to 25% of its population food insecure between 2019 and 2021. Thirdly, in stark contrast, North America and Europe exhibit notably lower levels of food insecurity, affecting less than 5% of their combined population.

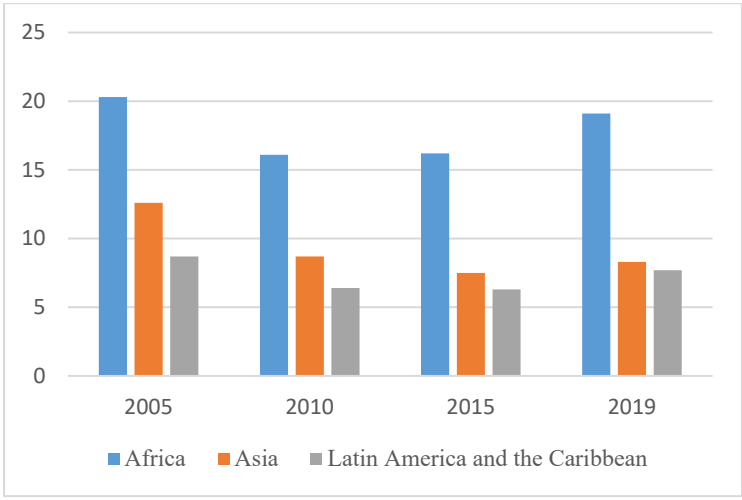
Figure 2 reinforces the alarming levels of food insecurity in Africa. In fact, this Figure shows the prevalence of undernourishment in different regions, and we can also see that the continent overall is more exposed to undernourishment compared to Asia and Latin America and Caribbean.

Figure 1: Prevalence of severe food insecurity in the total population (%)



Source: Author's construction based on FAOSTAT (2023).

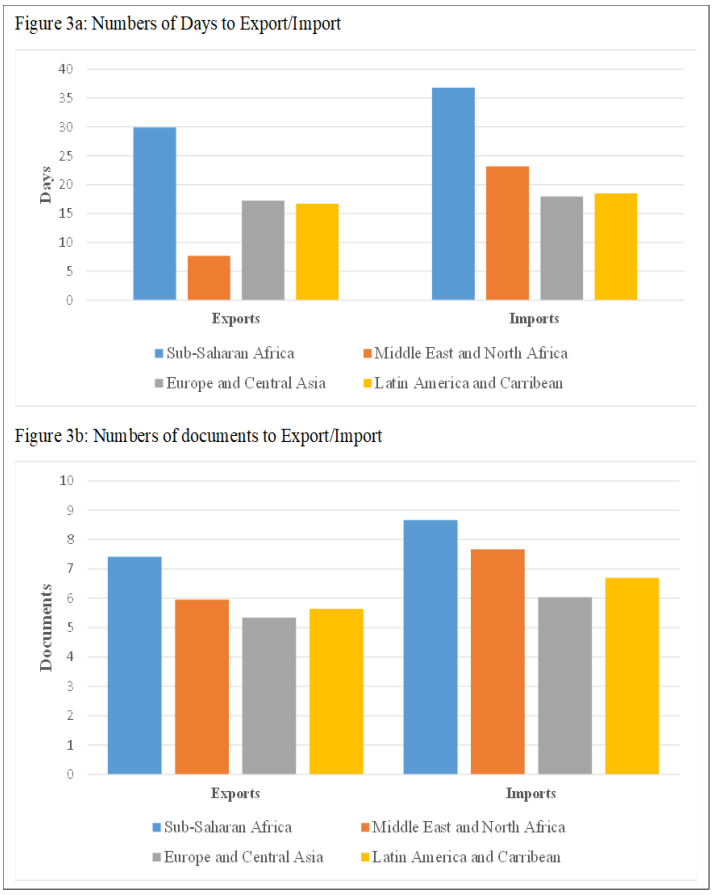
Figure 2: Prevalence of undernourishment (percent) (3-year average)



Source: Author's construction based on FAOSTAT (2023).

Figure 3 presents a comparative analysis of trade facilitation indicators across various regions worldwide. The data reveals that Sub-Saharan Africa (SSA) lags behind other regions in terms of trade efficiency. Specifically, Figure 3-a illustrates the number of days required to export and import products. SSA stands out for its lengthy trade procedures, with exports taking approximately 30 days, compared to less than 10 days in the Middle East and North Africa, and under 15 days in Latin America and the Caribbean, as well as Europe and Central Asia. Similarly, imports take over 35 days in SSA, whereas Europe and Central Asia require less than 15 days. Figure 3-b reinforces this trend, showing that SSA requires more documents for exports and imports than other regions. Collectively, these findings underscore SSA's relative inefficiency in trade procedures, both in terms of time and documentation required for exports and imports.

Figure 3: Number of days and documents to export/import



Source: Author's construction based on WDI data (2023).

Conceptual framework between trade facilitation and food security

Trade facilitation is theoretically linked to food security through its effects on trade. According to international trade theories such as the Heckscher–Ohlin (H–O) model, countries can gain[2] from trade if they specialize in the production and exportation of commodities of their comparative advantage and import products of their comparative disadvantage. Such gains include fuller utilization of otherwise idle domestic resources, better access to external markets, the inflow of foreign capital, new technology, greater competition and efficiency, improved

[2] It is important to note that H-O model does not only suggest that countries benefit from trade but also that some factors of production will gain, and others will lose.

productivity and incomes, and better prices. However, in the presence of poor trade facilitation, which increases trade costs and constrains access to regional and international markets, these welfare gains are not realized. The iceberg model (Samuelson, 1954), new trade theory (Krugman, 1980), heterogeneous firms (Melitz, 2003) show that trade costs drive a wedge between the relative prices faced by exporting and importing countries, which moves trading partners closer to their initial autarkic prices, discourages specialization, and erodes incentives for trade. High trade costs reduce trade and prevent countries from reaping the full benefits of trade liberalization and integration into global value chains (Moïsé and Sorescu, 2013; Takpara et al., 2023). Several studies have shown that, improved trade facilitation reduces trade costs, increases trade flows, and allows importers to benefit from lower prices and exporters to receive higher prices for the traded commodities (Portugal-Perez and Wilson, 2012; Moïsé and Sorescu, 2013 ; Odebiyi and Alege, 2019).

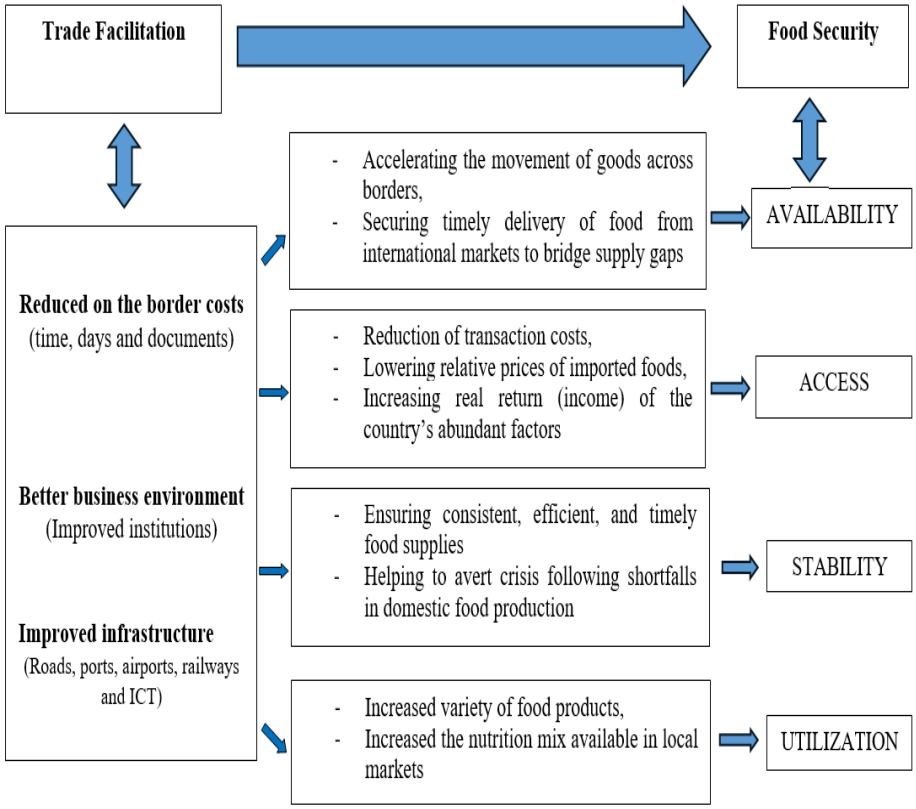
As defined by FAO (2003), food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This definition captures the multidimensionality of food security which includes four pillars encompassing availability, access, utilization, and stability of food. Availability implies the physical existence of food in adequate quantities to meet consumption needs. The access dimension of food security is ensured when people have the ability unimpaired by any physical, economic, and social barriers to acquire nutritious foods in adequate amounts to meet their dietary needs. Utilization captures biological absorption of nutrients in foods consumed as well as the food environment, including food preparation, allocation, safety and conservation, care and feeding practices, adequate sanitary facilities, and a healthy physical environment. The last one is stability which is achieved when food availability and people's ability to access and utilize food remain stable and sustained over time.

We conceptualized the link between trade facilitation and food security in Figure 4 below.

Trade facilitation implying the reduction of border costs, better business environment, and improved infrastructure, has the potential to increase food availability by accelerating the movement of goods across borders and securing timely delivery of food from international markets to bridge the supply gaps. Improved trade facilitation contributes to food accessibility by reducing the transaction costs, lowering relative prices of imported foods, and increasing income of the country's abundant factors. In terms of the stability dimension of food security, facilitating trade can ensure consistent, efficient, and timely food

supplies, and therefore can help to avert crisis following shortfalls in domestic food production. Trade facilitation also contributes to food security in its utilization dimension by increasing the variety of food products and the nutrition mix available in local markets. The direction of the link between both variables may however change depending on the nature of the consumer/producer.

Figure 4: Conceptual framework between trade facilitation and food security



Source: Author's construction, adapted from Spence and Karingi (2011) and Bonuedi et al. (2020).

The relevant empirical literature on the effect of trade/trade policies on food security is twofold (FAO, 2003 ; Sun and Zhang, 2021). Some authors estimated that trade/trade policies have positive effect on food security (Chikhuri, 2013 ; Brooks and Matthews, 2015; Dithmer and Abdulai, 2017; Fusco et al., 2020; FAO et al., 2021; Sun and Zhang, 2021), while other authors found negative effects (Paarlberg, 2000; Moon, 2011; Tanaka and Hosoe, 2011; Dang and Konar, 2018; Mary, 2019).

For the first case, Brooks and Matthews (2015) examined the different channels through which trade openness and reforms to achieve it can affect a country's food

security. The overall conclusion is that trade openness has a positive net impact on food security. Dithmer and Abdulai (2017) investigated the impact of trade openness and other factors on food security, measured by dietary energy consumption on 151 countries over the period spanning from 1980 to 2007. Using the system GMM estimator, their empirical results reveal that trade openness and economic growth exert positive and significant impacts on dietary energy consumption and contribute to improvements in dietary diversity. Additionaly, they found that besides calorie consumption, trade openness also improves dietary diversity and diet quality related aspects of food security.

In the same vein, Fusco et al. (2020) analyzed the impact of trade openness on the level of food security in European countries. In a dynamic panel, they used the GMM approach on two different indicators of food security namely the average protein supply and the average dietary energy supply adequacy over the period ranging from 2000 to 2017. The results showed that commercial opening has on average a statistically significant net positive impact on the food security of European countries. Moreover, their results also indicated that economic development, as well as the agricultural sector, improved food security levels in European countries.

The results of Sun and Zhang (2021) in Central Asia confirmed the one of Fusco et al. (2020) in European Countries. Indeed, these authors estimated the impact of trade openness and other factors on the four pillars of food security (availability, access, stability, utilization). They captured food availability by dietary energy supply, food access by rail lines density, food supply variability for food stability and population using safely managed drinking water services, as a proxy for food utilization. Using various estimators including the GMM, the results have shown a U-shaped relationship between trade openness and the four pillars of food security, meaning that beyond a certain threshold of trade openness, food security status tends to improve in Central Asian countries. They concluded that trade policy reforms can be conducive to improving food security in Central Asian countries.

Conversely, trade openness has a negative effect on food security considering that, it has the potential of lowering the level of food security and thus made the food supply more dependent on imports (Tanaka and Hosoe, 2011). For Moon (2011), this situation can make food supply less secure due to the fact that agriculture is incompatible with free trade area because of its innate role in managing ecological/natural resources at national and global levels. Dang and Konar, (2018) have found in their study that trade openness does not have a significant impact on total or industrial water withdrawals. Specifically, they have shown that a one percentage point increase in trade openness leads to a 5.21% decrease in

agricultural water withdrawals. Also, their results show that trade openness reduces water use in agriculture primarily through the intensive margin effect, by leading farmers to produce more with less water, such as through the adoption of technology. Among studies that found negative impact of trade openness on food security, we have the one of Mary (2019). Indeed, Mary (2019) focalized on agricultural exports and imports in a panel of 52 developing countries and found a negative relation between food trade openness and food security, measured by the prevalence of undernourishment. Additionally, the study found a positive and significant association between non-agricultural trade openness and food insecurity, which can be explained by an increase in competition for non-agricultural products.

In another dynamic study, Bonuedi et al. (2020) examined the effects of easing trade across borders through reductions in documents, time, and costs to export and import on food security outcomes in 45 African countries over the period ranging from 2006 to 2015. With the first-difference instrumental variable estimator, the results revealed that poor trade facilitation constitutes a significant driver of food insecurity in Africa. Indeed, they found particularly that ineffective trade facilitation is associated with significant increments in the prevalence of undernourishment and depth of food deficit, as well as reductions in dietary energy supply adequacy and access to sanitation facilities. Moreover, the results have shown that food availability and food access are significantly hampered by higher documentation requirements and lengthier export and import times.

From the above literature, we can see that there are many studies on the effect of trade policy on food security. However, studies on the effect of trade facilitation on food security are scarce with the exception of Bonuedi et al, (2020). Indeed, the difference between our study and Bonuedi et al. (2020) study is threefold. First, they evaluated the effect of ease of doing business on three dimensions of food security namely (availability, access, utilization) without considering the stability dimension as in our case. Second, these different dimensions of FS and the composite FS variable are based on selected simple indicators rather than a computed index. In fact, following Subramaniam et al. (2019), we employ a principal component analysis (PCA) on various indicators available in the literature on each specific dimension of FS as well as on the composite FS variable in our study. Third, Bonuedi et al. (2020) have used narrow aspect of six TF indicators with the simple average for the composite TF while in our study, the broader set of 14 TF indicators are used following Portugal-Perez and Wilson (2012) study with PCA.

2. Methodological Framework and Data

This section describes our methodology and the data to achieve the objectives. First, we present the methodological approach for achieving our objective including the estimation strategy. Second, we present the data and the measurement issues.

Theoretical foundation and model specification

The theoretical foundation of our study is the Heckscher-Ohlin-Samuelson (HOS) model of international trade. In fact, the analysis of Sub-Saharan African countries economic structure has shown that these countries have a comparative advantage in the production of raw materials. For Assoumou-Ella and Eba-Nguema (2019), this explains why the implementation of the HOS theory of international trade in these countries led to their specialization in the exports of raw materials and the imports of food products through export earnings. Thus, we assume that this specialization has a significant effect on food security in these countries. Therefore, this empirical study aims to see whether the effect of trade facilitation on food security is positive or negative.

Based on the theoretical foundation and the previous literature, specifically the ones of Kang (2015), Dithmer and Abdulai (2017), and Fusco et al. (2020), we estimate the following model :

$$FS_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 TFI_{it} + \eta_t + \mu_i + \varepsilon_{it} \qquad (1)$$

Where FS_{it} represents the food security variables (the aggregate food security index and the four dimensions of food security: availability, access, utilization, and stability) of country i at period t. The aggregate food security index is constructed based on principal component analysis (PCA). TFI_{it} represents the vector of trade facilitation indicators (physical infrastructure, ICT, trade and regulatory environment, border efficiency)[3]; we include in the model a set of control variables (X_{it}) that are deemed to influence food security. These variables include GDP growth, Population growth, Rural population, Agriculture productivity, Arable land, political stability inflation, environment degradation; η_t are the time-fixed effects; μ_i is a vector representing country fixed effects; ε_{it} is the error term.

[3] These four trade facilitation indices are aggregate indicators constructed following Portugal-Perez and Wilson (2012) study.

Estimation strategy

To analyze the contribution of trade facilitation to food security, it is important to choose an estimation strategy that addresses challenges due to the heterogeneity of African countries. Equation (1) can be estimated by traditional methods such as the Ordinary Least Squares (OLS) or fixed-effects and random-effects models. However, some studies have highlighted various biases in the estimated coefficients following the application of traditional estimation methods. Another econometric problem in panel data known in the literature is the endogeneity issues which have multiple sources such as the reverse causality between the dependent variable and other control variables. In this study, we consider trade facilitation variables which capture the non-tariffs aspects of trade policy as endogenous because there is a potential reverse causality between trade facilitation and food security variables. Indeed, while trade facilitation can influence food security, the later also could affect trade policy measures adoption because, for example, in response to past food security shocks, countries may adopt protectionist policies including non-tariffs measures (Dithmer and Abdulai, 2017 ; Bonuedi et al., 2020). To address the above-mentioned endogeneity concern, the econometric literature has developed many estimators that use instrumental variable methods and the Generalized Method of Moments (GMM) (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998). However, the GMM estimator must respond to the large sample properties when N — ∞, T is fixed which is not the case in our study. Given the difficulties encountered in finding appropriate instruments that would help address the endogeneity concerns, we employ an instrumental variable estimation: a two-stage least square (2SLS) by considering the one-period lag and two-period lags of trade facilitation indicators and derived the predicted values as instruments following Banerjee et al. (2022).

Thus, Equation (1) can be specified as follows:

$$FS_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 \hat{TFI}_{it} + \eta_t + \mu_i + \varepsilon_{it} \quad (2)$$

$$\hat{TFI}_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 TFI_{it-1} + \eta_t + \mu_i + \varepsilon_{it} \quad (3)$$

$$\hat{TFI}_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 TFI_{it-2} + \eta_t + \mu_i + \varepsilon_{it} \quad (4)$$

Where TFI_{it-1} is the one-period lagged value and TFI_{it-2} is the two-period lagged value of TFI in country i and at time t. The rest of the other variables remain the same as in Equation (1). Equations (3) and (4) are the first stage equations where we isolate the effect of trade facilitation. In the second stage, the fitted values of trade facilitation ($\widehat{TFI}_{it}$) derived from Equations (3) and (4) are inserted into

Equation (2) to address the endogeneity issue between TF and food security. We rely on the Hansen test of over-identifying restrictions, the Kleibergen and Paap test for under-identification and the Cragg-Donald Wald F test for weak identification for the consistency of IV-2SLS estimator.

Data and measurement issues

This study is based on data on food security, trade facilitation and other control variables for 36 Sub-Sahara African countries over the period starting from 2005 to 2019. The sample and study period are dictated by the availability of data. Tables 1 to 3 provide a summary of all these variables, data sources and how FS and TF measures are constructed.

Table 1: Definition of variables and data source

Variables	Description	Data Sources
Food Security variables		
$FS_{Availability}$	Average dietary energy supply adequacy (ADESA), Average protein supply (APS), Average supply of protein of animal origin (ASPAO), Share of dietary energy supply derived from cereals roots and tubers (SDES)	FAOSTAT
FS_{Access}	Gross domestic product per capita (in purchasing power equivalent) (GDPpp), Prevalence of undernourishment (PU)	FAOSTAT
$FS_{Stabilty}$	Per capita food production variability (PCFPV), Per capita food supply variability (PCFSV), Percent of arable land equipped for irrigation (PALEI)	FAOSTAT
$FS_{Utilization}$	Percentage of population using at least basic drinking water services (PPLBDWS), Percentage of population using at least basic sanitation services (PPLBSS), Prevalence of anemia among women of reproductive age (15–49 years) (PAAWRA)	FAOSTAT

Trade facilitation variables		
Physical Infrastructure (PI)	Development and quality of road, port, and airport infrastructure (varies from 1= extremely underdeveloped, to 7 = well developed)	WEF
Information and Communication Technology (ICT)	Extent to which an economy uses ICT to improve efficiency and productivity and to reduce transaction costs (1 to 7 = better).	WEF
Business and Regulatory Environment (RE)	Level of development of regulations and transparency (1=low to 7=high)	WEF
Border and Transportation Efficiency (BE)	Level of efficiency of customs and inland transportation that is reflected in the time and number of documents to export and import	DB
Controls variables		
GDP growth	Annual percentage growth rate of GDP at market prices based on constant local currency	WDI
Population growth (%)	It captures population pressure on food security.	WDI
Rural population	Refers to people living in rural areas as a share of total population (defined by national statistics offices)	WDI
Arable land	Arable land (hectares per person)	WDI
Agricultural productivity	It is measured by cereal yield (kg per hectare)	FAOSTAT
Inflation	It is a proxy for macroeconomic stability measured at consumer price	WDI
Natural desasters	It is computed as the number of people affected divided by the total population	EM-DAT

Political stability	It captures the institutional factors (ranging from -2,5 to 2,5)	WGI

Source: Author's construction

Note: The dimensions and elements of food security are based on Subramaniam et al. (2019) study while the trade facilitation indicators are based on the study of Portugal-Perez and Wilson (2012).

Food Security variables

According to Bonuedi et al. (2020), a good indicator of food security should take into account its multidimensional aspects which is based on FAO (2003) definition. The FAO (2003) definition implies that people will only be food secure when sufficient food is available, they have access to it, and it is well utilized. A fourth requirement is the stability of those three dimensions over time, which means the ability to manage risks effectively (Brooks and Matthews, 2015). Based on this definition and following Subramaniam et al. (2019), we constructed in this study, the different food security index for the four dimensions (the index of food availability (FSAv), food accessibility (FSAc), food stability (FSSt) and food utilization (FSUt), using the Principal Component Analysis (PCA).[4] PCA is a way to reduce the multidimensionality of the data, by transforming the data into a new coordinate system such that the largest variance by any projection of the data is in the first coordinate or principal component, the second largest variance in the second coordinate, and so on. The use of PCA is now established in the literature on index construction (African Development Bank (AfDB) et al., 2019). Since each element in each dimension is measured differently, we first bring the indicators to the same level of scale by normalizing all the data using min-max method and constructing the index of each dimension. The indices for food availability and food utilization are constructed as the first principal component scores of the primary variables while the food stability is constructed from the first two principal component scores of the primary variables. The index for Food access is constructed as the simple average of two primary indicators. Additionally, a composite food security index is constructed from the first component scores of the four dimensions of food security (see Table 2).

[4] Note that these authors have used simple average to construct the index. The simple average assumption is that the relative importance of each primary variable is proportional to its weight in the indicators.

Table 2: PCA results for food security variables

FS index	Eigenvalue	Proportion explained	Primary Variables	Eigenvectors	Correlation coefficients	Bartlett (p-value)
$FS_{Availability}$	2.37963	0.5949	ADESA	0.4095	0.3213	0.000
			APS	0.5536	0.6725	
			ASPAO	0.5691	1	
			SDES	-0.4494	-0.626	
FS_{Access}	-	-	GDPpp	-	-	-
			PU	-	-	
$FS_{Stability}$	1.18259	0.3942	PCFPV	0.7577	0.6436	0.000
	1.06398	0.3547	PCFSV	0.4277	0.8464	
			PALEI	-0.493	0.0455	
$FS_{Utilization}$	1.83628	0.6121	PPLBDWS	0.6171	0.8362	0.000
			PPLBSS	0.6693	0.907	
			PAAWRA	-0.4137	-0.5606	
Composite FSIndex	1.87325	0.4683	$FS_{Availability}$	0.6111	0.8364	0.000
			FS_{Access}	0.4228	0.5786	
			$FS_{Stability}$	-0.2461	-0.3368	
			$FS_{Utilization}$	0.6223	0.8517	

Note: The number of principal components was selected by the Kaiser criterion of eigenvalue greater than one. The null hypothesis of the Bartlett test of sphericity is that the variables are not intercorrelated.

Trade facilitation indicators

Trade facilitation is a concept that can be analyzed narrowly or broadly based on the literature (Portugal-Perez and Wilson, 2012 ; Beverelli et al., 2015; Sakyi et al., 2018 ; Bonuedi et al., 2020 ; Takpara et al., 2023). In this paper, we rely on the work of Portugal-Perez and Wilson, (2012) and construct four indices from several primary indicators extracted from the World Economic Frum and Doing Business. These four indices capture physical infrastructure, ICT, Business, and regulatory environment as well as Border and transport efficiency.

Physical infrastructure measures the level of development and quality of road, port, and airport infrastructures. *ICT* indices contain indicators on the availability,

use, absorption, and priority given by government to ICT and is interpreted as the extent to which an economy uses ICT to improve efficiency and productivity as well as to reduce transaction costs.

Business and regulatory environment is based on indicators of improper payments, favoritism, government transparency, and anti-corruption measures and analyzes the level of development of regulations and transparency. All the underlying indicators were originally reported on a scale of 1 to 7, with higher values signifying better outcomes.

Border and transport efficiency indices aim to quantify the level of customs and inland transport efficiency reflected in the time, cost, and number of documents required for export and import procedures. The construction of the four indices is based on PCA.

To facilitate comparison and interpretation, we normalized the primary trade facilitation indicators on a scale of 0 (worst) to 1 (best) through min-max transformation method. We expect that improvement in trade facilitation measures will positively contribute to food security. The principal component analysis results are provided in Table 3 and are based on the Kaiser criterion of eigenvalue greater than one. For all the aggregate indicators of TF, only the first principal component is retained as the composite index (see Table 3). Additionally, the composite trade facilitation index is constructed from the first three components scores of the primary variables (see PCA results of TF in Table 3).

Table 3: Construction of trade facilitation indices from primary indicators

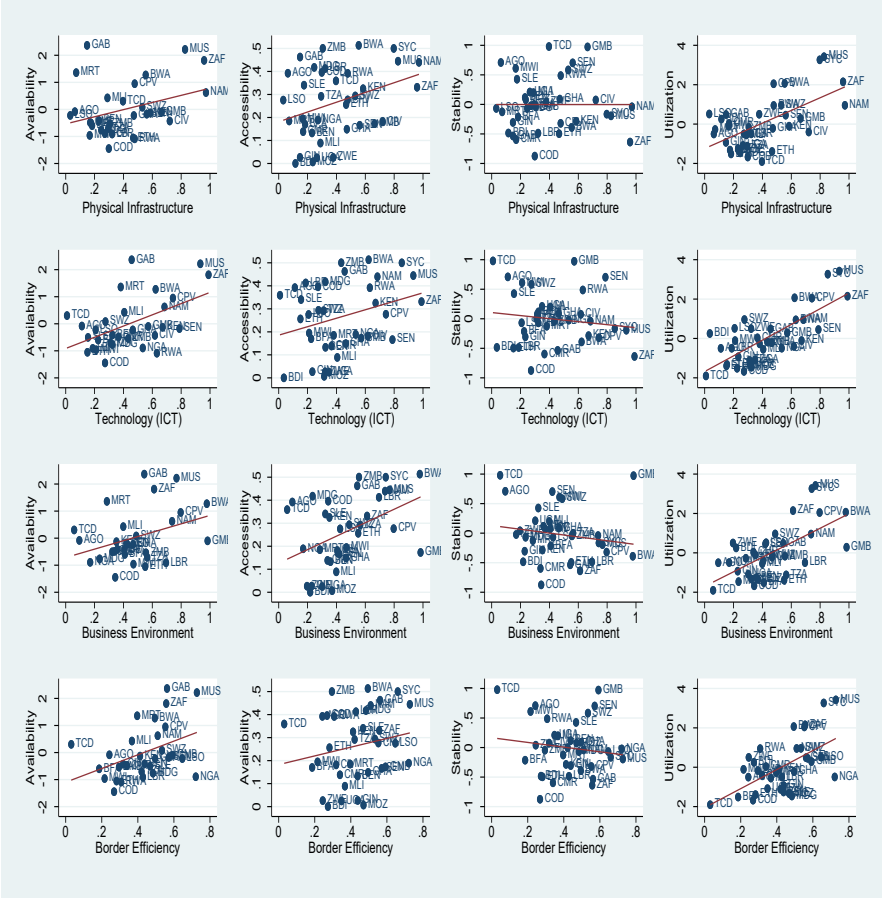
TF index	Eigenvalue	Proportion explained	Primary variables	Eigenvectors	Correlation Coefficients	Bartlett (p-value)
Physical Infrasturcture index	2.189	0.730	Quality of airport	0.590	0.873	0.000
			Quality of port	0.585	0.866	
			Quality of road	0.556	0.822	
ICT index	2.408	0.803	Availability of ICT	0.615	0.954	0.000
			Level of ICT absorption	0.599	0.930	
			Use of ICT	0.513	0.796	
Business Environment index	2.827	0.707	Transparency	0.477	0.801	0.000
			Trust in government	0.534	0.898	
			Irregular payments	-0.468	-0.787	
			Government favouritism	0.518	0.871	
Border Efficiency index	2.765	0.691	Days to export	0.514	0.855	0.000
			Days to import	0.519	0.862	
			Document to export	0.482	0.802	
			Document to import	0.484	0.805	
Composite Trade Facilitation Index	6.130	0.438	Quality of airport	0.307	0.649	0.000
	2.173	0.155	Quality of port	0.289	0.600	
	1.736	0.124	Quality of road	0.259	0.540	
			Availability of ICT	0.333	0.738	
			Level of ICT absorption	0.301	0.669	
			Use of ICT	0.318	0.778	
			Transparency	0.251	0.546	

Trust in government	0.219	0.503
Irregular payments	-0.301	-0.675
Government favouritism	0.181	0.422
Days to export	0.248	0.729
Days to import	0.256	0.748
Document to export	0.202	0.660
Document to import	0.225	0.700

Note: The principal component scores were normalized to a scale of 0–1 using min–max transformation with higher values corresponding to better outcomes. The correlation coefficients show the degree of correlation between the constructed index and the corresponding primary variables used. The number of principal components was selected by the Kaiser criterion of eigenvalue greater than one. The null hypothesis of the Bartlett test of sphericity is that the variables are not intercorrelated.

The scatterplots in Figure 5 clearly show that improvements in trade facilitation are strongly associated with better food security in all the dimensions except the stability one. This Figure also shows the disparities between countries. Since correlation is not causality, the regression results will guide us on the real effect.

Figure 5: Correlation between trade facilitation and food security (average 2005-2019)



Source: Author own elaboration based on data from FAOSTAT and WEF

Control variables

Several determinants of food security are used in the literature to analyze many factors that can affect it. In this study, based on several empirical studies (Dithmer and Abdulai, 2017 ; Bonuedi et al., 2020 ; Fusco et al., 2020), we consider the following control variables.

GDP growth: reflects a measure of economic development. According to Haddad et al. (2003), economic growth is the most important factor influencing income-

based and food poverty. This variable is expected to increase the availability of goods and services including food.

Population growth: captures broadly one important facet of demographic development. Population pressures as indicated by high population growth led to growing food requirements for the whole population and could reduce per capita food availability. Also, rapid population growth, particularly in rural areas, may either yield positive productivity effects or worsen food security by increasing pressure on limited resources (Bonuedi et al., 2020). Therefore, a positive or negative effect of this variable on food security is expected. *Rural population* variable indicates the importance of agriculture and refers to the share of people living in rural areas out of the total population.

Arable land: it captures the availability of resources for agricultural production and includes land under temporary crops, temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. *Agricultural productivity*: it measured by the cereal yield (kg per hectare). Agricultural productivity should positively affect the supply of food from domestic production.

Natural disasters: It's a measure of climate change computed as the number of people affected by natural disasters[5] divided by the total population following Dithmer and Abdulai, (2017). Climate change has been found in the literature to affect the level of food supply or production (Rasul & Sharma, 2016).

Political stability: It captures the institutional factors which are recognized as an important determinants of food security. We expect this variable to positively affect food security.

Inflation: It is measured by the consumer price index inflation rate and expresses the quality of domestic macroeconomic policy and environment. The inflation variable should positively or negatively affect food security.

3. Empirical Results and Discussion

The empirical results of the contribution of trade facilitation to food security in SSA using the fixed effects and the IV-2SLS are presented in Tables 4–13. The baseline results with fixed effects estimator are in Table 4-8. We can see from the fixed effects results that the average trade facilitation indicator and the four indicators

[5] The natural disaster data are from the Emergency Events Database (EM-DAT) and comprise of geophysical, meteorological, hydrological, climatological, and biological disasters (see http://www.emdat.be/).

positively affect food security at 1% level. Moreover, the effects vary when it comes to different dimensions of food security.

Table 4: Contribution of trade facilitation to food Security (FE results for Composite food security)

	Composite Food Security Index				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Trade Facilitation Index	1.497***				
	(0.171)				
Physical Infrastructure		1.431***			
		(0.186)			
Technology (ICT)			2.350***		
			(0.226)		
Business Environment				1.582***	
				(0.168)	
Border Efficiency					1.095***
					(0.186)
Population growth	-0.420***	-0.379***	-0.513***	-0.805***	-0.631***
	(0.100)	(0.105)	(0.120)	(0.115)	(0.116)
GDP growth	-0.508	-0.890	-0.034	0.093	-1.003
	(0.710)	(0.670)	(0.731)	(0.742)	(0.609)
Rural population	-6.493***	-6.002***	-3.411***	-6.288***	-4.405***
	(0.493)	(0.518)	(0.541)	(0.543)	(0.625)
Arable land	0.345	-1.873*	-6.140***	-1.000	-4.430***
	(1.116)	(0.988)	(1.139)	(1.222)	(1.164)
Agricultural prod	0.066	-0.011	0.012	0.265***	0.066
	(0.063)	(0.062)	(0.072)	(0.069)	(0.077)
Natural disasters	0.002	0.001	0.004	0.001	0.000
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Political stability	0.612***	0.738***	0.300***	0.013	0.652***
	(0.113)	(0.115)	(0.113)	(0.124)	(0.095)
Inflation	0.507	-0.241	0.592	1.894***	-0.853
	(0.571)	(0.557)	(0.610)	(0.610)	(0.521)
Constant	-1.317	1.604**	0.040	-2.194***	-0.053
	(0.894)	(0.640)	(0.654)	(0.641)	(0.728)
Observations	306	325	358	349	381
R-squared	0.937	0.931	0.904	0.899	0.926

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Source: Author estimates.

Table 5: Contribution of trade facilitation to food Security (FE results for Availability dimension)

	FS_Availability				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Trade F Index	1.161***				
	(0.122)				
Physical Infrastructure		1.206***			
		(0.125)			
Technology (ICT)			1.006***		
			(0.134)		
Business Environment				0.582***	
				(0.104)	
Border Efficiency					0.753***
					(0.125)
Population growth	-0.463***	-0.347***	-0.322***	-0.522***	-0.540***
	(0.068)	(0.071)	(0.066)	(0.070)	(0.064)
GDP growth	-0.598	-0.659	-0.389	-0.804*	-0.796*
	(0.514)	(0.481)	(0.404)	(0.463)	(0.422)
Rural population	-3.498***	-3.446***	-4.175***	-5.211***	-5.106***
	(0.287)	(0.283)	(0.305)	(0.333)	(0.302)
Arable land	2.141***	0.569	2.563***	3.615***	3.715***
	(0.607)	(0.604)	(0.945)	(0.792)	(0.689)
Agricultural prod	0.001	-0.054	0.085	0.055	-0.016
	(0.038)	(0.040)	(0.053)	(0.043)	(0.040)
Natural disasters	0.000	-0.000	0.000	-0.000	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Political stability	0.361***	0.316***	0.239***	0.234***	0.423***
	(0.079)	(0.080)	(0.068)	(0.076)	(0.065)
Inflation	1.491***	0.865**	0.189	-0.290	-0.595*
	(0.390)	(0.398)	(0.353)	(0.397)	(0.359)
Constant	-1.185***	0.156	-0.922**	-0.739*	-0.537
	(0.405)	(0.425)	(0.440)	(0.402)	(0.371)
Observations	306	325	358	349	381
R-squared	0.922	0.926	0.942	0.928	0.935

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Source: Author estimates

Table 6: Contribution of trade facilitation to food Security (FE results for Availability dimension)

	FS_ Access				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Trade F Index	0.171***				
	(0.033)				
Physical Infrastructure		0.168***			
		(0.033)			
Technology (ICT)			0.062*		
			(0.035)		
Business Environment				0.133***	
				(0.026)	
Border Efficiency					0.114***
					(0.031)
Population growth	0.007	0.005	-0.014	0.074***	0.074***
	(0.018)	(0.015)	(0.014)	(0.017)	(0.015)
GDP growth	0.068	0.063	0.112	0.119	0.035
	(0.101)	(0.156)	(0.149)	(0.112)	(0.100)
Rural population	-1.063***	-0.355***	-0.441***	-0.680***	-0.723***
	(0.071)	(0.052)	(0.055)	(0.049)	(0.045)
Arable land	0.437**	-0.348***	-0.178*	-0.026	0.045
	(0.179)	(0.086)	(0.091)	(0.115)	(0.100)
Agricultural prod	0.077***	0.007	0.007	0.012	0.000
	(0.013)	(0.011)	(0.012)	(0.010)	(0.009)
Natural disasters	-0.001	-0.001	-0.001	-0.000	-0.001
	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Political stability	0.085***	0.122***	0.119***	0.040**	0.076***
	(0.017)	(0.014)	(0.014)	(0.018)	(0.012)
Inflation	0.388***	0.520***	0.391***	0.371***	0.133
	(0.083)	(0.122)	(0.122)	(0.093)	(0.081)
Constant	0.169	0.323***	0.342***	0.752***	0.874***
	(0.127)	(0.095)	(0.096)	(0.100)	(0.089)
Observations	359	382	414	403	444
R-squared	0.866	0.600	0.593	0.782	0.813

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Source: Author estimates

Table 7: Contribution of trade facilitation to food Security (FE results for Utilization dimension)

	FS Utilization				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Trade F Index	1.012***				
	(0.119)				
Physical Infrastructure		1.923***			
		(0.201)			
Technology (ICT)			2.132***		
			(0.191)		
Business Environment				1.023***	
				(0.163)	
Border Efficiency					0.773***
					(0.151)
Population growth	-0.250***	-0.640***	-0.722***	-1.091***	-0.626***
	(0.071)	(0.110)	(0.102)	(0.106)	(0.085)
GDP growth	-0.301	-0.099	-0.505	-0.368	-0.065
	(0.413)	(0.698)	(0.622)	(0.700)	(0.472)
Rural population	-4.025***	-2.224***	-1.738***	-2.715***	-3.918***
	(0.572)	(0.357)	(0.300)	(0.311)	(0.340)
Arable land	-2.940***	-7.817***	-8.113***	-6.517***	-2.755***
	(1.037)	(0.643)	(0.605)	(0.712)	(0.650)
Agricultural prod	-0.079	-0.118*	-0.032	0.176***	-0.078
	(0.065)	(0.063)	(0.059)	(0.064)	(0.060)
Natural disasters	0.002	0.007**	0.010***	0.008***	0.005**
	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)
Political stability	0.288***	-0.119	-0.260***	-0.364***	0.155***
	(0.066)	(0.107)	(0.091)	(0.112)	(0.060)
Inflation	-0.246	-0.357	-0.721	-0.373	-1.336***
	(0.351)	(0.600)	(0.525)	(0.580)	(0.379)
Constant	1.818***	0.902	-0.236	-2.579***	0.649
	(0.560)	(0.672)	(0.574)	(0.628)	(0.569)
Observations	359	382	414	403	444
R-squared	0.967	0.891	0.901	0.871	0.939

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Source: Author estimates

Table 8: Contribution of trade facilitation to fod Security (FE results for Stability dimension)

	FS Stability				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Trade F Index	1.078***				
	(0.244)				
Physical Infrastructure		0.798***			
		(0.243)			
Technology (ICT)			0.228		
			(0.218)		
Business Environment				0.001	
				(0.221)	
Border Efficiency					0.697**
					(0.299)
Population growth	-0.119	0.038	0.213**	0.169	0.202
	(0.120)	(0.125)	(0.088)	(0.173)	(0.169)
GDP growth	-2.212**	-0.866	0.336	-0.098	0.578
	(0.984)	(0.964)	(0.924)	(0.910)	(0.843)
Rural population	-0.345	0.019	0.332	-3.667***	-0.803
	(0.374)	(0.366)	(0.343)	(1.287)	(0.629)
Arable land	1.852**	1.608*	-0.114	5.603**	1.837
	(0.790)	(0.835)	(0.569)	(2.284)	(1.506)
Agricultural prod	0.156*	0.042	-0.047	0.086	-0.185
	(0.089)	(0.092)	(0.072)	(0.148)	(0.114)
Natural disasters	0.001	-0.002	-0.002	-0.001	-0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Political stability	-0.177	0.107	0.057	-0.190	-0.068
	(0.139)	(0.128)	(0.088)	(0.149)	(0.114)
Inflation	1.084	0.411	0.490	0.818	0.293
	(0.762)	(0.845)	(0.756)	(0.777)	(0.678)
Constant	-1.679*	-0.988	0.657	0.660	1.979*
	(0.890)	(0.865)	(0.598)	(1.264)	(1.067)
Observations	357	380	412	401	442
R-squared	0.320	0.283	0.374	0.475	0.447

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Source: Author estimates

The results of the contribution of trade facilitation to food security in SSA with the IV-2SLS estimator (our preferred estimator), are reported in Table 9-13. Also, we have at the bottom of each table (Tables 9 to 13) the outcomes of the diagnostic tests that allow for the checking of the consistency of the IV-2SLS approach. Based on these outcomes, we note the rejection of the null hypothesis of under-identification since the p-values of Kleibergen and Paap, (2006) are significant at 5% for all specifications. Our model is therefore correctly identified. Moreover, when we compare the Cragg-Donald Wald F statistics values to the critical values of Stock and Yogo, (2005) to determine instrumental variable bias and size bias, we reject the weak instrument null hypothesis since the statistics are greater than the critical values of Stock and Yogo, (2005) at 10%. Finaly, the Hansen's p-values are also greater than 5% for all specifications. Based on the above, the two-stage least square estimator is appropriate for conducting empirical analysis.

The results presented in Table 9 below show the positive and significant effect of the average trade facilitation index as well as two out of the four trade facilitation indicators on composite food security. The coefficient of the average trade facilitation index is positive and statistically significant at the 5% level. This implies that a l % improvement in the average trade facilitation index is roughly associated with a 1.33-point increase in the composite food security in SSA. These results suggest that facilitating trade broadly in terms of reducing border costs, improving infrastructures and institutions, can exert beneficial effects on food security in SSA. These results are in line with the one obtained by Bonuedi et al. (2020). These authors found that poor trade facilitation can exert harmful effects on food security in Africa.

Table 9: Contribution of trade facilitation to food Security (IV-2SLS results for composite food security)

	Composite Food Security Index					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Trade Facilitation Index	1.334**					-
	(0.659)					-
Physical Infrastructure		1.225**				-1.312
		(0.539)				(0.841)
Technology (ICT)			1.720***			2.546***
			(0.667)			(0.977)
Business Environment				1.039		1.721*
				(0.766)		(0.944)
Border Efficiency					0.084	-0.308
					(0.720)	(0.694)
Population growth	-1.060***	-0.986***	-1.000***	-1.223***	-1.157***	-1.107***
	(0.242)	(0.210)	(0.183)	(0.199)	(0.228)	(0.236)
GDP growth	-0.981	-1.661	0.258	-2.453	-0.687	-1.061
	(2.028)	(2.052)	(1.482)	(2.309)	(1.531)	(2.675)
Rural population	-3.553***	-3.328***	-2.514***	-4.330***	-3.971***	-2.783**
	(1.022)	(1.032)	(0.952)	(0.850)	(1.020)	(1.121)
Arable land	0.622	-1.829	-0.359	1.082	-0.572	0.999
	(1.544)	(1.743)	(1.261)	(1.585)	(1.769)	(1.521)
Agricultural prod	0.142	-0.023	-0.119	0.176	0.053	0.145
	(0.160)	(0.193)	(0.198)	(0.148)	(0.209)	(0.165)
Natural disasters	0.004	-0.003	-0.001	0.007	-0.001	0.009
	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(0.008)
Political stability	0.640***	0.762***	0.574**	0.208	0.581**	0.301
	(0.225)	(0.252)	(0.253)	(0.256)	(0.231)	(0.257)
Inflation	3.401*	2.222	2.292	1.686	0.929	4.361***
	(1.761)	(2.210)	(1.657)	(1.610)	(1.929)	(1.673)
Constant	-4.628***	-2.594	-3.146*	-4.527***	-2.976*	-6.296***
	(1.627)	(1.996)	(1.744)	(1.246)	(1.744)	(1.523)
Observations	212	226	250	246	265	212
R-squared	0.772	0.737	0.732	0.732	0.683	0.783
Underindentification test	10.83	11.91	14.40	10.80	8.229	15.79
Prob>LM	0.004	0.002	0.000	0.004	0.016	0.003
Weak Identification Test (Cragg-Donald Wald F stat)	602.128	509.313	1150.667	508.061	551.400	19.734
Stock-Yogo critical values (10%)	19.93	19.93	19.93	19.93	19.93	-
Hansen P value	0.255	0.425	0.886	0.135	0.473	0.184

Note: Time dummies are included but not reported, Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * <0.1.

Source: Author's estimates

We note in Table 9 also that physical infrastructure plays a key role in reducing food insecurity in SSA countries. The coefficient associated with this variable is

positive and significant at 5% level. In fact, a 1% increase in the quality of roads, ports and airports leads to a 1.23-point increase in food security. With this result, we can say that better physical infrastructure (mostly airport infrastructure) could reduce transaction costs associated and thus reduce food insecurity. As stated by Mary (2019), most people that faced food insecurity are in rural area characterized by weak transport infrastructures which impede the movement of the imported/locally produced food products from surplus areas.

The ICT indicator has a positive and statistically significant contribution to food security. An increase in the availability of technology by 1% is associated with an increase in food security in SSA by 1.72-points. Thus, the use of ICT enables innovation, which favors the introduction of new, more sophisticated production methods, which in turn leads to the availability, accessibility and utilization of more goods including foods products. In the same line, Gouvea et al. (2022) results indicated the positive impact of technology on global food security in OECD countries. Specifically, they found that progress in technology, either ICT use, or technology adoption has an incremental positive effect on food security. The business environment and the border and transport efficiency indicators are found to be an important factor in explaining food security. However, their effects are not significant.

To identify which aspects of trade facilitation reforms are most promising in Sub-Saharan Africa's fight against hunger, we now analyze the results on the different dimensions of food security (Tables 10 to 13).

The hard trade facilitation indicator, namely the physical infrastructure indicator is positive and significant for two dimensions of food security (10% level for access dimension (Table 11), and 1% for utilization (Table 12). In Table 11 for example, a 1% increase in the quality of roads, ports and airports leads to a 0.148-point increase in food access. The role of physical infrastructure is also confirmed in Table 12 related to food utilization. In fact, we can see that a 1% improvement in physical infrastructure is associated with a 1.635-point increase in food utilization. For the ICT indicator, it has a positive contribution to food availability and food access, as well as positive and significant contribution to food utilization at 1 % with the coefficient of 2.247 (Table 12).

Regarding the soft trade facilitation indicators, the business environment contributes positively to food security in two dimensions (availability, access) and is statistically significant at 1% for food utilization (Table 12). The results of this variable which capture the level of development of regulations and transparency in the country underscored the critical role of institutions in ensuring food security. In fact, improved institutions by 1% in terms of reduction of corruption will facilitate trade and therefore enhance food security by 1.542-point. This confirms

the result of Qingshi et al. (2020) who found that increasing the level of corruption strongly negatively affects the food security level. Additionally, the level of development of regulations and transparency can support food security objectives by preparing policies that maintain the flow of goods and services ecosystem to agriculture (Subramaniam et al., 2022). The border efficiency indicator is positive and significant at 5% for food stability when all TF indicators are included in the regression. Improvement of trade procedures by 1% leads to the increase in stability of food by 1.080-point (Table 12). This implies that lowering trade costs for food items results in ensuring consistency and efficiency of food suppliers as well as increasing the variety of food products. Our results are consistent with the finding in the literature (Bonuedi et al.; 2020 ; United Nations Economic Commission for Africa (UNECA), 2015). In fact, according to UNECA (2015), the complicated trade procedures in terms of exports/imports of staple food have resulted in a low record of intra-African trade and therefore increased food insecurity.

In Columns 6 of Tables 9 to 13, we integrated all TF indicators at the same time. We can see that among the four TF indicators; it appears that ICT as well as business environment are the most promising in SSA fight against food insecurity. Moreover, related to the four dimensions of food security, TF contribution is more notable in terms of coefficients and significance on the utilization and access dimensions.

Concerning the control variables, they theoretically have mostly the expected signs. For example, population growth affects negatively and significantly food security (Table 9). In fact, a higher rate of population growth will reduce food security, because increasing population means a higher demand for food. As the population growth, the share of rural population in the total population negatively affects food security in SSA countries. Furthermore, the political stability variable affects positively and significantly food security in SSA (Table 9) confirming the role of quality of institutions in ensuring food security.

Table 10: Contribution of trade facilitation to food Security (IV-2SLS results for Availability dimension)

	FS Availability					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Trade Facilitation Index	0.402					-
	(0.509)					-
Physical Infrastructure		0.269				-1.267*
		(0.415)				(0.668)
Technology (ICT)			0.496			1.826***
			(0.433)			(0.701)
Business Environment				0.205		1.070**
				(0.457)		(0.524)
Border Efficiency					-0.302	-0.567
					(0.606)	(0.509)
Population growth	-0.674***	-0.703***	-0.688***	-0.710***	-0.746***	-0.713***
	(0.175)	(0.146)	(0.145)	(0.154)	(0.156)	(0.164)
GDP growth	-2.715	-2.536	-1.829	-2.567	-2.266	-2.408
	(1.848)	(1.652)	(1.474)	(1.658)	(1.530)	(1.520)
Rural population	-3.192***	-3.473***	-3.059***	-3.572***	-3.728***	-2.635***
	(0.775)	(0.656)	(0.661)	(0.747)	(0.643)	(0.847)
Arable land	0.961	0.543	1.430	1.581	1.463	1.441
	(1.624)	(1.510)	(1.287)	(1.424)	(1.257)	(1.480)
Agricultural prod	0.138	0.071	0.016	0.114	0.095	0.145
	(0.114)	(0.120)	(0.131)	(0.115)	(0.117)	(0.123)
Natural disasters	0.008	0.006	0.006	0.006	0.005	0.012
	(0.007)	(0.007)	(0.008)	(0.006)	(0.007)	(0.009)
Political stability	0.208	0.229	0.140	0.076	0.236	-0.022
	(0.225)	(0.213)	(0.224)	(0.221)	(0.171)	(0.221)
Inflation	-0.084	0.062	-0.213	-0.876	-0.747	0.831
	(1.234)	(1.180)	(1.231)	(1.286)	(1.239)	(1.141)
Constant	-2.061	-1.418	-1.560	-1.742	-1.476	-3.270**
	(1.428)	(1.296)	(1.239)	(1.199)	(1.157)	(1.330)
Observations	212	226	250	246	265	212
R-squared	0.687	0.697	0.644	0.629	0.655	0.675
Underindentification test	10.83	11.91	14.40	10.80	8.229	15.79
Prob>LM	0.004	0.002	0.000	0.004	0.010	0.003
Weak Identification Test (Cragg-Donald Wald F stat)	602.128	509.313	1150.667	508.061	551.400	19.734
Stock-Yogo critical values (10%)	19.93	19.93	19.93	19.93	19.93	-
Hansen P_value	0.636	0.750	0.968	0.417	0.370	0.272

Note: Time dummies are included but not reported, Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Source: Author estimates

Table 11: Contribution of trade facilitation to food Security (IV-2SLS results for Access dimension)

	FS_Access					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Trade Facilitation Index	0.156*					-
	(0.091)					-
Physical Infrastructure		0.148*				0.087
		(0.082)				(0.151)
Technology (ICT)			0.063			-0.058
			(0.107)			(0.163)
Business Environment				0.077		0.100
				(0.106)		(0.133)
Border Efficiency					-0.032	0.124
					(0.133)	(0.133)
Population growth	-0.020	-0.010	-0.033	-0.046	-0.039	-0.022
	(0.034)	(0.029)	(0.030)	(0.030)	(0.034)	(0.035)
GDP growth	-0.083	-0.110	-0.037	-0.335	-0.095	-0.206
	(0.346)	(0.343)	(0.357)	(0.361)	(0.344)	(0.397)
Rural population	-0.176	-0.156	-0.164	-0.276**	-0.260**	-0.206
	(0.138)	(0.143)	(0.152)	(0.110)	(0.132)	(0.156)
Arable land	-0.134	-0.423*	-0.209	0.009	-0.265	-0.154
	(0.243)	(0.235)	(0.281)	(0.295)	(0.307)	(0.230)
Agricultural prod	0.024	0.011	0.003	0.020	0.008	0.031
	(0.034)	(0.035)	(0.037)	(0.031)	(0.033)	(0.036)
Natural disasters	0.002*	0.001	0.001	0.002	0.001	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Political stability	0.103**	0.128***	0.090**	0.049	0.068	0.091*
	(0.041)	(0.049)	(0.044)	(0.047)	(0.043)	(0.054)
Inflation	0.603**	0.436	0.357	0.418*	0.241	0.529*
	(0.277)	(0.298)	(0.277)	(0.245)	(0.273)	(0.283)
Constant	-0.074	0.121	0.112	-0.008	0.213	-0.131
	(0.225)	(0.265)	(0.242)	(0.204)	(0.234)	(0.249)
Observations	246	261	285	280	304	246
R-squared	0.408	0.399	0.278	0.297	0.253	0.413
Underindentification test	12.90	11.71	15.67	12.02	8.306	19.48
Prob>LM	0.001	0.002	0.000	0.002	0.015	0.001
Weak Identification Test (Cragg-Donald Wald F stat)	674.697	550.355	1033.357	535.669	630.261	21.754
Stock-Yogo critical values (10%)	19.93	19.93	19.93	19.93	19.93	19.93
Hansen P_value	0.236	0.277	0.638	0.453	0.664	0.233

Note: Time dummies are included but not reported, Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Source: Author estimates

Table 12: Contribution of trade facilitation to food Security (IV-2SLS results for Utilization dimension)

	FS_Utilization					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Trade Facilitation Index	1.202***					-
	(0.423)					-
Physical Infrastructure		1.635***				-0.156
		(0.438)				(0.743)
Technology (ICT)			2.247***			1.888**
			(0.469)			(0.763)
Business Environment				1.542***		1.096**
				(0.420)		(0.462)
Border Efficiency					0.495	-0.946
					(0.486)	(0.662)
Population growth	-1.132***	-0.966***	-0.947***	-1.222***	-1.176***	-1.126***
	(0.187)	(0.177)	(0.146)	(0.186)	(0.221)	(0.169)
GDP growth	-2.605	-2.630	-0.770	-3.077	-0.797	-3.399
	(2.588)	(2.378)	(2.216)	(2.134)	(2.113)	(2.572)
Rural population	-2.024**	-1.444	-0.625	-2.367***	-1.983**	-1.320
	(0.942)	(0.949)	(0.864)	(0.858)	(0.999)	(0.836)
Arable land	-0.554	-2.962*	-2.059	-0.730	-1.922	-1.288
	(1.711)	(1.745)	(1.571)	(1.679)	(1.847)	(1.858)
Agricultural prod	-0.079	-0.180	-0.240	0.022	-0.031	-0.155
	(0.208)	(0.194)	(0.176)	(0.160)	(0.213)	(0.146)
Natural disasters	-0.004	-0.008	-0.006	0.001	-0.005	-0.000
	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)	(0.005)
Political stability	0.059	0.240	0.228	-0.203	0.404**	-0.181
	(0.267)	(0.250)	(0.219)	(0.204)	(0.197)	(0.201)
Inflation	1.594	-0.044	1.517	1.236	0.357	1.712
	(1.565)	(1.973)	(1.214)	(1.379)	(1.418)	(1.688)
Constant	-2.938*	-1.512	-2.534*	-3.861***	-3.267**	-2.963*
	(1.732)	(1.615)	(1.479)	(1.400)	(1.614)	(1.751)
Observations	246	261	285	280	304	246
R-squared	0.716	0.708	0.746	0.733	0.662	0.759
Underindentification test	12.90	11.71	15.67	12.02	8.306	19.48
Prob>LM	0.001	0.002	0.000	0.002	0.015	0.001
Weak Identification Test (Cragg-Donald Wald F stat)	674.697	550.355	1033.357	535.669	630.261	21.754
Stock-Yogo critical values (10%)	19.93	19.93	19.93	19.93	19.93	-
Hansen p-value	0.261	0.808	0.947	0.0508	0.268	0.405

Note: Time dummies are included but not reported, Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Source: Author estimates

Table 13: Contribution of trade facilitation to food Security (IV-2SLS results for Stability dimension)

	FS_Stability					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Trade Facilitation Index	0.616					-
	(0.565)					-
Physical Infrastructure		0.156				0.557
		(0.389)				(0.656)
Technology (ICT)			-0.230			-0.545
			(0.520)			(0.876)
Business Environment				-0.084		-0.134
				(0.613)		(0.530)
Border Efficiency					0.525	1.080**
					(0.658)	(0.531)
Population growth	0.230	0.142	0.095	0.090	0.170	0.239
	(0.157)	(0.132)	(0.122)	(0.126)	(0.119)	(0.151)
GDP growth	-0.973	-0.253	-0.473	-0.818	-0.106	-0.960
	(1.707)	(1.558)	(1.368)	(1.718)	(1.401)	(1.919)
Rural population	0.445	0.314	0.053	0.250	0.708	0.191
	(0.823)	(0.601)	(0.744)	(0.616)	(0.627)	(0.863)
Arable land	-0.231	-0.218	0.419	0.413	0.768	-0.234
	(0.918)	(0.899)	(0.799)	(0.887)	(0.836)	(1.072)
Agricultural prod	-0.053	0.003	-0.007	-0.104	-0.031	-0.037
	(0.111)	(0.108)	(0.109)	(0.109)	(0.098)	(0.116)
Natural disasters	0.009**	0.010***	0.007	0.005	0.006	0.007
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Political stability	-0.030	-0.022	-0.005	0.006	0.141	0.066
	(0.134)	(0.109)	(0.085)	(0.155)	(0.121)	(0.199)
Inflation	-0.511	-1.048	-0.411	0.156	-0.345	-0.763
	(1.226)	(1.221)	(1.030)	(1.184)	(1.267)	(1.275)
Constant	1.101	0.659	0.637	1.099	0.048	1.009
	(1.147)	(1.175)	(1.110)	(1.101)	(1.114)	(1.279)
Observations	244	259	283	278	302	244
R-squared	0.275	0.221	0.205	0.227	0.187	0.296
Underindentification test	12.90	11.76	15.63	12.02	8.337	19.21
Prob>LM	0.001	0.002	0.000	0.002	0.015	0.001
Weak Identification Test (Cragg-Donald Wald F stat)	669.402	546.013	1030.210	533.747	625.689	21.195
Stock-Yogo critical values (10%)	19.93	19.93	19.93	19.93	19.93	-
Hansen p-value	0.0215	0.945	0.368	0.222	0.127	0.592

Note: Time dummies are included but not reported, Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Source: Author estimates

4. Heterogeneity Analysis

In this section a similar analysis is done, focusing on whether the share of rural population plays a role in the relationship between TF and FS. The following interactive model is estimated:

$$FS_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 TFI_{it} + \beta_3 RurPop_{it} + \beta_4 TFI_{it} * RurPop_{it} \ \eta_t + \mu_i + \varepsilon_{it} \quad (5)$$

We are interested in both coefficients $\beta_2 \ and \ \beta_4$ which provide information on the marginal effect of trade facilitation on food security depending on the share of rural population. The results are provided in Table 14 for the composite FS and food utilization dimension.[6]

We note that the business environment indicator has positive and significant at 1% level while its interaction term with rural population variable displays a negative and significant coefficients also at the 1% significance level (Columns 4). With the two outcomes, we can say that there exists a level of the share of rural population above which the effect of TF on FS changes the sign and become negative. This turning point of the share of rural population is 0.63342925 [= (5.063/7.993)]. This turning point of the share of rural population for the business environment is lower than the maximum value of the share of rural population in the full sample which is 0.91 (see Appendix 1). This signifies that the business environment indicator only positively influences food security when the share of rural population is lower than 0.63342925.

For the food utilization (Table 14, Columns 6 to 10), we note also that the average trade facilitation indicator, the physical infrastructure, the ICT and business environment indicators have positive and significant (at 1% level) coefficients and their respective interaction terms with rural population variable display a negative and significant coefficients also at the 1% for the average TF and 5% significance level for the three indicators. We can also say that there exists a level of the share of rural population above which the effect of TF on food utilization changes the sign and become negative. This turning point of the share of rural population is 0.70439155 [= (6.865/9.746)] for the average TF, 0.83529011 [= (4.909/5.877)] for physical infrastructure, 0.96095131 [= (5.980/6.223)] for ICT and 0.75876623 [= (4.674/6.160)] for business environment. This implies that the average trade facilitation indicator, the physical infrastructure and business environment

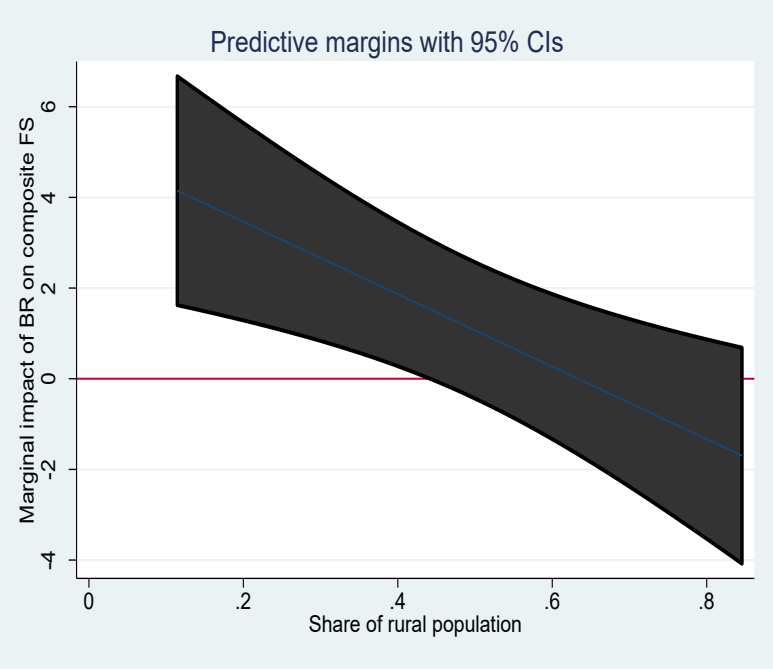
[6] We test the heterogeneity on composite food security as well as on food utilization because it is on these two FS aspects that our TF indicators have shown positive and significant effects (see Tables 9, 12). Also, when testing the interactions terms on the other dimension of FS, the results are found insignificant.

indicator only influence food utilization positively, when the share of rural population is lower than their turning points. For ICT, the effect remains positive over the full sample as the turning point 0.96095131 is higher than the maximum value of the share of rural population (0.91).

We deepen our understanding of the interaction between the average trade facilitation indicator and its component and the share of rural population by presenting in Figure 6 the development of the marginal effect of business environment on the composite food security for the share of rural population at the 95% confidence intervals. Alternatively, Figure 7 depicts the development of the marginal effect of TF and its components on food utilization for the share of rural population at the 95% confidence intervals. Figure 7 confirmed that the average trade facilitation indicator, the physical infrastructure, the ICT and the business environment indicators positively influence food utilization when the share of rural population is lower than the turning points.

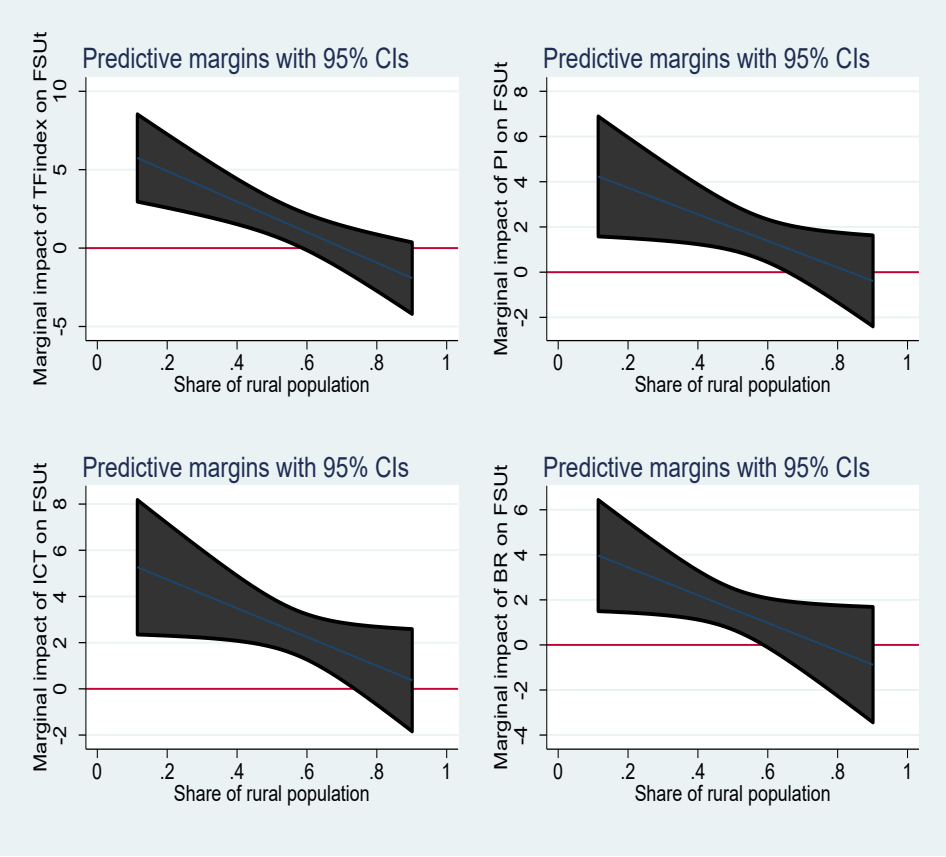
From the above analysis, we can conclude that countries with low rural population (high urban population) which are net consumers experienced positive effects of facilitating trade than countries with high rural population (net producers).

Figure 6: Marginal Impact of "trade facilitation" on "food security", for varying share of rural population



Source: Author's elaboration based on data from FAOSTAT and WEF.

Figure 7: Marginal Impact of "trade facilitation" on "food utilization", for varying share of rural population



Source: Author's elaboration based on data from FAOSTAT and WEF.

Table 14: 2SLS results with interaction terms

	Composite Food Security					FS Utilization				
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Trade F Index (TF)	**3.255***					**6.865*****				
	(1.713)					(1.736)				
TF*Rural population	-3.433					**-9.746*****				
	(2.623)					(2.942)				
Physical Infra (PI)		0.931					**4.909*****			
		(2.012)					(1.656)			
PI * Rural population		0.528					**-5.877****			
		(3.079)					(2.770)			
Technology (ICT)			**4.180*****					**5.980*****		
			(1.531)					(1.823)		
ICT 8 Rural population			-4.216					**-6.223****		
			(2.729)					(3.077)		
Business Environ (BR)				**5.063*****					**4.674*****	
				(1.548)					(1.589)	
BR * Rural population				**-7.993*****					**-6.160****	
				(2.705)					(3.043)	
Border Efficiency (BE)					-3.204					-2.648
					(2.974)					(2.109)
BE * Rural population					16.901					14.946
					(14.566)					(11.172)
Population growth	-1.069***	-0.989***	-0.920***	-1.293***	-0.774	-1.193***	-0.965***	-0.864***	-1.318***	-0.738
	(0.259)	(0.210)	(0.200)	(0.211)	(0.745)	(0.195)	(0.200)	(0.163)	(0.159)	(0.652)
GDP growth	-1.107	-1.758	0.500	-1.475	-14.752	-1.717	-1.138	0.433	-2.261	-11.386
	(2.041)	(2.084)	(1.454)	(2.455)	(15.577)	(1.887)	(1.974)	(1.820)	(1.763)	(10.126)
Rural population	-1.966	-3.536**	-0.560	-0.749	-11.095**	1.884	0.571	1.989	0.120	-7.556***
	(1.436)	(1.462)	(1.338)	(1.531)	(5.430)	(1.641)	(1.487)	(1.739)	(1.711)	(2.786)
Arable land	0.366	-1.783	-0.942	1.462	-0.887	-0.288	-3.117*	-2.359	0.014	-3.255
	(1.639)	(1.797)	(1.383)	(1.558)	(2.861)	(1.232)	(1.747)	(1.474)	(1.331)	(3.620)
Agricultural prod	0.132	-0.019	-0.122	0.251**	0.354	-0.065	-0.197	-0.235	0.095	0.092
	(0.154)	(0.199)	(0.192)	(0.121)	(0.321)	(0.147)	(0.179)	(0.156)	(0.142)	(0.188)
Natural desasters	0.004	-0.003	-0.001	0.004	0.032	-0.002	-0.008	-0.005	-0.000	0.017
	(0.006)	(0.006)	(0.007)	(0.006)	(0.028)	(0.005)	(0.005)	(0.005)	(0.005)	(0.018)
Political stability	0.593**	0.769***	0.594**	0.335	-1.870	0.046	0.216	0.308*	-0.088	-1.869
	(0.232)	(0.253)	(0.234)	(0.223)	(2.008)	(0.206)	(0.245)	(0.185)	(0.182)	(1.504)
Inflation	2.849	2.245	1.956	2.620*	-0.949	0.809	-0.137	1.273	2.071*	-1.576
	(1.832)	(2.213)	(1.652)	(1.493)	(4.471)	(1.286)	(1.833)	(1.249)	(1.234)	(3.883)
Constant	-5.399***	-2.521	-3.892***	-7.488***	0.220	-5.856***	-2.649**	-3.988***	-6.401***	1.029
	(1.366)	(1.967)	(1.497)	(1.225)	(4.443)	(1.155)	(1.251)	(1.169)	(1.296)	(4.189)
Observations	212	226	250	246	249	246	261	285	280	284
R-squared	0.775	0.737	0.739	0.759	-0.581	0.792	0.723	0.775	0.763	-0.361
Underidentification test	11.45	13.33	14.50	13.40	2.930	14.73	12.48	14.66	18.02	3.180
Prob>LM	0.009	0.003	0.002	0.001	0.403	0.000	0.005	0.002	0.000	0.365
Weak Identification Test	262.292	192.982	573.801	206.862	0.785	423.392	210.341	508.829	179.907	0.531
Stock-Yogo val (10%)	7.56	7.56	7.56	7.56	-	13.43	7.56	7.56	7.56	7.56
Hansen P_value	0.169	0.716	0.662	0.266	0.429	0.398	0.849	0.953	0.112	0.474

Note: Time dummies are included but not reported, Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Source Author estimates.

5. Conclusion and Policy Implications

In this study, we analyze the contribution of trade facilitation to food security in sub-Saharan Africa. We employed the Instrumental Variable Two Stage Least Square (IV-2SLS) estimator that accounts for potential endogeneity of the main explanatory variable in 36 countries over the period ranging from 2005 to 2019. Considering the multidimensional aspect of food security as well as the multifaceted trade facilitation, we constructed four dimensions of food security (availability, access, stability, and utilization) and four indicators of trade facilitation (physical infrastructure, ICT, business environment, border, and transport efficiency) using principal component analysis. The results of our estimation reveal positive and significant effects of the trade facilitation index (average) and two TF indicators on composite food security. However, the effects of TF on food security dimensions varies. We find that among the four trade facilitation indicators, ICT and business environment are the most promising in the SSA fight against food insecurity. Moreover, related to the four dimensions of food security, it appears that TF contribution is more notable in terms of coefficients and significance on the utilization and access dimensions. Finally, we found that countries with low rural population which are net consumers experienced positive effects of facilitating trade than countries with high rural population (net producers). From a policy perspective, these findings have some implications. First, the results underscored the critical role of ICT in reducing food insecurity in sub-Saharan Africa. Therefore, policymakers should prioritize the digitalization on the continent by implementing the African Continental Free Trade Area (AfCFTA) protocol on digital trade which provides a political framework to foster sustainable digital growth across the continent. Secondly, considering the positive and significant effect of business environment in improving food security, governments should intensify efforts to formulate necessary regulations (e.g., discouraging corruption) that are favorable to food security. This can be done by creating transparency in all food trade processes. Third, reducing trade costs, notably the number of days and documents, plays a key role in food stability by ensuring timely delivery of goods. To facilitate the cross-border movement of goods including food products in a consistent, timely, and efficient manner, SSA countries are encouraged to simplify and harmonize import and export procedures by pursuing the implementation of the World Trade Organization Trade Facilitation Agreement (WTO-TFA). Fourth, the heterogeneity results with the share of rural population underscore the need for specifics policies in SSA countries such as addressing transport infrastructure constraints and other market imperfections that can impede the movement of imported or locally produced food from surplus areas. More generally, as achieving food security is a long-term goal, facilitating trade should constitute a fundamental component of a

policy mix to enhance it. As it is well identified in the AfCFTA agreement, trade facilitation is a key element in promoting intra African trade including agrifood trade.

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Appendix

A1: Descriptive statistics

Variables	Obs	Mean	Std. dev.	Min	Max	Expected Signs
$FS_{Availability}$	387	-3.10E-09	1.00	-1.45	2.38	N/A
FS_{Access}	540	0.2631442	0.16	0.00	0.61	N/A
$FS_{Stabilty}$	466	-3.65E-09	0.75	-1.38	2.11	N/A
$FS_{Utilization}$	540	-4.81E-09	1.36	-2.11	3.80	N/A
Composite FSIndex	387	6.72E-09	1.37	-2.01	4.08	N/A
Physical Infrastructure	464	0.40	0.27	0	1	+
Technology (ICT)	502	0.43	0.26	0	1	+
Business and Regulatory Environment	489	0.45	0.26	0	1	+
Border and Transportation Efficiency	539	0.42	0.19	0	1	+
Composite Trade Facilitation Index	439	0.43	0.27	0	1	+
GDP growth	540	0.05	0.04	-0.21	0.21	+
Population growth	540	0.02	0.01	-0.03	0.06	+/-
Rural population	540	0.60	0.17	0.10	0.91	-
Arable land	540	0.19	0.09	0.00	0.43	+
Agricultural productivity	455	1493.28	1047.01	34.30	9453.70	+
Natural desasters	540	2.36	7.55	0	93.65	-
Political stability	540	-0.429	0.856	-2.403	1.201	+
Inflation	529	0.075	0.125	-0.089	2.553	+/-

A2: Correlation matrix between trade facilitation indicators

	Average Trade facilitation	Physical Infrastructure	Information and Communication Technology	Business and Regulatory Environment	Border and Transport Efficiency
Average trade facilitation	1.0000				
Physical Infrastructure	0.703***	1.0000			
Technology (ICT)	0.787***	0.729***	1.0000		
Business and Regulatory Environment	0.636***	0.536***	0.470***	1.0000	
Border and Transport Efficiency	0.814***	0.296***	0.502***	0.397***	1.0000

*** significance at 1%.

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