Profits versus jobs: evaluating alternative biofuel value-chains in Tanzania

By[1]

Giacomo Branca[§*], Luca Cacchiarelli[§], Irini Maltsoglou[#], Luis Rincon[α],
Alessandro Sorrentino[§], Stefano Valle[§],

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[1] Authors are listed in alphabetical order. However, G. Branca is the principal contributor. [§] Dipartimento di Economia e Impresa (DEIm), Tuscia University, Vie del Paradiso 47, 01100, Viterbo, Italy . [#]FAO, V.le delle Terme di Caracalla, 00100, Rome. [α]Universidad Nacional de Colombia, Cra 27 # 64-60 Manizales, Caldas, Colombia [*]Corresponding author, branca@unitus.it (+390761357646)

Abstract

Biomass production for bioenergy use may contribute to rural development by increasing household incomes, local employment and energy supply, especially in developing countries. This paper presents a value-chain approach to evaluating the profitability and competitiveness of producing biodiesel or ethanol. We apply a 'rapid appraisal' accounting framework to the case of Tanzania, which is a data scarce setting and therefore well-suited to the proposed approach. The framework also estimates the number of jobs created in the biofuel sector under different production arrangements and related demand for land resource. We evaluate the potential trade-offs between different scales of biofuel production (both the scale of feedstock production and biofuel processing). We find that only sunflower-biodiesel is profitable, especially if produced in large-scale estate farming systems. Estate farming is the best option for profits and competitiveness, even if domestic biofuel production is never competitive on the international market for energy. We also find that the number of jobs depends crucially on the involvement of smallholders. Establishing out-grower schemes (or similar arrangements), rather than estate farms, should be a key policy objective if biofuels production is going to improve rural economy. However social benefits may be gained at a cost of reduced international competitiveness and increased land exploitation.

Key words: liquid biofuel, smallholder, contract farming, production cost, rapid assessment

1. Introduction

Liquid biofuel[2] is a fast-growing market for agricultural products (Junginger et al. 2014, Lamers et al. 2011, Mathews 2007, Matzenberger et al. 2013). Many developing countries have initiated biofuels development programs and in some contexts production is expanding quite rapidly. A large body of literature has focused on the global and regional impact of biofuel production (Esposti 2008, Jaeger and Egelkraut 2011, Schmidhuber 2007). Many authors highlight that biofuel production in developing countries can enhance energy security, open export markets, create income-generating activities and new job opportunities therefore contributing to rural development and overall poverty reduction (Arndt et al. 2012, Ewing and Msangi 2009, Hill et al. 2006, FAO 2010 and 2012, Müller et al. 2008, Negash and Swinnen 2013, Pingali et al. 2008).

One key element of this debate is that biofuel investments could potentially enhance economic growth in rural areas but this will crucially depend on the role of smallholders in the biofuel economy and on the associated institutional set up (Arndt et al. 2010). As the biofuel industry is an emerging industry in most developing countries, fully developed supply chains hardly exist. Contract farming models can provide the coordination that is needed in newly developing supply chains (Bijman et al. 2009) while contractual arrangements that favour an outgrower configuration over estate farming may provide direct welfare benefits to smallholders (Ewing and Msangi 2009). There is evidence that food crop yields increase after engaging in outgrower programs due to technology spillovers when inputs and extension services are supplied (Benfica 2006, Glover 1990, Uaiene 2008). Additional benefits expected under the outgrower scheme include guaranteed markets, grants for community projects and employment opportunities (CSBF 2009, Mwakajie 2012, Phalan 2009; Porter and Phillips-Howard 1997).

However, private investors may favour different institutional arrangements which can be more profitable (e.g. estate farming), especially in developing countries where smallholders' productivity and profitability are held back by lack of access to and poorly functioning commodity markets, limited access to financial markets, poorly performing producer organizations and absence of input markets. Trade-offs between private and social optimal outcomes exist and this may result in market failures to be corrected through adequate policy incentives. For example, it is argued that governments should consider not only financial

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[2] In this paper biofuel refers to biologically based fuels produced from biomass, i.e. biodiesel and bioethanol. In Tanzania, straight vegetable oil is also used as a diesel alternative but it is not included as biofuel in this context.

incentives but also actions aimed at protecting smallholder by ensuring contracts mutually beneficial to growers and investors and supporting poorer households to overcome barriers to market entry (Ewing and Msangi, 2009).

In this frame, we present a value-chain approach to evaluating the profitability and competitiveness of producing biodiesel or ethanol. There is an extensive economic literature on the quantitative analysis of bioenergy value chains and food security in developing countries. Methodological approaches adopted can be grouped as follows. A first set of studies rely on Computable General Equilibrium (CGE) models. For example, FAO (2010) illustrates how biofuels investments in Tanzania affect economic outcomes and how economic growth is linked to household incomes; Arndt et al. (2010 and 2012) evaluate different biofuels production options and estimate their impacts on food crops, economic growth, income distribution and poverty in Mozambique and Tanzania; Timilsina et al. (2012) analyze the long-term impacts of large-scale expansion of biofuels on land-use change, food supply and prices, and the overall economy in several countries. A second group of studies makes use of various micro-econometrics approaches. For example, Negash and Swinnen (2013) apply endogenous switching regression methods on survey data to assess the impact of castor production on poor and food insecure rural households in Ethiopia. Rajcaniova et al. (2014) apply time-series analytical mechanisms to estimate the long-run relationship between energy prices, bioenergy production, agricultural commodity prices and production, and the global land use change. A third set of studies adopts Spatial Decision Support Systems (SDSSs) models. For example, Verstegen et al. (2012) illustrate a case study for Mozambique in which it is evaluated where bioenergy crops can be cultivated without endangering nature areas and food production, when population and food intake per capita will increase and thus arable land and pasture areas are likely to expand. Last, several studies rely on a set of indicators which usually consider socio-economic and environmental sustainability of bioenergy systems. For example, Dale et al. (2013) identify 16 indicators that fall into the categories of social well-being, energy security, trade, profitability, resource conservation, and social acceptability. Florin et al. (2014) review indicator assessments of biofuel production involving smallholders and highlight the importance of holistically considering a range of social, economic and environmental criteria. Maltsoglou et al. (2015) use interdisciplinary indicators (socioeconomic and natural resources, agriculture sector and food security, energy supply and demand requirements) to define the country context for investments in bioenergy production and estimate the biomass available for bioenergy production linking this amount to specific bioenergy supply chains.

We present here a ‘rapid appraisal’ accounting framework which decomposes the costs of supplying a product from producer to market, and partially assesses the impact on profitability of investments in biofuel production, under minimum (agronomic, engineering and economic) data requirements and different production arrangements, i.e. small scale production and outgrower schemes versus large scale and estate farming. This framework offers a more tractable approach to assessing first-order profitability and employment considerations than other approaches reviewed above which, in general, require more time and use more data-intensive methods. This is the main methodological contribution of the paper. The proposed approach could provide preliminary information to policymakers in developing countries on how to promote biofuel production calibrating adequately incentives structure, contractual arrangements and services provision. We apply the framework to the case of Tanzania, which is a data scarce setting and therefore well-suited to the proposed method.

The framework also allows estimating the size of land needed to produce biomass, and the number of jobs created in the biofuel sector which in the end may impact overall food security and rural development, for different scales of biofuel production (both the scale of feedstock production and biofuel processing) and related contractual arrangements. We discuss the possible trade-offs between profitability and job opportunities in the rural areas under different biofuel production settings. While it is acknowledged that threats to food availability consequent to biofuels investment are big concerns in developing countries and that there is a considerable debate on the trade-offs between biofuels and food production (Acosta-Michlik et al. 2011, Anderman et al. 2014, Cassman and Liska 2007, Molony and Smith 2010, Moschini et al. 2012, Tenenbaum 2008, Zezza 2007), this dimension of food security is not taken into account in this paper.

Apart the CGE modelling work from FAO (2010) and Arndt et al. (2010 and 2012) already taken into consideration above, other studies examine explicitly the role of smallholders in bioenergy chains and related contractual arrangements issues in South-East Africa. For example, investigating about jatropha production in Mozambique, Bijman et al. (2009) found that contract farming could reduce at least part of the transaction costs and risks related to biofuel production, also generating knowledge useful for smallholder farmers. According to Hoffmann et al. (2010), outgrower schemes might avoid most of the potentially negative environmental effects of intensive jatropha monocultures and promise to be more sustainable than and well accepted by producers and decision makers of Tanzania. However, most of these studies do not provide a quantitative analysis of the production costs in the biofuel value chain and fail to look at the implications of the scale of production which we address here.

The paper is organized as follows. Section 2 presents the model specification and describes the dataset used. Section 3 reports results of the case study. Conclusions are reported in Section 4.

2. Materials and methods

2.1 The model

The methodology presented here is based on a value-chain top-down spread sheet based framework aimed at estimating profitability of first generation liquid biofuel production from feedstock crops using ‘on-farm’ and ‘on-plant’ financial budgets. The model can simulate different legal contractual arrangements (i.e. outgrower and estate farming schemes) and estimate demand for biomass production and land resource. Also, in order to determine the potential smallholder involvements in biofuel production, a simple methodology was built to capture the land requirements and biofuel conversions in the feedstock production for the implementation of ethanol and biodiesel plants and translate them into the number of smallholders involved.

The spread sheets are organized among three core components: ‘crop budget’, ‘processing budget’, ‘employment & land use sub-model’. Crop budget component provides detailed estimation of feedstock production costs for three different technology levels (namely ‘low-’, ‘intermediate-’ and ‘high-input’), corresponding to three possible contractual arrangements (independent, outgrower and estate farming, respectively). Results from the crop budget are fed into the processing budget which estimates processing costs for different biofuels, scales of biofuel production and feedstock production schemes. Finally, the employment & land-use sub-model aggregates results from the crop and processing budgets, identifying potential employment generation in rural areas, computing number of smallholders involved and related land use, taking into account average farm sizes in the selected country. Model assumptions are summarised in what follows.

Low-input farmers use labour intensive techniques and do not have regular access to fertilizers, chemicals and improved seeds. Such farmers are smallholders operating on small-size farms using largely household labour. Intermediate-input farmers rely on modern cropping practices and improved seed varieties, manual labour with hand tools and/or animal traction or minimum mechanization, and limited use of fertilizer application and chemicals for pest disease and weed control. Labour use is semi-intensive, based on a mix of household and hired labour. High-input farmers are market oriented; they use high yielding improved seed varieties, mechanization, fertilizers and chemicals. Commercial farmers would fall within this category.

For each technology level a set of technical coefficients related to input use and output production is defined on the basis of available literature and in-country data. Crop yields increase moving from low- to high-input technology levels. Crop production represents the feedstock used in the processing phase. It is assumed that output sold on the food markets and feedstock delivered to processing plants are technically homogeneous.

The processing budget computes costs of biodiesel and ethanol production for different plant capacities (5, 50 and 100 million litres). Several sizes of biofuel processing plants could be considered representative of available technologies (Cardona et al. 2009). We analyze the cases of 5 and 100 million litres which represent the smallest and biggest sizes respectively. They represent potentially available technologies for first generation biofuel production (Naik et al. 2010) and identify the range of possible options so that most investments will fall within this range. However, since other studies for Tanzania consider 22 and 44 million litres as large plants (FAO 2012), we consider also an additional plant size of intermediate scale (50 million litres). The processing budgets account for input costs (including raw material purchased from farmers), skilled and unskilled labour costs, transport costs from the farm to the processing plant, investment costs, maintenance, storage and other costs such as the administrative costs.

Investments include building and installation costs. The individual investment costs are predefined for each plant size and biofuel production, ranging between 12.7 million US$ for a 5 million litres biodiesel plant and 27.7 million US$ for a 100 million litres bio ethanol plant. The depreciation was calculated using the straight line method, i.e. assuming that the item will depreciate by a constant amount over its economic life or depreciation period. Depreciation periods range between 10 and 20 years, according to investment typologies (e.g. 20 years for instruments and equipment, 10 years for pipes). Maintenance cost of all equipment was established by default as a 10% of the total annual depreciation of the investments.

The following assumptions are made for all plant sizes. The plants are assumed to operate eight thousand hours per year (i.e. 24 hours per day, 333 days per year) on a three eight-hour shift cycle[3]. The number of workers per shift was calculated based on the rule of thumb reported by Van Gerpen (2008) which states that one unskilled worker is required every four million litres of biodiesel produced. The number of skilled workers required is assumed to be one for every four unskilled workers working in the plant. Different wages are applied for the different labour types. Cost of transport of the feedstock from the farm to the processing plant is also taken into account.

Transport costs have been computed as follows: starting from the quantity of feedstock needed by each plant (depending on its production scale) and the average yields, the corresponding area (sq Km) needed to produce that amount of feedstock is derived. It is then assumed that each plant will be strategically located in a circular area so that the maximum transport distance will be equal to the radium of the circle. It is plausible to assume that most feedstock will be transported over a distance shorter than the radium. Transport costs estimated in the model represents therefore an upper-bound value. Values used in this analysis fall below 50 km, which is in line with the literature which suggests that feedstock transportation of less than 50 km is preferable to guarantee cost competitiveness (Ashworth 2004).

The model considers different contractual arrangements between feedstock production and biofuel processing. Three basic contracts are hypothesized, namely ‘independent producers’, ‘outgrower’ and ‘estate farming’. Different technology levels and farmer typologies correspond to such institutional arrangements as shown in Table 1.

Table 1: Farm typologies, technology level and contractual arrangements

Contractual arrangement	**Input level**	**Farmer typology**	
Independent	Low	Subsistence farmer	Smallholders
Outgrower	Intermediate	Market oriented small farmer	
Estate farming	High	Commercial farmer	

Source: own elaboration

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[3] It is worth to notice that deadweight loss due to climatic or other events may reduce feedstock availability and make the plants not to work at full capacity. However, for the sake of simplicity, these issues are not considered here.

Farm terminology in the literature is not consistent whereby subsistence farmers, smallholders and peasant farmers are often used to describe the very small scale of farmers. Also, there is no consistent definition of small-scale farmer, smallholder or small-scale agriculture (Bogdansky et al, 2011). Narayanan and Gulati (2002) identify a small-scale farmer as a “farmer (crop or livestock) practising a mix of commercial and subsistence production or either, where the family provides the majority of labour and the farm provides the principal source of income”. This definition allows for the inclusion in smallholders both of subsistence and market oriented small farmers as described here. Consistently, in our analysis, we will use ‘subsistence farmers’ to indicate low-input level farmers; ‘market oriented small farmers’ to indicate intermediate-input level farmers; and ‘commercial farmers’ to indicate those using high-input technology. The analysis also uses the term ‘smallholders’ to indicate both subsistence and market oriented small farmers as opposed to ‘commercial farmers’.

In the model we assume that independent farms are managed by local resource-poor farmers. These farmers normally do not have freehold title and cannot use land as collateral; therefore they do not have easy access to credit. For this reason these farmers tend to adopt low-input farming techniques.

Outgrower schemes are a form of contract farming in which farmers grow crops on their own land under contract to large-scale enterprises in exchange for various price guarantees, inputs, and services (Abwino and Rieks 2007, German et al. 2011, Glover 1990). Typically the grower provides land, labour and tools but is supplied with inputs (fertilizer, seeds, and insecticides) on credit. Extension services often also form part of the contractual package. Outgrower farmers are distinct from independent smallholder producers which lacks contractual purchase agreements with (and corresponding support from) industry (Brittaine and Lutaladio 2010). It is assumed here that outgrower farmers adopt intermediate level farm management techniques. The model considers that farmers will sell raw material to biofuel processors according to contractual agreements and that an agreed market price is used to regulate the transaction. However, there is always the possibility that farmers would occasionally sell raw material at a market price and without any predefined contractual arrangement. The model allows therefore the presence of independent producers who sell output to the market.

Estate farms typically have corporate (international) ownership. Such plantations are a common choice for large biofuel investors: they acquire the right to establish a farm which will be used exclusively for biofuel feedstock production, often from mono cropping. The farm can be directly managed by a dedicated manager (rather than the owner) or run by commercial farmers (on freehold or leasehold) which are sometimes referred as ‘concession farmers’. The corporation may own its own biofuel processing facility or sell the feedstock to mills (von Maltitz and Setzkorn 2012). Estate farming is conducted at high-input level. The model assumes that the biofuel processing enterprise owns agricultural fields; and that total feedstock is produced by the factory itself (vertical integration). Under this scheme, purchasing cost of the raw material corresponds to the feedstock production (on-farm) costs.

2.2 The dataset

A database with technical coefficients related to feedstock and liquid biofuel production has been built. Crop potential yields are derived from the Global Agro ecological Zone database (IIASA/FAO 2012) and are classified according to the level of inputs for rain fed agricultural production (low, intermediate and high input level). Data on fertilizers (type and quantity) are computed through a simple agronomic model which estimates the nutrients’ uptake of different crops on the basis of expected yield and of the nutrient content of different fertilizer sources used at farm level. National wage for agricultural labour is taken as manual labour cost (unskilled)[4]. National average values of land rental are used as land cost estimates. Type and quantity of other factors of production as well as input costs and output (crop) prices are derived from available literature.

Energy and mass balance data for biodiesel and ethanol production plants were derived using ASPEN Plus™ V7.3 software (Aspentech 2011). These data were utilized to generate the quantity of inputs (e.g. feedstock, water), and energy required for production of processed outputs at different scale, as well as for equipment size calculations. Unitary input costs have been derived from available literature. Data used also includes international prices of fossil fuels (diesel and gasoline) and liquid biofuels. Appropriate conversion factors are used to express all prices in fossil fuel equivalents.

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[4] However, opportunity cost of rural labour is often lower than the national wage. Assuming labour costs equal to national wage for unskilled labour will bring to an over-estimation of labour and total production cost of feedstock in the smallholders case. Model results reported here should be considered as conservative estimates, therefore limiting the risk of consequent investments and policy interventions.

3. Results and discussion

3.1 Country case-study and analytical scenarios

The empirical application presented here is aimed at estimating the profitability of biofuel production in Tanzania. It focuses on biodiesel obtained from sunflower, and ethanol produced from cassava. Sunflower can be considered as an industrial cash crop since smallholders produce sunflower oilseeds to be processed for cholesterol-free edible cooking oil with a by-product meal used as livestock feeds (RLDC 2008). Additionally, raw glycerol (by-product of biodiesel processing) can be sold to obtain additional revenue. Cassava is a basic staple crop which can be transformed in ethanol, obtaining also distiller's dried grains with soluble (DDGS). This by-product is marketed as protein rich animal feed.

Tanzania has abundant natural resources and potential for sustainable agriculture improvement and expansion (FAO 2010). The economy of Tanzania heavily relies on agriculture which contributes 26 per cent of GDP (WB 2009). The agriculture sector in Tanzania is characterised by structural poverty. Most of the rural poor are employed in agriculture and reside in rural areas. The sector is characterized by low productivity and lack of markets, with a large share of farmers engaging in subsistence farming. (Habib-Mintz 2010, Mwakaje 2012).

In the last few years the Government of Tanzania sought to develop biofuel sector to promote rural development (Habib-Mintz 2010) and biofuel industry development targets are explicitly taken into account in national development plans (Government of Tanzania 2008). A number of investors are looking for opportunities for biofuel development in Tanzania and initiatives are being taken in the country on a number of scales (Martin et al. 2009).

The impact of biofuel production on rural economy depends on the level of involvement of smallholders in the biofuel value chain. This can be modelled by building different hypothetical scenarios. Three basic scenarios correspond to the weight of possible contractual arrangements between processors and feedstock producers: scenario A in which 100% of feedstock biomass is sold by subsistence farmers; scenario B, where biomass is provided by outgrower farmers which use intermediate level farming techniques; and scenario C, where biomass is exclusively supplied under the 'estate farming' scheme, i.e. by farmers which use high-input technology level (see Table 2). Intermediate scenarios (mixed independent-outgrower-estate farming) have also been modelled, and results are discussed below. It is worth to notice that such scenarios are arbitrary. Even if they do not represent all possible cases, being purely indicative of some possible combinations, they can provide policy makers with useful examples of realistic results.

Table 2: Case-study hypothetical scenarios

Contractual arrangement	Input level	Farmer typology	Scenarios		
			A	B	C
			(% feedstock biomass)		
Independent	Low	Subsistence farmer	100	0	0
Outgrower	Intermediate	Market oriented small farmer	0	100	0
Estate farming	High	Commercial farmer	0	0	100

Source: own elaboration

3.2 Profitability of biofuel production and its international competitiveness

A first set of results provides information on the profitability of biofuel production and its international competitiveness. The ‘crop budget’ and ‘processing budget’ model components estimate (private) production costs of liquid biofuel production at farm and processing plant level. Table 3 reports on-farm production costs for sunflower and cassava under different contractual arrangements and input levels while Table 4 shows unit prices and costs used in the crop budget module. Feedstock market price paid to independent farmers is the same as the price paid to outgrowers. However, independent farmers face higher production costs, lower yields and negative net margins due to their low level of technology. On the contrary, outgrowers benefit of technical assistance and input provision as per their contractual arrangements, and gain better yields and net margins thanks to the intermediate level of technology. Estate farming is always much more profitable than alternative arrangements for feedstock provisioning.

Table 3: Feedstock on-farm production costs for sunflower and cassava

	SUNFLOWER			**CASSAVA**		
	A (indipendent scheme)	**B (outgrower scheme)**	**C (estate scheme)**	**A (indipendent scheme)**	**B (outgrower scheme)**	**C (estate scheme)**
	Low Input	**Intermediate Input**	**High Input**	**Low Input**	**Intermediate Input**	**High Input**
	$/ha					
Inputs						
Seeds	6.00	10.50	10.50	360.00	360.00	360.00
Chemical fertilizers	-	113.76	205.69	-	133.89	228.15
Organic fertilizer	73.00	-	-	73.00	-	-
Miscellaneous expenditure	7.90	12.43	21.62	37.30	43.39	52.82
Total inputs costs	86.90	136.69	237.81	470.30	537.28	640.97
Labour						
Land preparation	121.00	250.00	350.00	116.40	250.00	350.00
Sowing	10.00	10.00	50.00	21.60	21.60	21.60
Field Operations	50.00	25.00	50.00	27.00	13.50	100.00
Harvesting	35.20	50.92	43.67	18.85	25.70	217.36
Miscellaneous	21.62	33.59	49.37	18.39	31.08	68.90
Total labour cost	237.82	369.51	543.03	202.24	341.88	757.86
Land						
Land rental	30.00	30.00	30.00	30.00	30.00	30.00
Total land cost	30.00	30.00	30.00	30.00	30.00	30.00
Financial results						
Revenue (a)	352.00	636.44	1,150.74	698.29	1,189.90	2,027.62
Total operating costs	324.72	506.20	780.84	672.54	879.16	1,398.82
Gross margin	**27.28**	**130.25**	**369.90**	**25.75**	**310.74**	**628.79**
Land costs	30.00	30.00	30.00	30.00	30.00	30.00
Interest on working capital	11.69	18.22	28.11	24.21	31.65	50.36
Total costs	366.41	554.42	838.95	726.75	940.81	1,479.18
Net margin (b)	**-14.41**	**82.03**	**311.79**	**-28.47**	**249.09**	**548.44**
Unit production cost ($/t) (c)	416.38	348.45	291.62	104.08	79.07	72.95
(a) Yield*Market Price						
(b) Revenue - Total Costs						
(c) Total Costs / Yield						

Source: own elaboration

Table 4: Unit prices and costs used in the crop budget module

Item	Unit	Value
Input prices		
Sunflower seed price (traditional varieties)	$/kg	0.6
Sunflower seed price (improved varieties)	$/kg	1.5
Cassava seedlings ($/ha)	$/ha	300
Chemical fertilizer price	$/kg	0.7
Labour cost		
- person day ($/day)	$/day	1.8
- animal traction ($/day)	$/day	15.0
- machinery ($/hour)	$/hour	25.0
Land cost		
Land rental ($/ha)	$/ha	30.0
Output prices		
Sunflower price	$/t	400.0
Cassava price	$/t	100.0
Yields		
Sunflower - low input	t/ha	0.9
Sunflower - intermediate input	t/ha	1.6
Sunflower - high input	t/ha	2.9
Cassava - low input	t/ha	6.9
Cassava - intermediate input	t/ha	11.9
Cassava - high input	t/ha	20.3

Source: own elaboration

Profitability of feedstock production increases when going from independent to estate farming schemes. This is obviously related to the corresponding technology (input) levels and to the unit production cost, which decreases as technology level increases. Table 5 reports the production costs (net of co-products sales) for different plant sizes and the relative breakdown by cost component, while Table 6 compares them with cost of imported biofuel and market prices of diesel/gasoline. Under the outgrower and independent schemes, feedstock purchase cost is estimated using market prices for crop production: under these two schemes biomass suppliers (i.e. farmers) can sell their product either on the market or directly to processors market. Therefore, in Tables 4 and 5 scenarios A and B are reported together, since there is no difference in the feedstock purchase price (i.e. market price). Under scenario C (estate farming) feedstock cost corresponds to its on-farm production cost.

Table 5: Biofuel processing production costs (with co-products) – data in $/ litre[5]

Crop-biofuel	Scenario	Plant size	Feedstock	Energy	Other input costs	Labour	Other processing costs	Co-products	**Net production cost**
Sunflower-biodiesel	A & B	5 MLN	0.96	0.08	0.19	0.01	0.45	-0.08	**1.62**
		50 MLN	0.96	0.04	0.17	0.01	0.20	-0.08	**1.29**
		100 MLN	0.96	0.03	0.17	0.01	0.19	-0.07	**1.27**
	C	5 MLN	0.70	0.08	0.19	0.01	0.43	-0.08	**1.34**
		50 MLN	0.70	0.04	0.17	0.01	0.18	-0.08	**1.01**
		100 MLN	0.70	0.03	0.17	0.01	0.17	-0.07	**0.99**
Cassava-ethanol	A & B	5 MLN	0.56	0.19	0.04	0.01	0.38	-0.02	**1.16**
		50 MLN	0.56	0.29	0.04	0.00	0.18	-0.03	**1.03**
		100 MLN	0.56	0.25	0.04	0.00	0.16	-0.02	**0.99**
	C	5 MLN	0.38	0.19	0.04	0.01	0.37	-0.02	**0.97**
		50 MLN	0.38	0.29	0.04	0.00	0.16	-0.03	**0.84**
		100 MLN	0.38	0.25	0.04	0.00	0.15	-0.02	**0.79**

Source: own elaboration

Feedstock is the principal component of biofuel processing costs and has a significant impact on the economic viability of the activity. For example, we find that sunflower feedstock accounts for 52 and 59 percent of the costs for a 5 million litre biodiesel plant (estate and outgrower scheme); and 75 and 79 percent of the costs for a 100 million litre biodiesel plant (estate and outgrower scheme). Increasing plant size will reduce significantly unit processing cost due to the economies of scale. Economies of scale concern both investment and operating costs. Investment costs per

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[5] In “Other input costs” following costs items are included: Sodium Hydroxide, Methanol, Water, and Hexane costs as concerns Biodiesel production; Glucoamylase, Alpha-Amylase, Water, Ammonia, and Yeast costs as concerns Bioethanol production. “Other processing costs” include: energy costs (electricity and heat carrier); miscellaneous costs (total cost of operating supplies and laboratory charges required for the daily processing of biodiesel); costs for transporting feedstock from farm to plant; depreciation costs; maintenance costs; feedstock and product storage costs; plant overheads (plant overheads are general expenditures defined as a charge to the production for services, facilities, payroll overhead and are established by default as 50% of total labour and maintenance costs); and general and administrative costs (rent, insurance, managerial and administrative staff salaries, estimated at 8% of the sum of plant overheads, maintenance, total labour costs and the other costs except the expenditure for feedstock purchase). The following co-products are considered: raw glycerol and sunflower meal from sunflower processing; and Dried Distillers Grains with Solubles (DDGS) from Cassava processing.

unit of production decrease when going from a 5 million to 20 million litres plants, from 2.9 to 0.9 $/litre of biodiesel and from 4.9 to 1.8 $/litre of ethanol. Some operating costs also decrease when the scale of production increases: this is true for the operating costs which are computed as a fixed percentage of the investment costs, i.e. depreciation, maintenance, and miscellaneous; and for labour input. Other operating costs, e.g. feedstock, storage, transport, general and administrative costs increase linearly with the scale of production. One consideration for defining the scale is that the increased cost from the transportation of feedstock may outweigh economies of scale for larger-scale factories. This is particularly relevant for Tanzania given the limited infrastructure in rural areas and the high transport costs in the country. Hauling feedstock for long distances can become prohibitive for small-scale farmers and too costly for biofuel processors (FAO 2012). When keeping the plant and biofuel type constant, we find that processing costs under scenarios A and B, that involve both subsistence and smallholders, are always higher when compared to scenario C, the ‘estate farming’ option.

Table 6: Biofuel processing production costs, with co-products (on plant) and comparison with imported biofuels and equivalent fossil fuels prices in Tanzania – data in $/ litre

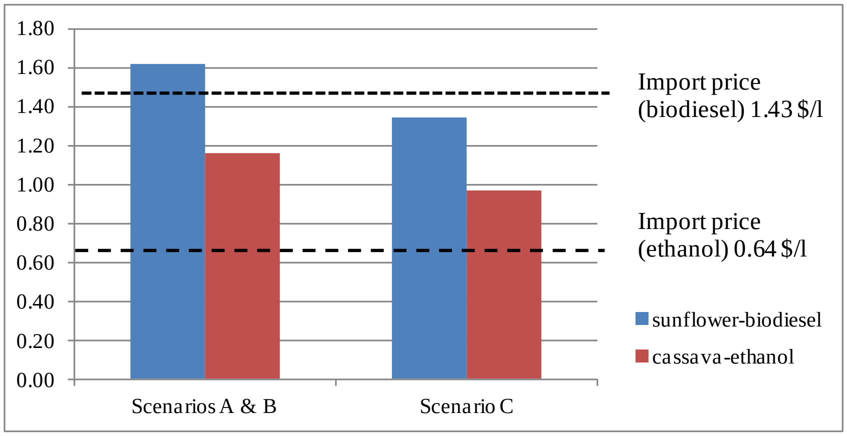
Crop-biofuel	Scenario	Plant size	**Net production cost**	Cost of imported biofuel	Diff.	Price in diesel/gasoline equivalent	Market price of diesel/gasoline	Diff.
			(a)	**(b)**	**(c=a-b)**	**(d)**	**(e)**	**(f=d-e)**
Sunflower-biodiesel	A & B	5 MLN	**1.62**	1.43	**0.19**	2.22	1.45	**0.77**
		50 MLN	**1.29**	1.43	**-0.14**	1.86	1.45	**0.41**
		100 MLN	**1.27**	1.43	**-0.16**	1.84	1.45	**0.39**
	C	5 MLN	**1.34**	1.43	**-0.09**	1.91	1.45	**0.46**
		50 MLN	**1.01**	1.43	**-0.42**	1.55	1.45	**0.10**
		100 MLN	**0.99**	1.43	**-0.44**	1.53	1.45	**0.08**
Cassava-ethanol	A & B	5 MLN	**1.16**	0.64	**0.52**	2.22	1.60	**0.62**
		50 MLN	**1.03**	0.64	**0.39**	2.03	1.60	**0.43**
		100 MLN	**0.99**	0.64	**0.35**	1.96	1.60	**0.36**
	C	5 MLN	**0.97**	0.64	**0.33**	1.92	1.60	**0.32**
		50 MLN	**0.84**	0.64	**0.20**	1.73	1.60	**0.13**
		100 MLN	**0.79**	0.64	**0.15**	1.66	1.60	**0.06**

Source: own elaboration

Production costs are then compared with diesel/gasoline equivalent price and international *cif* price of liquid biofuels for the case studies of biodiesel from sunflower and ethanol from cassava (see Table 6 and Figure 1). We used for the comparison data published by the Energy and Water Utilities Regulatory Authority (EWURA) which regulates prices of petroleum products in Tanzania. According to their July 2012 publication (EWURA 2012), the average price of diesel was about 1.45 US$ per litre and the average price of gasoline was 1.60 US$ per litre, with the prices rising in areas beyond the ports. Differences in energy content among various biofuel products should be taken into account when examining the competitiveness of domestic biofuel production on the international market for energy (diesel and gasoline). The equivalent fossil fuel prices consider that biodiesel and ethanol have about 8 and 34 percent less energy than diesel and gasoline respectively. Column (d) in Table 6 shows the price at which domestic biofuel production (transformed in diesel/gasoline equivalent for biodiesel/ethanol, respectively) could be sold, based on the costs of production. Fossil fuels price also includes additional regulatory and fiscal fees. Considering that taxes on conventional fuels are a significant source of revenue collection for Tanzania, it could be assumed that the same level of taxation is to be implemented for biofuel. According EWURA’s computational formula for indicative prices for petroleum products, taxes are estimated at around 0.35 US$ per litre (EWURA 2008). EWURA’s indicative prices also stipulate an estimate profit margin for fuel dealers of about 0.09 US$ per litre and the cost of transport of about 0.01 US$ per litre. Potential indicative fossil fuels-equivalent prices for biodiesel and ethanol are estimated using their production costs as a base, taking account of the energy basis and adding the regulatory fiscal fees. The diesel-equivalent and gasoline-equivalent indicative prices for biodiesel and ethanol are computed for each of the scenarios and are assessed against current diesel and gasoline prices at the pump.

Data reported in Table 6 show that: domestic ethanol production from cassava is never competitive with imported ethanol - see positive values in column (c); only biodiesel production from sunflower is competitive with imported biofuels in most cases - see negative values in column (c); domestic biofuel production is never competitive on the international market for energy - see positive values in column (f); biofuel production is more competitive under scenario C than under scenarios A & B (see also Figure 1). This is not surprising since investors may strongly prefer a vertically coordinated arrangement that supplies a more secure flow of raw material rather than an outgrower arrangement (Arndt et al 2010), especially for large-scale investments (where plantation-style farming may be advantageous).

Figure 1: Biofuel processing production costs in Tanzania and comparison with imported biofuels for 5 million litres plant ($/litre)



Source: own elaboration

When processing and marketing become more complex and centralized, plantations represent a solution to the need for vertical integration of production. Also, investors may have to build supporting infrastructure such as irrigation, roads and docking, which may be economical only under large scale operation (FAO 2008)[6]. Although from a pure production cost point of view scenario B may be preferred, it may not be desirable from a social point of view, since only commercial farmers would be involved and biofuel production would not benefit smallholders. In other words, investments in biofuel production could promote rural development if the institutional arrangements will guarantee smallholders' involvement in biofuel production, as would be the case for scenarios A & B. However, it should be stressed that for big plants contractual arrangements foreseen under scenario A may be very risky and hardly feasible. Feedstock procurement from subsistence farmers through independent contractual arrangements may not be reliable, therefore increasing production risk, even for small size plants.

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[6] Processors have also become interested at making additional investments on energy co-generation technologies. This modification would allow reducing energy costs, obtaining an additional co-product (i.e. electricity), generating additional revenues and improving overall investments profitability. However, co-generation is not taken into account here.

3.3 Domestic competitiveness and value chain implications

A second set of results concern the competitiveness of biofuel production at national level. Biofuel processors face different production costs depending on the specific contractual arrangement. Under the estate farming scheme, feedstock cost corresponds to total variable costs of crop produced under high-input technology: for example, producing 1 ton of sunflower would cost 291.62 $. As mentioned above, under the outgrower and independent schemes, feedstock purchase cost is estimated using market prices for crop production: same selling price is assumed in both cases. Market price therefore represents the minimum purchase feedstock price for biofuel processors, e.g. 400 $/t for sunflower.

The ‘processing budget’ component model also allows identifying the feedstock price that will sustain a long-term feedstock market and biofuel production. To illustrate, consider the long-run breakeven feedstock price for a biomass supplier (i.e., farmer) and biofuel processor. The long-run minimum price at which the farmer is willing to deliver feedstock to the biofuel conversion plant reflects the cost of production. The maximum price the biofuel processor can pay (i.e., derived demand) for feedstock in the long-run is equal to the unit energy value of the final product (i.e. biofuel import price) plus co-product value less costs of feedstock conversion. When the long-run derived demand for feedstock equals the long-run supply cost of feedstock, a competitive market equilibrium price is established.

This is shown in Table 7, with reference to the example of sunflower. Maximum price the biofuel processor can pay for feedstock in the long-run varies between 298 and 432 $/t (depending on the plant size). The long-run minimum price at which the farmer is willing to deliver feedstock to the biofuel conversion plant reflects the costs of production and varies between 292 and 398 $/t (depending on the level of technology). A long-run competitive market equilibrium price for sunflower to be processed in biodiesel will fall between 292 and 298 or 432 $/t (depending on the size of the plant that will be put in place).

Table 7: Long-run breakeven feedstock price for biodiesel production from sunflower

		Technology	Unit of measure	Plant size (million liters) 5 MLN	50 MLN	100 MLN
Biodiesel processor	Revenue (final energy product + co-product)		000$	7,150	71,500	143,000
	Costs of feedstock conversion		000$	3,306	16,809	31,305
	Costs of feedstock purchase		000$	3,844	54,691	111,695
	Feedstock requirement		t	11,962	119,617	239,234
	Maximum purchase feedstock price		$/t	298	423	432
Sunflower producer	Minimum selling biomass price	Low-input	$/t		398	
		Intermediate	$/t		342	
		High-input	$/t		292	

Source: own elaboration

Given this cost structure, it can be derived that smallholders would be willing to sell their biomass to the processor only if a big plant was established, since the minimum selling price falls below the maximum purchase price. Should a small plant be established, a subsidy will be necessary to lower (farm) production costs and include smallholders in the biofuels economy, e.g. 45$/t for outgrower farmers, 101 $/t for independent farmers.

3.4 Implications on labour and land use

A third set of results concern the social dimension of biofuel production which is computed using the ‘employment and land use sub-model’ aimed at estimating the number of smallholders potentially involved in feedstock production under different scenarios, and deriving the implications in terms of labour demand and land use. Results are shown in Table 8.

Table 8: Labour, land and number of smallholders involved in biofuel production

Crop-biofuel	Scenario	Plant size	Land demand	Labour demand	Smallholders
		(million litres biofuel)	(ha)	(man days/year)	(n.)
Sunflower-biodiesel	A	5	13,593	3,791	27,186
		50	135,929	37,728	271,857
		100	271,857	75,457	543,715
	B	5	7,518	1,242	4,699
		50	75,178	12,235	46,987
		100	150,357	24,470	93,973
	C	5	4,158	61	0
		50	41,579	425	0
		100	83,158	851	0
Cassava-ethanol	A	5	3,978	978	7,956
		50	39,780	9,599	79,560
		100	79,560	19,198	159,120
	B	5	2,334	323	1,459
		50	23,345	3,047	14,590
		100	46,689	6,095	29,181
	C	5	1,370	125	0
		50	13,700	1,223	0
		100	27,399	2,446	0

Source: own elaboration

In the model smallholders are involved in the biofuel supply chain only under scenarios A and B, mainly through the outgrower scheme set up. However, the number of smallholders supplying raw material varies depending on the crop: biodiesel produced from sunflower is found to be more smallholder intensive when compared to cassava as a larger number of feedstock producers are required per litre of biodiesel.

The demand for labour is calculated on the basis of labour requirements for feedstock production and processing. Due to the fact that a bigger number of smallholders are required to produce sunflower-based biodiesel, this production pathway can also generate higher labour demand when compared to cassava based ethanol. These results are coherent with existing literature which shows that employment benefits are highly variable, with higher employment rates associated with wider smallholder involvement (German et al. 2011).

The analysis also quantifies the amount of land used for feedstock production on the basis of quantity of raw material required to supply plants of different sizes under different scenarios. Scenario options range from a pure estate farming case (100-0-0 i.e. 100% estate, which corresponds to scenario C) to a much less realistic full independent farming case (0-0-100, i.e. 100% subsistence, which corresponds to scenario A). A number of intermediate scenarios have also been built, obtained by changing the weight of different contractual arrangements, i.e. the % of feedstock biomass produced (and delivered to the plant) by each farm type. The scenarios shown here should be considered only as a few possible examples which could be modelled. Profitability, number of smallholders involved, labour and land demand will change accordingly, since a different involvement of smallholders in biofuel production is hypothesized. This is shown in Figures 2-4, where scenarios are indicated with the % of the three possible contractual arrangements, i.e. estate-outgrower-independent farming.

Moving from a pure estate farming scheme (scenario C) to mixed schemes (see Figure 2) will increase the number of smallholders involved, through outgrower schemes or simple feedstock purchase from independent small farmers, and will generate social benefits in terms of increased labour demand (see Figure 3)[7]. It is worth to notice that labour demand is estimated only with reference to direct employment (holdings in agriculture and workers in the manufacturing sectors for feedstock processing and biofuel conversion) and may represent an underestimation. Total labour demand should also include indirect employment which is usually conducted using economic input-output tables (Silalertruksa et al. 2012). Additional indirect labour benefits of implementing biofuel value chain may include higher wages and bigger stability of salaries and, consequently, more regular household income flow (Norwana et al. 2011; Ewing and Msangi 2009).

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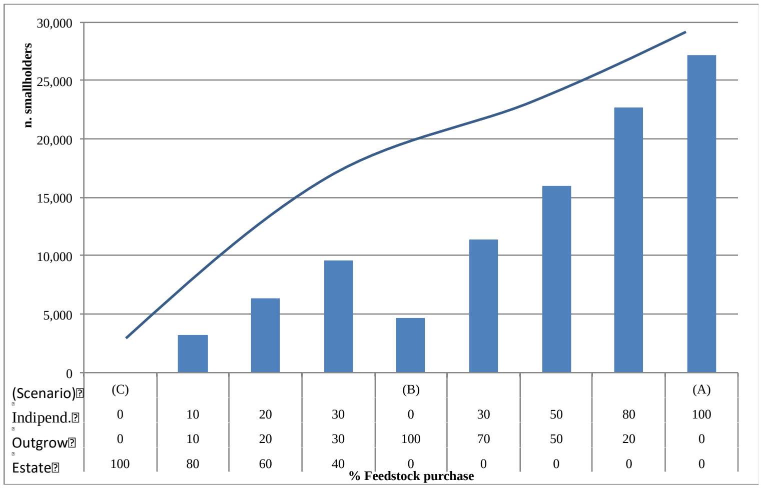
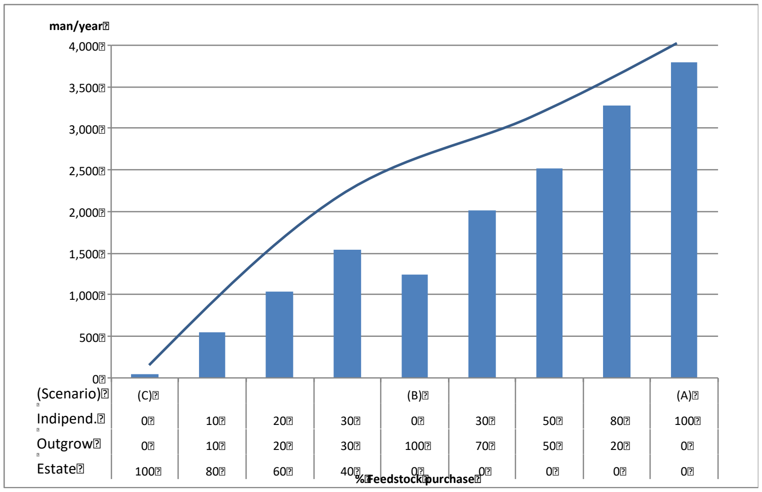
[7] There are obvious differences in the characteristics of employment and quality of jobs among people employed in agriculture and the biofuel processing sector. Although the model can quantify both categories of workers, such distinction is not highlighted and discussed here.

Figure 2: Involvement of smallholders in biofuel value chain: biodiesel production from sunflower biomass, 5 million litres plant



Source: own elaboration

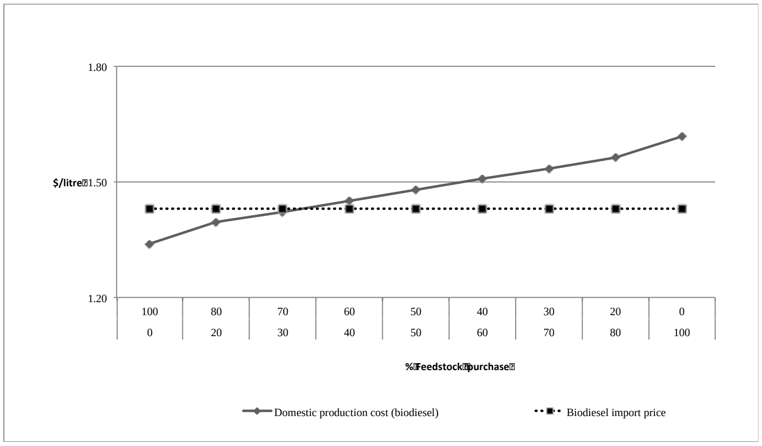
Figure 3: Labour demand corresponding to different scenarios: biodiesel production from sunflower biomass, 5 million litres plant



Source: own elaboration

However, gaining these social benefits come at a cost. Competitiveness of domestic biofuel production on international market decreases when smallholders’ involvement increases since overall processing costs increase when moving from pure estate farming (Scenario C) to pure outgrower/independent schemes (Scenario A&B) as shown in Figure 4.

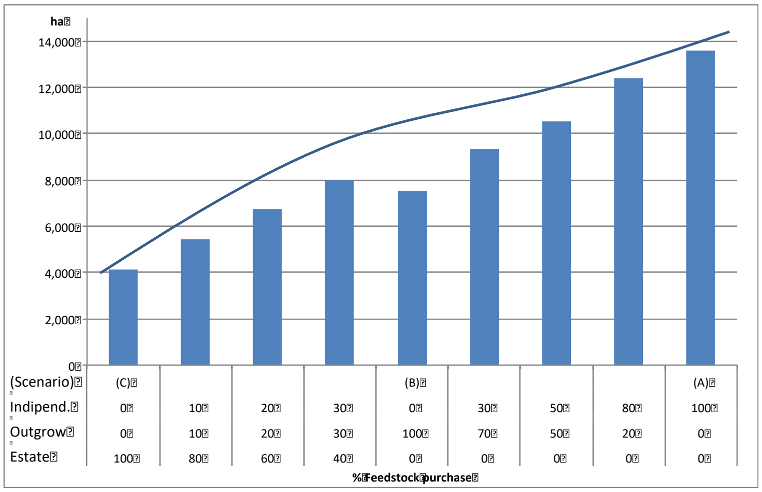
Figure 4: Production costs under different production schemes: biodiesel production from sunflower biomass, 5 million litres plant



Source: own elaboration

Also, since smallholders obtain lower yields, more land would be required with respect to the estate farming option to produce the same amount of feedstock. Some of this land may come from other cropland (social costs in terms of possible increased food insecurity) while new land could come from forests or grasslands (environmental social costs), which may face binding natural resource and emissions constraints. Figure 5 shows how land area cropped to produce feedstock biomass will change if an increased number of smallholders are involved (as depicted in the different scenarios). This is in agreement with results of another study related to Tanzania where it has been found that smallholders require more land than large-scale plantations and so face more binding natural resource and emissions constraints (Thurlow et al. 2015). Considering social environmental costs related to this land expansion would represent a binding constraint to the inclusion of smallholder agriculture into biofuel production chain, altering the economically optimal biofuel strategy for Tanzania by limiting potential poverty reduction. However, these important environmental implications are not considered in this study, as they would require a more comprehensive analysis which is not among the objectives of the rapid assessment proposed here.

Figure 5: Land use under different scenarios: biodiesel production from sunflower biomass, 5 million litres plant



Source: own elaboration

4. Conclusions

Liquid biofuels offer opportunities for local level employment and wider economic development but a case by case assessment is required to ensure that the added benefits claimed by this development route are actually achieved. This paper presented a value-chain methodology to rapidly assess if this is the case; and also applied it to a specific setting, the case of cassava-based ethanol and sunflower-based biodiesel in Tanzania, which is a data scarce country and therefore well-suited to the proposed approach.

Biofuel companies have been moving into Tanzania due to its agricultural potential. Feedstock purchase represents a major cost in liquid biofuels, therefore rural areas and agricultural production is heavily involved in biofuel economy. Agriculture in Tanzania is also a key sector to target for poverty reduction and economic growth. Biofuel investment solutions that can be smallholder inclusive are therefore essential to ensure that poverty reduction goals are achieved. However, under the static assumptions of the model discussed here, underproductive agricultural systems and underdeveloped marketing channels reduce smallholders' competitiveness and their involvement in biofuel production.

The independent farming approach within the value-chain is unprofitable. Farmers need at least the support of an out-grower scheme for becoming profitable in feedstock production and being included in the value chain. Estate farming is the best option for profits and competitiveness, even if domestic biofuel production is never competitive on the international market for energy. Estate farming also requires much less land therefore reducing pressure on natural resources and the likelihood of trade-offs between biofuel and food production. However, smallholder farming is best for creating the maximum number of low-skill job opportunities in biofuels, increasing wages and benefiting rural households.

By moving from pure estate farming towards scenarios that foresee a bigger involvement of smallholders (pure outgrower, pure independent or mixed combinations) social benefits in terms of job opportunities and number of farmers involved in biofuel economy increase. Outgrowers can benefit from inputs and technical assistance; therefore obtaining better yields. These results are in line with Arndt et al. (2012) who found that maximizing the poverty-reducing effects of biofuels production in countries like Tanzania will require engaging smallholder farmers; and that poor farmers gain welfare benefits from yield improvements for feedstock rather than land expansion. Nevertheless, social benefits may be gained at a cost of reduced international competitiveness. The trade-offs between profits and job opportunities should be carefully taken into account in the design and management of properly targeted biofuel policies.

The analysis has also taken into consideration different scales of biofuel production (both the scale of feedstock production and biofuel processing). We find that biofuel production is more competitive under large-scale estate-farming investments (plantation-style farming). Increasing plant size will reduce significantly unit processing cost due to the economies of scale concerning both investment and operating costs. Sunflower-biodiesel is profitable only when produced in large-scale estate farming systems. However, increasing processing scale implies an increase in land use required to supply feedstock to the processing plant with important trade-offs in terms of food security and environmental implications. Probably a combination of mixed small- and large-scale production systems could be promoted, as also suggested by Arndt et al. (2012), as this could secure feedstock supply for downstream processors through the large-scale component and, at the same time, contribute to poverty reduction from the small-scale component. Also, second generation biofuels, which are more energy efficient and more flexible regarding their feedstock could, in the future, contribute to reducing negative environmental effects of biofuel chains. For example, feedstock could be derived from marginal lands or from wood obtained from traditional forests managed in a sustainable way (Havlik et al. 2011).

The results of the case study in Tanzania represent a typical output of the methodology discussed here and could be used by stakeholders and policy makers as a first step of the decision process. Although the model can compute only a range of possible results, it is plausible to expect that real outcomes will most likely fall in between.

Interestingly, our case-study results and conclusions about potential trade-offs of biofuel production are quite similar to those derived from studies which use more time and data-intensive methods (e.g., CGE models) but are not very suitable to data scarce developing country settings. There are, however, a number of limitations to our analysis. The proposed approach is less capable to measure spillovers or to conduct welfare analysis than CGE models which can better capture sectoral linkage effects of expanding biofuels production, as those shown in the cited study from Andt et al. (2012). We propose a more tractable approach to assessing first-order profitability and employment considerations, even if it cannot properly measure spillovers or conduct welfare analysis. Also, the framework is mainly designed for planning investments in biofuels production at national level and can only limitedly consider the high variability in yield and cost at sub-national and local level, for which a spatial approach would probably be more appropriate.

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