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Biofuels and economic development: A computable general equilibrium analysis for Tanzania

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ABSTRACT

Biofuels could offer new economic opportunities for low-income countries. We use a recursive dynamic computable general equilibrium model of Tanzania to evaluate different biofuels production options and estimate their impacts on growth and poverty. Our results indicate that maximizing the poverty-reducing effects of biofuels production in countries like Tanzania will require engaging and improving the productivity of smallholder farmers. Evidence shows that cassava-based ethanol production is more profitable than other feedstock options. Cassava also generates more "pro-poor" growth than sugarcane-based systems. However, if smallholder yields can be improved rather than expanding cultivated land, then both sugarcane and cassava out-grower schemes generate similar pro-poor outcomes. We conclude that, in so far as the public investments needed to establish a biofuels industry are consistent with other development needs, then producing biofuels will enhance economic development in countries like Tanzania.

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1. Introduction

Many low-income countries see biofuels as an opportunity to promote development (Ewing and Msangi, 2009). Tanzania, for example, is considering establishing a domestic biofuels industry in order to stimulate agricultural growth, create jobs and reduce rural poverty (Arndt et al., 2011b). Evidence suggests that optimism about biofuels in developing countries may be justified. In Mozambique, for example, Arndt et al., (2011a) find that proposed large-scale biofuels investments will increase economic growth by half a percentage point each year over the coming decade and lift 5% of the population above the national poverty line. This supports the view held by some that biofuels could help low-income countries overcome their dependence on oil imports while also reducing greenhouse gas emissions and increasing farmers' participation in the growth process (see, for example, FAO, 2008).

Optimism over biofuels is countered by uncertainty over possible trade-offs between biofuels and food production, and the effects that declining food supplies may have on poverty and food insecurity. This concern has received considerable attention in the biofuels debate and has gained support after the 2008 global food crisis (Headey and Fan, 2008; Rosegrant, 2008). Shifting resources away from food production could increase households' reliance on marketed foods, and biofuels may not raise the incomes of poor households enough to offset higher food prices. Finally, biofuels may not reduce greenhouse gas emissions once the effects of land clearing and fertilizer use are considered (Melillo et al., 2009; Searchinger et al., 2008).

Possible trade-offs between biofuels and development have prompted low-income countries to consider a range of biofuel production options, such as smallholder versus plantation systems. In evaluating proposals from foreign investors, governments must decide which feedstocks and farming systems are both economically viable and contribute to national development. Most studies that evaluate biofuel policies use global models, group low-income countries into regions, and/or focus on developed countries' policies (see Kretschmer and Peterson, 2010 for a review). However, biofuel strategies in (smaller) developing economies should be informed by country-specific analysis. To illustrate the benefits of such analysis, we develop a recursive dynamic computable general equilibrium (CGE) model of Tanzania, and use the model to estimate the impact of alternative biofuels scenarios on economic growth and employment. The model is also linked to a micro-simulation module that estimates impacts on poverty. Section 2 outlines Tanzania's biofuels production options; Section 3 describes the model and how the various options are simulated; and Section 4 presents the

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results. The final section summarizes our findings and identifies areas for further work.

2. Options for producing biofuels in Tanzania

2.1. Identifying biofuels production scenarios

Tanzania is considering various biofuel production options (see Felix et al., 2010) that differ on three characteristics: (1) the type of feedstock used and biofuel produced (i.e., sugarcane or cassava); (2) the scale of feedstock production (i.e., smallholder versus estate); and (3) the way in which feedstock production is expanded (i.e., increasing yields or harvested area). Table 1 summarizes the six biofuels scenarios considered in this paper.

The first three scenarios (*Sugar 1–3*) refer to ethanol produced from sugarcane. In the first scenario (*Sugar 1*) all feedstock is produced by smallholder farmers through an out-grower scheme and is supplied to large processing plants. Conversely, the second scenario (*Sugar 2*) assumes that all feedstock is produced on large-scale commercial farms. These two scenarios allow us to contrast the impacts of small- and large-scale sugar production options. Finally, in the third scenario (*Sugar 3*), sugarcane is produced via an out-grower scheme, but by raising smallholders' yields of sugar for biofuel feedstock (from 43 to 70 tons per hectare) rather than by expanding the amount of land under sugarcane cultivation. This reduces the amount of land that is currently used for crops and which would have to be displaced by biofuel feedstock production.

We also consider cassava as a potential biofuel feedstock. In each scenario, we assume that production is by smallholders through an out-grower scheme and that processing is done by large-scale processing plants. The first two scenarios differ in that *Cassava 1* assumes that production is achieved through extensification (i.e., land expansion) while *Cassava 2* assumes that cassava feedstock yields are increased (from 10 to 20 tons per hectare) thereby limiting the amount of land displaced to produce biofuel feedstock. The *Cassava 3* scenario assumes a mixed production system, with 40% of feedstock obtained from smallholders through yield improvements (i.e., as in *Cassava 2*) and the rest produced by large-scale commercial farmers situated close to a large-scale processing plant. This mixed farming system offers a compromise between ensuring reliable feedstock supplies (from plantation farms) and reducing poverty (via smallholder participation).

The six biofuel production options allow us to compare feedstocks, scale of production, and intensive/extensive approaches. To make the scenarios comparable, we simulate the same biofuels production volumes in all scenarios. More specifically, we model the establishment of a biofuel industry in Tanzania capable of producing 1000 million liters of ethanol per year (i.e., 3 million liters per day) by 2015. This is greater than the capacity currently envisaged by either the Government of Tanzania or private foreign investors; however, it is useful for this exercise as it permits us to identify economywide impacts.[1]

2.2. Estimating production costs and technologies

The biofuels scenarios in Table 1 contrast the impacts of different feedstocks and processing plants. These scenarios will produce different outcomes because they use different technologies (i.e., factor and intermediate inputs) and generate different profit rates for farmers and downstream processors. Felix et al. (2010) estimate biofuel production costs for Tanzania, as shown in Table 2.

Producing ethanol in Tanzania costs US$0.37 per liter under a mixed small and large-scale cassava-based production system (i.e., *Cassava 3*) and US$0.43 per liter for large-scale commercial sugarcane-based production (i.e., *Sugar 2*). Both options compare favorably with ethanol production costs in countries such as Brazil (US$0.47), United States (US $0.46) and India (US$0.52). However, the estimated costs of producing ethanol from smallholder-based sugarcane (i.e., *Sugar 1*) suggest that not all biofuels production options in Tanzania are as competitive as production in other countries. In our analysis, we assume that the domestic ethanol price received by processing plants is US$0.56 per liter, implying that all six options have net operating surpluses although the returns to land and capital dedicated to biofuel production vary and may be below market in some scenarios (e.g., Sugar 1).

Using the estimated production costs and crop budgets, we derive production technologies for the six biofuels scenarios (see Table 3). The top half of the table shows the inputs required and outputs generated for 100 hectares of land allocated to feedstock production. From the first two columns, we see that smallholder crop yields (i.e., *Sugar 1*) are lower than larger-scale farmers' yields (i.e., *Sugar 2*), implying that small-scale farm land produces about half the output of plantations on the same amount of land (i.e., 4280 versus 8400 tons). Small-scale farms are also more labor-intensive (i.e., 0.4 hectares per worker versus 2.4 hectares per worker on larger farms). Increasing smallholders' sugarcane yields increases production levels per 100 hectares of land (i.e., to 6,999 tons), but requires additional labor for weeding and harvesting. Cassava production is also labor-intensive and requires more land per liter of ethanol than sugarcane. The mixed cassava production system (i.e., *Cassava 3*) is more labor-intensive than the equivalent smallholder scenario (i.e., *Cassava 2*) since new commercial farms require additional laborers whereas smallholders increase production by raising yields on their existing farm land.

The lower half of Table 3 shows the inputs required to produce 100,000 liters of ethanol. All scenarios use large-scale processing plants

Table 1
Simulated ethanol production scenarios for Tanzania.

CGE model scenario	Scale of feedstock production	Feedstock yield (tons per hectare)	Land expansion (% of land from displacement)
Sugar 1	Small	Low (43 mt/ha)	Yes (50%)
Sugar 2	Large	Low (84 mt/ha)	Yes (50%)
Sugar 3	Small	High (70 mt/ha)	No (0%)
Cassava 1	Small	Low (10 mt/ha)	Yes (50%)
Cassava 2	Small	High (20 mt/ha)	No (0%)
Cassava 3	Small/large mix	High (20 mt/ha)	Yes (30%)

Source: own calculations using information from Felix et al. (2010).

Table 2
Production cost estimates for ethanol scenarios.

	Sugar 1	Sugar 2	Sugar 3	Cassava 2	Cassava 3
Cost per liter (US$)	0.567	0.434	0.529	0.469	0.369
Raw materials	0.416	0.310	0.393	0.252	0.190
Service fluids	0.039	0.025	0.027	0.086	0.079
Labor	0.001	0.001	0.001	0.000	0.000
Maintenance	0.014	0.014	0.015	0.025	0.020
Operating charges	0.000	0.000	0.000	0.000	0.000
General plant costs	0.007	0.007	0.008	0.013	0.010
Administrative costs	0.038	0.029	0.035	0.030	0.024
Capital depreciation	0.063	0.063	0.070	0.064	0.045
Co-products	−0.011	−0.016	−0.019	0.000	0.000

Source: own calculations based on Felix et al. (2009).

[1] Instead of imposing growth of alternative biofuel production technologies on the model through growth in fixed factors (land and capital), it would be possible, in principle, to leave the level of biofuels production as endogenous and allow the model to determine the level of production given the international price. In practice, some response dampening formulation is almost invariably required (hence the ubiquity of the Armington and constant elasticity of transformation functions on imports and exports).

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