Biofuels, Poverty, and Growth

Computable General Equilibrium Analysis of Mozambique

Arndt, Channing; Benfica, Rui; Tarp, Finn; Thurlow, James; Uaine, Rafael

Publication date:
2008

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Arndt, C., Benfica, R., Tarp, F., Thurlow, J., & Uaine, R. (2008). *Biofuels, Poverty, and Growth: Computable General Equilibrium Analysis of Mozambique*. Washington: International Food Policy Research Institute.

INTERNATIONAL FOOD
POLICY RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty
IFPRI®
Supported by the CGIAR

IFPRI Discussion Paper 00803

October 2008

Biofuels, Poverty, and Growth

A Computable General Equilibrium Analysis of Mozambique

Channing Arndt
Rui Benfica
Finn Tarp
James Thurlow
Rafael Uaiene

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

FINANCIAL CONTRIBUTORS AND PARTNERS

IFPRI's research, capacity strengthening, and communications work is made possible by its financial contributors and partners. IFPRI gratefully acknowledges generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

AUTHORS

Channing Arndt, University of Copenhagen

Finn Tarp, University of Copenhagen

Rui Benfica, World Bank

James Thurlow, International Food Policy Research Institute
Research Fellow, Development Strategy and Governance Division
Correspondence can be sent to j.thurlow@cgiar.org

Rafael Uaiene, Ministry of Planning and Development, Mozambique

Notices

[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at www.ifpri.org/pubs/otherpubs.htm#dp.

[2] IFPRI Discussion Papers contain preliminary material and research results. They have not been subject to formal external reviews managed by IFPRI's Publications Review Committee but have been reviewed by at least one internal and/or external reviewer. They are circulated in order to stimulate discussion and critical comment.

Contents

List of Tables

ABSTRACT

Large private investments in biofuels are presently underway in Mozambique. This paper uses an economywide model to assess the implications of these investments for growth and income distribution. Our results indicate that biofuels provide an opportunity to enhance growth and poverty reduction. Overall, the proposed biofuel investments increase Mozambique's annual economic growth by 0.6 percentage points and reduce the incidence of poverty by about six percentage points over the 12-year phase-in period. However, the benefits depend on production technology. Our results indicate that an outgrower approach to producing biofuels is more pro-poor, due to the greater use of unskilled labor and accrual of land rents to smallholders in this system, compared with the more capital-intensive plantation approach. Moreover, the expected benefits of outgrower schemes will be further enhanced if they result in technology spillovers to other crops.

Keywords: biofuels, economic growth, poverty, developing countries, Mozambique

ACKNOWLEDGMENTS

We have benefited from comments from seminar participants at IFPRI, the Agricultural Promotion Center (CEPAGRI) in Maputo, and Mozambique’s Ministry of Planning and Development (MPD). Financial support was gratefully received from the Danish International Development Agency (DANIDA), Swiss State Secretariat for Economic Affairs (SECO) and Swedish International Development Cooperation Agency (SIDA) – the latter via its support for the Southern African Regional Strategic Analysis and Knowledge Support System (ReSAKSS-SA).

1. INTRODUCTION

Mozambique is a land-abundant country, with only one sixth of its 30 million hectares of arable land currently under cultivation. The land remains state-owned, and use rights must be requested from the state. As a country with significant untapped agricultural potential, Mozambique has captured the interest of biofuel investors. Currently, the government has pending use-rights requests for more than 12 million hectares, with nearly all of the requests relating to biofuels. The specific crops being considered are sugarcane and sweet sorghum for the production of ethanol, and jatropha for the production of biodiesel.

Biofuel production in Mozambique is considered profitable at world oil prices above US$70 per barrel (Econergy, 2008). Rising interest in biofuel production therefore reflects the current surge in world oil prices, as well as the desire to cut down on greenhouse gas (GHG) emissions particularly in European countries. These two factors are driving investor interest. Mozambique's government also views biofuels as an opportunity to increase economic growth and exports, as well as encourage rural development and poverty reduction. However, this raises a series of policy questions.

- Will lower-income people benefit from large-scale biofuel investments?
- What are the implications of producing on a plantation basis compared to contracting smallholder farmers?
- What is the demand for complementary investments, such as roads and ports?
- Are there potential threats to food security if biofuels displace food production?
- Should the government be concerned about the stability of world biofuel prices?

This paper examines some of these questions using a computable general equilibrium (CGE) model of Mozambique. Since it is not possible to address all of the issues associated with biofuels using a single framework, we focus on the impact of biofuel investments on economic growth and income distribution. We also compare plantation and outgrower approaches to producing biofuels. Finally, we consider the relationship between food crops and the biofuel sector.

Four sections follow this introduction. First, relevant information on the Mozambican country context is presented, followed by a brief review of the biofuel-related literature. The CGE modeling framework and results are then presented. A final section concludes and discusses policy implications and directions for future research.

2. AGRICULTURE AND RURAL POVERTY IN MOZAMBIQUE

While the situation in Mozambique has improved over the past 10 years, it remains sobering, particularly in rural areas where approximately 70 percent of the total population resides. About half of rural inhabitants are considered absolutely poor, meaning that they have difficulty acquiring basic necessities, such as sufficient food for meeting caloric requirements (Arndt and Simler, 2007). Rural dwellers, especially the poor, depend heavily on crop agriculture for their incomes. However, crop technologies are generally rudimentary and agricultural value-added remains concentrated in cassava, maize and beans. Only a small minority of rural households use improved seeds, fertilizers and pesticides (Uaiene, 2008). While the urban centers tend to be more diverse, agriculture remains the single largest employment sector for urban dwellers. Thus, despite being a key economic sector, agriculture remains underdeveloped, with negative consequences for both rural and urban populations.

Widespread rural poverty does not stem from a lack of agricultural potential.[1] On the contrary, agricultural conditions in Mozambique are considered to be favorable (Diao et al., 2007). However, low-yield technologies are typically employed and vast tracts of high-quality land remain unexploited. Water resources, in the form of multiple rivers, are also abundant and underexploited. Furthermore, the country's long coastline and multiple harbors open towards the dynamic markets of Asia and into expanding regional markets. Given such potential, a number of explanations exist for the underdevelopment of agriculture, including binding labor constraints within this land-abundant country, as well as inadequate investments in agricultural technologies and rural infrastructure. Private (foreign) investments in biofuels may thus provide an opportunity to exploit available resources and increase the contribution of agriculture to exports and economic growth.

Overall, Mozambican agriculture can be divided into two parts. On the one hand there exists a large and mainly subsistence-oriented sector focused on food crop production; this sector uses rudimentary technology and is subject to high levels of volatility. On the other hand, there is a small but growing commercial sector that is driven by external investment. Despite growth, the commercial sectors small size has implied only a small contribution to overall growth and poverty reduction.

Investments in commercial agriculture have occurred through two kinds of institutional arrangements. First, the tobacco and cotton sectors have been successful in using vertically-coordinated arrangements with smallholders. Beyond the immediate benefits to smallholders (i.e. income obtained from sale of cash crops), considerable evidence suggests the existence of technology spillovers, whereby farmers associated with outgrower schemes (and their neighbors) adopt improved technologies for other crops (Strasberg, 1997; Benfica, 2006; Uaiene, 2008). The second arrangement is that of production on a plantation basis, as is seen in the sugarcane sector. Employees on plantations have typically fared better than workers dependent on subsistence-oriented agriculture. However, the plantation approach has not been associated with technology spillovers and has failed to generate many jobs for farm laborers. Thus, while biofuels represent investments on a larger scale than existing traditional exports, the institutional arrangement of these new investments, including the associated production technology vectors and spillovers, will have strong implications for the character of growth. Accordingly, we focus on the impact of proposed biofuel investments under alternative institutional structures.

---

[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 of "poorest country in the world" in the early 1990s (Arndt, Jensen & Tarp, 1998). Most indicators point to substantial improvements since that time. However, the low starting point implies the necessity of rapid improvement for extended periods to achieve even the averages for developing countries.

3. LITERATURE REVIEW

With oil prices projected to remain well above US$70 per barrel for the foreseeable future (IEA, 2007), biofuel production is expected to remain profitable and grow dramatically. However, 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 biofuel production (Hausmann, 2007). Hausmann also views biofuels as being net positive for growth and development, particularly in Africa and Latin America, due to the large land endowments of these continents. Compared with the natural resource-extractive industries that often dominate investment, especially in Africa, biofuel production technologies tend to be more labor-intensive and hence more pro-poor. In addition, biofuel production requires general investment in roads and port infrastructure, as opposed to the dedicated investments normally associated with resource extraction. As a result, biofuel investments will "crowd in" other investments due to improvements in the transport infrastructure.

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 has already been associated with shifts to biofuel production. In addition, while recognizing the potential of biofuel production to provide market outlets for poor farmers and generate rural employment, they are concerned that biofuel plantations will take land from smallholders, employ capital-intensive technologies, and pay substandard wages.

The environmental implications of biofuel production are also the subject of debate. Biofuels have often been pointed to as a means for reducing GHG emissions. 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, thus creating a cycle (Hazell and Pachauri, 2006). However, this cycle is not completely closed, as biofuels require energy for their growth, processing, and transportation, thus implying positive net emissions. Pimentel (2003) calculates that the energy balance of ethanol from corn is actually negative. However, these calculations are disputed by Graboski and McClelland (2002), and the bulk of the evidence indicates that biofuels, particularly those derived from 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 that of fossil fuel depends upon land use and the source of land used for biofuel production. In particular, clearing new land for biofuel production can generate large emissions of GHGs (particularly CO_2) due to burning and decomposition of organic matter. Fargione et al. refer to these land-conversion emissions as the "carbon debt." This debt varies by the biome in which the land conversion occurs and the crop planted for biofuel production. In the case of production of sugarcane for ethanol on land cleared from Brazilian Cerrado, they estimate that it would take 17 years to repay this debt (in other words, 17 times the carbon savings per year from using the produced ethanol versus gasoline equals the carbon debt). The payback periods for some other biomes and crops are even longer.

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

While the biofuel boom has generated considerable discussion on the potential implications for poor countries, such debates are supported by relatively few quantitative economic analyses. A review of the literature yields no published articles estimating the growth and poverty implications of large-scale biofuel investment in a low-income country. In this context, an analysis of Mozambique is useful because the concerns of this country reflect many of the key aspects of the debate outlined above. Highly relevant issues include the choice of production technology, institutional arrangements in production (plantation versus outgrower), technology spillovers, land area expansion, diversion of resources from food production, and complementary investments. In the next section, we develop an economic modeling framework that captures the various transmission mechanisms linking biofuels to the above issues.

4. THE MODELING FRAMEWORK AND RESULTS

Background on CGE models

The impact of biofuel investment is simulated using an economywide computable general equilibrium (CGE) model of Mozambique. This class of model is frequently applied to issues of trade strategy, income distribution, and structural change in developing countries. CGE models have a number of features that make them suitable for such analysis. First, 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 are mediated through prices and markets. Secondly, the structural nature of these models permits consideration of new phenomena, such as biofuels. Thirdly, CGE models assure that all economywide constraints are respected. For instance, biofuels are expected to generate substantial foreign exchange earnings (or savings, as in the case of fuel import substitution), use a large quantity of land, and demand a substantial amount of labor. It is therefore important to consider the balance of payments and the supply of useable land and labor. Fourthly, CGE models contain detailed sectoral breakdowns and provide a "simulation laboratory" for quantitatively examining how different impact channels influence the performance and structure of the economy. Finally, CGE models provide a theoretically consistent framework for welfare and distributional analysis.

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

Experience with CGE models also highlights some disadvantages. An economywide 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 a detail highly relevant to the analytical question at hand is suppressed, the approach will obviously be poorly suited to the task. Similarly, some issues can be adequately addressed with economic frameworks that are less comprehensive, thereby allowing the analyst to spend more time on analysis and less time on data issues and modeling. Due to the potential scale of biofuel investments and their downstream implications for the whole economy, however, we herein adopted a CGE modeling-based approach.

Mozambique Modeling Framework

The CGE model of Mozambique 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 the model results. For example, because the produced biofuels will either be exported or used to replace fuel imports, substantial increases in biofuel 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 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 compared to non-traded sectors. The basic structural features of the Mozambican economy are presented in Table 1.

---

[2] The International Food Policy Research Institute's recursive dynamic model is used (see Thurlow, 2008).

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.

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 are employed such that 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 that distinguishes between exported and domestic goods, and by doing so, captures any time- or quality-related differences between the two products. Profit maximization drives producers to sell in markets where they can achieve the highest returns. These returns are based on domestic and export prices; 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 the 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 intermediate and final 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 the relevant taxes).

The model distinguishes among various institutions, including enterprises, the government, and 10 representative household groups. Households are disaggregated across rural/urban areas and national income quintiles. Households and enterprises receive income in payment for the producers' use of their factors of production. Both institutions pay direct taxes to the 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 incomes to households in the form of dividends. Households, unlike enterprises, use their incomes to consume commodities under a linear expenditure system (LES) of demand.

The government receives income from imposing activity, sales taxes, 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 expenditures, and the remaining income of the government is saved (with budgets deficits representing negative savings). 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-investment account. In order to bring about balance among 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 is assumed in order to balance the savings-investment account. Under this closure, the marginal propensities of households and enterprises to save are fixed, while investment adjusts to income changes to ensure that the level of investment and savings are equal. For the current account it is 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 to households and enterprises.

The CGE model is calibrated to a 2003 social accounting matrix (SAM) (McCool, Thurlow and Arndt, forthcoming), 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, 2004). 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. However, because biofuel investments 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. Therefore, the model must be "dynamized" by building in a set of accumulation and updating rules (e.g. investment adding to capital stock, after depreciation; labor force growth by skill category; productivity growth). In addition, expectation formations must be specified. Expectation formations represent a major distinguishing feature of many macroeconomic models. For the CGE model employed herein, a simple set of adaptive expectations rules are chosen, as we view these to be the most appropriate for the Mozambican context. We also do not explicitly model crowding-in of private investment in non-biofuel sectors, as suggested by Hausmann, opting instead to focus on the direct impact of biofuels. We do, however, consider potential technology spillovers.

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 each new investment can be directed to any sector in response to differential rates of return, but installed equipment must remain in the same sector (e.g. a factory 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 is linked to its corresponding representative household in the CGE model. This is the expenditure-side microsimulation component of the Mozambican model. In this formulation, changes in representative households' consumptions and the 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 our focus is on the *differential* impact across scenarios. From this vantage point, what matters most is whether our baseline scenario (which excludes biofuel investment) and the various biofuel scenarios are more or less reasonable. Examining the differences among these scenarios allows us to isolate the implications of biofuel investments. The modeling is not, however, an attempt to forecast particular economic outcomes.

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 the 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 that of unskilled labor.[3] There is also unbiased technological change in the baseline scenario, with the shift parameter on the production function increasing at three percent per year in non-agriculture and 0.8 percent per year in 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. 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 Mozambican CGE-microsimulation model. Exchange rate index is given in foreign currency units per local currency unit (i.e. a decline is an appreciation).

Biofuel Scenarios

In the biofuel scenarios, we create dedicated sectors of sugarcane for ethanol production and jatropha for biodiesel production. The outputs of these sectors are employed as the raw materials for dedicated processing sectors. Beginning from an effectively zero base, we increase the amount of land allocated to the biofuel raw material sectors. For all four biofuel sectors, the capital necessary for biofuel production is assumed to be 100 percent foreign-financed and is incremental to the foreign investment levels assumed

---

[3] Skilled/semi-skilled labor productivity grows at two/one percent. Total labor force growth is faster than population growth because the forecast population growth is below historical rates and the population pyramid is skewed towards the young (nearly 50 percent of the population is below 15 years old).

without biofuels. Returns to biofuel capital are assumed to be repatriated. The resulting biofuel production is assumed to be 100 percent exported.[4]

The production structures of the two considered crops are different (see Table 3). The proposed sugarcane investments in Mozambique are assumed to be plantation-based, whereas jatropha production 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, but it is substantially more capital-intensive, employing three times more capital per hectare than jatropha. Relative to the quantity of biofuel produced, jatropha is more land-intensive, requiring more than twice as many hectares to produce the same number of liters of fuel (biodiesel or ethanol). The technologies for processing both crops into biofuel requires an additional two to three workers for every 10,000 liters produced. Overall, jatropha processing is more labor-intensive, while sugarcane processing is more capital-intensive.[5]

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
Labor-capital ratio (persons / 100 units of capital)	5.0	23.0
Biofuel 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)		
Biofuel 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.

The results from the baseline scenario are compared with four biofuel scenarios. In Scenarios 2 and 3, we expand sugarcane and jatropha production separately. Since a similar amount of biofuels is

---

[4] For the purposes of this exercise, the difference between export of biofuels and import displacement of petroleum (which is a purely imported commodity) by biofuels is very small.

[5] It is worthwhile highlighting that some uncertainty surrounds the figures given in Table 3. The agronomics of jatropha are particularly uncertain due to the distinct paucity of experience with the crop in the Southern African region. The figures in Table 3 are based on the best available information. It may be that a different crop, such as sweet sorghum, will eventually prove itself more amenable to outgrower schemes. Nevertheless, the very high degree of interest in sugarcane and jatropha exhibited by serious investors leads us to focus our production technology estimations on these two crops.

produced in each scenario, this analysis provides a comparison between plantation and smallholder biofuel production. As mentioned earlier, Mozambique's experience with traditional export crops suggests that smallholders' food crop yields may increase following participation in outgrower schemes, due to technology spillovers (Strasberg 1997, Benfica, 2006). 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, respectively) we increase the amount of land allocated to these crops by 280,000 and 55,000 hectares, respectively (see Table 4).[6] As indicated earlier, Mozambique is a land-abundant country. However, access to large contiguous pieces of unused land is limited by insufficient road infrastructure, meaning that it is unlikely that biofuel investments 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 for existing crops by half the amount of land needed for biofuel crops, and then let the model determine the optimal allocation of the remaining land based on the production technologies and relative profitabilities of different crops.

Table 4. Agricultural production results

	Initial value, 2003	Baseline value, 2015 (1)	Deviation from baseline final value, 2015			
			Sugarcane scenario (2)	Jatropha scenario (3)	Jatropha + spillovers (4)	Combined scenario (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
Paddy rice	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 tons)						
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
Paddy rice	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 Mozambican CGE-microsimulation model.

---

[6] 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.

The reduction in land available to non-biofuel crops causes a decline in the production of food crops, especially cereals, which have relatively high import penetration. Accordingly, both scenarios show an increase in cereal prices relative to the baseline (see Table 2). This is most pronounced under the jatropha scenario, as this crop 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 currency appreciation. Food crops, on the other hand, are less affected by appreciation because they rely more heavily on domestic markets. Accordingly, the land allocated to traditional exports declines by a larger percentage than that allocated to food crops.

Given its lower input requirements, a larger share of the value-added generated from producing jatropha and biodiesel remains on the farm, leading to faster agricultural GDP growth compared to plantation-based production of sugarcane (see Table 5). However, land-intensive jatropha production has a more detrimental impact on traditional export crops, thereby reducing 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 production uses relatively less labor and land, thereby competing less with other domestic activities, and while it requires relatively more capital, this capital is assumed to come from abroad.

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 Mozambican CGE-microsimulation model.

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 280,000 hectares generates jobs for 94,000 farm laborers (see Table 6). Similarly, jatropha production employs 271,000 smallholder farmers. Biofuel processing employs 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 comes from within the agricultural sector. This captures the labor reallocated to jatropha production by smallholder farmers, 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 the non-agricultural sector. Most of these workers come from the 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 non-agricultural sectors and into rural farm production is larger for jatropha production.

Table 6. Labor employment results

	Initial employ., 2003	Baseline employ., 2015	Deviation from baseline final employment, 2015			
			Sugarcane scenario	Jatropha scenario	Jatropha + spillovers	Combined scenario
		(1)	(2)	(3)	(4)	(2 + 4)
Total (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 Mozambican CGE-microsimulation model.

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, jatropha production increases incomes the most, especially for lower-income households. This is shown by changes in the 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 benefit lower-income and rural households relatively more. In contrast, sugarcane production is more capital- and skill-intensive, thereby shifting the relative factor prices in favor of higher-income urban households.

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	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	4,860	7.52	0.64	0.73	1.00	1.60
Urban households						
Quintile 1	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	11,172	8.74	0.57	0.01	0.25	0.86

Source: Results from the Mozambican CGE-microsimulation model.

Uneven distributional impacts are also reflected in poverty outcomes once the 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. 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 Mozambican CGE-microsimulation model.

The impact of jatropha on poverty is even more pronounced when we account 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 total factor productivity

(TFP) growth rate for food crops by an additional 0.5 percentage points per year during 2003-2015. Viewed in partial factor productivity terms, the average maize yield increases from 0.96 to 1.22 tons per hectares under the baseline scenario, but rises to 1.30 tons per hectare under the spillover scenario. Similar productivity improvements are imposed on other cereals, root crops and vegetables. The result is a reversal in the decline of food crop production (see Table 5) and a 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 productivity.

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 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 the 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.

Displaced Investment and Relative Poverty Impacts

A national CGE model cannot consider regional development issues. Inevitably, biofuel production will concentrate in particular regions, with consequent implications for the patterns of public investment. For instance, biofuel production will require accompanying investment in transportation infrastructure, such as roads and ports. In the results presented above, the model implicitly assumes that existing budgets accommodate these needs. However, if investment is displaced to biofuel-producing regions, then other regions many experience a reduction in such investments.

We suggest three possible outcomes for this redirection of investment. First, regions not producing biofuels grow less rapidly, and these reductions in growth are not offset by increases elsewhere. In this case, the biofuel scenarios overstate the economywide gains from biofuel production. Secondly, regions not producing biofuels grow less rapidly but these reductions are entirely offset by incremental growth beyond the biofuel sectors in the biofuel regions. As pointed out by Hausmann, the use of transport infrastructure is non-exclusive (up to a capacity point). Thus, the extra investment in transport infrastructure for biofuel regions may well crowd-in additional economic activity, which could offset the activity foregone in the non-biofuel regions. In this case, the scenarios correctly project the economywide gains, but the national framework masks some regional disparities. Finally, regions not producing biofuels grow less rapidly but these reductions are more than offset by incremental growth beyond the biofuel sectors in the biofuel regions. This could occur if agglomeration economies or other spillover effects induce a crowding-in of a greater level of economic activity than was foregone in the non-biofuel regions. In this case, the benefits of biofuels are understated and the actual regional disparities are more pronounced. In the absence of a solid foundation for any particular outcome, we rerun the above scenarios under the assumption that the additional required public investment is raised via a proportional increase in commodity taxes and direct income taxes. These investment scenarios produced qualitatively similar results to the biofuel scenarios presented above.[7]

---

[7] These results are available from the authors upon request.

We have also not considered a counterfactual scenario in which Mozambique's government invests in alternative agricultural sectors, such as smallholder food crops. Thurlow (2008) compares the growth and poverty-reduction effects of alternative sources of agricultural growth in Mozambique and finds that biofuel crops are not the most pro-poor source of agricultural growth relative to other crops. For instance, the poverty-growth elasticity of biofuel crops is -0.43, which is significantly smaller than the elasticities for maize (-0.73), sorghum and millet (-0.65), and horticulture (-0.48). However, biofuel crops have far higher growth potential, allowing them to generate larger *absolute* poverty reductions than existing food and traditional export crops.

5. CONCLUSIONS, POLICY IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Our model results suggest that biofuels can provide Mozambique with an opportunity to substantially enhance economic growth and poverty reduction. Both modes of production considered here, ethanol produced from sugarcane grown using a plantation approach and biodiesel produced from jatropha using an outgrower approach, are projected to 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 biofuel production unavoidably imposes adjustments on other sectors due to competition for land and labor and the implications of increased foreign exchange availability on 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, the allocated areas and production levels of food crops also decline, while food prices and imports increase relative to the baseline. Overall, while welfare and food security broadly increase due to enhanced purchasing power, certain households may be adversely affected due to the price and quantity adjustments associated with rapid growth in biofuel production.

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

At current prices for fossil fuels, biofuel production for export is clearly competitive. There is little need to provide additional incentives for biofuel investment. At the same time, any insistence on a solely 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 wherein the initial investment occurs in plantation mode up to a certain threshold, beyond which further expansion of biofuel crops follows an outgrower arrangement, merits careful consideration.

There are numerous topics for further research, four of which are described in the following. First, water usage is not considered explicitly in the model. While irrigation is not strictly necessary for jatropha, sugarcane typically requires irrigation and therefore has implications for water resources. The large increase in water demand caused by biofuel crops is reflected in the water sector's high growth following new biofuel investments (see Table 5). Second, the model does not consider the potential spillovers to other exporting sectors due to increases in transport and other infrastructures required by biofuel production (i.e. the crowding-in highlighted by Hausmann, 2007). Such spillovers from foreign direct investment would enhance the benefits from biofuel production, thereby justifying concomitant public investment vis-à-vis other investment opportunities.

Third, the implications of converting unused land to biofuel production should be considered in the context of GHG emissions. 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 biofuel crops 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 CO_2 balance, it is more likely to receive a premium in international markets. A demonstrably green label is also likely to serve as a significant buffer to any downside price risk. While fossil fuel and biofuel prices are currently high and appear unlikely to fall substantially over 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 also be considered in greater detail.

REFERENCES

Arndt, C., H. T. Jensen and F. Tarp. “Stabilization and Structural Adjustment in Mozambique: An Appraisal.” *Journal of International Development*. 12(2000): 299-323.

Arndt, C. and K. R. Simler. “Consistent Poverty Comparisons and Inference.” *Agricultural Economics.* 37(2007):133-143.

Benfica, R. “An Analysis of Income Poverty Effects in Cash Cropping Economies in Rural Mozambique: Blending Econometric and Economy-Wide Models.” Ph.D. dissertation. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan. 2006.

Diao, X., P. Hazell, D. Resnick, and J. Thurlow. *The Role of Agriculture in Pro-Poor Growth in Sub-Saharan Africa*. IFPRI research report 144, Washington D.C. 2007.

Dimaranan, B. V., Editor. *Global Trade, Assistance, and Production: The GTAP 6 Data Base*, Center for Global Trade Analysis, Purdue University, W. Lafayette, IN. 2006.

Econergy. “Mozambique Biofuels Assessment.” Report prepared for Mozambique’s Ministries of Agriculture and Energy and the World Bank, Washington D.C. 2008.

Fargione, J., J. Hill, D. Tilman, S. Polasky, and P. Hawthorne. “Land Clearing and the Biofuel Carbon Debt.” *Science.* 319(2008): 1235-1238.

Graboski, M.S. and J.M. McClelland. “A rebuttal to 'Ethanol fuels: Energy, economics and environmental impacts’ by D. Pimentel.” *International Sugar Journal*. 2002.

Hausmann, R. “Biofuels can match oil production.” *Financial Times.* November 6, 2007.

Hazell, P. and R. K. Pachauri. “Bioenergy and Agriculture: Promises and Challenges.” 2020 Focus, 14. International Food Policy Research Institute. December 2006.

IEA (International Energy Agency). *World Economic Outlook 2007*. Organization for Economic Cooperation and Development, France. 2007.

INE (National Institute of Statistics). “Household consumption survey 2002-03 electronic data.” Maputo, 2004.

McCool, C., J. Thurlow, and C. Arndt. “Documentation of Social Accounting Matrix (SAM) Development” in *Taxation in a Low-Income Economy: the Case of Mozambique*. C. Arndt and F. Tarp, eds. Routledge, Forthcoming.

Oxfam International. “Biofueling Poverty: Why the EU Renewable Fuel Target May be Disastrous for Poor People.” Oxfam Briefing Note. November 2007.

Pimentel, D. “Ethanol Fuels: Energy Balance, Economics, and Environmental Impacts Are Negative.” *Natural Resources Research*. 12(2003): 127-134.

Strasberg, P. “Smallholder Cash-Cropping, Food-Cropping and Food Security in Northern Mozambique.” Ph.D. dissertation. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan. 1997.

Thurlow, J. “Options for Agricultural Growth and Poverty Reduction in Mozambique.” Mimeo. International Food Policy Research Institute, Washington D.C. 2008.

Uaiene, R. “Determinants of Agricultural Technical Efficiency and Technology Adoption in Mozambique.” Ph.D. dissertation. Purdue University, W. Lafayette, IN. May 2008.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

802. *Agricultural exit problems: Causes and consequences*. Derek Headey, Dirk Bezemer, and Peter B. Hazell, 2008.

801. *Cotton-textile-apparel sectors of India: Situations and challenges faced*. Jatinder S. Bedi and Caesar B. Cororaton, 2008.

800. *Cotton-textile-apparel sectors of Pakistan: Situations and challenges faced*. Caesar B. Cororaton, Abdul Salam, Zafar Altaf, and David Orden, with Reno Dewina, Nicholas Minot, and Hina Nazli, 2008.

799. *Race to the top and race to the bottom: Tax competition in rural China*. Yi Yao and Ziaobo Zhang, 2008.

798. *Analyzing the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia*. Temesgen Deressa, R.M. Hassan, Tekie Alemu, Mahmud Yesuf, Claudia Ringler, 2008

797. *Economic transformation in theory and practice: What are the messages for Africa*? Clemens Breisinger and Xinshen Diao, 2008.

796. *Biosafety at the crossroads: An analysis of South Africa's marketing and trade policies for genetically modified products.* Guillaume P. Gruère and Debdatta Sengupta, 2008.

795. *Publish or patent? Knowledge dissemination in agricultural biotechnology*. An Michiels and Bonwoo Koo, 2008.

794. *Agricultural growth and investment options for poverty reduction in Malawi.* Samuel Benin, James Thurlow, Xinshen Diao, Christen McCool, Franklin Simtowe, 2008.

793. *China: Shadow WTO agricultural domestic support notifications*. Fuzhi Cheng, 2008.

792. *India: Shadow WTO agricultural domestic support notifications*. Munisamy Gopinath, 2008.

791. *Agricultural growth and investment options for poverty reduction in Zambia.* James Thurlow, Samuel Benin, Xinshen Diao, Henrietta Kalinda, and Thomson Kalinda, 2008.

790. *Agricultural growth and investment options for poverty reduction in Uganda*. Samuel Benin, James Thurlow, Xinshen Diao, Allen Kebba, Nelson Ofwono, 2008.

789. *Agricultural public spending in Nigeria*. Tewodaj Mogues, Michael Morris, Lev Freinkman, Abimbola Adubi, and Simeon Ehui; *with* Chinedum Nwoko, Olufemi Taiwo, Caroline Nege, Patrick Okonji, and Louis Chete, 2008.

788. *Choosing sensitive agricultural products in trade negotiations*. Sébastien Jean**,** David Laborde, and Will Martin, 2008.

787. *An Updated Look at the Recovery of Agricultural Productivity in Sub-Saharan Africa*. Alejandro Nin Pratt and Bingxin Yu. 2008

786. *Migration, Poverty, and Inequality: Evidence from Burkina Faso*. F.S. Wouterse. 2008

785. *Insecticide use on vegetables in Ghana: Would GM seed benefit farmers?* Daniela Horna, Melinda Smale, Ramatu Al-Hassan, José Falck-Zepeda, and Samuel E. Timpo, 2008.

784. *Agriculture for development in Ghana: New opportunities and challenges*. Clemens Breisinger, Xinshen Diao, James Thurlow, and Ramatu M. Al-Hassan, 2008.

783. *Understanding the investment and abandonment behavior of poor households: An empirical investigation*. Ruth Vargas Hill, 2008.

782. *Access to irrigation and the escape from poverty: Evidence from Northern Mali*. Andrew Dillon, 2008.

781. *Structural changes in the Philippine pig industry and their environmental implications*. Maria Angeles O. Catelo, Clare A. Narrod, and Marites M. Tiongco, 2008.

780. *Evaluating alternative policy responses to higher world food prices: The case of increasing rice prices in Madagascar*. David Coady, Paul Dorosh, and Bart Minten,, 2008.

779. *Contract farming of swine in Southeast Asia as a response to changing market demand for quality and safety in pork.* Marites Tiongco, Maria Angeles Catelo, and Ma. Lucila Lapar, 2008.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: +251 11 6463215
Fax: +251 11 6462927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org