**Assessment of Biofuel Production and Its Impact on Environmental Quality and Food Security in Africa**

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*Abstract*

In recent years global hunger has increased across the world. A closer look at the world hunger reveals that Africa is the main contributor to this increment where more people are affected by undernourishment. This issue is likely to be exacerbated by the rapid development of the biofuels industry across the globe. However, to conclude that biofuels production needs to be neglected could be a very weird conclusion given that biofuels is among agent to preserve environmental quality. Hence, this study investigates the investigate the effect of biofuel on food security, given the level of environmental quality in 13 African countries starting from year 2011-2016. This study finds that the presence of biofuel will increase food security by increasing environmental quality in African countries. As a result, it is important to promote sufficiently large scale of biofuel industry so that it can push towards better environment quality and greater production of foods.

*Keywords: Biofuels, Environment, Food Security, Africa*

1. **Introduction**

Globally, the dominant challenges that society faces today are dealing with sufficient, safe, and nutritious food to maintain an active and healthy life (FAO, 2018, 2019). It signals that the number of hungry people in the world is still more than 820 million people (FAO, 2019). Specifically, much of the increases in hunger can be traced in African regions, making African the region with the highest prevalence of undernourishment compare to Asia, western Asia, Latin America, and the Caribbean. This means that nearly 227 million of the world’s hungry people live in African regions and become a detrimental hurdle to effective growth in African countries. Hence, it reflecting widespread food insecurity, crop production deficits and calorie deficiency for the population.

 Figure 1: Total Crop and Food Production Indices Figure 2: Total Biofuel and Food Production of 13 African countries[[2]](#footnote-2) between 2011 and 2018 13 African countries [[3]](#footnote-3) between 2011 and 2018.

Source: World Bank (2021).

Drawing on the issue of food security, this study also shows the trend of the crop and food production in African countries (Figure 1). It indicates the total crops production in Africa has been growing between 2011 and 2016, while the total food production has declined for the same period, although expected to also increase. Hence, this brings up the question of why the total production of food in Africa decreases, despite an increase in total crop production. One of the main facts is that an accelerated increment in the production of biofuels is likely to threaten the level of food security of the countries, and may eventually trigger the level of hunger to be more serious[[4]](#footnote-4). This is because the main feedstock of biofuel comes from agricultural products which in turn limits the availability of nutrition and safe foods or disability to acquire acceptable foods for an active and healthy life and increased undernourishment. This could be linked with Figure 2, which shows the relationship between the production of biofuels and food production over the period 2011 and 2016. The morale of Figures 2 is that the production of biofuel may reduce food production in African countries, and may eventually trigger the level of food security of the countries.

When biofuel production is currently threatening the level of food security, should we propose that biofuel production be abandoned in African countries? Admittedly, it has been forgotten that biofuel production is not always at the expense of food production. Msangi 's (2016) recent statement counter argues that producing bioenergy does not have to conflict with food security. Msangi (2016) views bioenergy as a way to improve energy security and food productivity as well as to ensure household food supplies. Likewise, Naylor et al. (2007) also raise the question of whether the sustainable development goals of alleviating global hunger can be achieved with the expansion of biofuel production. In this case, it is suggested that reductions in GHG emissions during biofuel production have the potential to bring an increase in food production to populations. Meanwhile, there is no specific theory available that is capable of linking biofuel, environment and food security. Accordingly, Figure 3 predicts that the effect of biofuels production on food security is contingent on the level of environmental quality. Initially, the production of biofuels offers emissions reduction and enhances environmental quality in developing countries. biofuels development is an important development strategy in the foreseeable future as it promises to be carbon neutral (Zeman and Keith, 2008). Meeting the reduction in greenhouse gas emissions during biofuels production has the potential to bring move agricultural outputs (Fischer et al., 2005). This highlights that a rise in agricultural output may play a vital role in increasing four dimensions of food security, namely food availability (e.g. production), the stability of food supplies, access to food and food utilization[[5]](#footnote-5). Therefore, this study wants to examine the impact of biofuels production on food security, if biofuels sufficiently promote environmental quality levels.

The impact of biofuel on food security

Negative

Biofuel expansion

Improving environmental quality

Create competition for demand between food consumption and biofuel production

Increase crop yield

Adversely affect food security

Rise agricultural outputs

Positively affect food security

Figure 3: The biofuels-food-environmental relationship.

Source: Author’s own illustration.

In the light of the above discussion, there are several noticeable reasons for food shortages that have been identified by past studies such as rapid population growth (Brown, 1981; Hanjra and Qureshi, 2010), loss of arable land (Liu et al., 2009; Yang et al., 2009), environmental degradation (Faisal and Parveen, 2004; Rasul and Sharma, 2016). The Malthusian theory identifies that food shortages exist due to the presence of too many people compared to the amount of food supply and thus exacerbated long-run food insecurity (Malthus, 1798). Population tends to grow at a much faster rate than human substances, such as foods and products based on agriculture. Accordingly, empirical studies of Godfray et al. (2010), Schneider et al. (2011), Masters et al. (2013), Mahmood et al. (2016), Tian et al. (2016), Hall et al. (2017) and others reveal that population growth has a negative impact on food security. The empirical analysis of population growth and food security relationships has two strands of argument in principle. The first strands of research explain that a substantial increase in populations leads to increased use of resources, which in turn affects the capacity of agricultural productivity (Schneider et al., 2011; Tian et al., 2016; Hall et al., 2017). The second set is related to Masters et al. (2013), Szabo (2016), Mahmood et al. (2016) and Hall et al. (2017) show that a growing number of populations, accompanied by growing demand for more food, contribute to insufficient food to feed the entire population. It discovers that the rapidly increasing demand for food with the lowest levels of food production implies that less food is available to people, thereby exacerbating the problem of food security in developing countries. Hence, this study can synthesize from past studies that population growth negatively affects food security.

In line with Malthus, neo-Malthusians add only to Malthus' classical theory that land is an important basis for food security, apart from the size of the population. This assumption has been empirically examined by Liu et al. (2009), Spiertz and Ewert (2009), Schneider et al. (2011), Negash and Swinnen (2013), Mahmood et al. (2016), Meyfroidt (2018), Tan et al. (2018), Zhang et al. (2018) and Delvaux and Paloma (2018). Liu et al. (2009), Spiertz and Ewert (2009), Schneider et al. (2011), Negash and Swinnen (2013), Meyfroidt (2018), Tan et al. (2018), Zhang et al. (2018) and Delvaux and Paloma (2018) explains that land will have an impact on the supply capability of crops and food production. This then leads to the production of more food thus, resulting in an improved level of food security. In sum, this study discovers that arable lands are the key to maintaining and achieving food security.

Moreover, Food Availability Decline (FAD) approach indicates that food production is vulnerable to environmental degradation. Empirically, a number of studies investigate the relationship between environmental quality and food production in a developed and developing countries, namely Appendini and Liverman (1994) for Mexico, Hanjra and Qureshi (2010) and Dawson et al. (2016) for global, Sarr (2012) for West Africa, Rasul and Sharma (2016) for North Africa and southern Africa, Connolly-Boutin and Smit (2016) for sub-Saharan Africa, Hall et al. (2017) for Africa others and Kurashima et al.(2019)for Hawaii. These studies have found that degradation of the environment has a significant negative impact on food production. Climate change is expected to cause increased temperature, thereby it reduces crop yield and production in the short- and long-term (Thomas et al., 2007). For instance, higher carbon emission (CO2), combined with an increment in temperature can lengthen the growing season for cereal crops in the tropics and subtropics as water needed is not supplied adequately (Connolly-Boutin and Smit, 2016). This will reduce crop yield, together with its quality and quantity. Overall, it suggests that environmental degradation poses significant threats to food security due to changes in crop productivity and food supply.

At present, biofuel have been reinforced and captured much attention, in particular to reduce greenhouse gas emission, to strengthen rural development and to deal with energy security. Increased biofuel production can undermine food supplies, while welcoming in environmental concepts. In this case, Elobeid and Hart (2007), Tilman et al. (2009), To and Grafton (2015), and Renzaho et al. (2017) for the United States, Negash and Swinnen (2013) for Ethiopia, (Kgathi et al. (2012) for Botswana, Herrmann et al. (2018) for Malawi, Renzaho et al. (2017) for Japan and Brazil, and Qui et al. (2011) for China indicate that biofuel production can adversely affect food security. Biofuels may have detrimental effects on food availability, as more crops are switched from food production to biofuels. While increased biofuel is likely to result in food deficits and, more importantly, it can cause health problems as crops such as fruit, vegetables and animal products shift from food production to biofuel production.

Whilst past studies have accused biofuel of having a negative impact on food security, Naylor et al. (2007) and Mswangi (2016) suggested that biofuel production may not threaten the food supply. Biofuel, in this event, will not just provide an environmentally friendly solution, but can also lead to an increase in food production. it is suggested that reductions in GHG emissions during biofuel production have the potential to bring an increase in food production to populations. This study thus enables us to draw a clear distinction on the effect of biofuel production on food security in African countries that are not present in previous studies when the biofuel sufficiently promotes the level of environmental quality. This emphasizes that production of biofuels can play an essential role in reducing greenhouse emissions, thus promoting a significant increase in food production in the improved environmental quality. Focusing on the ability of biofuel to generate quality environment, which later on translated into good production of food, the interaction term between biofuel and environmental quality is meant to capture this possibility. To our minimum understanding, the result of this study might be useful in providing a framework not only for food production but also for biofuel development in African countries to deal with current emissions and food supply flows.

In light of the discussion above, the rest of the study is organized as follows. In section 2 we outline has a discussion of the panel data regression model. In section 3 the empirical results are presented and discussed. Finally, section 4 is our conclusion.

**2. Methodology**

Referring to literature review, food security model can be based on Malthusian and FAD theories mentioned in the literature review. In other words, food security *(FS)* can be formulated as a function of three theories as follows:

*(1)*

Based on the theory of Malthusian (MALTHUS), population growth can be the most basic determining factor of food security. The theory of population claims that food shortage as an important outcome of a growing population (Malthus, 1798). Additionally, the modern neo-Malthusian theory suggests insufficient food supply per person is also due to limited and finite land resources. Then, the Food Availability Decline (FAD) claims that food scarcities occur dues to a decline in the quality of environment. Thus, based on the theory, the level of food security is determined by environmental quality (Dawson et al., 2016; Hall et al., 2017) and biofuels production (Renzaho et al., 2017; Herrmann et al., 2018). Therefore, food security function can then be specified as follows:

 *(2)*

To examine the second objective of this study that environmental quality can be a potential determining factor of the difference in the biofuels-food supplies relation across countries, this paper extends equationsby incorporating a measure of environmental quality interactively with biofuels *(or BP\*EQ).* These emphasized that biofuel production can play an important role in reducing greenhouse emissions, which contributes to a substantial increase in food production by improving environmental quality. The augmented model becomes the following:

 *(3)*

*Eq.(3)* expresses the general economic model to be employed in this study, particularly to get the answer for the research objective of this paper. Econometrically, *Eq.* *(4)* in logarithmic form can be expressed as follows:

 *(4)*

***Data***

This study uses a panel sample of 13 African countries such as Angola, Côte d'Ivoire, Egypt, Ethiopia, Kenya, Malawi, Mauritius, Mozambique, Rwanda, South Sudan, South Africa, Swaziland, and Zimbabwe over the period 2011-2016, the end and started year is dictated by the availability of data on biofuels productions. Additionally, the present study used various data sources to obtain the datasets on dependent and independent variables to developing countries from 2011-2016. Table 1 provides a summary of each variable.

Table 1: List of Variables, Definition and Sources

|  |  |  |
| --- | --- | --- |
| Variables | Definition/ Measurement | Sources |
| *POP* | Annual population growth rates | World Bank (2020) |
| *EQ* | Carbon dioxide emissions in metric tons per capita | World Bank (2020)  |
| *AL* | Land area in percentage of total land | World Bank (2020) |
| *BP* | Total biofuels production in thousand barrels per day | UNDATA (2020) |

In this study, we construct a new food security measurement for African countries based on the method of computations recommended by Subramaniam et al.  (2019) and Subramaniam et al. (2020)[[6]](#footnote-7). The new FS consider four dimensions of food security, namely, food availability, access, utilization and stability.[[7]](#footnote-8)

On the measurement of environmental quality, instead of directly apply CO2 emission metric tons per capita, this study reverses the measurement so that it can truly reflect environmental quality, by which the higher *EQ* will imply better quality. In doing so, this study designs the following formula:

*(8)*

Where World Worst *CO2* is represented by the world’s highest emission level of 10,357 million metric tons in China in the year 2017. The main reason for this transformation is to ease the interpretation of the results.

***Estimation Method***

On the basis of a short period employed in this study, this study estimates *Eq. (4)* by using dynamic panel Generalized Methods of Moments (GMM) estimator. Hence, the modified dynamic panel data model under GMM can be simplified and shown as in *Eq. (9):*

*(9)*

Where subscripts i and *t* refers to time series and cross-section, respectively. is the dependent variable, is intercept, is a vector of explanatory variables described above, is a vector of parameters to be estimated and known as an error term. Following Arellano and bond (1991), first differences GMM are applied in order to wipe out the country-specific effect (Arellano and Bond, 1991). The lagged difference dependent variable is correlated with the disturbance term and thereby it produces an endogenity of the explanatory variables ( (Choong et al., 2010). To deal with this problem, the first difference estimator further combined with an estimator in levels to produce a system estimator (Choong et al., 2010). There are several steps to overcome the problem and later became the benchmark for estimating *Eq. (9)* (Arellano and Bond, 1991). The first step is to eliminate the individual’s effect by transforming the variables into first differences, as follows:

 *(10)*

Arellano and Bond (1991) estimating *Eq. (10*) under the conditions that the disturbance term is not serially correlated and the level of the explanatory variables is weakly exogenous (uncorrelated with future error terms). Unexpectedly, the first difference GMM estimator neglects the potential information in the level relationship and in the relations between the levels and the first differences. To overcome this condition, Arellano and Bover (1995) recommended the first difference GMM regression further combined with an estimator in levels to produce a system, which is known as a system-GMM estimator. In the estimation, this moment conditions are applied to calculate the difference estimator, as follows:

 *(11)*

This is necessary for the estimation as the equation in levels uses the lagged differences of the explanatory variables as instruments under two conditions. As pointed out by Arellano and Bover (1995), these two conditions are the error term is not serially correlated and there is no correlation between the difference in the explanatory variables and the error term. Moreover, Blundell and Bond (1998) indicate that there are two different statistics such as serial correlation and Hansen test are used in these regressions to examine the validity of the GMM estimator. The serial correlation test tests the null hypothesis of no first-order serial correlation and no second order serial correlation in the residuals of the first differenced equation. Rejection of the null of the absence of the first-order serial correlation *AR (1)* and failure to reject the absence of the second-order serial correlation *AR (2)* are valid and the models are correctly specified. The second is the Hansen Test of over-identifying restrictions which is used to examine the overall validity of the instruments by comparing the moment’s conditions with their sample analog.

**3. Result and Discussion**

According to the descriptive statistics indicated in Table 2, the largest food security index (*FS*) is 51.538 and could be represented by the case of Egypt in 2013, whereas the lowest food security is observed at 34.336 and potentially refers to Sudan in 2011. In addition, Swaziland is the largest producer of biofuels as described by the maximum score of biofuels (43.358) relative to the lowest size of biofuels production (0.010) in Ethiopia in 2011. For arable land, the maximum value of 107.484 percent and minimum value of 2.682 percent are recorded in 2016 (for Rwanda) and 2014 (refers to Egypt), respectively. The mean and maximum value of population is recorded as 2.356 percent and 3.721 percent. Moreover, it is also reported that the mean value of the environmental quality for the countries is only at 94.186 percent while the maximum *EQ* is 99.856 percent in the year 2012 (for Côte d'Ivoire). Looking at the standard deviation, the statistics state that income has the greatest variation and is followed by price and biofuels production.

 Table 2: Descriptive statistics

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Mean | Std. Dev. | Min | Max |
| *FS* | 42.818 | 4.693 | 34.336 | 51.538 |
| *AVA* | 46.770 | 6.294 | 35.272 | 58.288 |
| *ACC* | 47.097 | 25.919 | 11.256 | 99.259 |
| *UTI* | 57.506 | 13.358 | 34.919 | 85.830 |
| *STA* | 19.898 | 11.858 | 3.409 | 50.926 |
| *POP* | 2.356 | 0.840 | 0.069 | 3.721 |
| *AL* | 17.856 | 17.083 | 2.682 | 107.484 |
| *EQ* | 94.186 | 15.912 | 2.277 | 99.856 |
| *BP* | 5.611 | 11.295 | 0.010 | 43.358 |

Table 3 reports the result of GMM estimation for *Eq. (4)*. As mentioned in the estimation method, the validity of GMM estimator is supported by the test of serial correlation and Sargan tests. Accordingly, the Sargan test does not reject the null hypothesis of over-identification restriction and suggests that we have a valid instrument. Secondly, the serial correlation test of *AR (1)* rejects the null hypothesis of no first-order autocorrelation while it fails to reject the null hypothesis of no second-order autocorrelation. Lastly, the p-value of the Scalar static in GMM approach is greater than the significance level and can be confident that system GMM achieves greater efficiency than difference GMM for the model. Due to that, this study focuses on SYS-GMM two-step.

As shown in Table 3, the explanatory variables such as arable land, population growth, biofuels production, and environmental quality carry the expected signs. Arable land is positively related to food security (Arnell et al., 2004; Negash and Swinnen, 2013; Mahmood et al., 2016; Tan et al., 2018). Increased arable lands increase agricultural productivity and therefore ensure an increased level of the food supply. As mentioned earlier, arable land expansion is essential for the production of food in countries of Africa, especially sub-Saharan Africa (Sasson, 2012). These countries suffer from food insecurity due to the lack of farmland and the subsequent deficiency in agricultural productivity, which led peoples in sub-Saharan Africa to struggle for access to adequate and healthy food. Beyond meeting agricultural production, arable land also plays an essential role in generating the income of farmers. A rise in farmers’ income is likely to have a positive effect on food security with better consumption of food (Mahmood et al., 2016).

Table 3: Regression Analysis [DV = *LFS*]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | *FS* | *FSAVA* | *FSACC* | *FSUTI* | *FSSTA* |
|  | DIFF-GMM | SYS-GMM | DIFF-GMM | SYS-GMM | DIFF-GMM | SYS-GMM | DIFF-GMM | SYS-GMM | DIFF-GMM | SYS-GMM |
| *L* | 0.584\*\*\*[2.74] | 0.045\*\*[2.11] | 0.328\*\*\*[3.45] | 0.080\*\*[2.13] | 0.527\*\*\*[11.54] | 1.233\*\*\*[3.94] | 0.954\*\*\*[3.08] | 1.018\*\*\*[5.24] | 0.460\*\*\* [2.46] | 0.334\*\*\*[2.81] |
| *LAL* | 0.012 \*[1.83] | 0.018\*[1.94] | 0.715\*\*\*[2.53] | 0.079\*[1.75] | 0.185\*[1.94] | 0.040\*\*[2.15] | - | - | 0.469\*\* [2.17] | 0.013\*\*[2.16] |
| *LEQ* | 0.101\*\*\*[5.57] | 0.047\*\*[2.12] | 0.015\*[1.81] | 0.088\*[1.89] | 0.285\*\*[2.23] | 0.018\*[1.93] | 0.190\*\*[2.20] | 0.454\*[2.16] | 0.067\*\*[2.11] | 0.023\*\*[2.19] |
| *LPOP* | -3.479\*\*\*[-13.47] | -4.057\*\*\* [-2.87] | -1.610\*\*\*[-6.43] | -6.337\*\*\*[-2.54] | -9.256\*\*\*[-2.99] | -3.040\*\*\*[-5.75] | -0.011\*[-2.05] | -0.386\*\*[-2.39] | -1.469\*\*\*[-3.17] | -2.875\*\*\*[-3.59] |
| *LBP* | -0.305\*\*\*[-6.68] | -0.492\*\*[-2.13] | -0.778\*\*[-2.26] | -1.292\*\*\*[-3.38] |  -0.582\*\*\* [-2.77] | -0.586\*\*[-2.28] | -0.144\*\*\* [-3.19] | -0.484\*\*\*[-2.55] | -0.511\*\*\*[-2.61] | -0.375\*[-2.08] |
| *LBP\*LEQ* | 0.149\*\*\*[2.71] | 0.160\*\*[2.18] | 0.067\*\*[2.12] | 0.163\*\*[2.14] | 0.785\*\*[2.37] | 0.058\*\*[2.28] | 0.020\*[2.07] | 0.115\*\*[2.29] | 0.587\*\*\*[2.48] | 0.359\*\*\*[2.91] |
|  | Model Criteria |
| *Sargan* | 0.700 | 0.182 | 0.541 | 0.133 | 0.195 | 0.311 | 0.846 | 0.890 | 0.604 | 0.187 |
| *AR(1)*  | 0.025\*\* | 0.019\*\* | 0.076\* | 0.022\*\* | 0.034\*\* | 0.066\* | 0.046\*\* | 0.049\*\* | 0.079\* | 0.031\*\* |
| *AR(2)*  | 0.862 | 0.624 | 0.897 | 0.645 | 0.860 | 0.917 | 0.372 | 0.923 | 0.467 | 0.280 |
| *Dif-Sar* | - | 0.981 | - | 0.994 | - | 0.799 | - | 0.999 | - | 0.999 |

**Note**: Asterisks \*, \*\*, and\*\*\* denote the 10%, 5%, and 1% levels of significance, respectively. Figures in [ ] stand for t- statistics. The values of the Hansen and AR tests stand for the p-value. The model is estimated using the two-step model with robust estimation.

From Table 3, population growth will decrease the amount of food needed to feed developing countries’ people. This finding is consistent with Brown (1981), Godber and Wall (2014), Szabo (2016) and Tian et al. (2016). The increase in population will increase the demand for natural resources such as land and water and thus affect food production capacity (Tian et al., 2016). This implies that an increase in the number of people impose a serious threat to food security as food supply becomes increasingly limited. Director of global migration and demography research at Pew Research Center, for example, projected population growth in African countries will grow from 1.3 to 4.3billion in the next 80 years increases the challenge of adequately meeting nutritional needs (Wilson Chapman, 2019).

Moreover, the results in Table 3 reveal that an increase in biofuels production decreases food production in developing countries. A rise in the production of biofuels can reduce the level of food production if the crops are switched from the production of food to biofuels (Nonhebel, 2012; Negash and Swinnen, 2013). This contributes to the increase in the price of food, resulting in a greater reduction in food consumption of the households. Consequently, it may pose a severe threat to human health due to inadequate and unbalanced consumption of nutritious food. In particular, African countries such as Malawi, Mauritius, Zimbabwe and Kenya that have undertaken biofuel development have continued to be a critical food security development strategy and caused the countries to be vulnerable to food insecurity. Hence, the production of biofuels substantially reduced food production and aggravated the problem of food insecurity.

Environmental quality also affects food security in a positive way. Sarr (2012), Rasul and Sharma (2016), Dawson et al. (2016) and Hall et al. (2017) are of the view that better environmental quality affects the food security through its effect on food production. For example, reduction in pollution, climate change and increase in rainfall can increase crop yields and its quantity. Specifically, North Africa and Southern Africa regions are affected by pollution that is likely to reduce agricultural production to meet their food consumption (Rasul and Sharma, 2016). In this case, the improvement in environmental quality may lead to an increase in food supply for people in developing countries. Hence, the findings show that the problem of food security could be small should there be an improvement in environmental quality.

Continue to the interaction term (*BP\*EQCO2*) employed in the analysis, the study highlights that the coefficient of *BP\*EQCO2* has a positive and significant impact on food security in developing countries. The positive impacts of the interaction terms in Table 3 bring huge relieve and hope about the relationship between biofuels and food security. The results show that environmental quality is able to be transformed, particularly via the enlargement of the size of biofuels production; the negative impact of biofuels can be turned into a positive impact for improving the food supply. In a simple way, biofuels are beneficial for food security improvement in developing countries if the production of biofuels is accompanied by better environmental quality. This is an interesting result as it provides evidence that biofuels are not necessarily aggravating the problem of food insecurity at all times, as the empirical result indicates that, biofuels production can also offer advantages in the forms of increasing food supply in developing countries.

One of the main assumptions of the study is that the accelerated growth of biofuels production is improving the quality of the environment by reducing greenhouse gas emission. This is because biofuels is deemed carbon neutral or carbon offsetting where the amount of carbon emitted when the fuel is burned is believed to be the same as the amount of carbon that the plant absorbed. DeCicco et al. (2016) and Lazarevic and Martin (2016) have found that the production of biofuels has the potential to reduce emission in the range of 20-90 percent relative to fossil fuels. For instance, the production of ethanol from sugarcane and sugar beet cuts emissions by 90 and 60 percent, respectively. Meanwhile, in the production of biodiesel, maize, palm oil, and rapeseed turn out to reduce emissions by 35, 80 and 60 percent, respectively. With this assumption in hand, the more production of biofuels can contribute to better environmental quality in developing countries. This, in turn, may cause the level of agriculture productivity of developing countries better off and thus meet the demand for food. As a result, the intensive development of biofuels should be the primary target of governments of developing countries as it is proven to be capable to preserve environmental quality, which in turn supports agriculture production.

Additionally, a robustness check is carried out to examine the sensitivity of the findings to alternative proxy for food security by using Global Food Security Index. The results are given in Table 4. Using the alternative measure of food security, the results soundly support the earlier conclusion that the relationship between biofuel and food security is conditional upon the level of environmental quality. This result suggests that the negative effect of biofuel production on food security declines as a country’s environmental quality improves. As a result, it is important to promote biofuel development that will lead to better environment quality and greater production of foods.

Table 4: Regression Analysis of Model 1 [DV: *LFS =* *LGFSI]*

|  |  |  |
| --- | --- | --- |
|  | DIF-GMM | SYS-GMM |
| *L* | 26.943 \*\*\* [11.46] | 1.784 \*\*\* [2.48] |
| *LAL* | 0.388 \*\*\* [2.35] | 0.289 \*\* [2.12] |
| *LEQ* | 0.062 \*\*\* [2.48] | 0.317 \*\* [2.22] |
| *LPOP* | -0.748 \*\*\* [-3.03] | -0.661 \*\*\* [-3.19] |
| *LBP* | -0.388 \*\* [-2.35] | -0.797 \*\*\* [-3.29] |
| *LBP\*LEQ* | 0.095\*\* [2.14] | 0.438\*\*\* [2.78] |
| **Model Criteria** |
| *Sargan* | 0.351 | 0.146 |
| *AR(1)* | 0.040 \*\* | 0.028 \*\* |
| *AR(2)* | 0.610 | 0.285 |
| *Dif-Sar* | - | 0.929 |

 **Note**: Asterisks \*, \*\*, and\*\*\* denote the 10 percent, 5 percent, and 1 percent levels of significance, respectively.

 Figures in [ ] stand for t- statistics. The values of the Hansen and AR tests stand for the p-value. The model is

 estimated using the two-step model with robust estimation.

**5. Conclusion**

This study is basically about finding the solution to the undesirable negative effect of biofuels on food security as this study believes there is a win-win situation about biofuels-food security nexus. The result of the model proves that biofuels production is capable of positively affect food security if biofuels can promote environmental quality suitable for agriculture. In this context, this study provides positive insight into the positive role of biofuels on food security which generally described as negative. As a result, it is important to promote biofuels development that will lead to better environmental quality and greater production of foods. In accordance with the objectives of this study, it is important to promote the sufficiently large scale of biofuels industry so that it can push towards better environmental quality and greater production of foods. Therefore, instead of designing a single policy for certain goals while expecting other goals will follow, this study suggests the government to have, a part form policy for each goal but also a complementary policy to ensure that no goal (environment) will vanish due to improvement in another goal (food security). More specifically, it will provide useful insights into analyzing the context of the allocation of resources between the production of biofuel and food. Hence, policymakers can be effective in redesigning national policies and guidelines on biofuel and the agriculture sector so that a win-win situation can be for the development of both sectors.

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2. 13 African countries such as Angola, Côte d'Ivoire, Egypt, Ethiopia, Kenya, Malawi, Mauritius, Mozambique, Rwanda, South Sudan, South Africa, Swaziland, and Zimbabwe [↑](#footnote-ref-2)
3. 13 African countries such as Angola, Côte d'Ivoire, Egypt, Ethiopia, Kenya, Malawi, Mauritius, Mozambique, Rwanda, South Sudan, South Africa, Swaziland, and Zimbabwe [↑](#footnote-ref-3)
4. Depending on the feedstock used in their production, biofuels may be segregated into the first, second and third generation. First generation biofuel produced from food crops while second-generation biofuels are produced from non-food residues or lignocellulosic biomass and the third-generation biofuels are produced from algae, sewage sludge, and municipal solid wastes (Nanda et al., 2018). in developing countries, biofuel is mainly produced using conventional techniques, also known as the first generation of biofuel, which derived from food crops (Gómez et al., 2008). [↑](#footnote-ref-4)
5. The 1996 World Food Summit, Mercy Corps defines food security as a situation whereby "all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (UN Food and Agriculture Organization, Maxwell, 1996, p.p3). From this concept, the FAO introduces four dimensions of food security, i.e. food availability (sufficient, safe and nutritious food), access (physical and economic access), utilization (to meet their dietary needs and food preferences) and stability (for all people at all times) (Ghattas, 2014). [↑](#footnote-ref-5)
6. Mathematically, there are three steps to construct the food security index. Firstly, the world minimum and best values or goalposts are set in order to normalize the indicators score between 1 and 100. Secondly, we create four separate indices for each of the four dimensions, then these dimensions indices are used to calculate the global food security index. The last step to calculate the food security index is to aggregate all these four dimensions into a composite index using the arithmetic mean in order to create the global food security index. the food security index is expressed as a value between 1 and 100 where higher the value of food security, the better the level is. [↑](#footnote-ref-7)
7. food availability (sufficient, safe and nutritious food), access (physical and economic access), utilization (to meet their dietary needs and food preferences) and stability (for all people at all times) (Ghattas, 2014). [↑](#footnote-ref-8)