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on Socio-economics and Sustainability

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An economy-wide assessment of the food security impacts of changes in bioenergy use

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Authors: Thom Achterbosch, Geert Woltjer, Hans van Meijl, Andrzej Tabeau, Heleen Bartelings, Siemen van Berkum; LEI, part of Wageningen UR, The Netherlands

Reviewer: Janske van Eijck, Utrecht University, The Netherlands
Dominik Rutz, WIP Renewable Energies, Germany

Contact: Thom Achterbosch, LEI Wageningen UR
Alexanderveld 5, 2585 DB The Hague, THE NETHERLANDS
Email: thom.achterbosch@wur.nl; telephone: +31 70 33 58 194

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Abbreviations

FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gas(es)
HLPE	High-level Panel of Experts on Food Security and Nutrition
UN	United Nations

1 Introduction

Thom Achterbosch

The purpose of this paper is to deliver a framework and initial application of a model-based assessment of the food security impacts of changes in bioenergy production and relevant policies on food security. The climate change impact of biofuels is left out of the discussion, although it is obvious that the potential contribution of biofuels in decelerating global warming and in making future global energy supplies more sustainable is a major impetus in this sector. Developments in biofuel production in the United States and the European Union have been largely policy-driven, setting these countries apart from a more market-oriented sector in Brazil. Government-imposed goals for substituting fossil fuel for transportation with biofuel were initially motivated on account of the positive greenhouse gas balance of biofuels. The public debate over induced deforestation and other undesired land use change effects has changed this positivism into concern. A clear response from the scientific community has been hampered by the methodological difficulties in assessing the land use effects of biofuels. Early contributions in the biofuel literature signalled negative greenhouse gas balances. Improved methods and data contributed to a more balanced discussion on differentiated biofuel commodities and production strategies (Wicke et al. 2012). At least a number of biofuel options show a potentially positive GHG balance.

This paper is organized as follows. After an introduction of the general concepts of food security below, section 2 discusses four possible impact pathways for biofuels on food security from an economic perspective. The pathways relate to land competition, impact on short and long term developments in food prices, impact on farm income and macroeconomic performance. Section 3 establishes a set of indicators for a quantitative exploration of the impact pathways, followed by an illustrative application in section 4 on the impact of increased biofuel production on food prices and macroeconomic indicators in Argentina, Indonesia and Brazil and the implications for food security in these regions and, via food prices, on several broadly defined regions in Africa. Section 5 discusses the limitations of the application in the form of a research agenda for model-based exploration in the future. The focus lies on the nutrition-related aspects of food security, which we expect to become more important in the future.

The current FAO definition of food security distinguishes four aspects: food availability, food access (consumption) at household and individual level, stability of food access over time, and food utilisation resulting in a good nutritional status – the ultimate goal (FAO 1996). Food security is a challenge at several inter-related levels. National food availability is determined by domestic supply and the extent to which farm output is complemented by means of imported food, whether through market transactions or food aid, and mutations in food stocks. Where markets or aid workers fail to connect regions of surplus to regions of deficit, a surplus of food at national level may coincide with compromised food availability at local level. On the consumer side of the market, household food access is determined by income (from farming, labour or other activities), household food production, household food stocks and other assets that serve as buffer. Household and individual food access (and its stability over time) needs to be accompanied by good diet diversity and food quality, good health, sanitation and safe drinking water in order to contribute to individual food utilisation that result in good nutrition status (IOB 2011).

Biofuels and food security are connected via multiple pathways, which can be analysed with markets and natural resources as key starting points (Figure 1). A useful reference for the analysis of socioeconomic mechanisms is the Bioenergy and Food Security (BEFS) project (FAO 2010, 201). Main focus in the debate on food-feed-fuel interaction has been on land competition, and volatile food prices. Limited attention has been given to bioenergy's potential to promote rural development. As the sector develops, the impact of biofuel developments on macroeconomic growth is gaining interest. There is a shortage of comprehensive assessments of the impact of biofuel policies and investments on food security or nutritional outcomes that bring the various aspects together. This has motivated the High Level Panel of Experts, a UN body to support food security strategies, to embark on a review on this topic. The first draft of this paper is largely focused on the ramifications of policy-driven biofuels use on land use and food prices (HLPE 2012), which follows the discussion in section 2.1 and 2.2. A discussion on the potential role of biofuel crops as a cash crop or as stimulus for upgrading the agricultural performance in a region is largely omitted. While the omission can partially be explained by a lack of clear scientific evidence in this area, sections 2.3 and 2.4 aim to complement the analysis.

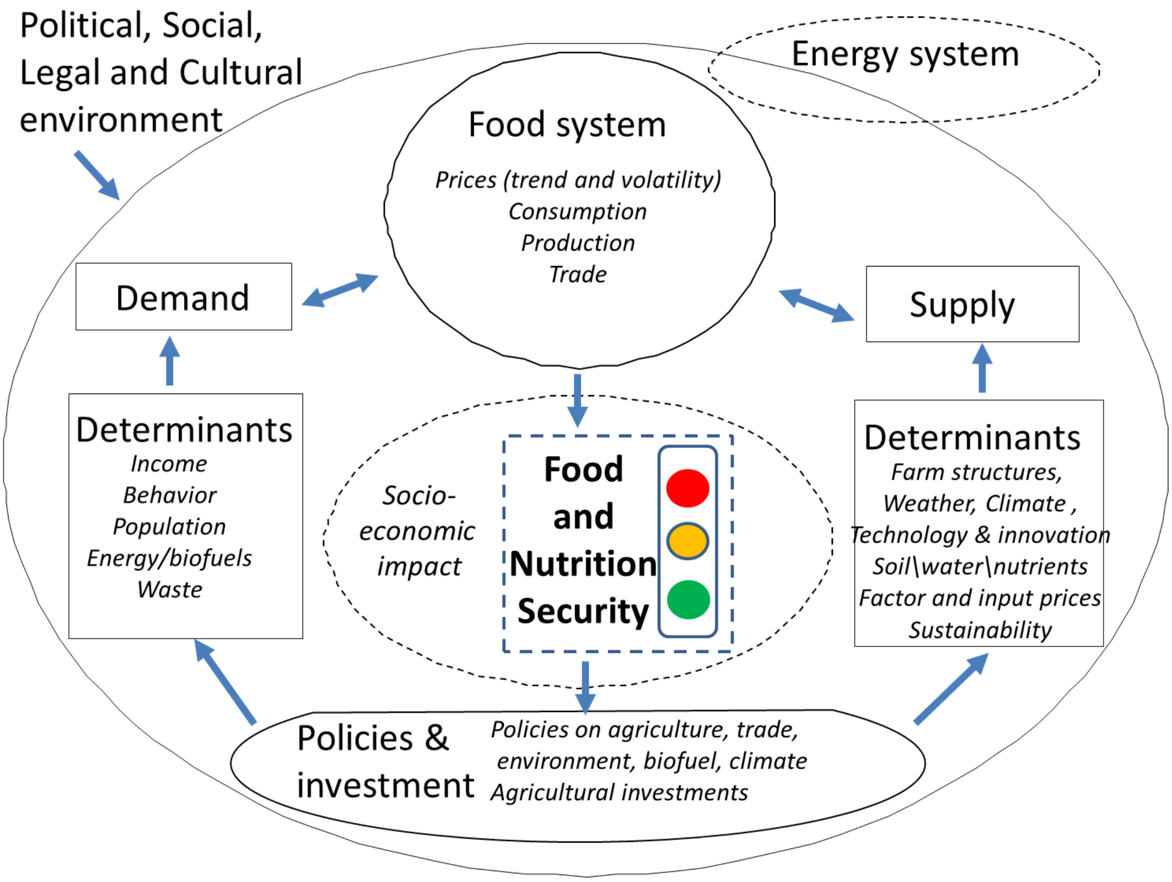

Figure 1 Conceptual Framework

2 Connections between food security and biofuels

Thom Achterbosch and Siemen van Berkum

Pathway 1: Food availability in connection with the competition for arable land

First generation biofuels are ethanol, biodiesel and pure plant oil, which are produced from agricultural feedstock such as corn, sugarcane, sugar beet, wheat, potato, rapeseed and soybean, sunflower and palm oil. Main biofuel producers in the world are Brazil, the USA and the EU. OECD/FAO (2012) indicate that currently some 65% of EU vegetable oil, 50% of Brazilian sugar cane, and 37% of US corn production is being used as feedstock for biofuel production. Other significant players are Thailand (ethanol and biodiesel), Argentina and Indonesia (biodiesel), yet also developing countries with a high potential in sugar cane and/or vegetable oil production like India, Columbia, Philippines and Malaysia are increasingly producing biofuels.

The production of bioenergy from feedstock typically reduces the availability of food, as the biomass is either used in the food/feed chain or in the energy chain. The main issue for food security may arise from land displacement and degradation, with consequently a reduction in food output, which could result in higher prices for staple food crops (FAO, 2010). Shortfalls in domestic production could require increases in food imports expenses. As bioenergy feedstock production tends to be resource-intensive (with widespread use of agrochemical, fertilizers and water), long-term soil quality and therefore land productivity could be affected adversely. In order to maintain its output, bioenergy production might have to further increase its use of land at the expense of land for food. If land displacement occurs, food producers may have to move to new lands where soil quality may be lower, hence affecting their productivity.

Recent literature suggests that a more differentiated discussion on biofuels is needed, particularly in relation to strategies for mitigating land displacement. Wicke et al. (2012) report on several options of reducing (direct and indirect) land use change. A main strategy for mitigating indirect land use change is the promotion of biofuels with low risks for land displacement, such as currently unused residues from agriculture, forestry and processing, as well as woody and grassy feedstocks for second-generation biofuels, particularly those produced on degraded and marginal land.

The trade-off between using land for food or fuel may be illustrated by the case on Ghana. Ghana’s economy is entirely dependent on imported crude oil and petroleum consumption is growing. As a consequence, Ghana’s oil import bill is increasing, especially since the oil price hikes in recent years. As part of the government’s energy programme, biofuels is considered an alternative option to reduce Ghana’s cost of oil imports. Production of jatropha and palm oil for biodiesel and sugar cane for ethanol would address energy security, climate change and balance of payments problems together with other problems such as high unemployment and low productivity in agriculture. Antwi et al (2010) explore the country’s potential to produce biofuels from agricultural products. They point at the fact that at present vegetable oil production is only at a very small scale. Hence, the country needs to invest in bioenergy production capacity, both in the processing as well as in the primary production if government’s targets to replace gasoline with biofuels are to be met. Furthermore, the expansion of energy producing crops would need land area which is presently used to grow food. If the country wants to use its potential for producing renewable energy from agricultural crops, the authors argue that productivity of agricultural land needs to increase rapidly in order not to create any food shortage or hikes in food prices on the market. However, yield increases are not expected to be achieved easily (see for an overview of yield improving bottlenecks (Van Dijk, Meijerink, and Shutes 2012), Van Berkum et al., 2011).

Antwi's argument that increasing overall agricultural performance mitigates the food-fuel trade-off is intuitive but over-simplifying the issue at stake for several reasons. The argumentation that biofuel investment must go hand in hand with wider yield growth to prevent food shortage in context of low agricultural productivity does not strictly apply to biofuels. Such reasoning would be valid for investments planned for any export or cash crop that does not contribute to local food supply. A priori rejections of biofuel investments in a context of (national) food insecurity may be motivated from the perspective of food sovereignty, which gives focus on the production for domestic consumption and food self-sufficiency (Vía Campesina 1996). The food sovereignty movement rejects trade-based strategies to achieve food security in the absence of well-functioning international markets) (Pieters et al. 2012). Applied to the case of biofuels, the benefits of the strategy in terms of reduced import dependency need to be balanced against the benefits of deeper global specialization.

Pathway 2. Controversy over the contribution of biofuel demand for feedstock to food price volatility

Agricultural prices peaked in 2011, exceeding levels reached in the 2007-08 crisis. Food prices increased 92% in nominal terms and 57% in real terms from December 2005 to January 2012. As biofuel production is an additional source of demand for agricultural commodities, it may present a partial cause for the price hikes, in the case where the supply has not adequately responded to this extra demand. The question is how and to what extend biofuels policies did affect agricultural commodity prices in the past and how it may affect international price developments in the future. Therefore, the food security impact induced by the demand of feedstock for biofuels relates to two separate price changes: more volatile food prices in the short run and upward pressure on food prices in the long run, which affect the access of poor consumers to food and the stability of access. A brief discussion of the impact of biofuels on the level and volatility of agricultural and food prices is presented below. Meijerink et al. (2011) provides a more elaborate discussion.

Rosegrant et al. (2008) and Mitchell (2008) argue that biofuels have been a major contributor to the rapid price increases on the international grain markets in the 2000s. Expanded production of ethanol from maize, in particular, has increased total demand for maize and shifted land area away from production of maize for food and feed, stimulating increased prices for maize. Rising maize prices, in turn, have affected other grains. On the demand side, higher prices for maize have caused food consumers to shift from maize (which is still a significant staple food crop in much of the developing world) to rice and wheat. On the supply side, higher maize prices made maize more profitable to grow, causing some farmers to shift from rice, soybeans and/or wheat cultivation to maize cultivation, with consequently price effects of those crops less produced. Rosegrant et al. (ibid.) quantify the food price effects of biofuel policies by comparing a simulation of actual demand for food crops as biofuel feedstock through 2007 and a scenario simulating biofuel growth at the rate of 1990-2000 before the rapid take-off in demand for bioethanol. The increased biofuel demand during the period, compared with previous historical rates of growth, is estimated to have accounted for 30% of the increase in weighted average grain prices, with the biggest impact on maize prices (+39%). Yet, several studies challenge the perception of biofuel policies having such a big impact on agricultural market balances and long term price developments. Baffes and Haniotis (2010) point at the fact that worldwide biofuels account only for about 1.5% of the area under gains/oilseeds. Furthermore, in analysing market developments, both authors note that 'maize prices hardly moved during the first period of increase in US ethanol production and oilseed prices dropped when the EU increased impressively its use of biofuels. On the other hand, prices spiked while ethanol use was slowing down in the US and biodiesel use was stabilising in the EU' (ibid., p 12).

The contribution of biofuel policies to the recent food price hikes has been hotly debated. Biofuel policies were particularly challenged as a factor contributing to the 2007-08 hike. There were several claims that biofuels raised the pressure on agricultural markets up to the point where failed harvests and sudden policy responses (e.g. export restrictions, lowering of import tariffs) could create large price movements. The common argumentation relates to the lack of flexibility in biofuels demand. Indeed, the blending mandates for biofuels introduce a rigidity in the demand for biofuel feedstock: without the mandates, rising feedstock prices would result in lower use of biofuels. Argumentation to the opposite has also been made; Wright (2011), DEFRA (2012), and Helming (2010) have proposed flexibility in delivery contracts for feedstock in biofuel supply chains as an instrument that contributes to stabilizing food prices. In time of tight food supply, market agents would be executing a call option on feedstock to divert supplies into the food market.

During the 2007-08 food price hike, prices of the biofuel substitutes – in particular fossil oil – were rising at the same time. This leads to the fact that price rises in energy markets have a strong influence on food prices via rising input costs of farming. There is more to say about the strengthened links between energy and food markets. Baffes and Haniotis (2010) explain that there is a level at which energy prices provide a floor to agricultural prices. The World Bank (2009) reported that crude oil prices above USD50/barrel effectively dictate maize prices, based on the strong correlation between maize and crude oil prices above that price and the lack of such a correlation below that price. Baffes and Haniotis examine the energy/non energy link, investigating among others six food commodities, and find that energy prices explain a considerable part of the commodity price variability. They conclude that prices of food commodities respond strongly to energy prices, with the responses further strengthening in periods of high prices. Next, the authors find that food commodity prices respond to energy prices by moving in a very synchronous manner, indicating that analysing food markets requires an understanding of energy markets as well. The authors also conclude that agricultural commodity market fundamentals appear, in the short term, to be playing somewhat a lesser role than in the past, tending to be overshadowed by the much stronger pull of energy prices.

While increasing biofuels demand added to the tightening of feedstock and food markets, the transitions to full-blown food price crisis had more to do with sudden policy responses than with gradual market movements. Gilbert and Morgan (2010), for instance, found little direct evidence that demand for grains and oilseeds as biofuel feedstock was the cause of the 2007-08 price spike. Interestingly, the energy-food nexus also sheds new light on the causes of price volatility. Hertel and Beckman (2011) examine how energy price volatility has been transmitted to commodity prices. They find that biofuels have played an important role in facilitating increased integration between energy and agricultural markets. Hertel and Beckman show that over the period 2001-2009 the correlation between monthly oil and corn prices was much stronger with oil prices exceeding USD75/barrel. In that price range US biofuel policy appears to be non-binding: more ethanol is being produced than required according to the policy targets as ethanol production (from maize) is competitive with petroleum. In the absence of binding biofuel policy targets, by 2015, the contribution of energy price volatility to year-on-year corn price variation will be much greater - amounting to nearly two-thirds of the crop supply-induced volatility. However, if the US biofuel policy targets are binding in 2015, then the role of energy price volatility in crop price volatility is diminished.

The discussion has addressed the impact of biofuels on food prices, which determines the price and is therefore a central factor in the accessibility of food to poor consumers. There is also a possible relation to be explored beyond food prices in relation to overall inflation. In countries that depend heavily on imported fossil fuels, oil price rises will give upward pressure on inflation rates – as indicated by rising consumer prices index CPI. The development of a substantial domestic biofuels supply will, under such conditions, help to ease price inflation pressures. In theory, this may help to stabilize consumer purchasing power and the stability of access to food of poor consumers.

Pathway 3. Biofuel markets provide a potential source of income opportunities for farmers operating at different scales

Limited attention has been given to bioenergy's marked potential to promote rural development, which some claim is particularly undeserved in relation to Africa. Lynd and Woods (2011), for example, argue that biofuel production could offer great opportunities to African farmers, especially pointing at the option to produce bioenergy from inedible plants (e.g. jatropha) that grow on marginal land that is not well suited for growing food, or from grass or Agave fibre. Producing these crops for bioenergy production on degraded soils or on particularly dry land would not compete for land for food production, and would offer rural Africa huge opportunities to benefit from the bioenergy market developments. The authors emphasise, though, that the impact of bioenergy on income generation and therefore food (in)security also depends on the technology employed (for biofuel production from agricultural commodity) and how the bioenergy supply chain is integrated into agricultural, social and economic systems. To date, modern bioenergy supply chains are practically lacking in Africa; there are no bioenergy clusters established like in Brazil where according to the authors biomass production has been lifting 10% of the Brazilian population out of poverty during the last decade. The latter suggests a very positive impact of Brazil's ethanol industry on food security in the country.

Such a positive effect of bioenergy production on food security depends on whether smallholder farmers and labourers are included or not in the biomass supply chain. The processor may well exert a strong influence on the crop choice and the scale of operation used for production. Private investors could favour large scale production because they entail lower production costs. However, the risk is that the smallholders are excluded from the supply chain or a fair share of value creation as they cannot provide the processing facilities with large quantities and/or are unable to invest in productivity growth.

Mozambique is one of the developing countries having experiences with biomass production for biofuels that show the difficulty of smallholders to benefit from bioenergy production. The country's biophysical potential exists with the long-term presence of sugar cane plantation in different parts of the country, while according to the national biofuels policy and strategy the exploitation of agro-energetic resources should contribute to the well-being of the population and promote socio-economic development particularly in rural areas. In practice, though, these objectives have not been achieved. Schut (2010) conclude that only few projects are located in remote rural areas while 'biofuel developments mainly take place in areas near good infrastructure where there is skilled labour available and access to services and goods, processing and storage facilities' (p. 5164). Job creation is lower than expected although the industry is contributing to the generation of income, employment and more indirect local spin-offs. The authors state that from promoting the biofuel production by smallholders for domestic purposes, the sector is currently dominated by foreign commercial investors whose main intention is supplying external markets (Schut et al., 2010). The results of this study suggest that without strong government incentives to include smallholders economic factors drive investment location decisions that determine the direction of the biofuel developments. Policy measures that could enhance the position of the rural population are among others to build infrastructure (roads, ports) or to facilitate the establishment of farmer cooperatives that could aggregate their output and represent the interests of smallholders supplying the bioenergy industry.

Pathway 4. The structure of the biofuels operations determines whether biofuels contribute to macroeconomic performance and rising living standards

While promoting biofuel production may have strong distributional effects, biofuel developments may contribute to an overall improved macroeconomic performance and living standards. This is because biofuels production may generate growth linkages (i.e., multiplier or spill over effects) to the rest of the economy. For example, producing biofuels requires intermediate inputs, such as transport services to get the biofuels to consumers or export markets. In this case, expanding biofuels use generates additional demand for locallyproduced services, which may create new jobs and income opportunities for workers and households linked to the biofuels supply chain. Moreover, these new incomes will eventually be spent on consumer goods and services, which again generate additional demand for non-biofuel products.

Finally, there are macroeconomic linkages through which biofuels may stimulate economy-wide growth. For example, biofuels exports can relieve foreign exchange constraints, which often limit developing countries' ability to import the investment goods needed for expand production in other sectors. Together, these economic linkages can generate gains that are far larger than those generated within the biofuels sector alone FAO (2010).

This is also illustrated in Arndt (2010) in the case study on Mozambique, where the authors compare the economic impacts of a large-scale operation (sugar cane/ethanol) with a more pro-poor out-grower schemes (producing jatropha/biodiesel). They find that large scale biofuel investments enhance growth and poverty reduction despite some displacement of food crops by biofuels. Benefits depend on production technology. An out-grower approach to producing biofuels is more pro-poor, due to the greater use of unskilled labour and accrual of land rents to smallholders, compared with the more capital-intensive plantation approach. Moreover, the benefits of out-grower schemes are enhanced if they result in technology spill overs to other crops. These results indicate that a carefully designed and managed biofuels policy holds the potential for substantial gains.

3 Methodology for an economy-wide assessment of food security and biofuels

Thom Achterbosch

Why to use economic models for assessing food security impacts?

The pathways for food security impact of biofuels and biofuel policies cover price effects, income effects and macroeconomic effects. Key underlying mechanisms relate to the allocation of available land of different qualities over its possible alternative uses, and to the impact of biofuels on the energy or fuel balance in the production country. In order to evaluate the full impacts and trade-offs of biofuels production on food security, a framework is needed that captures the direct and indirect or economy-wide linkages and constraints at the macro- and microeconomic level (FAO 2010). The economic method specifically designed to capture these impact pathways is known as "computable general equilibrium" (CGE) modelling.

A particular strength of CGE modelling is the capacity it provides for a consistent analysis across related economic systems that share or compete for resources such as land and investment capital. For biofuels and food security analysis, the interaction between the food and energy systems is pivotal. Global CGE analysis will allow analysis of energy and food price developments worldwide, which is important when comparing market interventions that will have implications for the global biofuel or agricultural markets. In contrast, a CGE analysis at the country level will allow a more in-depth examination of the cross-sector repercussions of demand and supply changes in biofuels, with often more attention on the distributional impact.

Table 1 provides a set of relevant indicators of food security for biofuel-related impact pathways, for use in applied equilibrium analysis. Typically these are proxy indicators for food security outcomes at national and household level. The indicator set will also capture key mechanisms that determine food security outcomes, and builds upon the four pathways identified in section 2. Whereas these types of indicators provide useful indications for ex-ante policy analysis, when used as a basis for policy recommendations, such indicators should be interpreted in relation to observed data. In the following section, an example of an application of these indicators in an empirical framework is presented. This is followed by a discussion on the limitations of the type of analysis.

One major limitation that should be addressed upfront is the lack of coverage of indicators on the stability of food security outcomes at the household or individual level. The main determinants of the risk of falling into a state of hunger and malnutrition are (excessive) price swings and fluctuations in income. Typically, these volatilities are not well addressed in the proposed framework, which has its strength in assessing developments and policy options over a time span of one or more decades. To put it simply, the strand of CGE modelling needed to assess the long term effects of biofuels on income and food prices, is of little use in assessing the fluctuations around a trend. Therefore, additional analytical frameworks are required to assess the relation between price and income volatility and food security. Such frameworks will, for the purpose of assessing the impact of biofuel developments on food security, need to advance well beyond the current state of the art in two areas: first, in disentangling the relative contribution of biofuels to (excessive) food price volatility from the other drivers (see the discussion above); second, in relating price and income fluctuations to food security and nutrition outcomes. The recent Global Monitoring Report provides an excellent overview of the state of affairs in this area (World Bank 2012).

Table 1. PROXY INDICATORS

Pathways for impact of biofuels on food security	Relevant indicators in an assessment
1. Food availability	Change in agricultural production
	Change in agricultural land use
	Change in agricultural land prices
	Food self-sufficiency ratio as the ratio of volumes of total food consumption over total domestic food production
2. Food prices	Change in agricultural prices, world market and regional prices
3. Household income from	Change in non-skilled wages
farming and other labour	Change in agricultural value added as proxy for farm income
	Change in food-basket purchasing power = composite indicator that weighs price and wage effects
	Change in per capita food consumption in different regions
4. Macroeconomic performance	Development of per cent share of biofuels in fuel consumption for transportation for selected regions
	Trade Balance in feedstock for biofuels
	Welfare change on the basis of Equivalent Variation

4 Quantitative analysis on the impacts of biofuel policies on food security

Geert Woltjer, Hans van Meijl, Andrzej Tabeau, Heleen Bartelings and Thom Achterbosch

This section provides an illustrative model application that quantifies the impact of increased biofuel production on food prices and macroeconomic indicators in Argentina, Indonesia and Brazil. Furthermore, it studies the implications for food security in these regions and, via food prices, in Tanzania, West Africa and several broadly defined African regions (North, East, Central and South Africa). This section illustrates the ability of CGE analyses to contribute to the biofuel-food security by providing various indicators identified before. Given the limited scope of these applications all quantitative outcomes should be seen just as illustrations as this is no full-fledged CGE model analyses on this sensitive topic.

We assess the socio-economic impact of a policy-driven impetus for the biofuel sector using a stand-alone MAGNET model, an economic simulation model of the world economy. For this purpose, we make use of a baseline and a global biofuel scenario, both developed under an on-going FP7 project called TAPSIM (Woltjer et al. 2013a, 2013b, 2013c, forthcoming)[1]. One of the key contributions within the TAPSIM projects is the addition of various biofuel sectors to the latest GTAP database (Woltjer et al., 2013c). Biofuel mandates in the transport fuel sector serve as a proxy for all biofuel policies. The methodology builds upon the approach developed in Banse et al. (2008), (2011) and Tabeau et al. (2011) . We confront the results with a scenario specifically designed for Global-Bio-Pact, that examines the impact of increased bioenergy production on food prices and macroeconomic indicators in Argentina, Indonesia and Brazil. In addition, we report on indicative food security implications for these regions, as well as for Tanzania and Rest of Western Africa, a country aggregate in the GTAP version 8 database that comprises Mali.

This paper explicitly examines the joint effect of obligatory biofuel shares in the EU, the US, Canada, Brazil, Rest of South America, India, and South-East Asia on land, food production, trade and prices of agricultural commodities. The analyses will focus on the Global-Bio-Pact biofuel policy countries (Brazil, Argentina, Indonesia) and on African regions and countries.

4.1 Quantitative approach

4.1.1 Database

In this section we describe of the data used to calibrate the model. The model is calibrated to the GTAP database, version 8, which is a fully documented, publicly available global database containing complete bilateral trade information, transport and protection linkages among 112 regions for all 57 GTAP commodities for a single year (2007 in the case of the GTAP 7 database, (Narayanan, Dimaranan, and McDougall 2012)). This set is linked with individual country input-output databases to account for inter-sectorial linkages. All monetary values of the data are in $US million. That is, for each of the 112 regions there are input-output tables with 57 sectors that depict the backward and forward linkages amongst activities.

The initial database was aggregated and adjusted to implement two new biofuel sectors, ethanol and biodiesel, represented by biofuel policies in the model (Woltjer et al. 2013c). To enable a better treatment of biofuel policies and the impact of their by-products on the feed market various sectors are segregated from their initial GTAP sectors: the feed sector is

[1] http://www3.lei.wur.nl/tapsim/

segregated from the other food sector, crude vegetable oil is segregated from vegetable oil sector and fertilisers are segregated from the chemical sector. These new sectors produce various products each, the main product and a co-product or by-product. The ethanol by-product is Dried Distillers Grains with Solubles (DDGS) in case of cereals and molasses in case of sugar cane\beets, and the co-product of biodiesel are oilcakes in case of oilseeds (includes soybeans). After aggregations, we distinguish 27 regions, 41 sectors and 44 products. The sectorial aggregation includes, among others, agricultural sectors activities that use land (e.g., rice, grains, wheat, oilseed, sugar, horticulture, other crops, cattle, pork and poultry, milk, vegetable oil, crude vegetable oils), the petrol industry that demands fossil resources (crude oil, petrol, gas, coal, fertilisers), and bioenergy inputs (ethanol and biodiesel), and biofuel production by-products (DDGS, molasses and oilcakes). The analysis covers all important countries and regions from an agricultural production and demand point of view. The following sectors and regions are of specific importance for this study:

- Biofuel products (substitute of processed crude oil): ethanol; biodiesel
- Feedstocks: maize (proxy: coarse grains), wheat, sugar cane/beet, crude vegetable oil (i.e. vegetable oils after first stage of processing). Co-products and waste streams are not considered in the analysis. Jatropha oil was not explicitly incorporated because of the underlying database is considered unreliable for this sub-sector.

The sectorial detail on the biofuels for the study countries in provided in table 2.

Table 2. Specific sectors and regions in the aggregation and analysis

Case study sector/markets	Proxies in the modelling analysis	
	GTAP v8, Sector group	GTAP v8, Country group
Sugar cane sector in Brazil	Sugar cane & beet Sugar	Brazil
Soybean sector in Argentina	Oil seeds (crude vegetable oils) Vegetable oils and fats	Argentina
Palm oil sector in Indonesia	Oil seeds (crude vegetable oils) Vegetable oils and fats	Indonesia

Note that we report on Tanzania separately, but not on Mali. Instead of Mali we report on Rest of Western Africa (group aggregate of Benin, Burkina Faso, Cape Verde, Guinea, Gambia, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Saint Helena, Sierra Leone, Togo).

4.1.2 The MAGNET modelling framework

The **M**odular **A**pplied **G**e**N**eral **E**quilibrium **T**ool (MAGNET) is a global computable equilibrium (CGE) model. As a stand-alone model, MAGNET analyses the effect of changes in trade and agricultural policies on international trade, production, consumption, prices and use of production factors (Woltjer et al, 2013c, forthcoming). The model is mainly used to simulate long-term scenarios and to analyse policy options and implications within these scenarios. It is from the class of multi-sectorial, multi-regional, recursive dynamic, and applied general equilibrium models.

The MAGNET model is based on neo-classical microeconomic theory and is the successor of the LEITAP model (Nowicki at al. (2009) and van Meijl et al.(2006)). It is an extended version of the standard GTAP model, as described in Hertel (1997). The core of the GTAP and MAGNET models is an input–output model that links industries in a value-added chain starting with primary goods, following continuously higher stages of intermediate processing, and ending with the final assembly of goods and services for consumption. Extensions incorporated in the MAGNET model includes improved treatment of the agricultural sector (through, for example, like various imperfectly substitutable types of land, an improved land use allocation structure, endogenous land supply function, and the possibility of substitution between various animal feed components), agricultural policies (such as production quotas and different land-related payments) and the biofuel policy sector (capital - energy substitution, fossil fuel - biofuel substitution). On the consumption side, a dynamic CDE (Constant Difference of Elasticities) expenditure function was implemented that allows for changes in income elasticities when purchasing power parity (PPP)-corrected real GDP per capita changes. In the area of factor markets modelling, the segmentation and imperfect mobility between agricultural and non-agricultural labour and capital was introduced.

To model biofuel use in fuel production, we adapt the nested CES function of the GTAP-E model from, and extend it for the petrol sector. To introduce the substitution possibility between crude oil, ethanol and biodiesel, we model different intermediate input nests for the petrol sector. The nested CES structure implies that biofuel demand is determined by the relative prices of crude oil versus ethanol and biodiesel, including taxes and subsidies. In the TAPSIM project much higher substitution elasticies between crude oil\petrol and biofuels are assumed than in the LEITAP model.

The feed by-products of biofuel production (DDGS and BDBP) are demanded only by the livestock sectors in MAGNET. This demand is generated through the substitution process in the feed nest in the livestock sector. To model substitution between different feed components and feed by-products of biofuel production, we use a two-level CES nest describing the substitution between different inputs in the animal feed mixture production. The top level describes the substitution possibility between concentrated feed and its components and grassland (i.e., roughage). The lower intermediate level describes the composition of different types of feed commodities (cereals, oilseeds, DDGS, oilcake, molasse and other compound feed).

4.2 Scenario description

A scenario is a consistent, coherent description of a possible future state of the world. In this analysis we distinguish a baseline, i.e. reference scenario, and two policy scenarios. The baseline and global biofuel scenario are based on the TAPSIM project (Woltjer et al. 2013, forthcoming)[2]. Specifically for Global-Bio-Pact, a new scenario was developed with biofuel policies in Argentina, Brazil and Indonesia.

"Baseline 2020"

The GTAP database reports historical data for 2007. In order to create a reference scenario towards 2020, assumptions are imported on key drivers of the economy between 2007 and 2020, including demographics, macroeconomic growth and technological advancement in agriculture. The model run which provides the best consistent fit to these assumptions is adopted as the "Baseline 2020". In this baseline, the global economy is assumed to develop towards 2020 in accordance with OECD projections for macroeconomic growth and UN projections for population growth and densities. Agricultural productivity develops in accordance with Bruinsma (2009) projections for yield developments expressed in tons per

[2] TAPSIM is an FP7 project that examines the structural adjustment in agriculture in India and the effect on India's trade relations with the EU and the rest of the world. See www.tapsim.eu.

hectare, aggregated according to the country aggregation of the IMAGE database. In this illustrative application to analyse the impact of biofuel policies the biofuels production is determined by the simplified assumption that biofuel shares in transport fuel do not change from the initial shares in 2007. The crude reasoning behind this assumption is that biofuels will not become profitable within the 2007-2020 period without stimulating policies. The baseline incorporates rising energy prices, in particular for crude oil, which creates additional demand for biofuel and causes agricultural input prices to rise. Both factors could, in theory, stimulate biofuel production. Figure 6 reports on the key assumptions for exogenous drivers of change in the baseline.

It is important to note that the baseline should not be interpreted as a forecast but rather as a consistent reference for the ex-ante evaluation of policies McCalla and Revoredo (2001). The Baseline 2020 is developed for the specific purposes of the TAPSIM project, which examined the potential impact of a very ambitious blending mandate in India. The model was calibrated with relatively large options to produce biofuel and to substitute crude oil for biofuel. With this caveat, the key baseline values for selected region provide several relevant insights (Figure 2. At the world level, economic growth outpaces population growth by a factor three, which implies that on the average, per capita incomes and purchasing power improve substantially over the projection period. There is an unequal distribution of economic growth across countries, and the specific regions under examination rank among the best performers, with Tanzania and Indonesia raking third and fourth at close distance to India and China.

The growth of agricultural productivity, in particular of crop yields, just exceeds population growth over the projection period at the global level. Yield more or less keep pace with demography for the countries under study except West-Africa. Rising yields could in principle compensate for an expanding population in these regions and if diets remained unchanged, food security could develop at status quo throughout the projections. There is, however, an increase in welfare that goes along with the population trend, and which is associated with acceleration towards a richer diet. The substitution of basic grains to consumption of meat and dairy products will likely result in reduced food availability towards 2020. West Africa, where population growth to 2020 is almost double the projected yield growth, will experience a decline in food self-sufficiency and becomes more dependent on food imports.

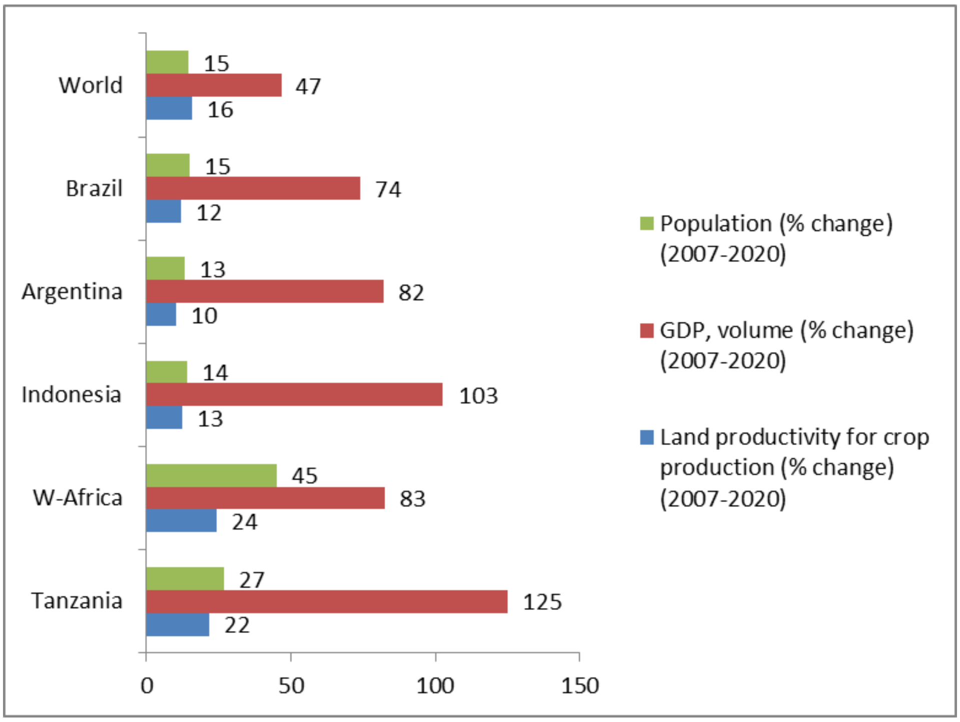

Figure 2. Baseline assumptions for population growth, GDP growth and land productivity for selected regions

Policy scenario 1 “Global biofuel scenario” called “Global”

Several regions in the world impose a scheme of targets for biofuel shares in transport use, which provides a substantial demand pull for the production of feedstock and spurs the growth of an international biofuels market. Biofuels are assumed to move across borders without export restrictions but may be charged import tariffs. Price-based allocation mechanisms determine the global specialization patterns for the production of feedstock and biofuels. The “Global” scenario will allow an assessment of socioeconomic effects of global biofuel demand on agricultural development in poor countries, and an indicative assessment of the effects on several dimensions of food security.

Table 3. Global biofuel scenario: target biofuel shares in transport fuel use (2020)

India	10%
China	15%
Indonesia	10%
Japan	5%
Oceania	3%
South East Asia	5%
EU27	5%
USA	10%
Canada	3%
Brazil	25%
Argentina	7%
Rest of Southern America	10%

Notes: Biofuel shares in transport sectors also used in the “local biofuel scenario”. The biofuels shares are based on Banse et al. (2012). For EU and India lower targets are used as they down-scaled their ambitions. The EU27 recently scaled down its ambition from 10% to 5%. The targets for the Global-Bio-Pact focus countries are: Indonesia: 10% of energy use in transportation in 2025. The target for 2025 is for 17% of energy to come from new and renewable sources, including 5% from biofuels (Wright (2011 a), (2011 b); Argentina: 7% of energy use in transportation in 2025. Minimum 5% blending requirement (on volume basis) for petrol with anhydrous bioethanol and diesel with biodiesel from the beginning of 2010 (Sabarra and Hilbert 2011); Brazil: 25% (Gerber Machado and Walter 2011)

Policy scenario 2 “Global-Bio-Pact domestic biofuel scenario” called “Local”

A second policy scenario is designed specifically for Global-Bio-Pact. Policy-makers in Brazil, Argentina and Indonesia are aware of the potential positive and negative effects of greater biofuels production and use, and place different weights on the importance of realizing the biofuel ambitions. This scenario examines the policy space for improving the food security outcomes in the countries listed as a consequence of a policy change regarding the domestic biofuel share in fuel transport use. This option is formulated as a domestic target where the rest of the world does not engage in additional biofuel policies: (BASE+3).

4.3 Sector and Food security analysis

This section describes the results of the Local and Global biofuel scenario’s. We will concentrate on the effects in the “local” biofuel countries (Brazil, Argentina and Indonesia) and in African countries.

4.3.1 Biofuel ambitions

This section illustrates the challenges related to the biofuel initiatives by a comparison from the initial and intended level of biofuels and what it means in terms of quantity changes.

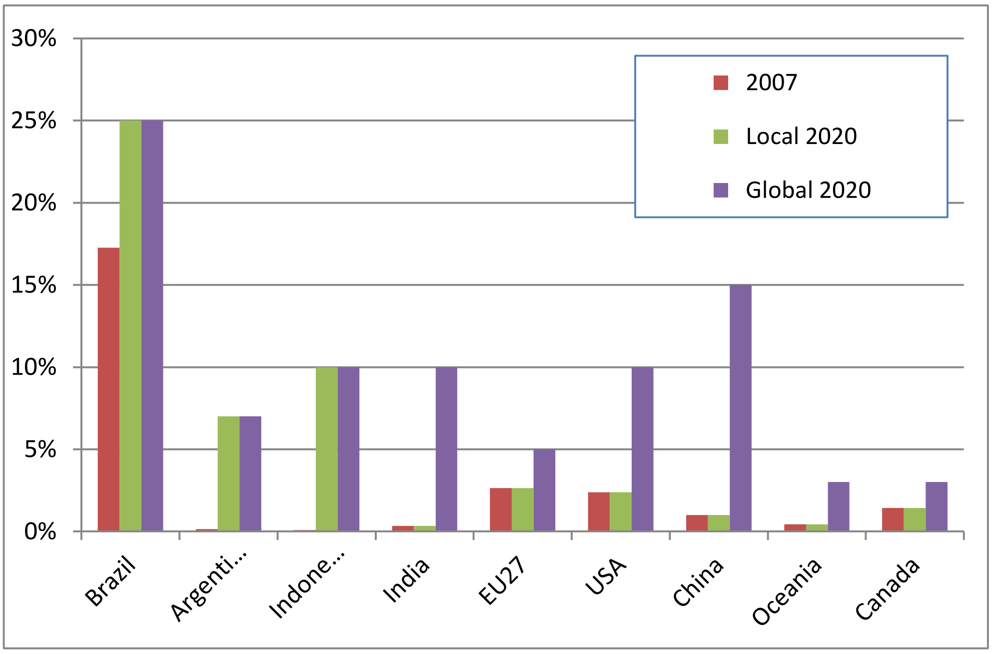

Figure 3. SHARE OF BIOFUELS IN FUEL CONSUMPTION FOR TRANSPORTATION FOR SELECTED REGIONS, 2020

Figure 3 gives a graphical illustration of the biofuel ambitions and biofuel challenges in the various parts of the world. The challenges can be deducted from a comparison from the biofuel share in 2007 and the ambitions of the biofuel policies. As can be seen, the biofuel shares in most countries are low. Only Brazil (17%), USA (2.6%) and EU27 (2.4%) use biofuels to a substantial degree. For Canada and China some minor initial biofuel shares are observed. In all other regions of the world, the initial biofuel shares are nil to negligible. The biofuel ambitions as intended in China, India but also in Indonesia and Argentina must therefore be qualified as very challenging to realize.

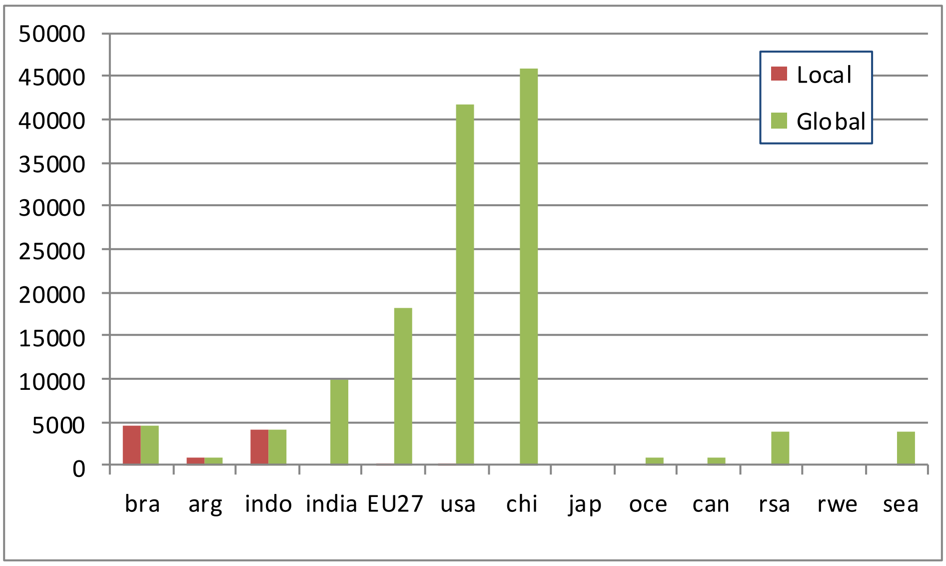

Figure 4. Biofuel use, change induced by local and global biofuel policies, 2020 (volume, absolute quantity change from situation without biofuel ambition in similar setting)

Figure 4 shows that in volume terms the biggest challenges are in China and the USA given the large size of their petrol markets and the relatively high level of ambitions. In volume terms the challenge related to the EU27 biofuel target is much lower, now that the EU27 recently scaled down its ambition from 10% to 5%. The volume challenge for India is very challenging as good agricultural land is relatively scarce in India, food demand is high and biomass trade relations are not very well developed.[3] The biofuel challenges in volume terms from a global perspective are moderate in the Local scenario.

4.3.2 Food availability: land demand for biofuel crops and agricultural output

The countries with more ambitious biofuel targets will depend on producer regions outside their territory for supplying feedstock for first generation biofuels. In the reference scenarios, the EU has a net import position in biofuel crops. South America and the US strengthen their position as net exporters. The impact of biofuels policy on the demand for land is shown. A priori, it is expected that increasing biofuel demand in the EU will increase demand for land in the focus countries where agricultural land can be brought into production.

[3] As indicated above, the baseline model is calibrated to bridge the difference between current low levels of use and an ambitious biofuel target.

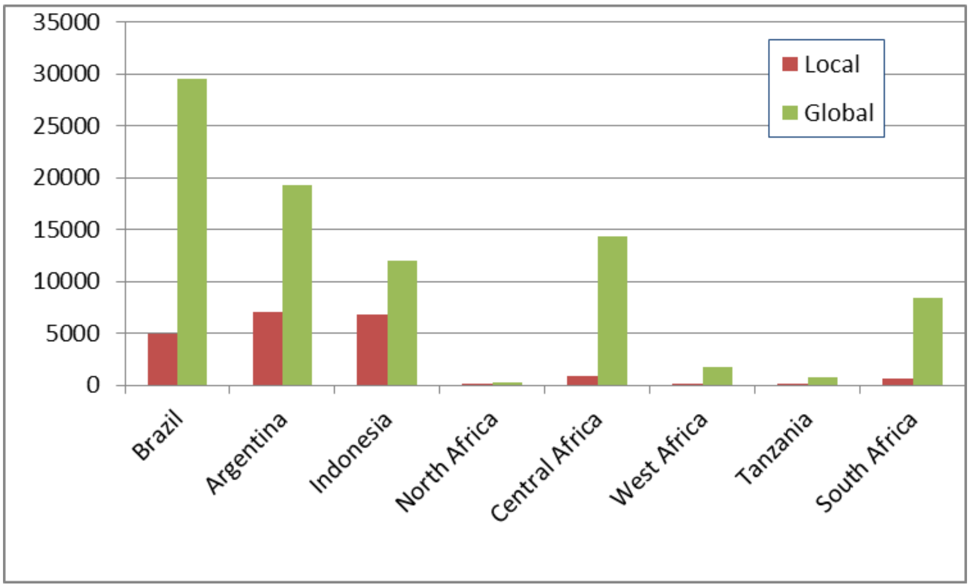

Figure 5. Impact of biofuels on land use in acres (change from baseline)

Land expansion at world level is projected 3 million hectares in the Local biofuel scenario and 46 million hectares in the Global scenario. Within the Local biofuel scenario the main impact on land are in the biofuel countries themselves as these countries have capabilities to produce a large part of the biomass themselves and these countries are able to extend their agricultural land by converting savannas or forestry land into agricultural land. There are some land use effects in Central Africa and South Africa. There are no land use effects in North Africa as there is almost no potential agricultural land left in this area.

In the Global biofuel scenario the land expansion is largest in Brazil and the USA. In Brazil there are still quite some opportunities to extend agricultural land and in the USA the pressure is high to extend the agricultural land given their large biofuel ambition. In the global initiatives the land extension in our focus countries is much higher than in the Local biofuel scenario despite the biofuel ambition in their own countries does not change. The land use expansion in Brazil is six times higher than in the Local scenario as Brazil is very competitive and is able to expand their agricultural land use. In Argentina and Indonesia the land use expansion is a factor 3 and 2 higher respectively. The impact on land use expansion in Africa is also large as they start producing biomass for biofuels in the countries with a biofuel ambition. In North Africa there is still no effect as there are no possibilities to increase land in North Africa according to our database. The impact for Tanzania and Western Africa appears limited, but we have to take into account that these are relatively small countries.

Table 4. Agricultural production, change in % 2020 relative to 2007 (deviation from baseline)

		World	Brazil	Argen-tina	Indo-nesia	North Africa	Central Africa	West Africa	Tanzania	South Africa
AGRI	Local	0.1	0.1	1.4	0.9	0	0	0.1	0	0
	Global	0.7	0.5	4	1.6	0.4	0.4	0.5	0.2	0.3
Grains	Local	-0.1	-1.2	0.1	-0.1	0.1	0	0	0	0
	Global	14.8	-2.8	1.9	0.3	1.2	0	0.1	0.4	0.3
Oilseeds	Local	1.4	0.8	3.9	6.6	0.5	0.2	0.2	0.6	1
	Global	8.2	6.1	12.4	10.7	4.5	1.9	1	2.5	3.8
Sugar	Local	0.9	5.3	-0.6	0.1	0.1	0.2	0.2	0.1	0
	Global	9.4	19	-1.5	-2	0.2	1.7	1.2	0.4	0.1

The biofuel targets lead to a modest increase in total agricultural production (AGRI). In the Local scenario the increase at world level is 0.1% and in the Global scenario it is 0.7%. The impact is quite small as biofuel related crops represent only a small share of total agricultural and food production (including food processing sectors such as beverages and tobacco). In the Local scenario the impact is highest in Argentina followed by Indonesia and Brazil. The relative impact in Brazil is rather limited as they have already a high initial biofuel share and related industry. In the Local scenario the impact is highest for oilseeds as both in Argentina (soybeans) and Indonesia (palm oil) this is the main feedstock. The increase in world production of sugar is largely driven by Brazil. The impact on world grains is negative in the local scenario as this feedstock is not the main feedstock for biofuels in the selected biofuel countries and this feedstock is competed away by feedstock (oilseeds, sugar) used for biofuels.

In the Global scenario world grain production increases with 15% which is mainly driven by increased maize production in the USA. Global oilseed production increases with 8% and this is driven by production in Argentina, Indonesia and Europe (oilseeds). Global sugar production increases with almost 10% and is driven by an increase in sugar production in Brazil with almost 20%. In general feedstock production for biofuels also increases in Africa. Oilseeds (jatropha) is the key feedstock in Africa and production increases with about 4% in North and South Africa, about 2% in Central Africa and Tanzania. Sugar production increases with almost 2% in Central Africa and 1% in West Africa.

In Brazil and Rest of America production growth exceeds the increase of land under biofuel crops in most scenario settings. As land is the scarce factor land prices increase relatively to other factor prices and farmers will intensify their production process by using more labour and capital. This causes an increase in land productivity. In countries such as Brazil and other South American countries where there is still land available to put into agricultural production this effect will be less than in countries that have almost no additional land to take into production (this effect is partly due by our land supply curve, see Meijl et al. 2006).

4.3.3 Food accessibility: producer and consumer food prices

The backdrop for our analysis of price impacts is that in the baseline real world prices for food and agricultural products fall at an annual rate of 0.5% over the projection period. This is caused by an inelastic demand for food in combination with a high level of productivity growth. The projected expansion of supply in Brazil and high income countries pushes prices downward. This result confirms a long term trend of the past decades, and would suggest that food over time becomes generally more accessible to the poor and vulnerable. Recently, however, arguments have been raised on reversals of this trend under the influence of population growth, diet change, depletion of natural resources, yield variation under altering climatic conditions, as well as first generation biofuels (Nelson 2009),(Godfray et al. 2010). Economist disagree what are the main causes of this recent price increase (e.g. weather) and whether this recent increase in agricultural prices is a temporary or structural change (see, Meijerink et al. 2011).

A priori, an expansion in the demand for biofuels is expected to lead to increases in food prices. As land is a relatively scarce resource, the extra land required to increase crop production for biofuels comes at a higher price. The higher crop price is transmitted to food prices either through direct input costs (e.g. grain) or through indirect input costs (e.g. feed grain costs that affect the price of meat).

The increased biomass demand by the higher biofuel ambition leads to higher agricultural prices. The impact on total agricultural prices is limited as biomass for biofuels is still a small share in total agricultural output. The impact of the Local scenario on world prices is limited. Relative to the Global scenario the volume involved is much lower and the selected countries can produce a large part of the required biomass themselves. The impact on the price of oilcakes is negative as a lot of this by-product is produced and oilseeds (soy, palm) is the main feedstock in the Local scenario. The large supply of this by-product provides downward pressure on prices at the feed market.

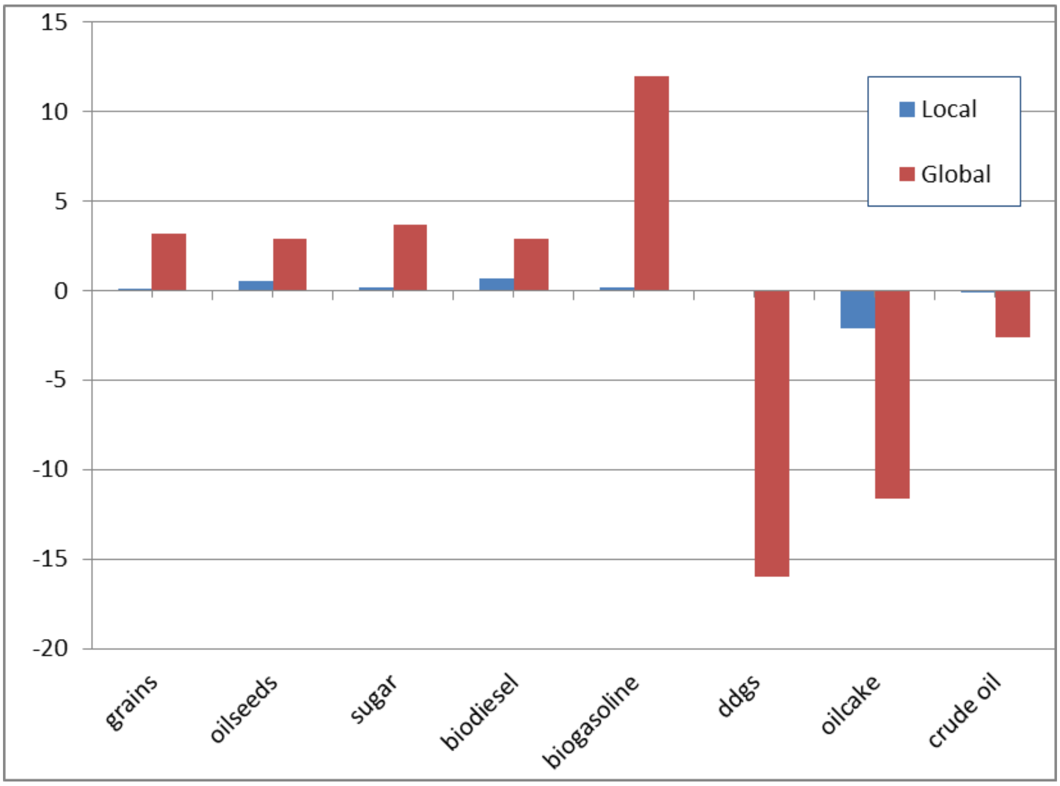

Figure 6. Change in world market prices (% change) (2020 relative to baseline)

In the Global biofuel scenario the impact on world prices is much higher. The global gasoline and biodiesel prices increase by 12% and 3%. Feedstock prices of grains, sugar and oilseeds increase all with about 3%. The prices of the by-products DDGS and oilcake decrease with about 15% and 10% respectively. The crude oil price decreases slightly with about 2% as demand for crude oil decreases as it is substituted by biomass. The price increases are lower than in e.g. Banse et al (2008) or (2012). One of the causes is the high elasticity of substitution between crude oil based petrol on the one hand and biodiesel\ethanol on the other hand.

4.3.4 Food accessibility: farm income and wage earners

In this section the perspective is shifted from availability and prices at the national level to the consumption side. Household income determines the room for expenditures; poor consumers in developing countries spend 60% of their income or more on food expenditures. Both climbing food prices and declining income may cause food to become less or more affordable. As poor and vulnerable households live on small surpluses and few assets to cushion crises situations, small income declines could mean a substantial marginalization of people's livelihood. In our framework of analysis, wages and farm earnings are employed as indicators and combined with food price changes to assess the impact of biofuels on the accessibility of food.

With increasing land and food prices, the a priori expectation is that biofuels will lead to a small reduction in food consumption in developing countries. The table reports on the overall impact of the global biofuels policy on food consumption (measured in changes in quantities, valued in constant prices).

We first analyse the impact of biofuels on food consumption. With increasing land and food prices, the a priori expectation is that biofuels will lead to a small reduction in food consumption in developed and developing countries. Table 5 reports on the overall impact of the EU biofuels policy on food consumption (measured in changes in quantities, valued in constant prices).

Table 5. Private food consumption under alternative biofuel policies (% change relative to base scenario)

	World	Brazil	Argentina	Indonesia	North Africa	Central Africa	West Africa	Tanzania	South Africa
Local	-0.02	-0.02	-0.21	-0.44	-0.03	-0.02	-0.01	0.00	-0.01
Global	-0.26	-0.05	-0.13	-0.35	-0.27	-0.45	-0.14	0.05	0.03

Table 5 shows that increased use of biofuels leads to small reductions in food consumption in countries that imply biofuel policies in the Local scenario. The impact are largest for Indonesia (-0.4%) and Argentina (-0.2%). For Brazil the impact is lower as they have already a large and competitive biofuel sector and the increased targets can more easily be met. The impact of the Local scenario on the rest of the world is limited as the increased amount of biofuels is limited and countries can meet a part of it with domestic production. The impacts in Africa are small.

In the global scenario the impact is higher at the global level but still not very high for total food consumption. Total Food consumption reduces with 0.3%. reduction. The reductions stay low in Brazil and are a bit less in Argentina and Indonesia than in the Local scenario. The latter is caused by higher export prices and therefore earnings for these agricultural exporters. For North and central Africa the results are negative with 0.3 and 0.5% respectively. Drivers are on the one hand are the higher food prices and on the other hand the lower crude oil price. The latter is important as these regions are relatively large exporters of crude oil. Lower oil prices reduce income in these countries which leads to lower consumption. For Tanzania and South Africa the effects are small but surprisingly positive. Key is that these regions are net exporters of agricultural products and importers of crude oil. The terms of trade improve and therefore the income in these countries increases.

Farm incomes are important as driver of food security in the rural areas because most farmers produce insufficient amounts of food to sustain the food needs in the household. Most farmers buy more food than they sell on the market, i.e. they are net buyers of food. Table 6 indicates that biofuel policies are beneficial for farm income (value added is used as a proxy). In the local scenario especially the farm incomes increase in the countries that imply the biofuel mandates. In the global biofuel scenario the increase in farm income in the biofuel crops (cereals, oilseeds, sugar) is about 12% globally. The farm income increase in

Brazil, Argentina and Indonesia is in line with this. The impact on the African countries which note engage themselves actively in biofuel policies see a modest increase of about 1.5% in terms of farm income in the biofuel crop sectors.

Table 6. Total income per sector at market prices (% change relative to baseline, 2020)

		World	Brazil	Argentina	Indonesia	North Africa	Central Africa	West Africa	Tanzania	South Africa
Biofuel crops	Local	0.7	2	3.3	7.3	0.1	0.1	0.2	0.2	0.2
	Global	11.7	9.7	12.5	12.5	1.5	0.2	1.4	1.4	1.2
AGRI	Local	0.2	0.7	1.9	1.6	0.1	0	0.1	0.1	0.1
PRIM	Global	3.1	3.5	7.6	3.3	0.8	-0.2	0.8	1	1

Next to farm income the wage rates of unskilled labour is important as these might be an indication of p0or people without a farm.

Table 7. Wages for unskilled labour in the agri-food sector (% change) (2020, relative to reference scenario)

	World	Brazil	Argentina	Indonesia	North Africa	Central Africa	West Africa	Tanzania	South Africa
Local	0.05	0.2	0.67	0.51	0.01	0	0.04	0.06	0.03
Global	0.71	1.18	3.89	1.52	0.14	-0.39	0.48	0.7	0.4

The segmented market assumption within the MAGNET model implies that wage development between agricultural sectors and other sectors within the economy can be different. A farmer or worker that is skilled in agriculture cannot easily switch to jobs in manufacturing and services as he lack these skills and it takes time to learn other skills. In this biofuel example something “good” happens to the agricultural sectors by an increased demand for their products and this implies that the intensively used specific factors such as land and unskilled labour benefit relatively more. Table 7 shows that the wages of unskilled labour increase in the agricultural sectors whereas they are almost stable in the manufacturing and service sectors. Workers in the agricultural sectors benefit .

In our framework of analysis, wages of unskilled workers are employed as indicators and combined with food price changes to assess the impact of biofuels on the accessibility of food

Table 8. Purchasing power indicators

		World	Brazil	Argentina	Indonesia	North Africa	Central Africa	West Africa	Tanzania	South Africa
Agri-unskilled	Local	-0.01	0.00	0.02	-0.05	0.00	0.01	0.02	0.01	0.02
labour	Global	-0.43	0.02	1.09	0.18	0.03	0.11	0.25	0.21	0.23
Non-Agri unskilled	Local	-0.06	-0.20	-0.65	-0.56	-0.01	0.01	-0.02	-0.05	-0.02
labour	Global	-1.14	-1.16	-2.80	-1.34	-0.11	0.50	-0.23	-0.49	-0.17

Note: Purchasing power indicator is computed as the % change in wages for unskilled labour in agriculture or non-agriculture minus the % change in primary agricultural consumer prices.

Table 8 confirms the earlier results that the food purchasing power of unskilled labour that work within agriculture increase and decrease for people in other sectors

4.3.5 Macro-economic performance

The GDP effects are slightly negative at world level. Biofuel policies imply that fossil based technologies are replaced by biomass based technologies. At the moment most biofuel based technologies are not competitive which from an economic point of view means that you replace an efficient technology by a less efficient technology. This leads to lower GDP as resources are allocated less efficiently. The GDP impacts are most negative in countries, such as Argentina and Indonesia, which imply the biofuel policies and where the biobased technologies are not competitive. In Brazil the GDP impact is slightly negative in the Local scenario and positive in the Global scenario. The first is due to the fact that biobased fuels in Brazil are competitive with fossil based fuels and therefore the negative impact on GDP is limited. The positive GDP effect is caused by a terms of trade improvement by higher agricultural prices. The impact of the Global biofuel directives is slightly negative for most African countries. For North and central Africa the results are slightly negative. Drivers are on the one hand are the higher food prices and on the other hand the lower crude oil price. The latter is important as these regions are relatively large exporters of crude oil. Lower oil prices reduce income in these countries. For Tanzania and South Africa the effects are small but surprisingly positive. Key is that these regions are net exporters of agricultural products and importers of crude oil. The terms of trade improve and therefore the income in these countries increases.

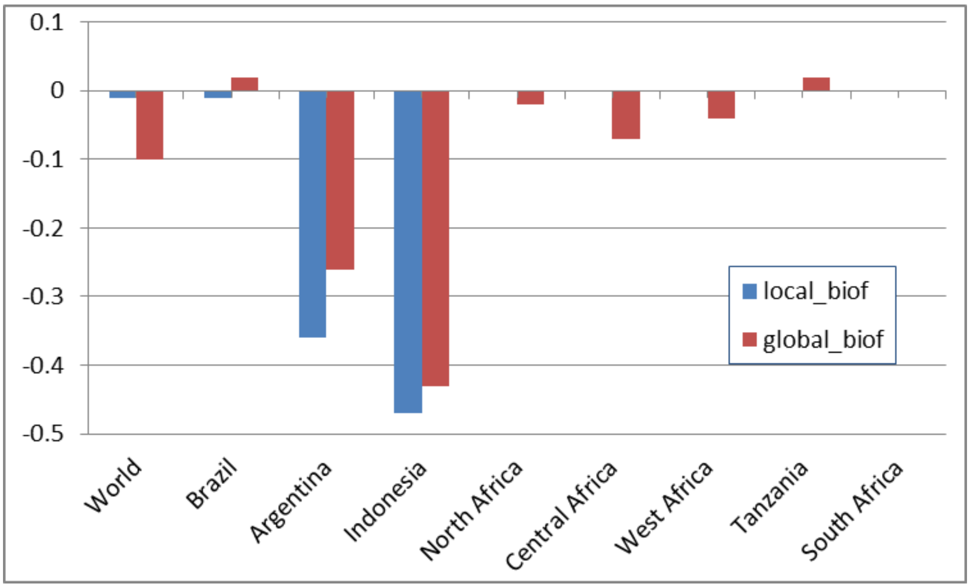

Figure 7. GDP volume (% change) (2020, relative to baseline)

5 Limitations of the CGE analysis

The above analysis uses a highly aggregated framework to indicate the impact of biofuel policies on food security at various levels. Of the impact pathways described, resource competition and income effects are aptly covered in this framework. The distributional analysis is basic, as price and income effects are related to a single representative household per country or region only. The analysis encompasses in the aggregate the net position with respect to production and consumption i.e. whether the household is a net producer or consumer. A net producer has a food surplus to sell for cash income on the market . A net consumer or produces insufficient food for home consumption and therefore relies on markets for food purchases. The analysis returns a budget share for food of the representative household. As the food share in the budget rises to 50% of all spending or more, households become particularly vulnerable to rising prices.

The first limitation on the model-based assessment that second generation biofuels are not taken into account. Further research on global biofuels policies and higher blending shares, together with 'second generation' biofuel technology will further inform research into the competing demand for food, feed and fuel uses. A related comment relates to the treatment of technical change which is largely exogenous to the system while it is one of the most important drivers. An alternative approach would be to endogenice technological change by an explicit treatment of R&D sectors or price induced technological change. Furthermore, sustainability criteria are not explicitly taken into account.

The second limitation concerns the inability of current CGE models to capture nutritional aspects (Rutten and Chant, 2012). This is not only important from the perspective of obtaining more realistic outcomes on quantities consumed (there is, for example, a biological constraint on what humans can physically stomach, which is a stronger constraint than those imposed by the Engel properties), but also important from the perspective of diet quality. To date, the CGE models that have looked at nutrition (including, for example, the global model by have narrowly focussed on dietary quantity (i.e. caloric intake) which has less correlation with nutrition-related chronic diseases (such as cardiovascular disease and cancers) than dietary quality (i.e. nutritional composition in terms of, for example, fat and micronutrient content).

Opening up the consumption basket in terms of nutrient content will enable identification of changes to nutrient adequacy of diets that may result from changes in the wider economy (monitoring function) and so where policy action may be needed. Several authors have identified this as a key area of research need in view of rising and increasingly volatile food prices and the need to redirect the diet transition. A nutrition module will incorporate detail on nutritional aspects of quantity (calorie content) and quality (nutrient content) of food items into the model. The module will account for the difference between the purchase and consumption of food. The nutrition module can take the form of a matrix incorporating nutritional aspects per unit of food consumption for all food items in the GTAP database.

In particular in periods of prolonged food price spikes, as we have seen in 2007-08 and 2010-11 households will need to find ways to sustain themselves through the crisis. Among the coping mechanisms that have been observed are reduced spending on high-value foods such as meat and dairy, fruit and vegetables, processed products. Divert food expenditure to more basic foods such as grains and legumes. A tentative observation from the recent food crises is that most of the world's undernourished population ultimately defended calorie intake, apart from people in particular areas with localized catastrophic shortages. The brunt of the impact of price spikes was the reduced intake of more nutritious foods, depriving hundreds of millions of people from key nutrients. The intake of macronutrients (calories) was rather stable at the expense of micronutrients including vitamin A, iron and zinc.

The third major limitation is the lack of coverage of determinants in relation to the stability of food security outcomes at the household or individual level. As was argued in section 2, food price volatility is a growing concern for the livelihoods of vulnerable households. The contribution of biofuels policies and investments on swings in food price is typically not covered by the modelling framework proposed, which then requires additional assessments. Moreover, the assessment framework is of limited value for an evaluation of the coping mechanisms of vulnerable households under biofuel-induced compromises to food access. At best, a diversification of the income base can be derived from the analysis. Additional data collection and analysis will be needed to examine the stability of livelihoods. Florin et al. (2012), for example, analyse with survey data how biofuels increase income source diversity of smallholder or family farmers. They find that the additional income source supports current risk management strategies. Florin et al. propose to collect data on the Simpson's diversity index of revenue,[4] on labour inputs and labour use efficiency (days per year; revenue per day); and on purchased inputs and purchased input use efficiency (revenue per year; revenue growth rate).

The fourth limitation relates to the mutual relation between biofuel/energy development and long term price developments. The push for biofuel development will be strong when fossil fuel prices are elevated, under the influence of rates of demand growth that outstrip discovery rates of new fossil fuel supplies. Other factors are conflict and geopolitical forces. A key concern is that high prices for crude oil are in themselves a critical of food insecurity: agricultural production costs climb (Solano-Hermosilla, Silvis, and Woltjer 2010) and, more important, general inflation (CPI) pressures erode purchasing power. Given the effect on real income and expenditures, we can identify the budget share of energy (whether for cooking, heating or transport) of vulnerable consumers as a factor that drives the weight of this particular impact pathway. Note the importance of distribution policies in the background. Agricultural input costs and household energy costs are subsidized in key food insecure regions (India and other countries in South Asia), which reduces the budget share of energy.

6 Conclusion

The relations between first generation biofuels and food security require careful examination, which take into account the idiosyncratic conditions surrounding a planned investment or policy that aims to advance the use of biofuels. From an economic perspective, there are at least four possible impact pathways that connect biofuels to their impact on food security. The pathways relate to land competition, impact on short and long term developments in food prices, impact on farm income and macroeconomic performance. Based on a limited qualitative assessment of these individual pathways, it is concluded that the direction of impacts on food security is not a priori clear. A basic framework is introduced for an encompassing analysis, and applied to a set of targets for biofuel share in fuel use for the purpose of illustrating the mechanisms at play. A preliminary conclusion from the illustrative exercise is that the level of biofuel ambition alone provides insufficient grounds to analyse their impact; the socioeconomic setting (e.g. a policy framework aimed more at global trade integration or self-sufficiency in the region) that forms the backdrop for a biofuel policy is a key determinant of the impact of the biofuel policy on agricultural markets and global food security.

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[4] The Simpson's diversity index of revenue (subsequently referred to as diversity index) (Simpson, 1949) is calculated as follows where I refers to the fraction of total revenue from activity i and n is the number of revenue earning activities. $\text{Diversity index} = 1 - \sum_{i=1}^{n} I_i^2$ The index takes values between zero and one where zero indicates no diversity (one source of revenue).

An illustrative analysis using a global modeling framework project shows that a global biofuels policy could contribute to upward pressure on land and food prices in several developing regions. While global price and land use effects appear to preclude a negative evaluation on food security, there are several positive in-country effects that call for further specification and analysis.

The focus countries of the analysis (Brazil, Argentina and Indonesia) and several African regions will expand land use and biofuel production in response to a strong demand on the world market, as simulated by ambitious targets for biofuel use in the largest economies of the world. The land use implications are substantial: competitive Brazil produces six times beyond its local use. Its production expansion is based on an expansion of agricultural land use and on increasing productivity. In Brazil, Argentina and Indonesia the land use expansion is a factor 6, 3 and 2 higher respectively than required for an ambitious national biofuel target. The impact on land use expansion in Africa is also large as they start producing biomass for biofuels in the countries with a biofuel ambition.

There are several arguments to underpin the consistency of these observations. First, there is an unused global land supply which is assumed to accommodate rising feedstock demand. Second, biofuel policies raise world feedstock prices, which induce intensification and technical change into the agricultural sector. The analysis suggests not only that technological change is a strong determinant of the overall impact of biofuels, but also that raising biofuel ambition may induce an acceleration of agricultural innovation. Third, biofuels potential is evaluated in the analysis against the backdrop of given crude oil prices; depending on the settings – in particular the assumed GDP growth – price incentives and market dynamics come a long way in promoting the development of a biofuel sector without policy intervention.

The combined impact of the price and income effects from a biofuels policy on food security can be assessed with the framework presented on various levels, from global food availability to national self-sufficiency and household-level affordability. The results suggest that an ambitious set of biofuel targets could structurally raise global crop prices by 3% in 2020, on top of an already elevated price level in the 2007 reference year.

A shortcoming was listed in terms of the limited scope to address (excessive) price swings and fluctuations in income, which are main determinants of the risk of falling into a state of hunger and malnutrition. Given the wide scope and multiple dimensions of the food security concept, a comprehensive framework is needed that covers all pathways and a broad set of indicators. Improved insight into nutritional impact – a basic determinant of food utilization – is a first priority for extending the framework towards maximum relevance for decision-making on food security. However, even to incorporate the impact pathways for food availability and food accessibility requires substantial progress the current state of the art. Starting from the existing and already advanced modelling framework, which integrates economics and biophysical perspectives on the food and energy systems, the following elements could be thought of as useful additions:

1. *The evaluation of the potential of bioenergy and biofuel to promote rural development.* The impact of bioenergy on income generation and therefore food (in)security depends partly on the production technology employed, and the institutional setting. The analytical framework would need to incorporate how the bioenergy supply chain is integrated into agricultural, social and economic systems. Large scale biofuel investments may enhance growth and poverty reduction despite some displacement of food crops by biofuels. Benefits depend on the production system, labour-intensity and the land rent scheme. Technology spill-overs will need to be assessed, as these have been identified as major contributors to positive growth effects, also for making growth inclusive. Further the analysis should incorporate a valuation of by-products to improve the representation of market incentives, and consider non-linear approaches to technological change.

2. Capture nutritional aspects, both for long term and short term implications. The individual and household level food security indicators presented in the paper can be strongly improved by providing more detailed impact assessments for typologies of households. Two other challenges appear at least as prominent. First, there is a need to open up the consumption basket in terms of nutrient content in order to enable the identification of changes to nutrient adequacy of diets. Modelling frameworks should move beyond dietary quantity (calories) towards quality (i.e. nutritional composition in terms of, for example, fat and micronutrient content). A nutrition module can take the form of a matrix incorporating nutritional aspects per unit of food consumption for all food items in the database of the MAGNET model. Second, the assessment framework is of limited value for an evaluation of the coping mechanisms of vulnerable households under biofuel-induced compromises to food access. At best, a diversification of the income base can be derived from the analysis. Complementary assessment frameworks are required to address the stability and risk dimensions of food security in relation to biofuels.

Notwithstanding the obvious merit of a macro-level modelling framework of analysis, a breadth of field survey and micro-level analysis is required to unravel the implications of biofuels for rural economic development and household livelihood.

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