FUELING FOOD INSECURITY?

The Impact of Biofuel Production on Food Access and Food Availability in Sub-Saharan Africa

Bachelor Thesis within the Program of International Relations and Organizations at Leiden University, Den Haag

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Abstract

The complexities around global food security and biofuel production are at the intersection of some crucial global challenges: hunger, energy security, resource governance and development. Although biofuels have received attention as a means to sustainably solve international energy concerns and promote rural development, the impacts of biofuel expansion in developing countries have set in motion a considerable debate about their impact on food security. In response to a lack of integrated scientific analysis, this thesis applies the theory of economic externalities to biofuel production and explores whether there is a general, negative effect on food security in Sub-Saharan Africa. The results of a multiple linear regression analysis confirm a negative impact of biofuel production on food security, although the effect is small in comparison to other food security determinants. Interestingly, the study reveals an important moderating role of regime types in the biofuel-food security nexus, showing that the negative effect is particularly the case in non-democratic regimes. In view of rising demand for renewable energy sources and increasing food insecurity in Sub-Saharan Africa, this study calls for more in-depth analysis of the interactions between these dynamics.

Keywords:

Food security, biofuels, externalities, governance, rural development, Sub-Saharan Africa

Table of Contents

List of Figures and Tables

1. INTRODUCTION

Achieving global food security is arguably one of the most complex and difficult challenges faced by mankind. In 2015, all member states of the United Nations adopted 17 Sustainable Development Goals (SDGs), which can be seen as a universal appeal to global collective action (United Nations, 2020). *Zero hunger* as the second SDG aims to achieve worldwide food security until 2030. Nevertheless, improvements in food security indicators have varied significantly across global regions. Much current discussion on SDG 2 focuses on Sub-Saharan Africa, where prevalence of undernourishment rose from 17.6% to 19.1% of the population between 2014 and 2019 (FAO et al., 2020).

In recent years, the rapidly growing biofuel sector worldwide and the cultivation of eatable crops for energy purposes in developing countries has been highly contested, dividing the academic arena along two sides of the so-called *fuel versus food* debate. Especially, the increasing commercialization of the bioeconomy in Sub-Saharan Africa raise questions about a potentially conflicting nature between biofuels and food security for several reasons. First, the region was identified as the most food insecure region worldwide inhabiting almost one-third of the 821 million people experiencing chronic hunger globally (FAO, 2018). Second, 70% of the Sub-Saharan population are dependent on subsistence agriculture for their livelihoods and a change from food-related agriculture to biofuel production can be expected to adversely affect food security in the region (Chinweze, 2015, p. 137). Third, the last 10 years have witnessed instances of international land grabbing for the production of energy crops in Sub-Saharan Africa, whereby impacts of this development are not sufficiently assessed (Giovannetti & Ticci, 2016, p. 678; Kiggundu et al., 2017, p. 1264).

“Food *versus* fuel” delivers a morally compelling message that resonates with public imagination: food crops should not be diverted from people for fuel. However, scientific evidence supporting this argument remains scarce and conflicting. As an empirical contribution to the debate, this thesis zooms into the relationship of the rapidly growing biofuel sector and food security on the African continent. By applying the theory of negative externalities to agricultural production of biofuels, the study conducts a quantitive study on 23 Sub-Saharan countries between the years 2008 and 2019 in order to analyze the effect of biofuel production on two different dimensions of food security. The results confirm a slightly negative impact on food security, although the effect differs based on the food security dimension. Interestingly, the study reveals the crucial moderating role of regime types in the biofuel-food security nexus, showing that the negative effect is particularly the case in non-democratic regimes.

After a review of the literature on the subject, a theoretical framework is elaborated in order to deduce the main hypotheses for the quantitative analysis. The thesis proceeds with presenting and discussing key results and concludes with implications and recommendations for future research.

2. LITERATURE REVIEW

2.1 The Evolution of Research on Global Food Security

Issues around food provision and food security are complex and different challenges in the global food system constitute an ever-growing research field. Early beginnings of research on the determinants of food security can be traced back to Malthusian theory from the 18th century, which links food insecurity to over-proportional population growth compared to the amount of feasible food supply (Malthus, 1798, pp. 6-12).

However, food security as a distinct policy issue was first outlined in reports by the World Bank, that set the tone for a neoliberal, growth-driven rationale for global hunger alleviation (World Bank, 1986). The report underlines the importance of financial investments that directly raise incomes of the poor and indirectly enhance food security (World Bank, 1986,

p. 50). The single focus on economic growth and individual purchasing power implies that the struggle for food security was centered around economic rationalities only.

Still highlighting the importance of economic growth in the context of food security, a new body of literature evolved around the so-called *green revolution,* describing the welfare successes of booming agricultural growth and productivity in Asia and Latin America in the 1960s (Dawson et al., 2016). Many scholars shifted the focus to *agricultural* development as an "engine of growth" (World Bank, 2008, p. 26), arguing that large-scale farming and agricultural productivity has lifted millions of people out of poverty and food insecurity (Pingali et al., 2008, p. 507; Toenniessen et al., 2008). Therefore, many scholars regard a green revolution to be the right policy goal for the African continent, where undernourishment is high and agricultural productivity is low in global comparison (Breisinger et al., 2011; Hunt, 2011; Pingali, 2012).

As a reaction to this focus on productivism, discourses around the emerging concept of *sustainable development* criticized the sole focus on growth and productivity and argued that solutions to food insecurity are dependent on the integration of multiple policy fields. Representatively, Lang and Barling (2012) underline the importance of a sustainable "food *system* approach" (p. 313). According to these authors, food security as a governance domain is not separable from other policy fields like climate change and energy governance (p. 317).

2.2 Biofuel Potential for Developing Countries

A recent dynamic that combines the policy fields of sustainability, energy- and food security is the rapid expansion of global biofuel production, which attracted much scholarly attention (Brinkman et al., 2020; De Fraiture et al., 2008; Ewing & Msangi, 2009; Nsiah & Fayissa, 2019; Pingali et al., 2008). Biofuels are a renewable energy source gained from processing biomass, which is consistent of various plant materials like woods, corn and sugarcane as well as vegetable and animal fats (Koizumi, 2015, p. 830). Since 2000, total biofuel production worldwide has increased nearly tenfold, with North America, South America and Europe being the three largest producers (Enerdata, 2021).

Originally, interests in biofuels grew out of the effort to enhance the advancement of renewable energy instead of the use of unsustainable fossil fuels (Subramaniam et al., 2019, p. 520). However, today's discourse around SDG 7 – *Affordable and Clean Energy* – and biofuel expansion goes beyond the need for green energy and simultaneously addresses (1) the mitigation of climate change, (2) concerns for energy security and (3) the potential for rural development in the Global South (Maconachie & Fortin, 2013, p. 253; *SDG 7 Results: Access to renewable energy*, 2021). Proponents of this biofuel expansion frame it as a "win-win dynamic" (Kinda, 2021, p. 2) for developing countries because it can harmonize low-carbon and sustainable development with other desirable outcomes such as employment (Jacob et al., 2015) and poverty reduction (Adeleke et al., 2019) which in turn, enhances local food security (Kline et al., 2016). While this positive spill over was documented for the case of biofuel projects in Brazil (HLPE, 2013; Killeen et al., 2011, p. 4819), scientific contributions on the development in Sub-Saharan Africa show increasing scepticism of such positive effect.

2.3 The Fuel versus Food Debate in the Context of Sub-Saharan Africa

As growing literature on 'land grabbing' shows, the past decade has seen a spread of large-scale land deals by multinational and national companies in developing countries, whereby Sub-Saharan Africa has become a primary target (Aha & Ayitey, 2017, p. 48; Fairhead et al., 2012; Giovannetti & Ticci, 2016). Oftentimes, the driving force behind this proliferation of large-scale agricultural investments is the cultivation of biofuel feedstock (Bottazzi et al., 2018; GRAIN, 2013). Facing the high rates of hunger in Sub-Saharan Africa, many authors voiced the concern that the rapidly rising biofuel sector may jeopardize food security in the region (Gasparatos & Strömberg, 2012; Kinda, 2021; Subramaniam et al., 2019). In reaction, in 2012, NGOs started calling for an end to the use of food-based crops as fuel. For instance, campaigns were organized by ActionAid ('Food not Fuel') and Oxfam ('The Hunger Grains') (Tomei & Helliwell, 2016). Normatively loaded protest against European biofuel policies in 2013 with slogans like "*feed people, not cars*" underline the ethical claim that it is inacceptable to grow eatable feedstock for energy purposes in regions with high levels of chronic hunger (FoEE, 2013). The caricature below critically highlights these ethical concerns and pictures the production of biofuels as reprehensible moral act of the 'Global North' (Figure 1).

Consecutively, the desirability of biofuel expansion in developing countries became an increasingly contested, academic debate - the so-called "fuel versus food" debate (Rosegrant & Msangi, 2014, p. 271). In simple terms, one side in the debate argues for the *synergic* relationship between biofuel expansion, focusing on the potential food security gains through economic development, technical innovations and employment opportunities (Kline et al., 2016, p. 565; Negash & Swinnen, 2013; Pingali et al., 2008). The other side argues for the

Figure 1. Caricature on the Fuel versus Food Debate
Retrieved from Tomei and Helliwell (2016)

conflictous nature of the relationship between the growing bioeconomy and food security in developing countries (Kinda, 2021; Koizumi, 2015; Renzaho et al., 2017).

The food security concerns can be distinguished between direct and indirect effects of biofuel expansion (Koizumi, 2015; Popp et al., 2014). *Direct* effects are the impacts that can be directly and exclusively linked to the production the bioenergy product (Popp et al., 2014, p. 571). These include the use of agricultural food commodities (e.g. corn, grains, oilseed) for energy purposes as well as the danger of land -use change, meaning the use of arable land for energy crops that was previously used for food production (Popp et al., 2014, p. 562; Subramaniam et al., 2019, p. 75). *Indirect effects* are the effects that are caused by the cultivation of biofuels, but cannot be exclusively linked to the production chain (Popp et al., 2014, p. 571). These include negative environmental effects like water depletion as well as economic impacts on food commodity prices (Koizumi, 2015).

The interlinkages between biofuel production and food security are numerous, touching upon economic, environmental and societal aspects. Although some studies have highlighted negative consequences of biofuels expansion in single African countries (Brinkman et al., 2020; Negash & Swinnen, 2013), a general assessment of these negative impacts on food security in the region as a whole has not been conducted. Establishing such a link however, would be highly relevant on theoretical and practical level.

Theoretically, is crucial to evaluate the legitimateness of the moral claim that *food versus fuel* makes. Scientific proof for a general negative effect of biofuels on food security would pose a serious ethical dilemma: the solutions to one SDG, namely *Clean Energy*, would inhibit the achievement of another, namely *Zero Hunger*. In this case, scholars would be obliged to rethink the compatibility of these Sustainable Development Goals.

Practically, more empirical evidence for a competitive relationship between biofuels and food security in Africa would shift policy attention to *human* impacts of biofuel intensification. It would pressure policy makers to either ban biofuel production or improve ways to maximize gains from the bioeconomy for human welfare and food security.

Hence, this thesis builds on previous studies that highlight possible dangers of biofuel expansion for food security and critically examines whether a general, negative link can be established in the region. Therefore, the analysis aims to answer the following research question: **what is the effect of biofuel production on food security in Sub-Saharan Africa?**

3. THEORETICAL FRAMEWORK

The mechanisms connecting biofuels and food security are numerous and thus, require some theoretical and conceptual clarifications. In the following, the theoretical framework of this thesis is presented. First, two *theories of famine* will be explained in order to establish two dimensions of food security. Second, this research makes use of the *theory of economic externalities* and applies it to biofuel production in Africa. Third, a nuanced theoretical link between biofuels and food security will be established based on these theories in order to derive three hypotheses for the quantitive analysis.

3.1 Two Theoretical Perspectives on Food Security

The emergence of theories on food security oftentimes relates to the policy concerns towards combating famine at the global level. One of the first collective efforts to counteract global food insecurity was the World Food Conference in 1974, which adopted the Universal Declaration on the Eradication of Hunger and Malnutrition. In this declaration, the main emphasis was placed on how to make enough food available to eradicate hunger (Bezu, 2018, pp. 336-337). The result of these efforts was the emergence of the theory of Food Availability Decline (FAD) (Devereux, 1988).

The FAD theory explains food insecurity by a decline of food *availability*, induced by anything that disrupts food production (Devereux, 1988, p. 270). This mainly relates to demographic and climatic factors. For example rapid population growth, conflict, or the competition over water and arable land (Bezu, 2018, p. 338). From a macro-economic perspective, the FAD model conceptualizes food security based on the supply-side of the food system. It implies that food security is essentially a matter of ensuring food availability. As a solution, it argues to increase the supply and consequently the availability of food to meet population demands. However, this theory is criticized for implicitly assuming an equal division of the available food, which does not always reflect the reality of food insecure countries (Milà-Villarroel et al, 2016).

The main criticism was voiced by Amartya Sen (1981), who has empirically shown that famine can occur with no obvious fall in regional or national food availability (Devereux, 1988, p. 270). As an alternative model to the FAD theory, Sen (1981) developed the theory of Food Entitlement Decline (FED). The entitlement approach shifts the focus to other determinants of food security. Sen argues that food scarcities are vested in a decline in "entitlement", which refers to the inability of certain population groups *access* enough food (Devereux, 1988, p. 171). Thus, the FED theory puts emphasis on the demand-side of food security. This mostly relates to factors on the individual level like employment, income, and purchasing power (Subramaniam et al., 2019, p. 75).

Recently, attention has turned to an additional dimension of food security, namely the *utilization* of foods, referring to nutritional aspects of food security (Upton et al., 2016, p. 135). Food utilization is related to a nutritious diet, adequate food preparation, and a fair intra-household distribution of food (FAO, 2021). All of these factors have to be measured on the household level and are dependent on many regional and cultural factors. Since the following study adopts a national level of analysis, measuring food utilization is not the research goal of this thesis. Accounting for supply- and demand-side determinants of food security, this study aims to combine The FAD and the FED theory and conceptualize food security in relation to two dimensions: food access and food availability.

3.2 Theory of External Economies & Agricultural Production

A central concept in economic theory is the one of economic externalities. A considerable number of authors have devoted their research to this subject, that was first introduced by British economist Arthur Pigou (1920) in his book 'Welfare Economics'. An externality can be understood as an external effect of production or consumption of goods and services, imposing costs or benefits on other entities that that are "not captured in the market relationship between the producer and its customers" (OECD, 2002; Van Horen, 1996, p. 14).

An important distinction to be made is between private (excludable) and public (non-excludable) externalities (Baumol & Oates, 1988). In theory, private externalities are those in which only a small number of agents are involved, and the externalities are internally absorbed (Baumol & Oates, 1988, pp. 18-20). However, as Baumol and Oates (1988) argue, many externalities are public and take the character of a public good (p. 18). The non-excludable nature of public goods implies that an increase in the consumption of the good by one individual does not reduce its availability to others (Adams & McCormick, 1993, p. 10). While this is beneficial for society in the context of public *goods*, negative public externalities – or public *bads* - can have concerning impacts on a large number of individuals simultaneously.

The theory of externalities serves as a helpful theoretical framework in explaining positive and negative consequences of agricultural growth. Several authors have applied externality theory to the case of agricultural production (Baum & Kozera-Kowalska, 2018; Buks et al., 2016; Grzelak, 2013; Pajewski & Gołębiewska, 2018). A characteristic feature of agricultural production are externalities of large-scale farming, which may be either positive or negative and relate to environmental, social and economic aspects (Grzelak, 2013, p. 97).

These agricultural externalities can be exemplified by recent studies on the growing bioeconomy in Africa. However, an important conceptual distinction between first- and second-generation biofuels has to be made. First generation biofuels refer to the chemical conversion of biomass like vegetable oils and starch crops to fuel. In distinction to that, second-generation biofuels are made of by-products and waste, which are considered to be more environmentally and socially desirable (Renzaho et al, 2017, p. 505; Birner, 2017, p. 24). The following analysis focuses on *first-generation* biofuel production, meaning the production of agricultural feedstocks for energy purposes.

According to Renzaho et al. (2017, p. 504), the commercialization of the biofuel sector in developing countries raises cause for concern on different levels. Renzaho et al (2017) outlines different negative impacts of large-scale biofuel plantations and distinguishes between *(1) environmental*, *(2) social* and *(3) economic* externalities in low-income countries, with a specialization on Africa. So far, the argument therefore is, that growing agricultural production for biofuel cultivation in Sub-Saharan Africa will lead to different negative externalities. In order to make the theoretical connection to food security, the following section categorizes findings on negative externalities of biofuel production according to Renzaho's (2017) distinction and links these to the two dimensions of food security.

3.3 Impact of Biofuel Production on Food Security

The *environmental* externalities Renzaho et al. (2017) name, are twofold. First, he claims that large-scale biofuel crops need extensive amounts of water resources. Several authors have highlighted water resources as important driver of large-scale land investments in developing countries, also related to biofuel production (De Fraiture et al., 2008, p. 67; Franco & Borras, 2019). Facing that Africa is considered to be particularly vulnerable to both quantitative and qualitative water risk (Freitas, 2013, p. 1), increased biofuels production is expected to reduce water availability for food production (Popp et al., 2014, pp. 562-563). Second, Renzaho et al (2017) highlight local environmental consequences resulting from the use of fertilizers and pesticides on large-scale plantations, favourable to the commercial production of biofuels. These adversely affect soil fertility, biodiversity and thus, the availability of arable land (Maconachie, 2019, p. 873). In sum, the consequence of these negative environmental externalities is potential crop competition for water resources and land, which is expected to cause food availability decline. Bottazzi et al. (2018) present statistical results from a study on Sierra Leone that show how farmers in biofuel investment areas have reduced their agricultural land area for food production (p. 128). In sum, the environmental conditions in Sub-Saharan Africa and the negative externalities of increased biofuel production threaten the availability dimension of food security.

The *social* externalities Renzaho et al. (2017) outline, are mostly related to tensions between large-scale biofuel projects and African smallholders. Representing up to 80% of the population in Sub-Saharan Africa (Cordaid, 2021), smallholders own small farms (<1- 10 hectares) and grow crops for the purposes of self-sufficiency and income (Gollin, 2014). There are increasing empirical records of smallholder displacements by the corporate agricultural sector (GRAIN, 2013; Maconachie, 2019, p. 872; Renzaho et al., 2017, p. 872). These instances cause land access losses of smallholders which simultaneously imply income and employment losses (Oberlack et al., 2021, p. 3). This has indirect, negative effects on food security. Thus, negative social impacts of the growing biofuel sector may lead to food entitlement decline of the smallholder population in Africa, thereby affecting the access dimension of food security.

The *economic* externalities Renzaho et al. (2017) underline, are mainly related to the contribution of the biofuel expansion to price changes of feedstock, which can have harmful impacts on the purchasing power of the rural population. Koizumi (2015) focuses his empirical research on the indirect, economic impact of biofuel production on higher food prices (p. 837). Additionally, Renzaho et al. (2017) address the possibility that large biofuel plantations drive the concentration of income, which may increase poverty in general. These negative externalities result in a loss of purchasing power of people in poor regions, which translates into a decline in food entitlement. Thus, the economic impacts of large-scale biofuel production are also expected to negatively affect the access dimension of food security.

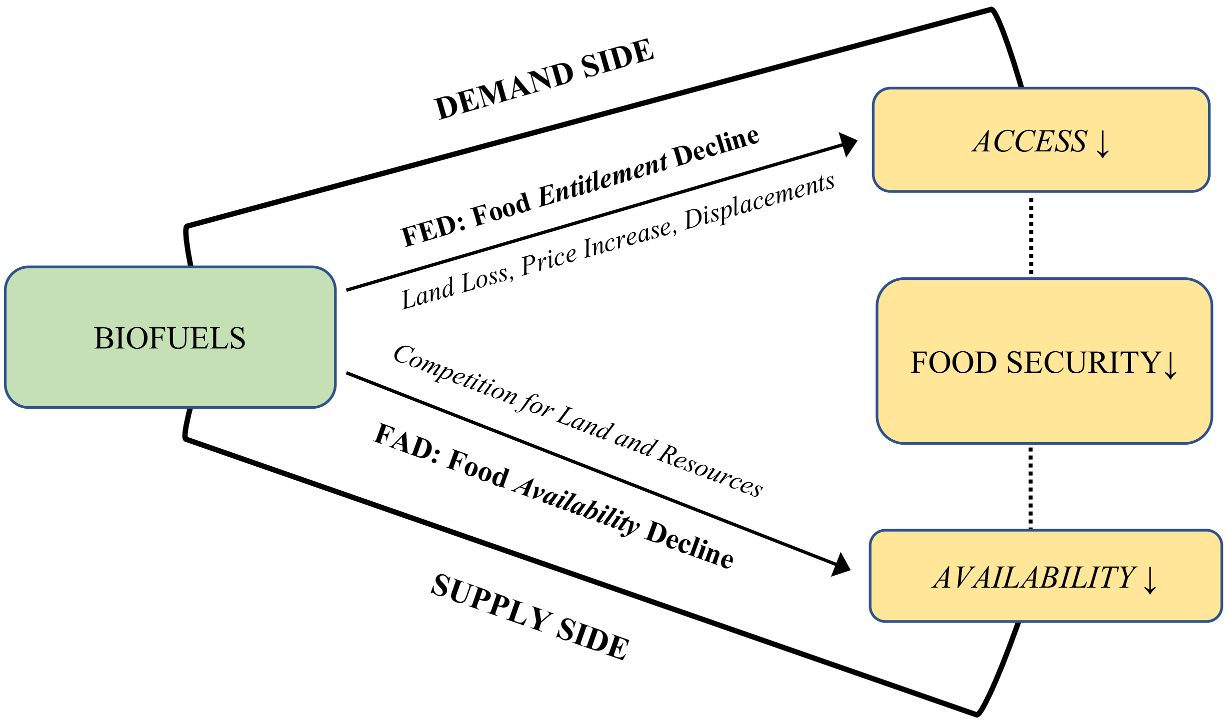
The main argument that results from the discussion of the theories is that the observed externalities of biofuel production negatively affect *both* dimensions of food security. On the one side, previously discussed *environmental* externalities of large-scale biofuel production are related to food *availability* decline. On the other side, *socio-economic* externalities can be linked to food *access* decline. Figure 2 visualizes the linkages of the proposed theoretical framework.

It is important to keep in mind that this research does not assume biofuel production and food security to be connected by a single causal mechanism. Rather, the constant growth of the biofuel sector is believed to set in motion a variety of micro-mechanisms that lead to environmental, social, and economic impacts on food security. A main advantage of this theoretical framework is that it allows for analytical comparison between two food security dimensions. It can assess whether the supply- or the demand side of food security is more affected by the growing biofuel economy in Sub-Saharan Africa. Together, these deliberations lead to the formulation of the following two hypotheses:

H_1: The increase of biofuel production has a negative effect on food *access*.

H_2: The increase of biofuel production has a negative effect on food *availability*

Figure 2. Theoretical Linkages between Biofuels and two Dimensions of Food Security



3.4 The Role of Regime Type in the Biofuel-Food Security Nexus

An important additional dimension to the biofuel-food security nexus is the role of political institutions. Several authors have highlighted the importance of democratic governance structures in achieving socially desirable and environmentally sustainable agricultural growth (Borras Jr. et al., 2010; Newell et al., 2019; Van der Horst & Vermeylen, 2011).

There are two main functions of political institutions in the development of desirable biofuel initiatives: first, enforcing and monitoring environmental protection and second, ensuring land rights and smallholder protection in deal-making process with incoming biofuel investors (Borras Jr. et al., 2010, p. 587; Schoneveld et al., 2010, p. 5). Scientific evidence suggests that democratic regimes have higher commitments to environmental protection than other types of regimes. This is explained by their commitment to international environmental agreements (Neumayer, 2016) and the fact that freedom of information promotes the interests of environmental groups and thereby encourages sustainability legislations (Li, 2006). Moreover, Newell et al. (2019) argue that the level of democratization manifests the promotion of human rights and the degree of civil society and smallholder participation in policy making (p. 3). In turn, these authors claim, that where basic features of democratic regimes, namely "transparency, accountability, responsiveness and legitimacy" (Borras Jr. et al., 2010, p. 586) are absent, the probability of equitable and sustainable outcomes is limited.

Many Sub-Saharan countries do not have explicit laws and frameworks that regulate environmental and socio-economic issues around biofuel production (Renzaho et al., 2017, p. 511). To give an example, Ribeiro et al. (2010) documented that World Bank financed biofuel policy in Mozambique did not engage civil society in the decision-making process while transnational corporations had almost one seventh of Mozambique's arable land under their control.

What these findings imply, is that negative externalities attributed to biofuel production can only be addressed and prevented, if a certain level of democratic, responsive governance structures is present. Related to the theoretical framework of the thesis, environmental protection measures have the potential to mitigate food *availability* decline, whereas the protection of civil rights violations and economic pressures can prevent food *entitlement* decline. In order to capture this moderating role of political institutions in the relationship between biofuel production and food security, this study adds a third hypothesis to the quantitative analysis with two sub-categories.

H_{3a}: The negative effect of biofuel production on food *access* larger in non-democratic regimes than in democratic regimes.

H_{3b}: The negative effect of biofuel production on food *availability* is larger in non-democratic regimes than in democratic regimes.

4. RESEARCH DESIGN

4.1 Level of Analysis & Sample Selection

Many contributions to the *fuel versus food* debate are theoretical and conceptual in nature (Ewing & Msangi, 2009; Kline et al., 2016; Ripa et al., 2021). Moreover, the short list of quantitative studies on the topic show limitations which this study aims to overcome. First, Koizumi (2015) measures biofuel impacts on food prices, which is too specific to analyse an overall effect on food security. Second, Brinkman et al. (2020) quantify projected impacts of biofuel production on food security in 2030, which is too hypothetical to assess the current impact. Last, Subramaniam et al. (2019) assess biofuel impacts on food security for all developing countries, which can be criticized for neglecting important regional differences across continents. To account for temporal relevance and special distinctiveness, this thesis aims to identify a recent, general trend in *one* vulnerable region, namely Sub-Saharan Africa.

The timeframe for the analysis was determined based on two mutually reinforcing factors. First, the rise of biofuels investments in Africa was driven by the EU and US policy targets, adopted in the mid-2000s, with the goal to increase the use of renewable sources (Future Agricultures, 2014). Second, the spike in oil prices in 2008 has driven global biofuel expansion and global production has constantly grown since then (Enerdata, 2021). Therefore, this timeframe is assumed to represent the expected effects. In line with this, and accounting for data availability, the sample for the multiple linear regression analysis includes 23 countries in Sub-Saharan Africa, covering 12 years between 2008-2019.

4.2 Predictor Variable: Biofuel Production

The independent variable of this study is biofuel production. The *fuel versus food* debate mainly centers around liquid biofuels -bioethanol and biodiesel – that are produced from biomass. Unfortunately, data on the liquid biofuel production sector is scarce and thus unsuitable for large N-studies. As alternative, *primary solid biofuels* cover "solid organic, non-fossil material of biological origin (also known as biomass) which is used for fuel purposes" (IEA, 2021b, p. 33). Although this indicator does not differentiate between traditional use of biomass for local heating and biomass for transnational production of liquid biofuels, the indicator includes *all* sorts of energy crops. Thus, it covers the *agricultural* dimension that is central to the debate. Therefore, it is assumed to be a valid indicator for the purpose of this research. Estimates for the yearly production of primary solid biofuels are derived from the International Energy Agency online database (IEA, 2021a). It is measured in absolute numbers of tera joules per year and country. The variable has been log transformed to treat highly skewed values.

4.3 Outcome Variable(s): Food Security

The main outcome variable of this research is food security. As established in the theoretical framework, food access and food availability should be analyzed separately. Respectively, two dependent variables are used for two distinct statistical analysis. The most comprehensive global database on food security indicators has been compiled by the Food and Agriculture Organization (FAOSTAT, 2021).

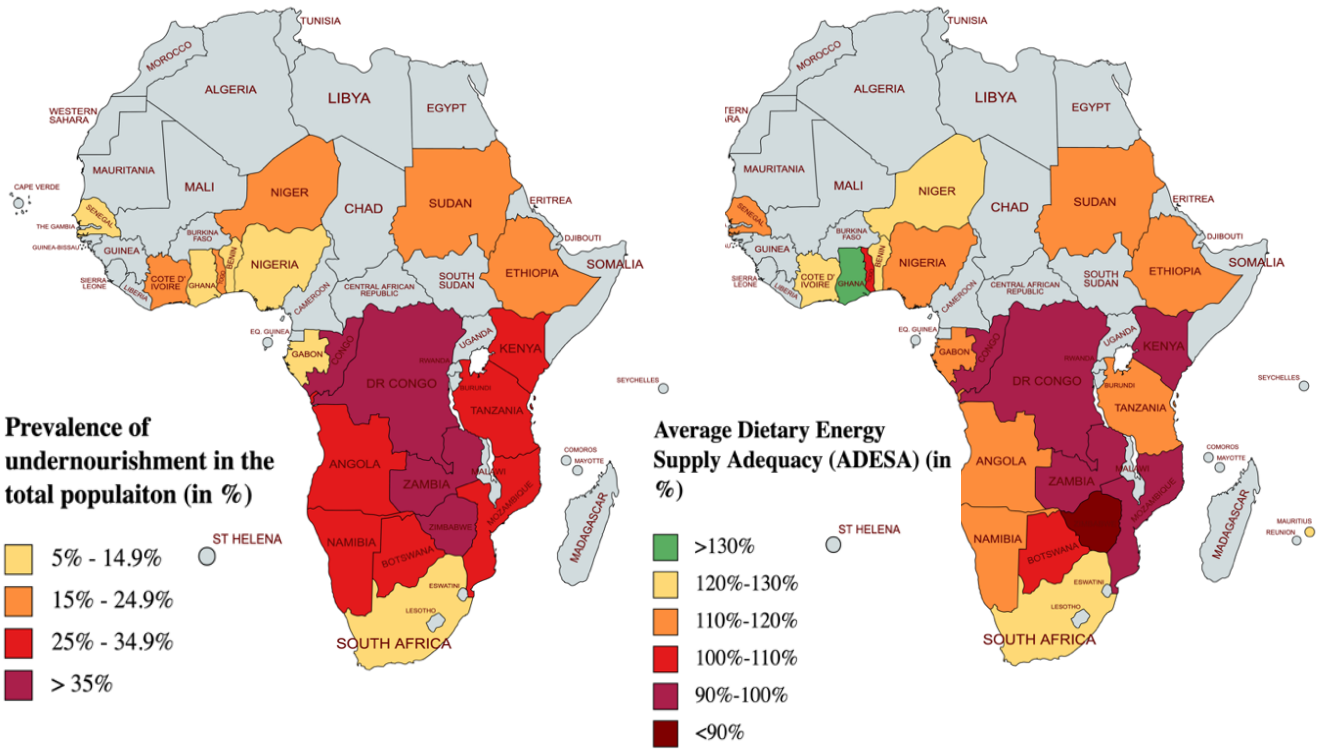
In order to measure *food access*, prevalence of undernourishment (in % of the population) is a widely used indicator in research on the access dimension of food security. This indicator expresses the probability that a randomly selected person from the population of a country consumes a number of calories which is insufficient to cover the energy requirements for a healthy life (FAOSTAT, 2021). For the sake of clarity in the interpretation, the variable was recoded to indicate the share of the population that is *not* undernourished. This enables the general interpretation that increasing coefficients imply increasing food access.

For the variable *food availability,* the chosen proxy is the Average Dietary Energy Supply Adequacy (in %). The indicator serves as an estimate of the amount of calories that are available for human consumption. This is useful for determining whether a country's food supply theoretically contains enough dietary energy to meet aggregate population needs (FAOSTAT, 2021). The indicator represents a proportion where 100% means that - theoretically - the food supply in a country perfectly covers the energy requirements of the given population. If the food supply exceeds aggregate energy demands, the indicator can take values above 100%.

These two indicators – food access and food availability - are valid and reliable indicators for this study. First, in line with the theoretical framework of this thesis, they cover the demand- and supply side of the food insecurity. Second, an analytical advantage of the indicators is that they have been compiled for almost every country for decades, allowing for a standardized comparison over time and across countries (INDEX, 2021). As an indication of a meaningful difference between the supply- and demand side of food security, Figure 2 visualizes levels of food access and food availability in the countries included in the analysis.

Figure 3. Levels of Food Access (Left) and Food Availability (Right) in Sample Countries

Data source: FAOSTAT (2019)



4.4 Control Variables

Population growth as a long-known cause for food insecurity can be traced back to Malthus (1798). The exceptionally high population growth rates in Sub-Saharan Africa are unmatched by those assessed in other regions of the world and are understood to be a leading cause of food insecurity on the African continent (Hall et al., 2017, pp. 124-125; UNDP, 2012, p. 2). Therefore, *population growth,* proxied by the annual population growth rate (in %) per country, is included as a control variable. The data was retrieved from the World Development Indicators database (World Bank, 2021).

In order to include *economic development*, GDP per capita (in current US dollars) is the chosen proxy for the analysis. The degree of economic development has been identified as a central determinant of food security, often explained by the mediating effect of poverty alleviation. The rationale behind this link is that the level of GDP translates into personal increasing real incomes of the population, which is detrimental for household food purchasing power (Świetlik, 2018, p. 127; Tweeten, 1999, p. 127). This is in line with the neoliberal approach to food security elaborated in the literature review. The variable was log-transformed in order to conform to normality and improve the overall model fit.

Political stability is included as a control variable to both models. The indicator is retrieved from the Worldwide Governance Indicators database and measures the likelihood of political instability and/or politically-motivated violence, including terrorism (World Bank, 2021). Although it has been argued that the relationship between political stability and food (in)security is complicated and not necessarily direct or causal, scholars agree on the fact that food security can be upset by conflict and the lack of political stability (Deaton & Lipka, 2015; Verwimp, 2012). This occurs via the effect of conflict on income sources of many farmer households (Verwimp, 2012, p. 1), the disruption of the transportation infrastructure and the decrease of foreign investments that are detrimental for economic and agricultural development (Deaton & Lipka, 2015, p. 31).

Regime type covers an important political dimension in explaining food security dynamics. Higher levels of democracy are commonly associated with better overall food security (Rossignoli & Balestri, 2017). Thus, it is included as a control variable in the regression models. Moreover, as previously explained, political institutions are expected to have a moderating role in the biofuel-food security nexus. In order to measure *regime type,* the Democracy Index compiled by the Economist Intelligence Unit is used (Gapminder, 2021). The data classifies regimes along a 10-point scale where a score of 1 is assigned to full autocracies and a score of 10 to full democracies. The thesis argued that a certain level of democratic governance structures is required to mitigate different negative externalities from biofuel production. The index covers five dimensions, including 'political participation' and 'civil rights', which were said to be particularly important in the theoretical framework (EIU, 2020, p. 3). In order to determine a sufficient level of democracy, a threshold was based on the index' classification of a (flawed) democracy, which starts with a score of 6. Based on this argument, a dichotomous variable was computed. All values from 1 to 5 have been coded as non-democratic regimes and values between 6 to 10 as democratic regimes (EIU, 2020).

Being aware that the list of controls is not exhaustive, it serves the purpose of testing the theory of negative externalities vis-à-vis other dominant theoretical approaches.

4.5 Estimation Model

To predict how much the degree of food access and food availability (DVs) changes, if the value of biofuel production (IV) changes, controlling for other determinates of food security, two multiple linear regression models have been selected as the most suitable estimation model, performed in SPSS 28. In statistical terms, the models can be summarized as follows:

(1) Food Access = $b_0 + b_1$* (*BiofuelProduction*) + b_2* (*PopulationGrowth*) + b_3*(*GDPperCapita*) + b_4*(*PoliticalStability*) + b_5*(*RegimeType*) + b_6* (*BiofuelProduction*RegimeType*) + εi

(2) Food Availability = $b_0 + b_1$* (*BiofuelProduction*) + b_2* (*PopulationGrowth*) + b_3*(*GDPperCapita*) + b_4*(*PoliticalStability*) + b_5*(*RegimeType*) + b_6* (*BiofuelProduction*RegimeType*) + εi

The statistical assumptions for linear regression have been tested and there is no cause for concern[1]. An overview of the variables and the different data sources in presented in Table 1.

Table 1. Overview of Indicators and Data Sources

	Variables	Indicator	Data Source
Main Variables			
	Biofuel Production	Production of primary solid biofuels (in terajules per year)	International Energy Agency (IEA)
	Food Access	Prevalence of undernourishment (in % of the population)	Food and Agriculture Organization (FAOSTAT)
	Food Availability	Average Dietary Energy Supply Adequacy (ADESA) (%)	Food and Agriculture Organization (FAOSTAT)
Control Variables			
	Population Growth	Annual growth rate (%)	World Bank Development Indicators
	Economic Development	GDP per capita (in current US dollars)	World Bank Development Indicators
	Political Stability	likelihood of political violence, including terrorism (1-100)	World Bank Governance Indicators
	Regime Type	Democracy Index (0-10)	Economist Intelligence Unit (EIU)

[1] for detailed discussion see Appendix A

5. RESULTS & DISCUSSION

The results of the multiple linear regression models are reported in Table 2. They are ordered based on the included predictor variables: (**1**) models including the main predictor variable; **(2)** models including control variables and; (**3**) models including the interaction effect. Subdivision '**a**' predicts *food access* while subdivision '**b**' predicts *food availability*.

5.1 Baseline Estimations

Before reporting and discussing the results it is important to note that the variables *biofuel production* and *GDP per capita* were log-transformed and are thus interpreted in percent changes[2]. In the baseline models, excluding control variables, the effects of *biofuel production* on *food access* and *food availability* are insignificant, although they hint at a food security – worsening effect. The R^2 value for the models without controls are very low which indicates that biofuel production alone is not explaining much of the variation of food security (M1a: $R^2 = 0.09$; M1b: $R^2 = 0.06$). However, when including control variables, the negative biofuel effect on *food access* becomes significant at the 5% level. More specifically, 1 % increase in *biofuel production* decreases *food access*, measured by the 'share of the population that is not undernourished', by the 0.031% ($p < 0.05$). Model 2b shows that the effect of *biofuel production* on *food availability* is also negative, although insignificant. To be precise, 1 % increase in *biofuel production* decreases *food availability*, meaning the 'average dietary energy supply adequacy', by 0.02% ($p > 0.05$).

Therefore, the null-hypothesis of no significant relation can be rejected in favor of hypothesis 1, that biofuel production decreases food access. However, the null-hypothesis of no significant relation cannot be rejected for hypothesis 2, implying that there is no significant

[2] 1% increase in the independent variable is meant to increase (or decrease) the dependent variable by (coefficient/100) units

Table 2. Multiple Linear Regression Results for Food Access and Food Availability

	Model 1a Food Access	**Model 1b** Food Availability	**Model 2a** Food Access	**Model 2b** Food Availability	**Model 3a** Food Access	**Model 3b** Food Availability
(Constant)	-9.487	118.181***	-14.581	102.372***	-31.587	78.858***
	(6.502)	(6.609)	(12.059)	(12.946)	(16.291)	(17.438)
Biofuel Production (log)	-1.885	-1.537	-3.182*	-1.949	.640	3.336
	(1.221)	(1.241)	(1.618)	(1.737)	(2.950)	(3.158)
Population Growth			2.224*	2.557*	1.420	1.446
			(0.968)	(1.040)	(1.097)	(1.174)
GDP per capita (log)			9.043***	9.002***	8.930***	8.846***
			(2.063)	(2.215)	(2.059)	(2.204)
Political Stability			-.325***	-.242***	-0.309***	-.218***
			(.046)	(.05)	(0.048)	(.051)
Regime Type			-15.585***	-12.390***	9.594	22.424
(Ref. = democracy)			(2.229)	(2.393)	(16.420)	(17.576)
Interaction					-4.915	-6.795*
(BioProd(log)*RegType)					(3.175)	(3.399)
R^2	.009	.006	.267	.179	.273	.191
N	276	276	276	276	276	276

Note: standard errors in brackets

***p <0.001, **p <0.01, *p <0.05

relation between biofuel production and food availability. Overall, the food access model 2a fits the data better than the food availability model 2b, as the R^2 values indicate that 26.7% of the variance of *food access* and 17.9% of the variance of *food availability* can be explained by the variance of the predictor variables. Nevertheless, it has to be noted that the effect sizes of biofuel production on food security are very small, as the standardized β-coefficients are -0.157 in model 2a and 0.095 in model 2b.

It can be established that biofuel production affects the two dimensions of food security to a different degree. The findings imply that food access is more affected than food availability. Linked to the theory of negative externalities, this means that socio-economic impacts of intensified biofuel production seem to be more detrimental to food security than competition for arable land and resources. This is an interesting finding facing the common understanding of the issue, that suggests that the use of eatable crops for energy is unethically diverted from available food *supply*. The result show that the moral argument ('crops for fuel should not divert food from people') is compelling, yet misleading. In line with the theoretical framework, the results of the linear regression paint a more complicated picture. Since the negative effect of biofuels is only significant on food access, the results highlight the importance of other issues around biofuels that do not directly affect the available food supply, but affect the demand side of food security. Thus, the simplified rationale that crops are taken *from* people and used *for* fuel fails to capture much of the complexities and nuances around the issue.

This does not necessarily mean that the impact on food availability is not existent. First, the direction of the effect still hints at a food availability-worsening effect. And second, biofuel projects in Africa are a relatively new dynamic, so the negative environmental impacts on resource scarcity and land degradation might not be measurable yet, but might negatively affect food supply in the years to come.

5.2 Control Variables

In contrast to the main predictor variable, the control variables have higher effects on the dependent variables and are mostly significant at the 0.1% level in all model specifications. While the effect of *GDP per capita* and *regime type* is in line with arguments of the thesis, *population growth* and *political stability* have effects that are at odds with the study's expectations. Nevertheless, there are explanations for these findings.

Against Malthusian theory, *population growth* seems to have a slightly positive effect on food access and availability (M2a: $b = 2.22$, $p < 0.05$; M2b: $b= 2.56$, $p < 0.05$). This could be explained by pointing out critics of Malthus (1798) who argue that the relation between population growth and food security can be positive in certain contexts or timeframes. For instance, Boserup (1965) theorizes that population growth is a force that enhances productivity and technological innovation and thereby decreases vulnerability to food insecurity.

The control variable for *economic growth* has a significant, positive effect on food security in all models. Statistically, 1% increase in *GDP per capita*, measured in current US dollars, increases *food access* and *food availability* by 0.9% ($p < 0.01$). This result proves the centrality of economic growth as a predictor variable in questions of development and human welfare and ultimately food security as well.

Against the studies expectations, higher levels of *political stability* present a negative effect on *food access* and *food availability* across all models. However, it is important to note that aggregate estimate for political stability by the World Bank is based on the number of sources documenting instances of politically motivated violence. These instances are local occurrences and as Segovia (2017) argues, food security disruptions due to political violence do not necessarily have an impact on food security nationwide but instead are felt at the local and regional level. Since the present analysis measures food security at the country level of analysis, the results might not capture the effect of political stability on food security adequately enough.

The control variable *regime type* shows to have a very strong effect on food security. Holding everything else constant, *food access* in non-democratic regimes is expected, on average, to be 15.6 % lower than in democratic regimes ($p < 0.01$). Similarity, *food availability*, is expected, on average, to be 12.4 % lower in non-democratic than in democratic regimes ($p < 0.01$). Since the standardized β-coefficients for *regime type* are over-proportionally high in comparison to the other predictors in both models, the importance of political institutions in the effort to explain general levels of food insecurity have to be highlighted in particular.

5.3 Interaction Effect: Biofuel Production & Regime Type

For testing hypothesis 3, an interaction effect between biofuel production and regime type was included in the estimations, with democratic regimes as reference category. The results show that as 1 % increase in the production of biofuels in non-democratic regimes has a worse effect on *food access* than in democratic regimes, although this difference is insignificant ($b = - 4.92$, $p > 0.05$). By contrast, 1% increase in biofuel production in non-democratic regimes has a significantly worse effect on *food availability* than in democratic regimes ($b = -6.795$, $p < 0.05$).

Interestingly, the inclusion of the interaction effect switches the direction of the *biofuel production* coefficient, which is now positive, although insignificant. This hints at the possibility that biofuel production is not only less harming in democracies than in non-democracies, it even has a *positive* effect on food security, holding everything else constant (3a: $b = 0.640$, $p > 0.05$; 3b: $b = 3.336$, $p > 0.05$). This finding implies that democratic governance structures could have the ability to be mitigate negative externalities of biofuel production in order to exploit the full development potential of the biofuel sector.

Strictly speaking, the null-hypothesis of no significant relation can be rejected in favor of hypothesis 3b, but not for hypothesis 3a. However, in both interaction models, the standardized β-coefficients of the interaction effects are higher than the β-coefficients for all other predictors, which underlines the importance of regime type in explaining the relationship between biofuels and both dimensions of food security. Moreover, the fact that the directions of the interaction effect align with the hypotheses of the study calls for more in-depth research on different regime types and governance structures and their features that aggravate or mitigate the negative externalities of biofuel production.

5.4 Robustness Check: Country-Fixed Effects

Further regressions are run to assess the robustness of the discussed findings. Therefore, country-fixed effects have been tested by including a dummy variable for each country, with Angola as reference country. This is meant to detect whether certain effects are the product of unobserved, time-invariant factors specific to some of the countries in the sample (Bell et al., 2018). In other words, the fixed models are supposed to show whether some single Sub-Saharan countries have a significant effect on the estimated relationship between biofuels and food security[3].

The inclusion of country- dummies in models 2a & 2b causes most predictors to lose significance, although *GDP per capita* remains significant in both. Overall, some country dummies have a statistically significant effect at the 0.1% level in all model specifications. Hence, the inclusion of country-fixed effects might, indeed, account for previously unobserved factors specific to single Sub-Saharan countries.

Importantly, the interaction effect between biofuel production and regime type in the food availability model 3b *is* robust to the county fixed effects as it remains significant at the

[3] For robustness test estimation models, please refer to online appendix A

5% level. Additionally, in the food access model 3a, the interaction effect obtains significance at the 10% level. This lends firm support to the finding that regime type plays a moderating role in the biofuel-food security nexus *across* regions.

6. CONCLUSION

In the end, what is the effect of biofuel production on food security in Sub-Saharan Africa? This research question was put forward presenting the puzzle of whether biofuel production, which is said to promote rural development, could in fact endanger food security. Building on the theoretical framework of economic externalities, the thesis hypothesized that biofuel production threatens food access as well as food availability due to negative environmental and socio-economic externalities of large-scale biofuel production. The answer to the research question is not straight forward. The effect of increased biofuel production on *food availability* is indeed negative, although not significant in the quantitive analysis. However, the results show a significant, negative impact on *food access*. Since food access was theoretically linked to the demand side of food security, one interesting finding is the relative importance and danger of socio-economic externalities of intensified biofuel production. In spite of this, it has to be noted that the impact of biofuels is still small in comparison to other determinants of food security, particularly economic growth.

Moreover, the study could identify regime type as a crucial moderator variable in explaining the impact of biofuels on food security. As initially hypothesized, the results suggest that increased biofuel production is more detrimental to food security in non-democratic regimes than in democratic ones. In fact, the data shows that biofuel production is not only less harming, the results suggest a *positive* impact on food security in democratic regimes.

Before expanding into pathways for further research in this field, it is important to consider the limitations of the present study. First, data constraints had a considerable impact on the design of this research. Biofuel production was proxied by *primary solid biofuel production* in tera joules per year (IEA, 2021a). This indicator is not ideal, since it does not differentiate between traditional use of plant materials for heating and electricity purposes and modern production of liquid biofuels like ethanol and biodiesel. It is therefore likely that the indicator does not capture modern production of biofuels and its consequences in their entirety. Moreover, the lack of available data resulted in the omittance of some Sub-Saharan countries from the analysis, which bears the potential for causing sampling bias. Especially Sierra Leone, Malawi and Mali could not be included in the analysis although there have been recent, documented biofuel initiatives in these countries (Maconachie, 2019; Sekoai & Yoro, 2016).

Second, collapsing various regime types into a dichotomous regime type measure might have affected some of the results' accuracy. Quantitive measures cannot assess the differences within the group of non-democratic regimes adequately enough. Especially recently emerging hybrid regimes differ widely because they combine various elements of both, authoritarian and democratic structures and are particularly present in many African states (Menocal et al., 2008). Thus, although useful for the quantification, the regime type variable in the analysis could not sufficiently assess nuances regarding the role of political institutions in the biofuel food security nexus.

These limitations create interesting pathways for future research. First, due to local concentration of biofuel projects, *quantitative* data collection is highly needed on the on the sub-national level. This would enable more sophisticated assessments of environmental impacts of biofuels on resource scarcity and levels food production. Second, *qualitative* studies on large-scale land grabs for biofuel production could shed light on the socio-economic impacts of biofuel expansion that are detrimental to local food security. For this purpose, a new independent global land-monitoring initiative called ‘Land Matrix’ might be valuable, since it provides information about large-scale land deals in developing countries (Land Matrix, 2021). Based on this dataset, further studies could identify regions that are particularly affected by large-scale biofuel investments and conduct surveys of the local populations in these regions. This would enable an exploration of the direct impact of biofuel production on land access losses of smallholders, displacements and household food security.

Until more scientific clarity will be reached in the field, the *fuel versus food* debate will most likely continue to divide the international community. As demand for renewable energy sources will only increase in the next decades, this thesis aims to underline the crucial importance of further quantitative and qualitative studies on the issue. On this note, the main conclusion from this thesis is twofold. *First*, the moral claims around the *fuel versus food* debate have to be taken seriously because the analysis showed the negative impact that biofuels can have on food security in Sub-Saharan Africa. *Second,* however, framing the issue as a dilemma between biofuels or food security is misleading. It obscures the complexities around the issue and morally demarcates a space for debates in which positive effects of biofuels cannot be discussed. However, the potential impact of biofuel production on food security could differ widely, based on regional environmental conditions, social inequalities, and governance structures. Therefore, it is time for a more nuanced debate between researchers and policy makers that takes into consideration various positive and negative impacts of biofuels but always orients the attention towards ensuring global food security as a first priority.

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APPENDICES

APPENDIX A

Test of Statistical Assumptions, Syntax and Outputs of all Models

A separate document for Appendix A was uploaded online. It contains the SPSS Syntax and Outputs of models 1-3, including checks of assumptions, the interaction effect and the country fixed effects.

It can be accessed through the following link:

https://www.dropbox.com/s/wvabgweh9mkst75/Thesis_Nelly%20Reinstorf_AppendixA_final.pdf?dl=0

APPENDIX B

Descriptive Statistics

Table B1

Descriptive Statistics of the Variables Included in the Analysis

Variable	N	Mean	Standard Deviation	Minimum	Maximum
Food Access	276	79.583	12.583	47	96.4
Food Availability	276	110.05	12.771	79	134
Biofuel Production (log)	276	5.288	.62	3.88	6.69
Population Growth	276	2.557	.814	0.032	4.948
GDP per Capita (log)	276	3.237	.41	2.48	4.05
Political Stability	276	34.959	23.9	.949	93.75
Regime Type	276	.75	.436	0	1

APPENDIX C

List of Countries Included in the Analysis

Table C1

Sub-Saharan Countries Included in the Analysis

Angola	Mauritius
Benin	Mozambique
Botswana	Niger
Cameroon	Nigeria
Congo, DR	Senegal
Congo	South Africa
Cote D'Ivoire	Tanzania
Ethiopia	Togo
Gabon	Uganda
Ghana	Zambia
Kenya	Zimbabwe