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Article

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Does the green economy really foster food security in Sub-Saharan Africa?

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Abstract: Over the last decade, the green economy concept has emerged as a fundamental policy framework for sustainable development in developing countries. This paper contributes to the current debate by providing an empirical investigation of the effect of the green economy on food security in 35 Sub-Saharan African countries for the period of 2001–2015. The results provide evidence that green economy indicators have controversial effects on food security (food availability and the proportion of undernourished people). Indeed, the results show that biofuels contribute to decreased food security in Sub-Saharan African countries, whereas renewable energy improves food security. Carbon dioxide emissions have no effect on food security. The results are robust to alternative robustness checks, such as the two-step Generalized Method of Moments (GMM) system.

Subjects: Economics and Development; Environment & the Developing World; Economics; Environmental Economics

Keywords: Green economy (O44); food security (Q18); Africa (N57)

1. Introduction

After a decline over the period of 2005–2014, global hunger has risen since 2014. According to the Food and Agriculture Organisation (FAO, IFAD, UNICEF, WFP & WHO, 2020), the number of

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PUBLIC INTEREST STATEMENT

Over the last decade, the green economy concept has emerged as a fundamental policy framework for sustainable development in developing countries. This paper contributes to the current debate by providing an empirical investigation of the effect of the green economy on food security in 35 Sub-Saharan African countries for the period of 2001–2015. The results provide evidence that green economy indicators have controversial effects on food security (food availability and the proportion of undernourished people). Indeed, the results show that biofuels contribute to decreased food security in Sub-Saharan African countries, whereas renewable energy improves food security. Carbon dioxide emissions have no effect on food security.

undernourished people has increased from 628.9 million to 687.8 million between 2014 and 2019. Food security is a daunting challenge in Sub-Saharan Africa (SSA). According to the 2020 Global Report on Food Crises (Food Security Information Network (FSIN), 2020), five (5) out of the ten (10) worst food crises in the world occurred in SSA. Moreover, despite national and international efforts aimed at reducing food insecurity, the number of people suffering from chronic hunger rose from 174.3 million to 234.7 million between 2005 and 2019. In other words, 22 percent of Africa's total population is undernourished. Globally, the food situation in most African countries has continued to deteriorate despite an abundance of water and arable land resources.

The persistence of food insecurity can be attributed to several factors, such as institutional quality and conflicts (Rossignoli & Balestri, 2018), and climatic events (Kinda & Badolo, 2019). The threefold crisis of 2008/2009 (financial, energy, and food crises) has thus highlighted the fragility and interrelatedness of our lifestyle. The event also appeared as an opportunity for the scientific and human community to question the current development model and put forward a new development model based on a green economy (UNEP, 2009).

Over the last decade, the green economy concept has emerged as a fundamental policy framework for sustainable development in developing countries. Indeed, the UN Conference on Sustainable Development (Rio+20) defined the green economy as one of the several approaches and tools for achieving sustainable development (The Future we want, UN, 2012). According to the Rio+20 Outcome Document, a green economy should “contribute to eradicating poverty, as well as sustained economic growth, enhancing social inclusion, improving human welfare, and creating opportunities for employment and decent work for all, while maintaining the healthy functioning of the Earth's ecosystem”. Though implementation is at different stages, several African countries (such as Ethiopia, Kenya, Rwanda, Senegal, Mozambique, and Tunisia) have adopted green economy strategies or policies (UNECA, 2020). Green policies are mainly implemented in agriculture, energy and mining, industry and manufacturing, transport infrastructure, construction and green building, water and the environment, urban infrastructure development and waste management. For instance, some countries (Ghana, Kenya, and Uganda) have invested in climate technologies and technology parks. Others have invested in renewable energy sources (hydroelectric, geothermal, solar and wind).

Several studies note that a transition to a green economy would contribute to improving human well-being and reducing inequalities while not exposing future generations to significant environmental risks and ecological scarcity (Schmitz & Becker, 2013). For instance, Hallegatte et al. (2012) state that the “green economy is about making growth processes resource-efficient, cleaner and more resilient without necessarily slowing them”. In addition, authors seem convinced that a green economy represents a “win-win” option for developing countries because it can reconcile low-carbon and sustainable development with other valued outcomes such as job creation (Jacob et al., 2015) and poverty reduction (Adeleke & Josue, 2019). However, other authors (Barbier, 2016; Resnick et al., 2012) are not fully convinced that a green economy is intrinsically sustainable and pro-development. According to Barbier (2016), many developing countries are characterized by high levels of natural resource dependence. In addition, a substantial part of the rural population is poor and located in remote areas and on less favourable agricultural land. To foster development and reduce poverty, green policies and reforms should be targeted at alleviating these two structural characteristics.

This paper contributes to the debate on the effect of the green economy in developing countries, especially in Africa. Contrary to previous empirical studies that have mainly focused on poverty (Adeleke & Josue, 2019) and employment (Jacob et al., 2015), the present work examines the effects of the green economy on food security. Moreover, to the best of our knowledge, the use of both econometric tools and macroeconomic analysis for SSA countries has not been included in the literature. Using alternative econometric tools (fixed-effects estimator and two-step GMM

system), this work provides an empirical and macroeconomic analysis of 35 SSA countries for the period of 2001–2015.

The results show that green economy indicators have controversial effects on food security (food availability and the proportion of undernourished people). They provide evidence that biofuels contribute to increased food insecurity in SSA countries, whereas renewable energy reduces food security. Finally, carbon dioxide emission reduction has no effect. The results are robust to alternative robustness checks.

The paper includes four sections. Section 2 presents a discussion of the literature on the relationship between the green economy and food security. Section 3 discusses the empirical strategy used to analyse the effect of the green economy on food security, and section 4 presents empirical results and a discussion. The last section provides a conclusion and policy implications.

2. Literature review

Food security is a multidimensional and flexible concept that has emerged and gained prominence since the World Food Conference of 1974. According to several authors (Maxwell, 1996; Upton et al., 2016), many definitions have been proposed. Such definitions have evolved from a focus on food production and importing capabilities at the macrolevel towards a focus on households and individuals and their ability to avoid hunger and undernutrition (Foster, 1992).

Even if there is no consensus in the literature (Cafiero et al., 2014; Dilley & Boudreau, 2001; Mechlem, 2004; Upton et al., 2016), the definition provided by the United Nations Development Programme is widely accepted by the World Bank and several nongovernmental organizations. The United Nations Development Programme (UNDP, 1994) defines food security 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”. From this definition, food security includes four dimensions (FAO, 2008): food availability, food accessibility, food utilization and food stability. The first dimension is food availability or the amount of available food in a national territory obtained through food production or food imports. The second dimension of food accessibility refers to the ability for people to secure economic resources to obtain food for consumption. The third dimension, food utilization, refers to the physical use of food derived from human distribution and depends on several factors, such as food habits and practices. Finally, food stability refers to the volume of food available for households remaining constant throughout the year.

Green economy policies can affect food security in SSA countries through its dimensions: food availability and stability, food accessibility and food utilization.

2.1. Food availability and stability

Green economy policies can affect food availability and stability by stimulating agricultural productivity and production and promoting better land management of natural ecosystems.

First, starting from the premise that food availability is insufficient in Africa due to the high growth rate of the African population (2.5 percent per year) and low yields of agricultural productivity, it would be essential to step up efforts aimed at increasing agricultural production. Several authors, such as Manda et al. (2016), have shown that the adoption of ecological agricultural practices (such as organic farming) has increased agricultural productivity and production in several African countries.

However, several authors (Herrmann et al., 2018; Kgathi et al., 2012; Subramaniam et al., 2019) are concerned about the negative effects of green policies such as biofuel production on food availability. Indeed, according to these authors, biofuel production may increase competition for production factor access (labour, water, and land) with a transition from food to biofuel

production. Moreover, food availability for consumption can be negatively affected because in the production process, biofuels use agricultural products (cereals, sugar, grains, and oilseeds).

2.2. Food accessibility

Green economy policies can affect food accessibility by promoting the development of infrastructure, creating jobs and business opportunities and stimulating economic growth.

Firstly, the African continent has a major deficit in infrastructure, which slows economic growth, reduces private sector productivity, and affects food security. African countries can draw advantages from their infrastructure deficit to set up more ecological investments by using environmentally friendly technologies and available innovations. For instance, the implementation of renewable energies can increase the potential for microenterprises to generate employment opportunities in rural and urban regions of developing countries (International Labour Organization, 2018). This approach will help eradicate extreme poverty and hunger. In addition, according to several authors (Ekouevi & Tuntivate, 2012; Oparaocha & Dutta, 2011), fuelwood collection reduces girls' and women's opportunities to access education or engage in income-generating activities. By increasing the incomes of poor and vulnerable populations, renewable energies improve their ability to buy food in local markets.

However, some authors have shown that the inclusion of biofuel in the green economy agenda can reduce food security. According to (Koizumi, 2015), the development of biofuel production can increase competition for both agricultural resources and infrastructure (fertilizers, pesticides, machinery, labour, capita, and land) and food and reduce the availability of food for people.

Secondly, the transition to a green economy requires increased investments in a number of areas (agriculture, agri-food industry, construction, transportation, etc.) and can thus be a source of green job creation (Montt et al., 2018). In the agricultural, agri-food, and environmental sectors, the promotion of activities in the area of natural heritage protection (in the agri-food industry) or environmental law has been identified as a generator of employment. Furthermore, the development of jobs related to waste collection, transportation, and recycling provides major potential for employment. In this regard, the African States could structure the entire sector from collection to recycling, generating jobs that, for the most part, could be made profitable by producing added value from recycled waste. Structuring this sector thus would not only significantly contribute in terms of sanitary conditions, health, and the environment but could also generate income for populations and reduce food insecurity. According to the International Labour Organization (2018), the transition to a green economy would create approximately 18 million net jobs internationally before 2030. However, this net job creation would be concentrated in developed countries, whereas African countries would be negatively impacted. Other authors (Green, 2011) have identified a negative effect of green economy transition on employment. By reducing employment in African countries, a green economy may reduce households' incomes and ability to access resources.

Thirdly, the transition to green growth could encourage businesses to increase their production of goods and services, such as agricultural, market gardening, arboriculture, fishery, and livestock products. Porter (1991) and Porter and Van Der Linde (1995) explain that environmental policies could stimulate technological innovation and increase productivity and competitiveness. In fact, when businesses face potentially high costs due to the adoption of environmental policies (e.g., reducing emissions), they are encouraged to change their production methods, invest in innovative activities, and find new ways to both meet environmental goals and produce new goods. Such businesses could thus adopt new production techniques that reduce their production costs (by making efficient use of resources) and at the same time increase the quality and competitiveness of goods produced. This is Porter's (1991) assumption. According to the UNEP (2010), the international market for organic food and beverages was projected to grow to US\$ 105 billion by 2015 from the total value of US\$ 62.9 billion in 2011. African countries, such as Uganda, have already

benefited from this opportunity, and the implementation of green practices would open up additional export markets and generate revenues for smallholder farmers.

Fourthly, African countries could increase their competitiveness gains by gearing their growth strategies towards the export of green goods and services. In fact, the international market for goods that use low-carbon and energy-efficient technologies could reach US\$ 2000.2 billion in 2020. This market could accelerate the industrialization of such economies and benefit from niches sectors such as through the transformation of agricultural, market gardening, arboriculture, fishery, and livestock products. The transition to an inclusive green economy could thus increase production and potential for growth in African countries by increasing production and exports (Jones & Olken, 2010). As they affect economic growth (through exports), green growth strategies are able to increase the resources available to governments. Indeed, several authors, such as Narayan and Doytch (2017), have shown that renewable energy stimulates economic growth, which may contribute to food security because economic performance (Wiesmann, 2006) increases countries' abilities to purchase food in international markets; to invest in technology, services, and infrastructures that support food and agricultural production; and to finance public services and investments in health and education (Smith & Haddad, 2000; Wiesmann, 2006).

However, Resnick et al. (2012) show that the implementation of green growth comes with trade-offs. In many countries, green growth strategies are essentially carbon emissions reduction policies. In the short term, the green growth agenda may be extremely costly because countries can deviate from their traditional development trajectories. In analysing case studies of African countries (Malawi, Mozambique and South Africa), the authors conclude that the poor may lose as a result of shifting to a green growth strategy. By increasing poverty, green growth strategies may reduce households' access to food in SSA countries.

2.3. Food utilization

Green economy policies can affect food utilization by improving basic social services. Indeed, food utilization refers to the ability for people to make good use of the food they can access and requires a diet providing sufficient energy and essential nutrients, clean water, and adequate sanitation and health care (UN World Food Program, 2007). By opening people's minds (Robeyns, 2006), education allows people to obtain better information on health, nutrition, and hygiene. Therefore, the educated make better use of the food they have access to.

Poor and vulnerable populations in Africa have very limited access to safe drinking water, and most populations that live in rural areas do not have access to proper sanitation services. According to Sperling et al. (2012), the rural average electrification rate in Africa is 10 percent, and only 28 percent of the population in SSA has access to improved sanitation facilities. Setting up green growth policies (for instance, renewable energies) in favour of access to drinking water, sanitation and public health would make it possible to reduce poverty and improve people's sanitary conditions. For example, the installation of boreholes with manual pumps in several West African Economic Monetary Union (WAEMU) countries has afforded poor populations access to drinking water and the ability to develop revenue-generating activities in the agricultural sector, such as market gardening.

Secondly, the improvement of energy services can contribute to improving basic social services, such as health care, education, and water supply. For example, modern cooking energy resources (biogas, biocoal, etc.) can make women's daily lives easier (health), as they no longer need to spend so much time gathering firewood (or charcoal) for energy and cooking with traditional stoves that are highly polluting. African countries could thus strengthen their energy potential through the use of hydropower, solar power, and bioenergy (biogas, agricultural residues, and biofuels). The transition to a green economy can also promote the development of local businesses and economic structures and help improve people's living conditions.

Furthermore, the African continent has a very young and low-skilled population, particularly in terms of vocational qualifications in rural areas. Establishing skills and professional training geared towards green jobs would improve young Africans' levels of training and considerably reduce not only poverty levels but also the youth unemployment rate. For example, modules on corporate social responsibility could be included in management studies; climate change can be introduced in tourism studies; life cycle analysis and waste management could be introduced in engineering studies; and green building could be introduced in building and civil engineering studies. Focusing on training and matching skills to the requirements of new emerging trades in the economy could thus substantially reduce medium- and long-term levels of poverty among vulnerable populations and improve food security.

Lastly, green growth strategies can potentially improve the health status of individuals and households and improve their ability to use food. In areas with limited access to drinking water and sanitation infrastructures, diarrhoeal diseases are very common and compromise people's health, particularly for children (very high child mortality rates). Improving basic social services could thus improve people's health and facilitate better absorption of nutrients.

3. Empirical strategy

This section describes the empirical specifications and data sources used.

3.1. Empirical model

The objective of this paper is to investigate the effect of the green economy on food security in 35 SSA countries for the 2001–2015 period. Following previous macroeconomic studies on food security (Jenkins & Scanlan, 2001; Kinda & Badolo, 2019; Santangelo, 2018; Wimberley & Bello, 1992), equation (1) is used:

$$FS_{i,t} = \alpha_i + \beta GE_{i,t} + \Omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (1)$$

Where $FS_{i,t}$ is food security, and similar to previous authors (Kinda & Badolo, 2019; Santangelo, 2018), food availability and the proportion of undernourished people are used as Proxies; $GE_{i,t}$ is the green economy variable for country i in year t ; $\varepsilon_{i,t}$ is the error term; α_i and γ_t denote country and time effects, respectively; and $X_{i,t}$ are control variables.

Control variables are taken from the economic literature on the macroeconomic determinants of food security. They include economic performance (proxied by income per capita (Breisinger et al., 2012; van Noordwijk et al., 2014)), climate factors (precipitation (Battisti & Naylor, 2009; Ochieng et al., 2016), demographic factors (proxied by population growth (Malthus, 1992; Ophuls & Boyan, 1992)) and institutional quality (proxied by democratic institutions (Rossignoli & Balestri, 2018)).

Firstly, food insecurity can be the result of a reduction in food availability. This argument is from Malthus (1992), who develops the relationship between population growth and a population's ability to produce food. By reducing food availability, population growth can affect food insecurity.

Secondly, economic performance can affect food security. The economic literature has shown that food insecurity is not due to food production but food access. Poor households struggle to satisfy their basic needs (food, health, water, and education) and to achieve food security. Authors such as van Noordwijk et al. (2014) and Breisinger et al. (2012) have suggested that by improving human development, economic growth contributes to increasing household incomes, thereby increasing access to food and reducing hunger. At the national level, Wiesmann (2006) and Smith and Haddad (2000) believe that economic resources may improve countries' health environment and population education and can boost food availability by improving resources available to purchase food in international markets. Therefore, economic performance can be a source of food security.

Thirdly, food security in SSA countries is affected by climatic factors such as precipitation. Indeed, because their economies heavily depend on climatically sensitive sectors such as agriculture (Mendelsohn et al., 2006), SSA countries are highly vulnerable to climate factors. Several authors, such as Battisti and Naylor (2009), Ochieng et al. (2016), and Kinda and Badolo (2019), have found that climate factors negatively affect agricultural productivity and production, household incomes and food security.

Finally, the role of democratic institutions has been highlighted as a determinant of food security. Indeed, by promoting electoral competition, democracy can increase accountability and encourage public action to fight hunger. Rossignoli and Balestri (2018) concluded that the democratization process contributed to improving food security in 106 low- and middle-income countries from 1990 to 2012.

3.1.1. Estimation strategy

To estimate an empirical model, adequate econometric techniques must be used. Panel data from 35 SSA countries for the period of 2001–2015 are thus adopted. Panel data take into account transversal temporal dimensions and the observed and unobserved heterogeneity of countries. Because ordinary least squares (OLS) does not take into account the unobserved heterogeneity of countries, it is adequate to apply fixed effects (FE) or random effects (RE). The Hausman test results (Appendix 1) show that the FE model is more appropriate than the RE model in this case.

3.2. Variable descriptions and data sources

3.2.1. Food security

Food security is a broad and multidimensional phenomenon because it comprises four dimensions: food availability, food accessibility, food stability and utilization.

Regardless of the multitude of indicators for food security, no consensus is provided in the literature (Cafiero et al., 2014; Dilley & Boudreau, 2001; Mechlem, 2004; Upton et al., 2016). In other words, at the macro level, it is difficult to find single or global indicators that cover all dimensions of food security and are available for SSA countries and for the 2001–2015 period.

Following previous studies (Kinda & Badolo, 2019; Santangelo, 2018), we use the level of food availability per capita and the proportion of undernourished people.

3.2.2. Green economy variables

Because the green economy is a very broad concept, there is no consensus on indicators used to measure it. The OECD's green growth framework (OECD, 2011) has widely been implemented to monitor progress towards green growth in several studies of developed countries. Kim et al. (2014) identify twelve indicators¹ for OECD countries and Korea. Following these authors (Kim et al., 2014; OECD, 2011) and taking into account data availability for SSA countries for the study period, we use three variables: carbon dioxide (CO₂) emissions per capita, renewable energy and biofuel production.

3.2.3. Data sources

This study is based on yearly panel data and covers the period of 2001 to 2015 for 34 SSA countries. The period and countries are selected exclusively based on data availability. Data on carbon dioxide (CO₂) emissions per capita, population growth, and income per capita are extracted from the World Development Indicators. Data on food availability, rainfall levels and democratic institutions are taken from the Food and Agriculture Organization, Centre d'Etude et de Recherche sur le Développement International (CERDI) and Polity IV, respectively. Data on renewable energy and biofuels come from the International Energy Agency (IEA). The appendices provide data sources and variable definitions (Appendix 2), descriptive statistics (Appendix 3), and country lists (Appendix 4).

4. Results and discussion

This section presents and discusses the results.

4.1. Results

Tables 1 and 2 report the effect of green economy indicators on food availability and malnutrition in SSA countries.

We start by running equation (1) with each green economy indicator (columns 1 to 3). In column (4), we include all green economy variables². The results show that the green economy indicators have controversial effects on food security (food availability and malnutrition). Indeed, the results indicate that renewable energy has a positive effect on food security (food availability and malnutrition), whereas biofuel production has a negative effect on food security. Carbon dioxide emission reduction has no effect on food security.

The control variables have the expected effect on food security in SSA countries. Economic resources (GDP per capita), precipitation, and democracy increase food security, whereas population growth reduces it.

Three robustness checks are implemented to validate our results.

Firstly, in (Tables 3 and 4), we add additional control variables for agricultural inputs such as arable land (column 2), fertilizer use (column 3), temperature (column 4) and trade openness (column 5). The results show that regardless of the additional control variables applied, green economic variables have controversial effects on food security in SSA countries. These results indicate that arable land, fertilizer use and trade openness help increase food security in the studied countries, whereas temperature reduces food security. Moreover, fertilizers play a vital role in shaping food security by improving agricultural productivity.

Secondly, the results may be biased due to endogeneity problems such as an inertia phenomenon affecting food security (food availability and malnutrition). Indeed, authors such as Kinda and Badolo (2019) have shown that the current level of food availability can be explained by the lagged level of food availability. The lagged level of food availability and malnutrition should be included in equation (1). The fixed effects (FE) estimator is thus no longer adequate. Therefore, it is necessary to use the system-generalized method of moments (GMM) estimation from Blundell and Bond (1998), Arellano and Bover (1995), and Arellano and Bond (1991) given the dynamic nature of the specified model. We use the two-step GMM system estimator because it is more efficient than the one-step GMM-system estimator even if standard errors can be severely downward biased in a small sample. This potential bias is addressed through the correction (Windmeijer, 2005) of a covariance matrix in a finite sample.

Columns (2) and (4) of Table 5 show that green economy variables have similar effects on food security. Moreover, there is no inertia food availability or malnutrition in SSA countries because the lagged levels of food availability and malnutrition have no effect on their current levels.

Finally, we use SSA regions for robustness checks. Indeed, several reports (FAO, IFAD, UNICEF, WFP & WHO, 2020; Food Security Information Network (FSIN), 2020) have shown that Eastern Africa (117.9 million) was home to the majority of the undernourished people in SSA countries in 2019, followed by Western Africa (59.4 million), Middle Africa (51.9 million) and Southern Africa (5.6 million). It may thus be interesting to analyse the effect of the green economy on food security in these four subregions. Tables 6 and 7 show that green economy indicators still have controversial effects on food security in subregions.

Indeed, the results show that carbon dioxide emissions per capita have no effect on food security in any subregion (Eastern Africa, Middle Africa, Southern Africa, and Western Africa).

Table 1. Effect of green economy on food availability per capita (Fixed effects)

	Food availability per capita (log)			
	(1)	(2)	(3)	(4)
Renewable energy (log)	0.0329*** (5.421)			0.0377*** (6.446)
CO2 per capita (log)		0.0200 (1.167)		0.00765 (0.437)
Biofuels (log)			-0.0174*** (-2.834)	-0.0171*** (-2.759)
GDP per capita (log)	0.151*** (6.688)	0.189*** (7.618)	0.217*** (11.02)	0.129*** (4.986)
Population growth	-0.0185** (-2.293)	-0.0243*** (-3.019)	-0.0192** (-2.303)	-0.0188** (-2.437)
Democratic Institutions	0.00292* (1.656)	0.00484*** (2.754)	0.00496*** (2.810)	0.00239 (1.402)
Precipitations (log)	0.0796*** (2.951)	0.0759*** (2.709)	0.0929*** (3.369)	0.0576** (2.147)
Constant	5.339*** (22.71)	5.194*** (19.82)	4.904*** (21.70)	5.702*** (21.83)
Observations	544	525	544	510
R-squared	0.728	0.739	0.748	0.716
Countries	35	35	35	35

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1%, 5% and 10%, respectively. The study period is 2001–2015.

Moreover, renewable energy improves food security (food availability and malnutrition) in each subregion (Eastern Africa, Middle Africa, Southern Africa, and Western Africa). Finally, biofuel production has a negative effect on food security in each subregion (Eastern Africa, Middle Africa, Southern Africa, and Western Africa).

4.2. Discussion

The results show that green economy indicators have controversial effects on food security. We find that renewable energy has a positive effect on food security (food availability and malnutrition), whereas biofuel production has a negative effect on food security. Carbon dioxide emission reduction has no effect on food security.

Firstly, the results show that renewable energy improves food security by increasing food availability and reducing malnutrition. According to Sola et al. (2016), in SSA countries, more than three-quarters of households have no access to modern energy and rely on biomass fuels for cooking and heating. This poor access to energy leads to the reallocation of people's resources from food production to energy procurement. In other words, access to clean energy may allow households to spend more time engaged in productive and economic activities such as food and agricultural production.

Secondly, biofuel production has a negative effect on food security. This result echoes those of previous authors, such as Kgathi et al. (2012), Herrmann et al. (2018), and Subramaniam et al. (2019). According to these authors, biofuel production increases competition for production factor access (labour, water, and land) with a transition from food to biofuel production. In addition, food

Table 2. Effect of green economy on proportion of undernourished people (Fixed effects)

	proportion of undernourished people			
	(1)	(2)	(3)	(4)
Renewable energy (log)	-0.00689*** (-7.039)			-0.00778*** (-7.937)
CO2 per capita (log)		0.00195 (1.149)		-0.0199 (-1.336)
Biofuels (log)			0.0939*** (3.362)	0.130*** (2.955)
GDP per capita (log)	-0.354*** (-6.270)	-0.603*** (-12.35)	-0.574*** (-11.44)	-0.207*** (-3.160)
Population growth	0.0311 (1.541)	0.0180 (0.897)	0.0338 (1.583)	0.0238 (1.207)
Democratic Institutions	0.00313 (0.712)	-0.00357 (-0.832)	-0.00275 (-0.607)	-0.00328* (-1.667)
Precipitations (log)	-0.155** (-2.424)	-0.135** (-2.070)	-0.184*** (-2.741)	-0.104* (-1.901)
Constant	6.567*** (11.27)	8.352*** (15.56)	8.183*** (14.61)	4.736*** (9.828)
Observations	576	570	576	540
R-squared	0.605	0.665	0.730	0.737
Countries	35	35	35	35

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1%, 5% and 10%, respectively. The study period is 2001–2015.

availability for consumption can be reduced because in the production process, biofuels use agricultural products (cereals, sugar, grains, and oilseeds). In addition, by reducing food availability, biofuel production can reduce access to food. Several authors have shown that biofuel production contributes to increased food prices (FAO, 2008; Mitchell, 2008). Because the demand for food is highly price inelastic and food is a basic good, a reduction in food availability can increase food prices considerably, which can reduce food accessibility and increase malnutrition.

Finally, carbon dioxide emissions per capita have no effect on food availability or malnutrition. This result is counterintuitive because air pollution may have a negative effect on agricultural production. According to several studies (Nagajyoti et al., 2010; Sun et al., 2017), air pollutants (sulphates, nitrates, and heavy metals) can enter the food chain through diffusion and affect plants and food security. Moreover, in the long term, greenhouse gases, which cause climate change, can reduce agricultural productivity (Lobell & Gourdji, 2012). The observed noneffect on food availability may be partially explained by the fact that agriculture is extensive in several African countries.

Control variables have an effect on food security in SSA countries. Economic resources (gross domestic product (GDP) per capita), precipitation, and democracy increase food security, whereas population growth reduces it. Because they have more economic resources, rich countries can invest more in the agricultural sector. In addition, these countries can adopt agricultural crop varieties that increase food availability. Finally, such countries are able to import foods from international markets. The positive effect of precipitation (rainfall) can be explained by a predominance of rain-fed agriculture in several African countries, which is highly sensitive to

Table 3. Effect of green economy on food availability per capita (Fixed effects): More control variables

	Food availability per capita (log)				
	(1)	(2)	(3)	(4)	(5)
Renewable energy (log)	0.0377***	0.00261***	0.00278***	0.00256***	0.00282***
	(6.446)	(6.061)	(6.408)	(5.657)	(6.220)
CO2 per capita (log)	0.00765	-0.00357	-0.00299	-0.00309	-0.00551
	(0.437)	(-0.207)	(-0.198)	(-0.190)	(-0.344)
Biofuels (log)	-0.0171***	-0.0210**	-0.0270***	-0.0203**	-0.0221***
	(-2.759)	(-2.566)	(-3.463)	(-2.480)	(-2.850)
GDP per capita (log)	0.129***	0.179***	0.193***	0.217***	0.209***
	(4.986)	(6.508)	(7.142)	(7.130)	(6.826)
Population growth	-0.0188**	-0.0343***	-0.0350***	-0.0364***	-0.0320***
	(-2.437)	(-3.934)	(-3.961)	(-4.093)	(-3.515)
Democratic Institutions	0.00239	0.00305	0.00269	0.00215	0.00282
	(1.402)	(1.588)	(1.393)	(1.044)	(1.382)
Precipitations (log)	0.0576**	0.0676**	0.0505*	0.0662**	0.120***
	(2.147)	(2.378)	(1.793)	(2.333)	(8.093)
Arable lands		1.60e-08***			
		(2.592)			
fertilisers			0.00269**		
			(2.209)		
Temperature				-0.000638**	
				(-2.347)	
Trade openness					0.0347**
					(2.264)
Constant	5.702***	3.439***	4.491***	3.200***	3.225***
	(21.83)	(12.91)	(4.171)	(11.14)	(11.07)
Observations	510	510	510	495	492
R-squared	0.716	0.739	0.731	0.738	0.742
Countries	35	35	35	34	34

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1%, 5% and 10%, respectively. The study period is 2001–2015.

precipitation (Mitra et al., 2008). The negative effect of population growth on food availability can be validated by Malthus (1992) logic. According to Malthus, population growth can reduce food availability through high pressure on agricultural resources and a negative effect on agricultural productivity. Finally, by increasing food availability and reducing the number of undernourished people, democracy improves food security in SSA countries. This result is echoes those of other authors, such as Sen (2000) and Rossignoli and Balestri (2018). According to these authors, by promoting electoral competition, democracy can increase accountability and encourage public action to fight hunger.

Table 4. Effect of green economy on proportion of undernourished people (Fixed effects): More control variables

	proportion of undernourished people				
	(1)	(2)	(3)	(4)	(5)
Renewable energy (log)	-0.00778***	-0.00712***	-0.00776***	-0.00844***	-0.00853***
	(-7.937)	(-7.606)	(-7.860)	(-8.218)	(-8.354)
CO2 per capita (log)	-0.0199	-0.0282	0.00461	0.00370	-0.0134
	(-1.336)	(-0.664)	(0.103)	(0.0819)	(-0.298)
Biofuels (log)	0.130***	0.0689**	0.0760***	0.0699***	0.0709***
	(2.955)	(2.494)	(4.564)	(3.973)	(2.680)
GDP per capita (log)	-0.207***	-0.213***	-0.305***	-0.205***	-0.244***
	(-3.160)	(-3.594)	(-4.982)	(-2.998)	(-3.556)
Population growth	0.0238	0.0359*	0.0329	0.0293	0.0233
	(1.207)	(1.884)	(1.630)	(1.452)	(1.130)
Democratic Institutions	-0.00328*	0.000283	0.00212	-0.00188	0.00105
	(-1.667)	(0.0672)	(0.479)	(-0.401)	(0.226)
Precipitations (log)	-0.104*	-0.115*	-0.148**	-0.147**	-0.142**
	(-1.901)	(-1.852)	(-2.230)	(-2.230)	(-2.136)
Arable lands		-9.93e-08***			
		(-7.361)			
fertilisers			-0.0677***		
			(2.781)		
Temperature				0.00153**	
				(2.474)	
Trade Openness					-0.000524
					(-1.374)
Constant	6.240***	5.597***	6.637***	5.618***	5.874***
	(10.55)	(9.839)	(2.769)	(8.807)	(9.090)
Observations	540	540	540	525	522
R-squared	0.737	0.785	0.718	0.711	0.720
Countries	35	35	35	34	34

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1%, 5% and 10%, respectively. The study period is 2001–2015.

Additional control variables, including agricultural inputs such as arable land, fertilizer use, temperature, and trade openness, have an effect on food security. Arable land helps increase food security in various countries (Wirsenius et al., 2010). Moreover, fertilizers play a vital role in explaining food security by improving agricultural productivity (Larson & Frisvold, 1996). In addition, temperature has a negative effect on food security. Trade openness helps improve food availability (Dithmer & Abdulai, 2017). According to these authors, by providing access to the global food market, trade openness allows developing countries (including SSA countries) to increase national food availability.

Table 5. Effect of green economy on food security (the two-step GMM system estimator): The inertia phenomenon

	Food availability per capita (log)		proportion of undernourished people	
	(1)	(2)	(3)	(4)
Lag of food availability per capita		0.0251 (1.246)		
Lag of proportion of undernourished people				0.00876 (0.510)
Renewable energy (log)	0.0377*** (6.446)	0.0362** (2.195)	-0.00778*** (-7.937)	-0.0166*** (-2.693)
CO2 per capita (log)	0.00765 (0.437)	0.00103 (0.0647)	-0.0199 (-1.336)	-0.130*** (-2.955)
Biofuels (log)	-0.0171*** (-2.759)	-0.0390** (-2.339)	0.130*** (2.955)	0.0721*** (2.726)
GDP per capita (log)	0.129*** (4.986)	0.204*** (3.130)	-0.207*** (-3.160)	-0.207*** (-3.160)
Population growth	-0.0188** (-2.437)	-0.104* (-1.901)	0.0238 (1.207)	0.0144** (2.439)
Democratic Institutions	0.00239 (1.402)	0.0135 (1.008)	-0.00328* (-1.667)	-0.00269** (-2.209)
Precipitations (log)	0.0576** (2.147)	0.0576** (2.147)	-0.104* (-1.901)	-0.122* (-1.887)
Constant	5.702*** (21.83)	0.280 (0.554)	5.436*** (8.382)	-0.0714 (-0.506)
Observations	510	510	540	540
R-squared	0.716		0.737	
Countries	35	35	35	35
AR(1)		0.009		0.002
AR(2)		0.562		0.512
Hansen Test		0.303		0.26
Instruments		17		17

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1%, 5% and 10%, respectively. The study period is 2001–2015.

5. Conclusion

Over the last decade, the green economy concept has emerged as a fundamental policy framework for sustainable development in developing countries. This paper contributes to the current debate on the effect of the green economy on development through an empirical investigation of the effect of the green economy on food security in 35 SSA countries for 2001–2015. The results show controversial effects of green economy indicators on food security (food availability and the proportion of undernourished people). The results provide evidence that biofuels contribute to increased food insecurity in SSA countries, whereas renewable energy reduces food security. Finally, carbon dioxide emission reduction has no effect. These results are robust to alternative robustness checks.

Our results are important in terms of policy recommendations, as they show that the green economy transition is not the panacea for development, especially food security. African countries

Table 6. Effect of green economy on food security (Fixed effects): Taking into account the subregion

	Food availability per capita (log)			
	(1)	(2)	(3)	(4)
Renewable energy (log)	0.0381***	0.0365***	0.0517***	0.0255***
	(5.636)	(5.745)	(8.953)	(3.824)
CO2 per capita (log)	0.0132	0.0136	-0.00141	-0.0309
	(0.754)	(0.766)	(-0.0846)	(-1.499)
Biofuels (log)	-0.0198***	-0.0156**	-0.0234***	-0.0295***
	(-3.200)	(-2.150)	(-3.528)	(-2.617)
Biofuels (log) *Eastern Africa	-0.00394***			
	(-4.771)			
CO2 per capita (log) *Eastern Africa	-0.000528			
	(-0.611)			
Renewable energy (log)*Eastern Africa	0.0183** (2.483)			
Biofuels (log)*Middle Africa		-0.00386***		
		(-5.815)		
CO2 per capita (log) *Middle Africa		0.000342		
		(0.557)		
Renewable energy (log)*Middle Africa		0.0141*		
		(1.955)		
Biofuels (log)*Southern Africa			-0.00396***	
			(-6.019)	
CO2 per capita (log)*Southern Africa			-0.00595	
			(-0.419)	
Renewable energy (log)*Southern Africa			0.0189***	
			(3.061)	
Biofuels (log)*Western Africa				-0.00170**
				(-2.484)
CO2 per capita (log)*Western Africa				0.00893
				(0.639)
Renewable energy (log)*Western Africa				0.0221*
				(1.820)
GDP per capita (log)	0.112***	0.132***	0.150***	0.164***
	(3.995)	(5.065)	(6.128)	(6.033)
Population growth	-0.0207***	-0.0198**	-0.0146**	-0.0182**
	(-2.683)	(-2.569)	(-1.996)	(-2.385)
Democratic Institutions	0.00257	0.00202	0.00113	0.00140
	(1.524)	(1.177)	(0.703)	(0.832)
Precipitations (log)	0.0570**	0.0545**	0.0463*	0.0525**
	(2.155)	(2.038)	(1.843)	(1.996)
Constant	5.674***	5.736***	5.634***	5.440***
	(21.84)	(22.00)	(22.93)	(20.25)

(Continued)

	Food availability per capita (log)			
	(1)	(2)	(3)	(4)
Observations	510	510	510	510
R-squared	0.734	0.732	0.740	0.737
Countries	34	34	34	34

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1%, 5% and 10%, respectively. The study period is 2001–2015.

Table 7. Effect of green economy on food security (Fixed effects): Taking into account the subregion

	proportion of undernourished people			
	(1)	(2)	(3)	(4)
Renewable energy (log)	-0.00554*** (-7.026)	-0.00948*** (-4.155)	-0.00872** (-2.158)	-0.00893** (-2.229)
CO2 per capita (log)	-0.0226 (-1.556)	-0.0147 (-0.858)	0.00913 (0.452)	-0.0449 (-0.968)
Biofuels (log)	0.119*** (7.383)	0.0830*** (3.291)	0.0839*** (3.244)	0.0799*** (3.061)
Biofuels (log) *Eastern Africa	0.0399** (2.536)			
CO2 per capita (log) *Eastern Africa	0.109 (1.006)			
Renewable energy (log) *Eastern Africa	-0.000549** (-2.455)			
Biofuels (log)*Middle Africa		0.0447*** (2.825)		
CO2 per capita (log) *Middle Africa		-0.00805 (-0.147)		
Renewable energy (log)*Middle Africa		-0.000674*** (-3.256)		
Biofuels (log)*Southern Africa			0.0576** (2.458)	
CO2 per capita (log)*Southern Africa			0.0661 (1.174)	
Renewable energy (log)*Southern Africa			-0.000506** (-2.285)	
Biofuels (log)*Western Africa				0.0655*** (2.667)
CO2 per capita (log)*Western Africa				-0.0432 (-0.280)

(Continued)

Table 7. (Continued)

	proportion of undernourished people			
	(1)	(2)	(3)	(4)
Renewable energy (log)*Western Africa				-0.000673*** (-3.193)
GDP per capita (log)	-0.180*** (-2.631)	-0.208*** (-3.164)	-0.238*** (-3.834)	-0.260*** (-4.223)
Population growth	0.0201 (1.053)	0.0247 (1.252)	0.00348 (0.186)	0.0121 (0.661)
Democratic Institutions	0.00341 (0.810)	0.00347 (0.787)	0.00669 (1.621)	-0.00712* (-1.761)
Precipitations (log)	-0.121* (-1.951)	-0.121* (-1.876)	-0.0952 (-1.569)	-0.117** (-1.974)
Constant	5.713*** (9.050)	5.458*** (8.382)	5.611*** (9.135)	5.777*** (9.339)
Observations	540	540	540	540
R-squared	0.790	0.740	0.718	0.742
Countries	36	36	36	36

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1%, 5% and 10%, respectively. The study period is 2001–2015.

should carefully identify green policies that favour food security. For instance, such countries can invest in the development of renewable energies (for instance, solar and wind power). Indeed, according to the International Energy Agency (2018), the demand for electricity in SSA increased by approximately 45% from 2000 to 2012. This demand is expected to grow at an average rate of 4% per year until 2040. To meet this demand, SSA countries should increase their electricity generation capacity. In 2017, renewable energies represented approximately 20% of the total installed electrical capacity. Unfortunately, at the current rate of electrification, more than 600 million people will not have access to electricity by 2040.

Countries with limited public funds should initiate green programmes and projects that target renewable energies. Indeed, there are growing opportunities to mobilize external resources for programmes and projects on renewable energies. In addition, governments should stimulate the participation of the private sector and development partners, as governments can play an active role in creating an enabling environment for private sector development.

To broaden the scope of our study, it would be interesting to take into consideration several green economy indicators. It would be interesting to obtain data on government expenditures on the environment (as a percentage of GDP), the share of green research and development (R&D) in government budgets, biodiversity and ecosystems. However, these data are not available for SSA countries.

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Notes

1. The indicators include greenhouse gas emissions, GDP (%) from services, energy use, the share of renewable energy, the withdrawal of ground and surface water of

- total available water, the inverse of DMC, the proportion of land area covered by forest, public transportation modal split, government expenditure on the environment as a percentage of GDP, patents in environment-related technology, the share of ODA in GNP, and the share of green research and development of the government budget).
- To check the correlations between green indicators, we calculate correlations between biofuel production, renewable energy and carbon dioxide per capita emissions. In Appendix 4, results show that the correlations between green economy indicators are weak and not significant at 1%, 5% or 10%.
 - Kcal per year

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Appendix 1. Hausman Test

	Coefficients		(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
	(b) eq1	(B).		
LRenewable~y	.037726	.0395869	-.0018609	.0008399
LCO2emissi~c	.0076534	.0091508	-.00838546	.0028305
LBiofuelPr~n	-.0170856	-.01722	.0541344	.
LGDPpercap~S	.1292295	.1154036	.0138259	.005022
Population~P	-.0188378	-.0188419	4.10e-06	.
polity2	.0023918	.0026415	-.0002497	.0000535
Lpre	.057554			

b = consistent under Ho and Ha; obtained from xtreg
 B = inconsistent under Ha, efficient under Ho; obtained from xtreg
 Test: Ho: difference in coefficients not systematic
 $\chi^2(7) = (b-B)'[(V_b-V_B)^{-1}](b-B)$
 = 24.85
 Prob>chi2 = 0.0008
 (V_b-V_B is not positive definite)

Appendix 2. Data sources and variables definition

Variables	Definition	Sources
Biofuel	Total biofuel production in thousand barrels per day	International Energy Statistics from the US EIA (EIA)
Renewable energy	Renewable energy is electricity production from renewable sources (i.e. wind, solar, hydropower, geothermal and biomass) in billion kilowatt-hour (kWh),	
Food availability per capita	Refers to the total amount of the commodity available as human food during the reference period. Food availability is the total of food production + food import- food exports+ variation in food stocks.	FAO
Income Per Capita	Gross Domestic Product per capita	WDI
CO2 emission Per Capita	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	
Population Growth	Annual population growth rate	
Percentage of total undernourished population	The percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously.	

(Continued)

(Continued)		
Variables	Definition	Sources
Arable land (% land area)	Arable area as percentage of total land area	
Precipitation	Total annual rainfall	Base de données Climat au niveau pays 1901–2016, mimeo, CERDI
Temperature	Average annual temperature	
Democratic institutions	The Polity Score captures the regime authority spectrum on a 21-point scale ranging from –10 (hereditary monarchy) to +10 (consolidated democracy).	Polity IV

Appendix 3. Descriptive statistics of variables

Variable	Mean	Std. Dev.	Min	Max
Biofuel	17.91707	9.027619	1	62
Reenergy	53.41587	34.10372	1	136
Food availability ³	1105.471	365.2708	285	2000
GDP Per capita	2219.592	3216.675	194.8731	20,512.94
CO2 Per Capita	.9298009	1.825792	.0172641	9.979458
Population growth	2.518992	.9840865	–2.628656	5.027804
Undernourished population	24.18306	13.01236	4.3	68.9
Arable land	14.17225	13.29078	.3043478	48.72219
precipitation	1088.124	618.869	79.95513	3127.172
temperature	24.80739	3.238356	12.2977	29.36678
Democratic Institutions	2.014286	5.225727	–9	10

Appendix 4. Countries

Eastern Africa	Middle Africa	Southern Africa	Western Africa		
Angola	Benin	Burkina Faso	Botswana	Central African Republic	Cameroon
Ethiopia	Gabon	Ghana	Guinea	The Gambia	Guinea-Buissau
Kenya	Liberia	Lesotho	Madagascar	Mali	Mozambique
Mauritania	Mauritius	Malawi	Namibia	Niger	Nigeria
Rwanda	Senegal	Sierra Leone	Sao Tome & Principe	Chad	Togo
Tanzania	Uganda	South Africa	Zambia	Zimbabwe	

Appendix 5. Correlation between green economy indicators

	Biofuel (log)	CO2 per capita (log)	Renewable energy (log)
Biofuel (log)	1.0000		
CO2 per capita (log)	0.1307	1.0000	
Renewable energy (log)	0.1730	0.0812	1.0000



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