Biofuels, Poverty, and Growth: A Computable General Equilibrium Analysis of Mozambique

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Discussion Paper

No. 63E

April 2008

National Directorate of Studies
and Policy Analysis

Ministry of Planning and
Development

Republic of Mozambique

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The logo was kindly provided by the artist Ndlozy.

Acknowledgements: The authors would like to thank CEPAGRI and members of the biofuels working group for fruitful collaboration and comments on an earlier version. Financial support from the development cooperation programs of Sweden and Switzerland is gratefully acknowledged.

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Abstract: Large investments in bio-fuels are currently in process in Mozambique. This analysis seeks to assess the macroeconomic implications of biofuels investment for growth and income distribution using an economywide framework. Results suggest that biofuels provide Mozambique with an opportunity to substantially enhance economic growth and poverty reduction. The primary biofuels scenario modeled here results in increases in the average annual economic growth rate of 0.6% and reductions in poverty incidence by six percentage points at the end of a 12 year phase-in period. Institutional arrangements and production technologies matter. We find that an outgrower approach is much more strongly pro-poor due to greater use of unskilled labor and the accrual of land rents to smallholders compared with a plantation approach. The growth and poverty reduction benefits of outgrower schemes are further enhanced if the schemes result in technology spillovers to other crops.

1 Introduction

Large investments in bio-fuels are currently in process in Mozambique. In 2006, approximately five million hectares were planted countrywide. This represents about one sixth of total arable area available in Mozambique. Land remains state owned and use rights must be requested from the state. Currently, the state has requests for use rights for more than 12 million hectares, or more than double the area currently planted. The majority of these requests relate to bio-fuels, particularly sugarcane and sweet sorghum for the production of ethanol and jatropha for the production of biodiesel.

The surge of interest in bio-fuels production potentially constitutes a significant opportunity for Mozambique. However, it also raises a series of policy questions including (but not limited to):

- Will lower income people benefit from large scale bio-fuels investment?
- What are the implications of production of crops for biofuels on a plantation basis compared with on contract with smallholders?
- What is the demand for complementary investments in roads, irrigation, ports, etc?
- Are there potential threats to household food security if bio-fuel crops substitute for food production?
- Should the government be concerned about the stability of the world price of bio-fuels?

This analysis seeks to provide insight into some of these questions via a computable general equilibrium model of Mozambique. It is not possible to address all of the issues associated with biofuels in a single framework. Focus here is on assessment of the macroeconomic implications of biofuels investment for growth and income distribution. In particular, plantation versus outgrower schemes for biofuels production are compared. In addition, the analysis considers the strength of interaction between the subsistence and the bio-fuels sectors.

Four sections follow this introduction. First, relevant information on the Mozambican country context is presented. Next, relevant literature on bio-fuels is reviewed. The CGE modelling framework and results are then presented. A final section concludes and discusses policy implications as well as directions for future research.

2 Country Context

While improved from 10 years ago, the current reality in Mozambique, particularly in rural areas, remains sobering. Approximately 70% of the total population resides in rural areas. About half of these are considered absolutely poor, meaning that these households have difficulty acquiring even the most basic necessities, such as sufficient food for meeting calorie requirements (Arndt and Simler, 2007). Rural dwellers, particularly the poor, depend heavily on crop agriculture for their incomes. Technology is generally rudimentary and agricultural value added remains concentrated in cassava, cereals (particularly maize), and beans. Only a small minority of rural households report using improved seeds, fertilizers, and pesticides (Uaiene, 2008). While urban zones tend to be somewhat more diverse, agriculture remains the single largest sector in terms of employment for urban dwellers. Further, more than half of urban dwellers engaged in agriculture are categorized as absolutely poor (Chiconela, 2004).

Overall, approximately three fourths of the Mozambican population (rural and urban) depends upon subsistence agriculture for the majority, typically the very large majority, of their income. These households, particularly those in rural areas, tend to consume most of their production directly with a relatively small share marketed. Even among those not dependent on agriculture for their income, consumption is composed, in substantial measure, of the surpluses sold by subsistence producers. Hence, living standards for the majority of the total population currently depend in significant measure upon outcomes in subsistence agriculture.

The deep and widespread poverty that characterizes Mozambique does not stem from a lack of agricultural potential.[1] To the contrary, Mozambican agricultural potential is, by almost universal consensus, large. This is especially true when potential is compared to current agricultural value added. As indicated earlier, vast tracts of decent quality land exist and only a relatively small fraction of this available land is actually exploited. Water resources, in the form of multiple rivers, are relatively abundant and an even smaller

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[1] Historical factors involving the character of Portuguese colonization, a failed socialist experiment, and a vicious civil war that lasted until 1992 contributed to Mozambique earning the label “poorest country in the world” in the early 1990s (Arndt, Jensen, and Tarp, 1998). Most indicators point to substantial improvements since that time; however, the very low starting point implies the necessity of rapid improvement for extended periods to achieve even the averages for developing countries.

fraction of these available water resources are currently exploited. The long coastline contains multiple harbors. Further, these harbors open East towards the dynamic markets of Asia. Regional markets also offer promise in both the short and the long terms.

Overall, Mozambican agriculture can be divided into two sectors: (1) a large subsistence sector characterized by rudimentary technology, home consumption, and high levels of volatility and (2) a small but growing commercial sector. Combinations also occur. For tobacco and cotton (export crops), some success has been obtained via vertically coordinated arrangements with smallholders. Furthermore, considerable evidence exists for technology spillovers whereby farmers associated with outgrower schemes (and their neighbors) adopt improved technologies for other crops (Strasberg 1997; Benfica 2006; Uaiene 2008). For these reasons, the institutional arrangement of production, including associated production technology vectors, as well as the potential for technology spillovers are considered in the analysis.

3 Literature Review

Recent increases in the price of oil combined with concerns about global warming have created a torrent of activity and discussion with respect to biofuels. One thing is clear. With oil currently trading at greater than $100 per barrel, production of biofuels is profitable. If oil prices remain anywhere close to this level, production of biofuels can be expected to grow dramatically. The implications of this growth are less clear. Optimists, such as Ricardo Hausmann, Director of the Center for International Development at Harvard University, foresee a world in which biofuels blunt the monopoly power of OPEC thus leading to a stabilization of world fuel prices at approximately the marginal cost of producing biofuels. Hausmann also views biofuels as net positive for growth and development particularly in Africa and Latin America due to the large land endowments on these continents. Compared with the natural resource extractive industries that often dominate investment particularly in Africa, biofuel production technologies tend to be more labor intensive and hence more pro poor. In addition, biofuels production requires general investment in roads and port infrastructure as opposed to the dedicated investments associated with resource extraction. As a result, biofuels investment will “crowd in” other investment due to the improved transport infrastructure (Hausmann 2007).

Others, such as Oxfam (2007), are less sanguine. They point to the rise in food prices, and concomitant aggravation of poverty, particularly urban poverty, that the shift to biofuels production is already provoking. In addition, while recognizing the potential of biofuel production to provide market outlets for poor farmers and to generate rural employment, they worry that biofuels plantations will abscond with land from smallholders, employ capital intensive technologies, and pay substandard wages.

The environmental implications of biofuels production are also the subject of debate. Biofuels have often been pointed to as a means of reducing emissions of greenhouse gasses (GHG). This is because plant biomass captures carbon from the air. Conversion of this biomass to biofuel and subsequent combustion returns the carbon to the air creating a circle (Hazell and Pachauri 2006). The complete circle is not closed as biofuels require energy to be grown, processed, and transported implying positive net emissions. Pimentel (2003) calculates that the energy balance of ethanol from corn is actually negative. These calculations are disputed by Graboski and McClelland (2002). The large weight of evidence indicates that biofuels, particularly the more efficient crops, are a substantial net energy contributor.

More serious concerns regarding environmental impacts, including GHG emissions, center on land use. Recent work by Fargione et al (2008) indicates that GHG reduction from biofuel use compared with fossil fuels depends upon land use and the source of land for biofuels production. In particular, clearing of new land for biofuels can generate large emissions of GHGs (particularly CO2) due to burning and decomposition of organic matter. They refer to these land conversion emissions as the carbon debt. The carbon debt varies by the biome in which the land conversion occurs and the crop planted for biofuel production. For the case of production of sugar cane for ethanol on land cleared from Brazilian Cerrado, they estimate that 17 years would be required to repay this debt (in other words, 17 times the carbon savings per year from using ethanol produced from sugarcane on Brazilian Cerrado versus gasoline equals the carbon debt). Payback periods for other biomes and other crops are much longer.

These observations are pertinent because biofuels optimists, such as Hausmann, assume that global land area under production can be expanded by up to 50% (from 1.4 billion hectares to 2.1 billion hectares) in order to accommodate biofuels production. If dedicated to biofuels, this land expansion would generate annual energy roughly equivalent to the energy content of current oil production.

While the biofuels boom has generated a great deal of discussion, this discussion is supported by surprisingly little quantitative economic analysis. A review of the literature yields no published articles estimating the growth and poverty implications of large scale investment in biofuels in a low income country. Analysis of the case of Mozambique is useful because the issues in Mozambique run to the heart of the debates outlined above. Highly relevant issues include the choice of production technology, institutional arrangements in production (plantation versus outgrower), technology spillovers, land area expansion, and complementary investments. We turn now to a discussion of the modeling framework.

4. The Modeling Framework and Results

The impact of biofuels investment is simulated using an economywide computable general equilibrium (CGE) model of Mozambique. CGE models are frequently applied to issues of trade strategy, income distribution, and structural change in developing countries.

CGE models have a number of general features that make them suitable for this analysis.

- They simulate the functioning of a market economy, including markets for labor, capital, and commodities, and provide a useful perspective on how changes in economic conditions will likely be mediated through prices and markets.

- The structural nature of CGE models permits consideration of new phenomena, such as biofuels.

- They assure that all economy-wide constraints are respected. Biofuels are expected to generate significant foreign exchange earnings (savings in the case of fuel import substitution), use large quantities of land, and demand substantial quantities of labor. In this context, it is important to consider the balance of payments, the supply of land, and the supply of labor.

- Because they can be fairly disaggregate, CGE models can provide an economic "simulation laboratory" for examining how different factors and channels of impact will affect the performance and structure of the economy, how they will interact, and which are (quantitatively) the most important.

- They provide a theoretically clean framework for welfare and distributional analysis.

In CGE models, economic decision-making is the outcome of decentralized optimizing by producers and consumers within a coherent economy-wide framework. A variety of substitution mechanisms are specified including substitution among labor types, between capital and labor, between imports and domestic goods, and between exports and domestic sales all occurring in response to variations in relative prices. Institutional rigidities and imperfect markets can be captured by the exogenous imposition of features such as immobile sectoral capital stocks, labor market segmentation, and home consumption, which permit the more realistic application of this class of model to developing countries.

Experience with this class of models also highlights some disadvantages. An economy-wide approach is not well suited for the analysis of all issues. In striving to develop a comprehensive picture of the entire economy, some detail is necessarily suppressed. If detail highly relevant to the analytical question at hand has been suppressed, the approach is obviously poorly suited. Similarly, some issues can be adequately addressed with economic frameworks that are less comprehensive allowing the analyst to spend more time on analysis and less time on data issues and modeling.

Due to the potential scale of biofuels investment and the downstream implications across the economy, the CGE approach was adopted.

4.1. Mozambique Modeling Framework

The model contains 56 activities/commodities, including 24 agricultural and 7 food processing sectors.[2] Five factors of production are identified: three types of labor (unskilled, semi-skilled and skilled), agricultural land, and the factor capital. This detail captures the structure of the economy and will substantially influence model results. For example, because biofuels production will either be exported or will replace fuel imports, substantial increases in biofuels production will have implications for foreign exchange availability and hence trade. Due to expanded foreign exchange availability, Mozambique will have the capacity to import more and to reduce exports of other products (besides biofuels). As a result, one might expect sectors with high trade shares (either a large share of production exported or a high degree of import competition) to be more strongly affected than sectors that are non-traded. Basic structural features of the Mozambican economy are presented in Table 1.

[Table 1]

Within the existing structure and subject to macroeconomic constraints, producers in the model maximize profits under constant returns to scale, with the choice between factors governed by a constant elasticity of substitution (CES) function. Factors are then combined with fixed-share intermediates using a Leontief specification. Under profit maximization, factors receive income where marginal revenue equals marginal cost based on endogenous relative prices.

Substitution possibilities exist between production for domestic and foreign markets. This decision of producers is governed by a constant elasticity of transformation (CET) function which distinguishes between exported and domestic goods, and by doing so, captures any time or quality differences between the two products. Profit maximization drives producers to sell in those markets where they can achieve the highest returns. These returns are based on domestic and export prices (where the latter is determined by the world price times the exchange rate adjusted for any taxes). Under the small-country assumption, Mozambique faces a perfectly elastic world demand curve at a fixed world price. The final ratio of exports to domestic goods is determined by the endogenous interaction of relative prices for these two commodity types.

Further substitution possibilities exist between imported and domestic goods under a CES Armington specification. Such substitution can take place both in final and intermediates usage. These elasticities vary across sectors, with lower elasticities reflecting greater differences between domestic and imported goods. Again under the small country assumption, Mozambique faces infinitely elastic world supply at fixed world prices. The final ratio of imports to domestic goods is determined by the cost minimizing decision-making of domestic demanders based on the relative prices of imports and domestic goods (both of which include relevant taxes).

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[2] The International Food Policy Research Institute’s standard recursive dynamic model is used in this study (see Arndt et al., 2000; Lofgren et al., 2001 and Thurlow, 2008).

The model distinguishes between various institutions, including enterprises, the government, and ten representative household groups. Households are disaggregated across rural/urban areas and national income quintiles. Households and enterprises receive income in payment for producers' use of their factors of production. Both institutions pay direct taxes to government (based on fixed tax rates), save (based on marginal propensities to save), and make transfers to the rest of the world. Enterprises pay their remaining income to households in the form of dividends. Households, unlike enterprises, use their income to consume commodities under a linear expenditure system (LES) of demand.

The government receives income from imposing activity, sales and direct taxes and import tariffs, and then makes transfers to households, enterprises and the rest of the world. The government also purchases commodities in the form of government consumption expenditure, and the remaining income of government is (dis)saved. All savings from households, enterprises, government and the rest of the world (foreign savings) are collected in a savings pool from which investment is financed.

The model includes three broad macroeconomic accounts: the government balance, the current account, and the savings and investment account. In order to bring about balance between the various macro accounts, it is necessary to specify a set of 'macroclosure' rules, which provide a mechanism through which macroeconomic balance can be achieved. A savings-driven closure was assumed in order to balance the savings-investment account. Under this closure, the marginal propensities to save of households and enterprises are fixed, while investment adjusts to changes in incomes to ensure that the level of investment and savings are equal. For the current account it was assumed that a flexible exchange rate adjusts in order to maintain a fixed level of foreign savings. In other words, the external balance is held fixed in foreign currency terms. Finally, in the government account, the fiscal deficit is assumed to remain unchanged, with government revenues and expenditures balanced through changes in direct tax rates on households and enterprises.

The CGE model is calibrated to a 2003 social accounting matrix (McCool, Thurlow and Arndt, 2008), which was constructed using information from national accounts, trade and tax data, and household income and expenditure data from the 2002 national household survey (INE, 2003). Trade elasticities are taken from the Global Trade Analysis Project (Dimaranan, 2006). The model is calibrated so that the initial equilibrium reproduces the base-year values from the SAM.

The features described up to now apply to a basic single-period "static" CGE model. But, because biofuels investment will, even under the most optimistic scenarios, unfold over a dozen years or more, the model must be capable of moving forward and looking at growth trajectories. So, the model must be "dynamized" by building in a set of accumulation and updating rules (e.g. investment adds to capital stock, after depreciation; labor force growth by skill category; productivity growth). In addition, expectations formation must be specified. This latter point, expectations formation, represents a major distinguishing feature of many macroeconomic models. For the CGE model employed here, a simple set of adaptive expectations rules are employed. Adaptive expectations rules were chosen as we view adaptive expectations as the most appropriate mechanism for the Mozambican context.

A series of dynamic equations are also required to "update" various parameters and variables from one year to the next. For the most part, the relationships are straightforward. Growth in the total supply of each labor category and land is specified exogenously, sectoral capital stocks are adjusted each year based on investment, net of depreciation. Factor returns adjust such that factor supply equals factor demand. The model adopts a "putty-clay" formulation whereby new investment can be directed to any sector in response to differential rates of return; however, installed equipment must remain in the same sector (e.g., a brewery cannot be converted into a railroad). Sectoral productivity growth is specified exogenously with the possibility of different rates of productivity growth by factor. Using these simple relationships to update key variables, we can generate a series of growth scenarios, based on different biofuel investment scenarios.

The dynamic CGE model also estimates the impact of alternative investment scenarios on household incomes. Each household questioned in the 2002 national household survey are linked to their corresponding representative household in the CGE model. This is the expenditure-side micro-simulation component of the Mozambican model. In this formulation, changes in representative households' consumption and prices for each commodity in the CGE model are passed down to their corresponding households in the survey, where total consumption expenditures are recalculated. This new level of per capita expenditure for each survey household is compared to the official poverty line, and standard poverty measures are recalculated.

It is important to highlight that focus is on the *differential* impact across scenarios. From this vantage point, what matters most is whether our base scenario, which excludes biofuel investment, and the biofuels scenarios are more or less reasonable. Examining the differences between these scenarios allows us to isolate the implications of biofuels investments. The modeling is not an attempt to forecast particular economic outcomes.

4.2. Baseline Scenario

We first produce a baseline growth path that assumes that Mozambique's economy continues to grow during 2003-2015 in line with its recent performance. For each time period, we update the model to reflect changes in population, labor and land supply, and factor productivity (see Table 2). Since Mozambique is a land-abundant country, we assume that land supply grows alongside population at two percent per year. We capture the rising skill-intensity of the labor force by allowing the supply and productivity of skilled and semi-skilled labor to grow faster than unskilled labor.[3] There is also unbiased technological change in the baseline scenario, with the shift parameter on the production function increasing at 3.0 percent per year in nonagriculture and 0.8 percent per year in

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[3] Skilled and semi-skilled labor productivity grows at two and one percent respectively.

agriculture. Together, these assumptions produce a baseline scenario in which the Mozambican economy grows at an average of 6.1 percent per year.

[Table 2]

4.3 Biofuel Scenarios

In the following scenarios, we increase the amount of land allocated to sugarcane for ethanol production and jatropha for biodiesel production. The production structures of these two crops are different (see Table 3). The proposed sugarcane investments in Mozambique are assumed to be plantation-based, whereas jatropha is assumed to be undertaken primarily through smallholder outgrower schemes. Jatropha is thus more labor-intensive, requiring almost 50 workers for every 100 hectares planted. Sugarcane requires only 34 farm laborers for every 100 hectares planted. It is also substantially more capital-intensive, employing three times more capital per hectare than jatropha. This capital requirement reflects both capital-intensive plantation production, as well as sugarcane's heavier crop yield, with one hectare producing 15 tons of sugarcane compared to 3 tons of jatropha. However, ethanol production typically requires more plant matter than biodiesel (i.e., it has low feedstock yields). Based on expert interviews, we assume that one hectare of jatropha production produces 300 liters of biodiesel, while one hectare of sugarcane produces 480 liters of ethanol. Processing both crops into biofuels requires an additional 2-3 workers for every 10 000 liters produced. Jatropha processing is again more labor-intensive and sugarcane is more capital-intensive.

[Table 3]

In this section, we compare the results from the baseline scenario with four biofuel scenarios. In Scenarios 2 and 3, we expand sugarcane and jatropha production separately. Since a similar amount of biofuels is produced in each scenario, they provide a comparison between plantation and smallholder biofuel production. As mentioned earlier, Mozambique's experience with traditional exports crops suggests that smallholders' food crop yields may increase after participating in outgrower schemes due to technology spillovers (Strasberg 1997, Benfica). This may arise from the transfer of better farming practices or improved access to fertilizers and other inputs. Scenario 4 captures this possibility by repeating the jatropha scenario but with faster productivity growth for food crops. Finally, in Scenario 5, we combine the expansion of both sugarcane and jatropha, including technology spillovers, to assess the overall impact of biofuels on growth and poverty in Mozambique.

In the Sugarcane and Jatropha scenarios (i.e., Scenarios 2 and 3) we increase the amount of land allocated to these crops by 280 000 and 550 000 hectares respectively (see Table 4).[4] As indicated earlier, Mozambique is a land abundant country. Nevertheless, access to large contiguous pieces of unused land is limited by road infrastructure. It is unlikely that

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[4] This is well below the 13 million hectares of biofuel crop production currently being proposed in Mozambique. However, many of these proposals may only be speculative and so the Sugarcane and Jatropha scenarios provide a more plausible assessment of near-term investments.

biofuels investment will be undertaken entirely on new lands. In the biofuel scenarios, we assume that half of the production of biofuel crops takes place on unused land, while the remainder occurs on land already under cultivation. We therefore reduce the amount of land available to existing crops by half the amount of land needed for biofuel crops and then let the model determine the optimal allocation of remaining land based on the production technologies and relative profitability of different crops.

[Table 4]

The reduction in land available to non-biofuel crops causes a decline in the production of food crops, especially cereals. Accordingly, in both scenarios there is an increase in cereals prices relative to the base (see Table 2). This is most pronounced under the Jatropha scenario, which requires more land and more labor than sugarcane. Food imports rise in response to falling production and rising prices. This is further encouraged by an appreciation of the real exchange rate caused by the increase in biofuel exports. However, while food imports replace declining domestic production, it is the traditional export crops that suffer most. These crops not only have to compete for scarcer land and labor resources, but they also lose competitiveness in international markets due to the appreciation. Food crops, on the other hand, are less affected by the appreciation because they rely more heavily on domestic markets. Accordingly, the land allocated to traditional exports declines by a larger percentage than for food crops.

Given its lower input requirements, a larger share of the value-added generated from producing jatropha and biodiesel remains on the farm. Thus, it leads to faster agricultural GDP growth than plantation-based sugarcane (see Table 5). However, land-intensive jatropha has a more detrimental impact on traditional export crops, which reduces the supply of inputs for traditional export crop processing. While sugarcane and ethanol production has a smaller effect on agricultural growth, it has a larger impact on manufacturing and overall GDP growth. This occurs because sugarcane and ethanol use more relatively less labor and land, which competes with other domestic activities, and relatively more capital, which is assumed to be provided from abroad.

[Table 5]

Competition over scarce labor resources also explains some of the decline in non-biofuel GDP growth under the biofuel scenarios. Since approximately one worker is required for every three hectares of land planted with sugarcane, the expansion of sugarcane production by a 280 000 hectares generates jobs for 94 000 farm laborers (see Table 6). Similarly, jatropha creates employment opportunities for 271 000 smallholder farmers. Biofuel processing also generates an additional 36 000 and 55 000 manufacturing jobs for ethanol and biodiesel production respectively. The model assumes that all workers are already engaged in productive activity and must therefore be drawn away from other sectors. Under the Sugarcane and Jatropha scenarios, the model results indicate that around half of the labor pulled into biofuel production would come from within the agricultural sector. This captures the labor embodied in the land that smallholder farmers reallocate to jatropha production, as well as the migration of farmers off their own land to work as laborers on sugarcane plantations. The remaining jobs created by biofuel crop production are filled by workers previously employed within nonagriculture. Most of these workers come from construction and trade services. Although the model does not specify separate rural and urban labor markets, it is likely that these workers will be drawn from both the rural nonfarm and urban economies. Finally, while the share of agricultural workers in the total labor force increases under both the Sugarcane and Jatropha scenarios, the reallocation of labor out of the nonagricultural sectors and into rural farm production is larger for jatropha production.

[Table 6]

Compared to sugarcane, jatropha creates more employment opportunities and a larger share of additional land returns accrue to smallholder farmers, who in turn spend a larger share of their incomes on goods produced domestically and in rural areas. As such, while both sugarcane and jatropha production benefits rural households, it is jatropha that increases incomes the most, especially for lower-income households. This is shown by changes in equivalent variation (EV), which measures welfare improvements after controlling for price changes (see Table 7). The results indicate that, in the Jatropha scenario, welfare improves more for lower-income rural households than for higher-income and urban households. This is because jatropha production is more land and unskilled labor intensive and the resulting increases in these factor returns benefits lower-income and rural households relatively more. By contrast, sugarcane production is more capital-intensive and thus a greater share of the benefits of increasing production accrues to plantation owners. Most of these capital returns or profits generated by biofuel production are either paid to higher income urban households or are remitted abroad. Thus, higher-income urban households benefit more under the Sugarcane scenario.

[Table 7]

Uneven distributional impacts are also reflected in poverty outcomes once income-effects from the CGE model are passed down to the microsimulation module. Both biofuel scenarios lead to significant declines in poverty at the national-level (see Table 8). However, rural poverty declines faster under the Jatropha scenario. Smallholder jatropha production is also twice as effective at reducing poverty amongst the poorest rural households, as evidenced by its larger impact on the depth and severity of poverty.

[Table 8]

The impact of jatropha on poverty is more pronounced after accounting for technology spillovers. In the Spillovers scenario, we again allocate 550 000 hectares to jatropha production, with half of production taking place on previously unused land. However, we now raise the TFP growth rate for food crops by an additional 0.5 percentage points per year during 2003-2015. For example, while the average maize yield increased from 0.96 to 1.22 tons per hectares under the Baseline scenario, it now rises to 1.30 tons per hectare under the Spillovers scenario. Similar yield improvements are imposed on other cereals, root crops and vegetables. The result is a reversal in the decline in food crop production (see Table 5) and the rise in food prices relative the Baseline scenario (see Table 2). Improving yields also reduces the amount of land needed to produce food crops thereby alleviating some of the resource competition between traditional export and biofuel crops (see Table 4). This accelerates agricultural growth and poverty reduction for both rural and urban households, with the latter benefiting from lower food prices. This scenario highlights the benefits of technology spillovers from producing biofuels through outgrower schemes, as well as the continued importance of improving non-export crop yields.

In the final scenario, we combine the effects of jatropha and sugarcane production. The results indicate that biofuel production has a substantial impact on the Mozambican economy. GDP growth accelerates by 0.65 percentage points per year. This growth acceleration is concentrated in the agricultural and manufacturing sectors, which grow faster by 2.4 and 1.5 percentage points per year respectively (see Table 5). Biofuel crop production and processing creates 455 000 jobs, most of which are filled by workers from construction and trade services (see Table 6). The national poverty headcount declines by an additional 5.9 percentage points by 2015, which is equivalent to lifting an additional 1.4 million people above the poverty line. At the same time, the macroeconomic impact of rapid export-led growth is a sharper appreciation of the real exchange rate. This again increases import competition in domestic markets and reduces the competitiveness of existing exports, especially traditional export crops. This may lead to short-term adjustment costs as farmers reallocate their land and workers migrate between sectors and regions.

4 Conclusions, Policy Implications and Recommendations for Future Research

The model results suggest that biofuels provide Mozambique with an opportunity to substantially enhance economic growth and poverty reduction. Both the modes of production considered here, ethanol produced from sugarcane grown using a plantation approach and biodiesel produced from jatropha using an outgrower approach, increase production and welfare and reduce poverty. However, the outgrower approach, as represented by jatropha, is much more strongly pro-poor due to greater use of unskilled labor and the accrual of land rents to smallholders rather than plantation owners. The growth and poverty reduction benefits of outgrower schemes are further enhanced if the schemes result in technology spillovers to other crops.

Large scale growth of biofuels production unavoidably imposes adjustments on other sectors due to competition for land and labor and due to the implications of increased foreign exchange availability for the real exchange rate. In relative terms, traditional export crops shrink the most relative to the Baseline scenario in order to make space for biofuels. However, area allocated to and production of food crops also decline. Food prices and imports increase relative to the Baseline. Overall, while welfare and food security broadly increases due to enhanced purchasing power, certain households may be negatively affected due to the price and quantity adjustments associated with rapid growth in biofuels production.

The results suggest that careful attention should be paid to the labor intensity of production methods employed for biofuel crops. The model indicates that the degree of labor intensity has the potential to strongly influence the distribution of income. In addition, schemes, such as the outgrower schemes discussed here, that increase the probability of technology spillovers to other crops are shown to be highly desirable.

At current prices for fossil fuels, biofuels for export are clearly competitive. There is little need to provide additional incentives for biofuels investment. At the same time, insistence on uniquely an outgrower model may not be the best approach as investors may strongly prefer vertically coordinated arrangements that supply a more certain flow of raw material. A hybrid approach whereby initial investment occurs in plantation mode up to a limit and then further expansion of crops for biofuels occurs under an outgrower arrangement appears to be worthy of consideration.

There are numerous topics for further research. Four priority topics are considered here. First, water usage is not considered explicitly in the model. Irrigation is not strictly necessary for jatropha; however, sugarcane typically requires irrigation with implications for water resources. Second, the model does not consider the potential spillovers to other exporting sectors due to the transport and other infrastructure that biofuels production will require (e.g., the “crowding in” highlighted by Hausmann (2007)). The potential for these spillovers should be examined in greater detail and maximized wherever possible.

Third, the implications of conversion of unused land to biofuels production for greenhouse gas (GHG) emissions should be considered. It is likely that the mode of conversion and the crops planted for biofuels could substantially influence the GHG emission balance. As a perennial crop, it is possible that jatropha possesses significant advantages over other sources of biofuels in terms of overall GHG balance due to relatively mild emissions as a result of conversion of new land. This is important. If Mozambican biofuel production is demonstrably “green” in terms of CO2 balance, it is highly likely to receive a premium in international markets. A demonstrably “green” label is also likely to serve as a significant buffer to downside price risk. While fossil fuel and hence biofuel prices are currently very high and appear unlikely to drop significantly even in the medium term, this situation is not guaranteed to continue indefinitely. Finally, other methods for mitigating downside price risk for biofuels, such as generation of electricity and identification of potential substitute crops for biofuels, should be considered.

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6 Tables

Table 1. Structure of Mozambique's economy in 2003.

	Share of total (%)				Export intensity (%)	Import penetration (%)
	GDP	Employment	Exports	Imports		
Total GDP	100.0	100.0	100.0	100.0	9.7	21.9
Agriculture	25.9	50.9	20.3	2.6	9.6	3.3
Food crops	18.2	32.6	3.8	2.0	2.2	3.7
Traditional exports	1.1	1.7	1.2	0.4	19.5	15.4
Other agriculture	6.7	16.6	15.4	0.2	24.4	0.8
Manufacturing	13.7	5.0	59.4	70.6	29.9	52.5
Food processing	5.0	3.0	2.0	14.3	1.7	23.1
Trad.crop proc.	0.9	0.5	3.4	3.6	38.1	51.5
Other manufact.	7.8	1.5	54.1	52.7	62.3	75.8
Other industries	9.5	15.0	12.5	5.7	9.1	9.0
Private services	42.2	26.7	7.7	21.2	2.0	10.9
Government services	8.7	2.4	0.0	0.0	0.0	0.0

Source: Mozambique 2003 social accounting matrix (SAM).

Note: 'Export intensity' is the share of exports in domestic output, and 'import penetration' is the share of import in total domestic demand.

Table 2. Core macroeconomic assumptions and results.

	Initial, 2003	Baseline scenario (1)	Sugarcane scenario (2)	Jatropha scenario (3)	Jatropha + spillovers (4)	Combined scenario (2 + 4)
		Average annual growth rate, 2003-15 (%)				
Population (1000)	18,301	2.00	2.00	2.00	2.00	2.00
GDP	100.0	6.09	6.41	6.32	6.46	6.74
Labor supply	63.9	2.09	2.09	2.09	2.09	2.09
Skilled	10.7	3.00	3.00	3.00	3.00	3.00
Semi-skilled	13.9	2.50	2.50	2.50	2.50	2.50
Unskilled	39.3	2.00	2.00	2.00	2.00	2.00
Capital stock	30.0	6.35	6.75	6.73	6.74	7.14
Land supply	6.1	2.00	2.21	2.40	2.40	2.60
		Final year value, 2015				
Real exchange rate	1.00	0.95	0.89	0.86	0.88	0.81
Consumer prices	1.00	1.00	1.00	1.00	1.00	1.00
Cereals price index	1.00	1.20	1.22	1.24	1.19	1.22

Source: Results from the Mozambique CGE-microsimulation model. Exchange rate index is foreign currency units per local currency unit (i.e., a decline is an appreciation).

Table 3. Biofuel production characteristics.

Production characteristics for biofuels (inputs and outputs per 100 hectares)	Sugarcane & ethanol	Jatropha & biodiesel
Land employed (ha)	100	100
Crop production (tonnes)	1,500	300
Farm workers employed (people)	33.6	49.2
Land yield (tonnes / ha)	15.0	3.0
Farm labor yield (tonnes / person)	44.7	6.1
Land per farm worker (ha / person)	3.0	2.0
Capital per hectare (capital unit / ha)	6.6	2.2
Bio-fuel produced (liters)	75,000	36,000
Processing workers employed (people)	15.6	11.9
Feedstock yield (liters / tonne)	50.0	120.0
Processing labor yield (liters / person)	4,816	3,018
Production characteristics for biofuels (inputs and outputs per 10,000 liters)		
Bio-fuel production (liters)	10,000	10,000
Feedstock inputs (tonnes)	200	83
Land employed (ha)	13.3	27.8
Farm workers employed (people)	4.5	13.7
Processing workers employed (people)	2.1	3.3
Capital employed (capital units)	80.6	42.9

Note: The same fundamental production coefficients are depicted per 100 hectares of land and per 10,000 liters of biofuel produced.

Table 4. Agricultural production results.

	Initial value, 2003	Baseline value, 2015	Deviation from baseline final value, 2015			
			Sugarcane scenario	Jatropha scenario	Jatropha + spillovers	Combined scenario
		(1)	(2)	(3)	(4)	(2 + 4)
Total land (1000 ha)	4,482	5,684	140	275	275	415
Biofuel crops	0	0	280	550	550	830
Sugarcane	0	0	280	0	0	280
Jatropha	0	0	0	550	550	550
Food crops	4,291	5,371	-73	-183	-193	-292
Maize	1,300	1,597	-62	-122	-96	-180
Sorgh. & millet	621	666	-2	-6	-20	-19
Rice paddy	179	225	-13	-24	-20	-37
Traditional exports	191	313	-67	-92	-82	-123
Tobacco	17	8	-1	-2	-2	-3
Sugarcane	27	55	-6	-9	-7	-12
Cotton	115	216	-59	-78	-72	-105
Production (1000 tonnes)						
Biofuel crops						
Sugarcane	0	0	4,200	0	0	4,200
Jatropha	0	0	0	1,650	1,650	1,650
Food crops						
Maize	1,248	1,949	-52	-107	-5	-103
Sorgh. & millet	363	497	4	6	14	16
Rice paddy	200	326	-14	-26	-9	-32
Traditional exports						
Tobacco	12	8	-1	-2	-2	-3
Sugarcane	397	996	-82	-125	-109	-188
Cotton	116	284	-70	-91	-87	-128
Production (1000 liters)						
Ethanol	0	0	210,000	0	0	210,000
Biodiesel	0	0	0	198,000	198,000	198,000

Source: Results from the Mozambique CGE-microsimulation model.

Table 5. Sectoral growth results.

	GDP share, 2003	Average annual growth rate, 2003-15 (%)				
		Baseline scenario (1)	Sugarcane scenario (2)	Jatropha scenario (3)	Jatropha + spillovers (4)	Combined scenario (2 + 4)
Total GDP	100.0	6.09	6.41	6.32	6.46	6.74
Agriculture	25.9	4.29	5.13	5.82	6.03	6.69
Food crops	18.2	4.29	4.31	4.24	4.54	4.45
Trad. exports	1.1	3.53	2.15	1.49	1.68	0.47
Biofuel crops	0.0	0.00	na	na	na	na
Other agr.	6.7	4.39	4.29	4.10	4.24	4.16
Manufacturing	13.7	5.46	6.66	5.71	5.82	6.98
Food proc.	5.0	5.54	5.52	5.29	5.51	5.35
Trad. proc.	0.9	8.53	6.07	5.21	5.40	3.58
Biofuel proc.	0.0	0.00	na	na	na	na
Other manu.	7.8	4.99	4.82	4.63	4.67	4.42
Other industries	9.5	10.25	9.68	9.44	9.46	8.98
Water	0.3	8.71	13.11	11.90	11.99	15.39
Private services	42.2	6.17	6.28	6.07	6.20	6.26
Govt. services	8.7	5.88	5.96	5.93	6.07	6.04

Source: Results from the Mozambique CGE-microsimulation model.

Table 6. Labor employment results.

	Initial employ., 2003	Baseline employ., 2015 (1)	Deviation from baseline final employment, 2015			
			Sugarcane scenario (2)	Jatropha scenario (3)	Jatropha + spillovers (4)	Combined scenario (2 + 4)
Total workers (1000s)	3,577	4,586	0	0	0	0
Agriculture	1,820	2,484	59	165	127	165
Food crops	1,166	1,666	-2	-34	-88	-117
Trad exports	60	68	-10	-16	-15	-22
Biofuel crop	0	0	94	271	271	365
Other agr.	594	750	-23	-56	-41	-60
Manufacturing	178	179	20	22	28	50
Food proc.	107	91	-3	-10	-6	-10
Trad. Proc.	20	27	-9	-12	-11	-16
Biofuel proc.	0	0	36	55	55	90
Other manu.	52	61	-5	-11	-10	-15
Other indust.	537	743	-76	-125	-117	-167
Water	9	10	6	3	3	8
Private services	955	1,080	-3	-62	-39	-49
Govt. services	86	100	1	-1	1	1

Source: Results from the Mozambique CGE-microsimulation model.

Table 7. Equivalent variation results.

	Initial per capita spending, 2003	Baseline growth, 2003-15 (1)	Deviation from baseline growth rate, 2003-15			
			Sugarcane scenario (2)	Jatropha scenario (3)	Jatropha + spillovers (4)	Combined scenario (2 + 4)
Rural households						
Quintile 1 (low)	1,147	6.36	0.56	1.28	1.65	2.00
Quintile 2	1,401	6.47	0.57	1.08	1.42	1.87
Quintile 3	1,856	6.59	0.57	0.98	1.31	1.78
Quintile 4	2,410	6.84	0.58	0.95	1.24	1.75
Quintile 5 (high)	4,860	7.52	0.64	0.73	1.00	1.60
Urban households						
Quintile 1 (low)	1,297	6.31	0.46	0.57	0.98	1.36
Quintile 2	1,731	6.95	0.50	0.38	0.74	1.24
Quintile 3	2,180	6.72	0.50	0.36	0.72	1.22
Quintile 4	3,384	7.64	0.53	0.21	0.51	1.07
Quintile 5 (high)	11,172	8.74	0.57	0.01	0.25	0.86

Source: Results from the Mozambique CGE-microsimulation model.

Table 8. Poverty results.

	Initial poverty rates, 2003	Final year poverty rates, 2015 (%)				
		Baseline scenario (1)	Sugarcane scenario (2)	Jatropha scenario (3)	Jatropha + spillovers (4)	Combined scenario (2 + 4)
Headcount poverty, P0						
National	54.07	32.04	29.70	28.45	27.54	26.11
Rural	55.29	32.98	30.68	28.54	27.58	26.54
Urban	51.47	30.06	27.63	28.26	27.44	25.21
Depth of poverty, P1						
National	20.52	10.19	9.29	8.65	8.27	7.61
Rural	20.91	10.92	9.98	9.02	8.66	8.07
Urban	19.69	8.67	7.83	7.88	7.43	6.64
Severity of poverty, P2						
National	10.33	4.59	4.12	3.77	3.58	3.27
Rural	10.67	5.09	4.59	4.08	3.90	3.61
Urban	9.62	3.53	3.13	3.11	2.90	2.55

Source: Results from the Mozambique CGE-microsimulation model.