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Economic impacts of developing a biofuel industry in Mozambique

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Abstract: Mozambique is one of the most promising African countries for producing biofuels and the national biofuel policy of 2009 identifies measures to incentivize biofuel production. Demand for biofuels in the Southern African Development Community is expected to increase over the next few years as 7 of its 15 member states have implemented or proposed the implementation of blending mandates by 2020. South Africa is one of these countries. Using a dynamic recursive computable general equilibrium (CGE) model, we estimate the impacts of expanding biofuel production in Mozambique under both commercial and smallholder-type farming models, including and excluding bagasse cogeneration.

Keywords: biofuel, computable general equilibrium, food security, Mozambique

JEL classification: C68, Q16, Q18

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1 Introduction

Globally, country strategies to reduce greenhouse gas (GHG) emissions have included the use of biofuels in the transport sector. Countries have actioned this strategy through the implementation of blending mandates for domestic fuel sources. In 2013, the average global fuel ethanol blending rate was 6 per cent, generating around 120 billion litres of bioethanol demand (IEA 2015). It is estimated that the average global blending rate could potentially rise to 11 per cent by 2020, significantly increasing the demand for ethanol fuels globally (Braude 2015).

Biofuel demand in the Southern African Development Community (SADC) is also expected to increase over the next few years as 7 of its 15 member states have implemented or proposed the implementation of blending mandates by 2020. The announcement of blending mandates in South Africa of 2–10 per cent bioethanol and 5 per cent biodiesel, provides an anchor market for biofuels production in the SADC region. Given the size of fuel demand in South Africa, blending mandates could potentially result in bioethanol and biodiesel demand in excess of 1,400 and 90 million litres by 2025 respectively. Under a flex fuel car scenario, this demand could potentially increase to 2,500 and 130 million litres (Stone et al. 2015).

Southern Africa (excluding South Africa) has been identified as a potential source of biofuel supply due to its favourable climate, sizeable arable land availability, and abundant water supply (Schut 2010). Mozambique specifically is believed to be a key potential producer due to its biophysical characteristics, significantly underutilized agriculture potential, and well-developed sugar production sector. The government of Mozambique has also identified the biofuels sector as a potential source of energy security, economic growth, and poverty alleviation for the country. In March 2009, the government of Mozambique published its National Biofuel Policy Strategy (Resolution No. 22/2009; OGM 2009) which provides a framework and general set of guidelines for the development of a biofuels industry. In 2012, the government regulated the blending of all fuel with biofuels. A 10 per cent ethanol and biodiesel blend mandate was implemented for 2015, rising to 20 per cent by 2021.

Biofuel production offers many potential benefits to developing countries, especially those that are dependent on the agriculture sector for employment and economic growth. The development of the new sector could, it is argued, create new jobs and streams of income that would have a positive impact on households, particularly in rural areas. Tembe and Baloi (2016) report that the sugar industry has provided 30,000 direct employment opportunities as well as school, road, and water infrastructure to more than 4,250 households. This has assisted in poverty reduction in the country. Biofuel production may also have a positive impact on the country's trade balance either through exports, or, if produced for domestic consumption, through a reduction in needed fuel imports. It can assist developing countries in reducing emissions as it is a cleaner source of fuel, and can be used as an alternative to biomass for cooking and heating, reducing the level of deforestation.

In this paper, we assess the economic and welfare impacts of the development of a sugarcane-based bioethanol sector in Mozambique using a dynamic computable general equilibrium (CGE) model. Given the centrality of food security in biofuel and industrial crop discussions, we analyse in detail the impact of the sector on agriculture and processed food prices, household food consumption, and overall welfare. The potential impacts of cogeneration as a by-product from the bioethanol sector are also assessed as the increase in sugarcane output will result in increased waste (i.e. bagasse), which could be used for power generation. Furthermore, we aim to highlight the differential impacts of smallholder versus commercial sugarcane farming, as well as the potential impacts that the displacement of normal agricultural land use for industrial crop use may have.

The remainder of this paper is structured as follows: section 2 discusses the potential for biofuel production in Mozambique and the associated production costs; section 3 outlines the modelling methodology and scenarios assessed; section 4 discusses the model results; and section 5 concludes with key points from the analysis and the implications thereof.

2 Potential for biofuel production in Mozambique

2.1 Feedstock crops and farming models

The government of Mozambique approved the use of sugarcane and sweet sorghum as feedstock crops for bioethanol production in its National Biofuel Policy Strategy. Sugarcane was identified due to its energy efficiency and associated low production costs (Tembe and Baloi 2016). Sweet sorghum was identified as it has low input requirements, is drought-tolerant, and can serve simultaneously as a biofuel feedstock (using the plant stalk) and food crop (using the grain). While the country produces sizeable cassava volumes (5.1 million tonnes in 2014), the food status of and potential competition for the crop may render it unattractive for use in bioethanol production. Food security is of concern in Mozambique, particularly over the last three years, as lower rainfalls have left districts dependent on dryland agriculture vulnerable (Tembe and Baloi 2016). Jatropha and coconuts were approved for biodiesel production. However, previous negative experiences with jatropha have left farmers hesitant about growing the crop.

Support in Mozambique seems to be strongest for the use of sugarcane as a feedstock for biofuel production. This is due to the well-established sugar industry, high sugarcane crop output, and the non-food crop status of the commodity – very little of the sugarcane produced and refined in Mozambique is used for domestic consumption. Lower global demand for Mozambican sugar (due to the removal of limits for beet sugar production in the European Union [EU] from 2017) along with lower global sugar prices also encourage the search for alternative higher value uses for sugarcane grown in the country. For these reasons, we only consider sugarcane as a feedstock to biofuel, specifically bioethanol, production in this paper.

In 2014, Mozambique produced just over 3.6 million tonnes of sugarcane (FAOSTAT 2016) on 46,296 hectares (ha) of land, resulting in a yield of 77.7 tonnes per ha (t/ha). Sugarcane is largely produced by the four sugar companies in the country, namely Marromeu, Mafambisse, Maragra, and Xinavane. Xinavane is the largest sugar producer, accounting for around 50 per cent of total sugar production in Mozambique. Under the Xinavane structure, 70 per cent of the required sugarcane for milling operations is produced by the company. The remaining 30 per cent is sourced from private medium-sized and community farmers as the sugar companies' farm lands are fully utilized. The sugar company plays an important role in non-company sugarcane farming, particularly in the case of community farmers, who account for 12.5 per cent of total sugarcane output in the country. The company enters sugarcane purchasing agreements with community farmers and provides most of the needed inputs, including irrigation infrastructure and fertilizer inputs. Community farmers mostly only provide their labour and land. Payment for the sugar company inputs are deducted from receipts by community farmers for the sugarcane produced. Sugar companies also provide technical training to provide community workers with the necessary skills for sugarcane production. This is done to assist medium-scale and community farmers achieve crop yields of at least 100t/ha (Tembe and Baloi 2016). In 2015, private medium and community farmer sugarcane crop yields averaged between 60 and 78t/ha. The Centro de Estudos de Políticas e Programas Agroalimentares (CEPPAG) anticipates commercial and community yields of 92.3 and 90.5t/ha in 2016/17 (CEPPAG 2016).

Land availability is not expected to be a constraint to the expansion of sugarcane farming and hence bioethanol production. As part of their study to identify the constraints to biofuel production in Mozambique, Tembe and Baloi (2016) identify approximately 3 million ha of land appropriate for sugarcane farming in the country. An additional 19 million ha was identified as being moderately appropriate. Furthermore, about 80,000 ha of land equipped with irrigation infrastructure is also available in the country. The use of this land, however, has not been determined and is dependent on local priorities. While cash crop farming is still largely based on dryland farming methods, sugarcane production uses irrigation infrastructure.

The availability of infrastructure to transport bioethanol to neighbouring countries is necessary for the success of the sector. Schut et al. (2010) explored biofuel projects formally submitted to government, expressions of interest, and the inventory of implemented projects and found that biofuel projects have generally been proposed in areas with good infrastructure where sufficient access to ports is available. Ports, and road infrastructure used to access these ports, are reported to be in good condition. Ports are also equipped with fuel storage facilities, which the government is planning to rehabilitate, expand and modernize. However, we do not consider the impacts of additional infrastructure needed for transport in this study.

1.2 Costs of bioethanol production

To inform this analysis, sugarcane production costs and farming yields were collected by CEPPAG. The data collected by CEPPAG was based on the Xinavane sugarcane farming operations (including own farm costs as well as outsourced sugarcane operations). This data is used to inform the technology vectors included in the modelling exercise. Sugarcane yields are used to calculate the amount of land needed for sugarcane farming. CEPPAG has advised that the costs of other operators are like those of the Xinavane operations and that these costs would therefore fairly reflect average new sugarcane production costs in the country. The budget data did not offer information on the returns to the production factor capital. We use shares derived in a similar study for Zambia (see Hartley et al. 2016).

The sugarcane-to-ethanol conversion rate is reported to be 10 litres per tonne via the molasses route and 80 litres per tonne through direct conversion (Shumba et al. 2011). In this study, we assume that additional sugarcane grown is for bioethanol use only. Thus, we apply the direct conversion rate in line with other studies (Arndt et al. 2012; Hartley et al. 2016; Sinkala et al. 2013). Table 1 illustrates the potential cost of sugarcane feedstock in Mozambique. Due to data confidentiality, information is presented in aggregate form. Feedstock costs are found to be less than US$0.20 per litre (/L).

Very little bioethanol production occurs in Mozambique. Production that does take place is largely for own use with no large-scale commercial production taking place (Tembe and Baloi 2016). Thus, there is no Mozambique-specific data available for bioethanol processing. Following the approaches of Sinkala et al. (2013) and Hartley et al. (forthcoming), estimates from international experience are used. Specifically, we use information from Sinkala et al. (2013), which is based on a 2010 study by the Asia Pacific Economic Cooperation Secretariat (APEC 2010) in which the processing costs are considered for Brazil, Malaysia, and the USA over a 10-year period. Table 2 reports the bioethanol costs used. Including the costs of the sugarcane feedstock (see Table 1), it would cost between US$0.32 and US$0.33 to produce 1 litre of bioethanol in Mozambique.

Table 1: Bioethanol feedstock costs in Mozambique

	Farm type	
	Community	Commercial
Total production cost (US$)	3,786,936	16,036,166
Land area (ha)	2,934	11,349
Total cost (US$/ha)	*1,291*	*1,413*
Yield (tonne/ha)	90.50	92.30
Total cost (US$/tonne)	*14.26*	*15.31*
Ethanol conversion rate (litres/tonne)	80	80
Litres/ha	7,240	7,384
Total cost (US$/litre)	0.18	0.19

Source: CEPPAG (2016), own calculations.

Table 2: Bioethanol processing costs

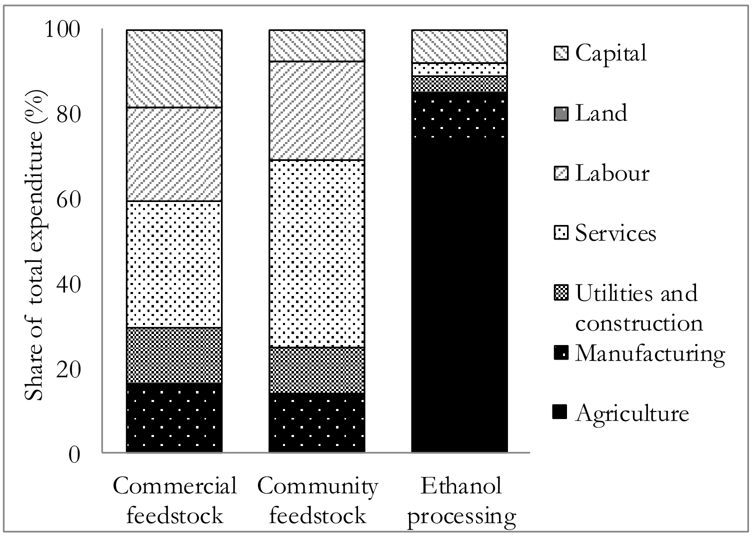
	US$/litre
Feedstock unit cost	0.18–0.19
Capital cost and interest	0.00
Chemical/enzymes	0.01
Energy/utility	0.02
Operations/maintenance	0.04
Unforeseen (extra required)	0.02
Total cost	0.32–0.33

Source: Sinkala et al. (2013), CEPPAG (2016), own calculations.

The production structures of commercial and community farmers are very similar, as illustrated in Figure 1. This is because community farmers receive the bulk of their inputs from the sugar company that owns the commercial farms. The result is also influenced, however, by the government's ban on mechanization for harvesting. Labour is therefore a relatively large share of costs for both commercial and community farmers. Capital costs make up a smaller share of community farmer budgets, thus community feedstock farmers seem to have stronger links to the domestic economy, as they spend a larger share of their budget on labour and intermediate goods and services. Commercial feedstock producers spend 20 per cent of their budgets on capital returns, most of which are likely to be offshore payments. In terms of intermediate consumption, farmers spend a large share of their budgets on services, primarily on transportation and storage.

As expected, feedstock crops are the largest input into the ethanol production process. This is presented by the share of expenditure on agriculture. Relative to commercial and community feedstock budgets, labour makes up a very small share of ethanol processing costs. This indicates that employment gains are likely to come from feedstock farming rather than ethanol processing.

Figure 1: Feedstock and processing expenditure by component



Source: CEPPAG (2016), Sinkala et al. (2013), own calculations.

2 Modelling methodology

2.1 A dynamic recursive CGE model for Mozambique

A dynamic recursive CGE model for Mozambique is used to quantify the economy-wide impacts of introducing a bioethanol industry in the country. The model is based on a newly developed 2012 Social Accounting Matrix (SAM) for Mozambique developed by van Seventer (2015) using data from the Instituto Nacional de Estatística and the International Monetary Fund (IMF). The SAM consists of 55 industries and commodities, 4 labour groups, and 10 representative household groups.[1] Representative household groups are defined by quintile for rural and urban areas using per capita expenditure data. Labour categories are defined by educational attainment and are categorized into incomplete primary, complete primary, complete secondary, and complete tertiary education. Other institutions: government, enterprises, and the rest of the world are also represented. The SAM also includes household production for own consumption, which makes up a large share of total rural household consumption.

Behavioural equations in CGE models capture the decision-making process of industries and households that maximize profits and utility subject to costs and purchasing power respectively. Producers consume both domestic and imported intermediate goods and services as well as factors of production. Production factors include capital, labour, and, in the case of agriculture, land. Intermediate goods and services consumption is governed by Leontief functions, while the consumption of production factors is specified according to constant elasticity of substitution (CES) functions. As a result fixed shares of goods and services are required in the production process, but production factors can be substituted according to changes in their relative prices.

For this specific model, we assume that each activity only produces one commodity. Commodities are sold to other industries as intermediate inputs and to households, government, and the rest of the world for final consumption and as investment goods. The level of commodities supplied to

[1] While existing sugarcane production and consumption is included in the 2012 SAM, the underlying data for this sector is not based on the fieldwork referred to earlier. Information from the fieldwork is used to inform new sugarcane production for bioethanol use.

domestic versus international markets is based on relative prices and is governed by a constant elasticity of transformation (CET) function. Similarly, the volume of goods and services imported is also based on relative prices and is represented by an Armington function. We assume that Mozambique is too small to directly affect global prices, which therefore remain fixed.

Households earn an income from providing labour, land, and capital to industries; and from government and foreign transfers. Returns to foreign labour, land, and capital are repatriated. Households consume both domestic and foreign commodities, pay taxes, transfer money abroad, and save. Consumption is based on a linear expenditure system (LES) of demand.

Structural equations ensure macroeconomic consistency between incomes and expenditures within the model. Closure rules are used to describe the functioning of the economy; these include the behaviour of exchange rates, investment, government savings, prices and quantities production factors supplies. In this exercise, we assume that the exchange rate adjusts to absorb shocks to the economy while foreign savings remain fixed. The level of investment is determined by total savings in the economy (private, government, and foreign). Government savings adjusts to changes in income and expenditure – all tax rates remain unchanged. The domestic price index is used as the model numéraire. To fully assess the impact on resource shifts, we assume that all labour and land in the economy is initially fully employed. Capital, not used in the biofuel industry, is also fully employed but is activity-specific. Existing capital can therefore not shift to other sectors in the economy.

2.2 Structure of the Mozambique economy

Apart from the service sector, agriculture is the largest contributor to gross domestic product (GDP) in Mozambique. In 2012, the agriculture, fishing, and forestry sector accounted for 28.5 per cent of total GDP and employed more than 75 per cent of the working population. More than 90 per cent of workers in the sector are unskilled with primary education or less.

Mozambique is dependent on imports for food security. In 2012, imports account for 20.3 per cent of total food crop demand and 40.4 per cent of processed food demand. Almost 40 per cent of cereal crops supplied to the market (maize, sorghum, rice and other cereals) are imported. Food crops and processed foods account for a relatively small share of exports (8.7 per cent) and total output (7.8 per cent). Food crops are largely used as intermediate inputs into cereal and vegetable processing for domestic intermediate and final consumption.

Mozambique is a net exporter of mining commodities. In 2012, 64.3 per cent of total mining output was sold on the world market. Manufactured metals and metal products were the largest exported commodity in 2012 with about 70 per cent of total output exported, accounting for 27 per cent of total exports. The service sector is the largest contributor to GDP and main consumer of capital and high-skilled labour.

Figure 2 illustrates household consumption by main commodity group. As highlighted previously, the 2012 SAM for Mozambique includes production for own use (i.e. subsistence consumption). The figure illustrates that, in 2012, subsistence consumption accounted for more than 40 per cent of total household consumption in Mozambique. For rural households, production for own use comprised 36.7 per cent of total consumption and almost 80 per cent of agriculture, fishing, and forestry consumption. This highlights the importance of subsistence farming for food security to poorer households in Mozambique. Subsistence consumption is not as important for urban households, accounting for less than 12 per cent of total consumption and around only 9 per cent of agriculture, fishing, and forestry consumption. Rural and urban households receive the bulk of their incomes from the supply of low-skilled labour. Urban households, however, also receive a large share of income from capital returns, while rural households receive additional income from land returns (see Figures 2 and 3).

Table 3: Structure of Mozambique economy, 2012

	Share of total (%)						
	GDP	Labour income	Employment	Exports	Imports	Exports/ output (%)	Imports/ demand (%)
Total GDP	100.0	100.0	100.0	100.0	100.0	17.6	27.3
Agriculture, forestry and fishing	28.5	29.3	75.4	4.6	5.5	5.9	13.6
Food crops	20.6	20.3	40.2	1.9	4.7	5.5	20.3
Other agriculture	4.1	4.0	10.6	1.0	0.5	6.7	7.2
Forestry and fishing	3.8	5.0	24.6	1.6	0.2	5.9	5.1
Mining	3.4	1.4	1.0	13.9	0.2	64.3	4.6
Manufacturing	11.7	8.7	2.2	47.0	74.5	40.2	63.2
Food processing	4.4	4.5	0.9	6.8	14.7	12.8	40.4
Other manufacturing	7.3	4.2	1.3	40.2	59.8	54.3	74.1
Utilities and construction	6.4	4.9	3.7	9.9	5.1	20.9	16.0
Services	50.1	55.8	17.7	24.7	14.7	8.0	6.7

Source: 2012 Mozambique SAM, van Seventer (2015), Jones and Tarp (2015), Pauw et al. (2012).

Figure 2: Household consumption, 2012

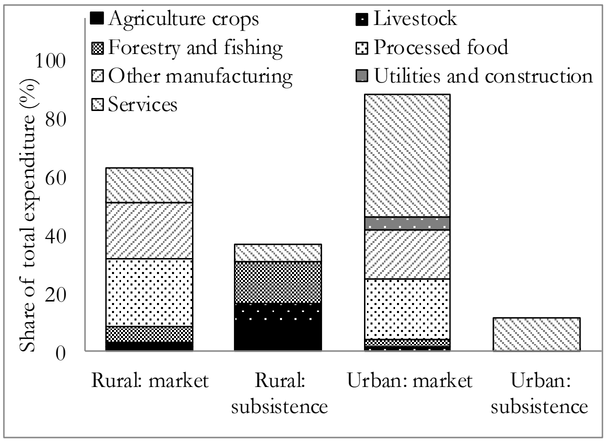
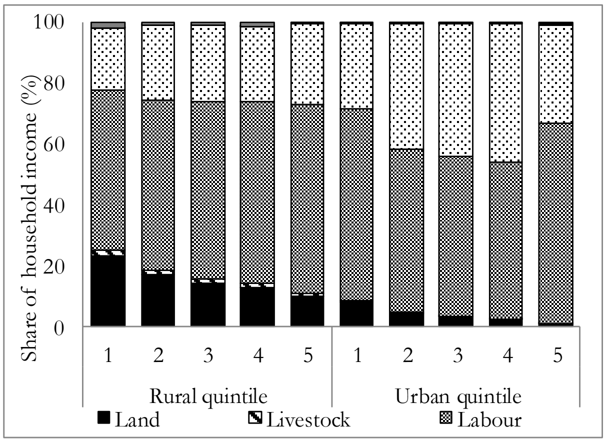


Figure 3: Household income by source



Source: 2012 Mozambique SAM, van Seventer (2015).

2.3 Baseline growth path

The baseline scenario represents a potential growth path for the Mozambique economy for the 2012 to 2025 period. The 2012 SAM is used as the starting point for defining relationships and parameters used in the CGE model. This structure is extended to 2025 using endogenous model solutions and exogenous growth assumptions for labour, livestock, and land supply; government expenditure and foreign savings. Capital stocks are updated in each period by investment from the previous period, after accounting for depreciation. Increases in sector capital stocks are a function of profitability in the previous period as well as share of total capital stock. Total factor productivity is adjusted for broad industry groups (agriculture, industry, and services) such that the baseline reflects historical and projected growth trends. Real GDP growth for the 2015 to 2025 period reflects the IMF projections for growth of about 7.2 per cent per annum (IMF 2016). On average, sector total factor productivity is adjusted upward by about 2.8 per cent per annum. The first column of Table 4 illustrates the core macroeconomic assumptions used in the development of the baseline scenario.

Table 4: Core macroeconomic assumptions and results, 2015–25

		Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Baseline	Bioethanol, status quo	Bioethanol, 50–50	Bioethanol + cogeneration	Bioethanol + displacement
Average annual growth rate (%)					
Total GDP	7.2	7.204	7.203	7.219	7.202
Labour supply	4.0	4.000	4.000	4.000	4.000
Capital stock	5.3	5.336	5.336	5.341	5.336
Biofuel capital stock	0.0	155.451	149.932	201.859	155.451
Livestock stock	1.0	1.000	1.000	1.000	1.000
Land supply	1.0	1.273	1.275	1.273	1.254
Deviation from baseline final year value, 2025 (%)					
Real exchange rate*	-	0.041	0.043	0.046	0.051
Real food prices	-	0.000	-0.001	0.002	0.004

* A postive (negative) value indicates an appreciation (depreciation).

Source: Authors' calculation based on the results from the Mozambique CGE model.

While we have attempted to include a realistic baseline scenario for the Mozambique economy, the choice thereof is not critical for the purposes of this study. The focus of this study is to assess the economy-wide impact of bioethanol production in Mozambique. We are therefore mainly interested in the differences between the base and various scenario outcomes.

2.4 Incorporating bioethanol production

The 2012 SAM for Mozambique is extended to include biofuel crop farming and bioethanol production using the technology vectors described in section 2.2. Sugarcane farming for bioethanol use is separated from general sugarcane farming for ease of modelling. We distinguish between commercial and community bioethanol crop farming as illustrated in Table 1. Both commercial and community farmers, as well as bioethanol processing firms, use capital from foreign markets. This is a reasonable assumption not only for commercial but also community farmers, as the latter currently produce for the sugar companies which are modelled to be foreign owned. Mozambique has also received significant interest from international investors for biofuel production since 2004, when the government announced its support for biodiesel production using jatropha (Schut et al. 2010). To reflect this in our modelled economy, almost all post-tax capital returns are repatriated to foreign commercial lenders, adding little to domestic incomes. About 0.1 per cent of capital returns go to the wealthiest urban household group. A new factor account is introduced into the SAM to capture this. In the baseline scenario, bioethanol crop and processing production is set to (almost) zero, providing a counterfactual for assessing the economic impacts of bioethanol production.

The introduction of the new industry creates a demand for bioethanol crops, which is supplied by the local market. To simulate the expansion in ethanol production, we exogenously increase the supply of land made available to feedstock farmers for the specific scenario. Farmers draw (foreign) capital, labour, and intermediate inputs into their production process. Feedstock outputs are used by the processing sector, along with capital, labour, and intermediate inputs, to produce bioethanol.

The development and upgrading of processing infrastructure for bioethanol production, if coupled with the development of cogeneration capacity, can also add to electricity supply. Sugarcane waste, bagasse, is typically used to meet the energy needs of the sugar mill, but in most cases there is an excess supply that can be supplied to the national grid. Mauritius has been successful in using bagasse for electricity production. In 2013, the country produced around 475 GWh (Gigawatt hours) of electricity from bagasse, comprising just over 16 per cent of total electricity production and 20 per cent of local electricity demand (Ministry of Energy and Public Utilities 2015). Deepchand (2005) estimated that Africa had the potential to produce 10,000 GWh of electricity from existing sugarcane waste. Mozambique specifically was estimated to have potential cogeneration power of between 154 and 242 GWh. These numbers are based on conversion factors of 70 kWh/tonne (kilowatt hours) and 110 kWh/tonne respectively. The potential for electricity production from little additional investment can significantly increase the benefits of bioethanol production in Mozambique. To assess this impact we include the potential for cogeneration through the introduction of a new bioethanol and cogeneration processing sector. The technology vector for this sector is like that of the bioethanol processing sector but also includes the cost of capital for generating electricity using bagasse. The levelized cost of electricity is estimated to be US$0.08/kWh (2015 prices). This estimate is derived from the Mauritius experience of building two 35 MW (megawatt) bagasse plants for a cost of US$90 million in 2000 (Deepchand 2005). Electricity is a by-product from bioethanol production, adding to domestic supply in the country. Based on Deepchand's (2005) estimates, we assume that 70 kWh of electricity is produced from 1 tonne of sugarcane.

We assume that all bioethanol is exported. It is likely, particularly in Mozambique given blending mandates, that some of the bioethanol produced may be used domestically. Previous biofuels projects proposed, however, were for meeting international demand (Schut et al. 2010). Either way, this does not have a significant impact on the results as the country is dependent on imports for its fuel needs. Domestic use of bioethanol would reduce exports of bioethanol but also reduce imports of petroleum.

2.5 Scenarios and assumptions

As highlighted in the introduction, the blending mandates announced in South Africa provide a key anchor market for biofuels in the SADC and Southern African region. Stone et al. (2015), assuming an average growth rate of 2.7 per cent for the 2007 to 2040 period (real GDP growth averaged 2.3 per cent between 2007 and 2015), estimates that bioethanol demand in South Africa could potentially increase to between 300 and 1,400 million litres per annum by 2025 under a 2 and 10 per cent blending mandate respectively. We therefore consider the economic impacts for Mozambique if it were to meet the upper end of this demand by 2025. Production is assumed to increase by about 160 million litres per annum over a 10-year period, such that by 2025 the sector produces 1,400 million litres of ethanol. We consider four scenarios in our analysis.

Scenario 1 (Bioethanol, status quo) assesses the impact of developing a sugarcane bioethanol sector in Mozambique. We assume that the current structure of the sugarcane farming system is maintained; that is, 87.5 per cent of sugarcane is produced by commercial farmers and the remainder by community farmers. Macro and factor assumptions are described in section 3.1. Capital for bioethanol crop farming and processing is assumed to be funded by international investors and therefore has no direct impact on the domestic capital supply and demand by other industries. Land for feedstock crop farming is acquired from currently unused land. Total land use in the economy therefore increases.

Scenario 2 (Bioethanol, 50–50) is the same as scenario 1 except that the sugarcane needed for bioethanol production comes equally from both commercial and community farmers. The implication of this is that marginally more land is needed for the same level of sugarcane production as community farmer yields are lower; and more labour resources are required as community farmers are more labour intensive. The purpose of this scenario is to assess whether there are significant welfare gains from using a larger share of community farmers relative to the status quo.

Scenario 3 (Bioethanol, status quo + cogeneration) is the same as scenario 1 but includes the impact of cogeneration as described under section 3.4.

While there is little evidence to suggest that growing sugarcane as a feedstock for ethanol production would result in the displacement of food crops – sugarcane is not considered a food crop and sugar companies have agreed with farmer associations to set aside 30 per cent of irrigated community farm lands for food crop production – some farmers interested in bioethanol crop farming have indicated that they would move their livestock operations to rain-fed land. For this reason, as well as due to the importance of food security in Mozambique, we assess the impact of bioethanol production should 50 per cent of land needed by smallholder farmers for growing sugarcane farming displace other agricultural activities. All other assumptions in this scenario (scenario 4: Bioethanol, status quo + displacement) are the same as in scenario 1.

While climate variability may potentially have a significant impact on crop production yields in Mozambique, the impact on sugarcane is likely to be smaller as farmers use irrigation systems instead of rain for watering. Drier and hotter climatic conditions, however, are likely to lead to more frequent watering, which would raise the costs of irrigation. This would lead to higher sugarcane prices and increase the cost of bioethanol, potentially making it less competitive relative to alternative fuels and suppliers. The potential size of this cost increase is unknown. For this reason, we do not include the impact of climate variability in our analysis.

3 Results

This section reports the results from the modelling exercise. Unless otherwise specified, the results are presented as the percentage point change in the average annual growth rate over the 2015 to 2025 period relative to the baseline scenario. The 'Total GDP' result of 0.0032 for scenario 1 in Table 5 is therefore interpreted as an increase in the average annual growth rate from 7.2 per cent in the baseline to 7.2032 per cent in scenario 1 (see Table 4).

3.1 Impacts on economic growth

The results show that the development of a bioethanol sector in Mozambique has the potential to increase average annual real GDP growth, particularly if the bagasse waste from the process is transformed into electricity (see Tables 4 and 5). Average annual real GDP growth increases by 0.003 percentage points in scenario 1 versus 0.018 percentage points in scenario 3. This is equivalent to a 0.03 and 0.17 per cent increase in the level of real GDP by 2025. Increasing the share of bioethanol feedstock grown by smallholder farmers results in a marginally smaller increase in average annual real GDP growth. The switch to industrial crop farming also has a very small impact on the overall impact on real GDP growth, but remains positive.

To produce 1,400 million litres of bioethanol by 2025, sugarcane output must increase by 17.5 million tonnes per annum, requiring about a further 19,000 ha of land each year. We assume that land is acquired through the utilization of idle arable land in Mozambique, expanding the total land supply used in the country. Land supply increases by about 1.3 per cent per annum relative to 1 per cent in the baseline (see Table 4). In scenario 4, the expansion in land supply is smaller as we assume that 50 per cent of the increase needed for smallholder farmers is acquired through the displacement of other crops.

As indicated in section 3.1, the supply of labour remains unchanged between scenarios, increasing by 4 per cent per annum. The introduction of the bioethanol sector, however, increases the demand for labour. Thus, the average wage in the economy increases relative to the baseline. This increases the costs of production elsewhere in the economy and negatively affects sectors with price sensitive demand. The decline in valued added in some sectors offsets some of the gains from bioethanol production, thereby muting the positive impact on real GDP across all scenarios.

Sectors that experience a decrease in activity, however, release resources into the economy to be used elsewhere. This includes land which, across scenarios, is released primarily from the maize agriculture sub-sector to more profitable agriculture sub-sectors such as pulses, cassava, sorghum, and groundnut. These crops account for about 50 per cent of rural and lower income urban households' food crop diets. The endogenous shift in land use therefore limits the negative impact of industrial crop production on food security. With the displacement, land available to all non-bioethanol feedstock growers decreases, leading to a decline in volume of agriculture food crops available for consumption.

Food crop prices remain relatively unchanged in scenario 1 when bioethanol processing is introduced. Marginally lower food prices are experience in scenario 2 as the cost of land is lower than in scenario 1 due to larger additional supply. Food prices increase in scenario 3 relative to the baseline as increased demand for labour stimulated by lower electricity prices places further upward pressure on wages. The largest food price increases are experienced in scenario 4 as food production decreases due to land constraints. The exchange rate appreciates relative to the baseline scenario to maintain the current account balance due to increased bioethanol exports.

3.2 Changes in sector production

Table 5 presents some sector impacts. Average annual growth in agriculture and manufacturing gross value added (GVA) increase by 0.01 and 0.005 percentage points in scenario 1 due to increased sugarcane production and bioethanol processing. Sub-sectors in agriculture and manufacturing with few links to the bioethanol industry experience slower growth, however, as higher average wages in the economy place pressure on these sub-sectors. The mining sector experiences the largest decrease in average annual growth as it is also negatively affected by the appreciation in the real exchange rate. The services sector, primarily transport and financial services, experiences an increase in average annual growth due to strong links (directly and indirectly) with the bioethanol industry.

The impacts on electricity-intensive sectors are less negative in scenario 3, where electricity is produced as a by-product of bioethanol processing. Approximately 1225 GWh of electricity is produced from bagasse by 2025, adding 4 per cent to the volume of electricity supply in the country and reducing the price of electricity by 0.14 per cent. While, the higher labour price induces a shift to using more capital across all scenarios, this is amplified in scenario 3 due to the lower electricity price. Overall, however, the inclusion of cogeneration leads to stronger real GDP gains.

Displacing other agricultural activities for sugarcane farming leads to lower gains in real GDP growth relative to scenario 1, as food crop production declines. This increases prices and has knock-on effects on the rest of the economy through the linkages between sectors. Gains in real GDP growth are also smaller in scenario 2 (relative to scenario 1), where a larger share of sugarcane from community farmers is used for bioethanol processing. This is because smallholder farmers demand more labour placing further upward pressure on average wages.

Table 5: Sector growth, 2015–25

			Deviation from baseline growth rate, 2015–25 (% point)			
			Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Share, 2012 (%)	Baseline growth, 2015–25 (%)	Bioethanol, status quo	Bioethanol, 50–50	Bioethanol + cogeneration	Bioethanol + displacement
Total GDP	100.0	7.2	0.0032	0.0025	0.0187	0.0021
Agriculture	28.5	7.7	0.0095	0.0079	0.0100	0.0054
Food crops	20.6	7.6	0.0008	0.0009	0.0021	-0.0027
Other agriculture	4.1	8.0	-0.0373	-0.0392	-0.0411	-0.0480
Forestry and fishing	3.8	8.3	-0.0062	-0.0066	-0.0051	-0.0062
Mining	3.4	5.7	-0.0110	-0.0122	-0.0123	-0.0099
Manufacturing	11.7	5.8	0.0053	0.0026	0.1511	0.0057
Food processing	4.4	5.5	-0.0065	-0.0068	-0.0059	-0.0064
Other manufacturing	7.3	5.9	-0.0078	-0.0094	-0.0014	-0.0072
Utilities and construction	6.4	7.6	-0.0020	-0.0035	-0.0002	-0.0015
Services	50.1	7.2	0.0004	0.0008	0.0022	0.0005

Source: Authors' compilation based on results from the Mozambique CGE model.

3.3 Sector employment shifts

The bioethanol industry is estimated to create around 56,000 jobs directly through feedstock and processing activities by 2025. In the case of larger community farmer sugarcane use (scenario 2), the number of potential jobs that can be created is almost 3,000 more, as community farmers are more labour intensive than commercial farmers. The bulk of employment generated by the bioethanol industry occurs in the production of the bioethanol feedstock as the processing activity is not very labour intensive.

The shift of labour into the bioethanol industry is matched by a shift of labour out of other sectors due to our assumption of full employment. Sectors that experience the largest declines in average annual growth are also those that experience the largest decreases in employment relative to the baseline scenario. Larger outflows are experienced in scenario 2 as more labour is needed in the bioethanol industry. Other manufacturing, and utilities and construction, experience smaller outflows of workers in scenario 3 as lower electricity prices reduce the decline in activity in these sectors. Sectors experiencing positive GVA growth relative to the baseline also experience smaller outflows of workers.

The employment shifts presented in Table 6 illustrate the significance of employment constraints on the economy-wide impacts of bioethanol and cogeneration production in Mozambique. Constrained labour will result in decreased activity in sectors less able to compete and smaller overall economic benefits. If this constraint is released, the GDP gains from bioethanol processing may be higher and lead to increased employment.

Table 6: Sector employment, 2015–25

		Deviation from baseline growth rate, 2015–25 (% point)			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Baseline employment growth, 2015–25 (%)	Bioethanol, status quo	Bioethanol, 50–50	Bioethanol + cogeneration	Bioethanol + displacement
Total	4.0	0.0000	0.0000	0.0000	0.0000
Agriculture	4.4	0.0068	0.0070	0.0059	0.0060
Food crops	4.5	-0.0080	-0.0083	-0.0083	-0.0074
Other agriculture	5.1	-0.0445	-0.0467	-0.0493	-0.0534
Forestry and fishing	3.6	-0.0082	-0.0086	-0.0082	-0.0080
Mining	0.4	-0.0234	-0.0255	-0.0308	-0.0208
Manufacturing	3.5	-0.0128	-0.0139	-0.0123	-0.0119
Food processing	4.0	-0.0095	-0.0099	-0.0106	-0.0092
Other manufacturing	3.1	-0.0170	-0.0189	-0.0146	-0.0153
Utilities and construction	6.6	-0.0041	-0.0062	-0.0019	-0.0033
Services	3.6	-0.0011	-0.0007	-0.0008	-0.0009

Source: Authors' compilation based on results from the Mozambique CGE model.

3.4 Household welfare and food security

The impact on household welfare by quintile for rural and urban households is presented in Table 7. In this paper, we use real per capita consumption as an indicator of welfare as it measures the real purchasing power of households. Overall, the introduction of a bioethanol industry in Mozambique has small but positive impacts on welfare, as expected, more so for households in rural areas.

Table 7: Real per capita consumption, 2015–25

			Deviation from baseline growth rate, 2015–25 (% point)			
			Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Per capita consumption, 2012	Baseline growth, 2015 (%)	Bioethanol, status quo	Bioethanol, 50–50	Bioethanol + cogeneration	Bioethanol + displacement
Rural	**9,104**	**5.5**	**0.0012**	**0.0012**	**0.0026**	**-0.0011**
Quintile 1	3,173	5.6	0.0007	0.0007	0.0020	-0.0020
Quintile 2	5,190	5.5	0.0010	0.0010	0.0024	-0.0016
Quintile 3	13,661	5.5	0.0012	0.0012	0.0025	-0.0013
Quintile 4	10,823	5.5	0.0012	0.0013	0.0026	-0.0011
Quintile 5	15,218	5.5	0.0013	0.0014	0.0028	-0.0004
Urban	**17,567**	**4.4**	**0.0010**	**0.0011**	**0.0033**	**0.0005**
Quintile 1	2,694	4.5	0.0008	0.0008	0.0025	-0.0011
Quintile 2	1,859	4.5	0.0000	-0.0002	0.0020	-0.0008
Quintile 3	3,965	4.4	0.0001	0.0000	0.0024	-0.0005
Quintile 4	11,473	4.4	0.0003	0.0002	0.0026	-0.0003
Quintile 5	49,241	4.3	0.0012	0.0013	0.0035	0.0008

Source: Authors' compilation based on results from the Mozambique CGE model.

In scenario 1, average annual growth in rural household welfare increases by 0.0012 percentage points with all quintiles experiencing an improvement in welfare. This is equivalent to an improvement of 0.01 per cent by 2025. The increase in rural household welfare is the result of increased incomes from land and labour. Land incomes increase due to increased supply, while labour incomes rise due to higher wages. Welfare gains are marginally smaller for urban households as enterprise income (i.e. returns on capital) decreases relative to the baseline scenario. Enterprise income is lower due to lower non-bioethanol production, as scarce resources are shifted away towards biofuels-related activities. Welfare impacts are only marginally stronger under scenario 2, as higher wage incomes are offset by lower land incomes. Land incomes are marginally smaller in scenario 2 than scenario 1 as the larger increase in supply lowers the return to land.

Both rural and urban households experience larger welfare gains in scenario 3. This is expected as overall activity in the economy is higher. Gains to urban household welfare, however, are larger than to rural household welfare as the additional electricity favours capital-intensive industries. Welfare losses are experience under scenario 4 as lower land availability for non-bioethanol use results in lower production and hence less demand for other factors of production. Welfare is also negatively affected in this scenario by higher prices in the economy.

Across scenarios, household food consumption increases. While the consumption of both food crops as well as processed food increases, there is a marginal shift to consuming more processed foods by both rural and urban households. Urban households, primarily low-income households, decrease their consumption of own-produced foods, choosing instead to consume more store-bought foods. While rural households increase their consumption of both own-produced and purchased foods, the share of purchased foods increases.

3.5 Releasing the constraint of unskilled labour

In addition to the scenarios considered above, we also assess the impact on the Mozambique economy if sufficient unskilled labour (i.e. labour with primary school education or less) was available to meet the increase in demand. Experience from existing sugar operations suggests that, to a degree, labour is constrained during peak harvesting times as sugar companies import labour from other regions to meet the increase in labour demand. The option to draw in labour, however, suggests that workers are available to supply the demanded labour.

Table 8: Economic impacts under unconstrained low-skilled labour

	Deviation from baseline growth rate, 2015–25 (% point)			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Bioethanol, status quo	Bioethanol, 50–50	Bioethanol + cogeneration	Bioethanol + displacement
Total GDP	0.0068	0.0062	0.0220	0.0056
Agriculture	0.0149	0.0135	0.0155	0.0107
Mining	-0.0090	-0.0101	-0.0103	-0.0078
Manufacturing	0.0088	0.0063	0.1502	0.0092
Utilities and construction	0.0017	0.0004	0.0035	0.0022
Services	0.0029	0.0033	0.0048	0.0029
Total employment	0.0052	0.0053	0.0053	0.0051
Agriculture	0.0153	0.0156	0.0146	0.0141
Mining	-0.0177	-0.0195	-0.0248	-0.0150
Manufacturing	-0.0063	-0.0072	-0.0055	-0.0054
Utilities and construction	0.0017	-0.0001	0.0040	0.0024
Services	0.0017	0.0022	0.0021	0.0019
Per capita consumption				
Rural	0.0057	0.0058	0.0072	0.0034
Urban	0.0038	0.0040	0.0062	0.0033

Source: Authors' compilation based on results from the Mozambique CGE model.

We therefore assess the impact of bioethanol production in Mozambique were the industry able to pull in additional labour supply. Labour supply in these scenarios (as well as the baseline scenario) is modelled as an upward sloping supply curve, which means that while labour can be drawn in by a higher wage, the supply of this labour is not infinite. Skilled labour is still assumed to be fully employed. The release of the unskilled labour constraint in all scenarios, including the base, results in larger GDP gains as average wage increases in the economy are partly offset by the increase in labour supply. Average annual real GDP growth is almost 0.004 percentage points higher relative to the baseline scenario. Welfare impacts (reported here as per capita consumption increases) remain positive and improve relative to the labour-constrained scenarios. Average annual employment growth is around 0.005 percentage points higher. As expected, the bulk of jobs are created in the agriculture sector. The mining sector continues to experience a decrease in activity and employment due to the appreciation in the exchange rate.

4 Conclusions and recommendations

Developments in EU trade policy, Mozambique's main sugar exporting market, along with the current global sugar surplus has brought about the need for the government of Mozambique to think about reforming the sector to ensure continued growth and protect the workers in the sector. Biofuel production provides the country with an alternative market for its sugarcane. Expected demand from the SADC region, particularly from South Africa, provides a particularly good opportunity for Mozambique given existing relations between the countries, favourable tariffs under the SADC Protocol, and its proximity to this market. Transforming the sugar industry into a bioethanol industry will require very little change for large benefits (Schut et al. 2010). Furthermore, coupling bioethanol production with biomass cogeneration provides additional economic opportunities and can assist the country in energy security.

Studies by Schut et al. (2010), Arndt et al. (2012), and Tembe and Baloi (2016) highlight that the country possesses the biophysical properties needed to become a key ethanol producer on the African continent. Furthermore, investor interest in previous attempts to develop a biodiesel sector (see Schut et al. 2010) indicates that the necessary investment for the development of the sector is highly likely to be available. Estimated sugarcane farming budgets from field studies by CEPPAG, coupled with international processing budgets, show that Mozambique has the potential to produce bioethanol at internationally competitive prices of around US$0.30/L.

Ethanol production is found to have a positive impact on economic growth and employment. The production of 1,400 million litres for the South African market by 2025 is likely to increase real GDP growth by 0.03 percentage points per annum; however, if cogeneration from bagasse is also adopted these gains increase to 0.19. GDP gains may be higher if sufficient labour resources are available. This is illustrated in Table 8, where the unskilled labour constraint is eased. This finding highlights the importance of enabling efficient labour markets that allow labour mobility. The bioethanol industry directly creates around 56,000 jobs. The bulk of these occur in feedstock farming, which primarily uses unskilled labour. The results also show that the introduction of sugarcane for industrial use does not necessarily have to jeopardize food security in the case of Mozambique; and, for many households, welfare increases.

To reap the benefits from the development of a bioethanol industry in Mozambique, mistakes from previous experiences must be avoided (see Kegode 2015; and Tembe and Baloi 2016). The most crucial of these is the guarantee of purchase for bioethanol feedstock crops. In the case of biodiesel production in Mozambique many farmers were left stranded with jatropha which was supposed to be used in biodiesel production. Transport and logistic constraints, while potentially avoidable through appropriate ethanol processing plant placement, require further analysis as high costs may reduce the international competitiveness of Mozambique as a bioethanol supplier. The vulnerability of the sector due to climatic changes, while not considered in this paper, is also important and should be considered in future research.

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