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The Distributive Effect and Food Security Implications of Biofuels Investment in Ethiopia

A CGE Analysis

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Abstract

In response to global opportunities and domestic challenges, Ethiopia is revising its energy policy to switch from high-cost imported fossil fuel to domestically produced biofuels. Currently, there are biofuel investment activities in different parts of the country to produce ethanol and biodiesel. However, there is no rigorous empirical study to assess impacts of such investments. This paper assesses the distributive effect and food security implications of biofuels investment in Ethiopia, using data from 15 biofuels firms and 2 NGOs in a CGE (computable general equilibrium) analysis. Findings suggest that biofuels investments in the context of Ethiopia might have a 'win-win' outcome that can improve smallholder productivity (food security) and increase household welfare. In particular, the spillover effects of certain biofuels can increase the production of food cereals (with the effect being variable across regions) without increasing cereal prices. When spillover effects are considered, biofuel investment tends to improve the welfare of most rural poor households. Urban households benefit from returns to labor under some scenarios. These findings assume that continued government investment in roads allows biofuels production to expand on land that is currently unutilized, so that smallholders do not lose land. Investment in infrastructure such as roads can thus maximize the benefits of biofuels investment.

Key Words: biofuels investment, CGE model, food security, household welfare, equivalent variation, Ethiopia

JEL Codes: Q56, Q42, O44, O5

Contents

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Introduction

Rising prices of fossil fuels together with apprehension about the environmental harm created by them have resulted in increasing efforts to search for alternative energy sources. Biofuels are considered renewable and relatively cleaner substitutes for conventional energy sources. However, there is ongoing debate on the opportunities created and challenges posed by biofuel production (Azar, 2011; World Watch Institute, 2007). Some skeptics see the trend as land grabbing by cross-border transnational corporations and foreign governments and as the new scramble for Africa (ABN, 2007). The extreme view is that the effect of biofuel on food security amounts to a crime against humanity.[1] Others have argued that greater production of biofuels might not necessarily be harmful for the poor and that they can become more food secure with the adoption of proper production technology (van Rheenen and Olifinbiyi, 2007).

The central question in this paper is whether there will be a positive or negative impacts on smallholder farmers and people living in rural areas as more agricultural land is used for biofuels production. The paper uses firm survey data in a CGE (computable general equilibrium) analysis to assess the distributive effect and food security implications of biofuels investment. We focus on Ethiopia, using data from 15 biofuels firms and 2 NGOs involved in biofuel production. We find that the spillover effects of certain biofuels can increase the production of food cereals (with the effect being variable across regions) without increasing cereal prices.

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[1] The UN's special rapporteur on the right to food, Jean Ziegler, stated at a press conference in New York that it is a crime against humanity to divert arable land to the production of biofuels crops as a replacement for petrol (Mathews, 2008).

When spillover effects are considered, biofuel investment tends to improve the welfare of most rural poor households. Urban households benefit from returns to labor under some scenarios. These findings assume that continued government investment in roads allows biofuels production to expand on land that is currently unutilized, so that smallholders do not lose land. Ethiopia is said to have tremendous potential for ethanol and biodiesel production. Some estimates put the potential area of land suitable for production of biodiesel feedstock at about 25 million hectares (Gebremeskel and Tesfaye, 2008). However, it is not obvious how much production could come from first generation biofuels, such as cultivation of biofuel trees and cereal crops, and how much from second generation biofuels, both from agricultural residues and industrial byproducts such as molasses.

The Ethiopian government is currently in the process of revising its energy policy and has recently announced a strategy that encourages the expanded development and utilization of biofuels. One of the justifications for this policy is the possibility of saving scarce foreign currency that is used to import fossil fuels and shifting from high-cost fossil fuels to cost-effective biofuels (MoME, 2007). In addition, Ethiopia has adopted a standard of a 5% blend of biofuels in transport fuel, which was recently increased to 10%. Ethiopia's Growth and Transformation Plan (GTP) also stipulates increasing production of bio-ethanol to 194.9 million liters and bio-diesel to 1.6 million liters over five years (i.e., 2010/11 to 2014/15). These goals are to be achieved through coordination of governmental and private sugar industries, in the former case, and through involvement of private investors and farmers, in the later case (MoFED, 2010). In line with this, the GTP also envisages oil companies increasing the number of blending facilities to 8 for ethanol and 72 for biodiesel.

It is imperative for low-income, food-deficit countries such as Ethiopia to investigate the distributional and food security questions raised by such investments. Specifically, unintended effects on poverty and growth need to be examined. To date, there has been no such analysis conducted for Ethiopia. The questions include: Will such biofuels investment be pro-poor or will it lower the income of vulnerable people or groups? Which group in Ethiopia, if any, will be affected negatively due to increasing biofuel investment in Ethiopia? Will such investments undermine the country's food production or food security?

A review of existing literature identifies the following outstanding issues. First, the empirical evidence is mixed and there is no consensus so far, particularly regarding the distributional consequences and food security implications of biofuels investment. Specifically, little is known about the actual impact of these new investments on smallholder farmers. Therefore, country-specific case studies such as this one contribute to the debate and enhance our understanding of the real effects of biofuels expansion, including its differential impacts across different regions and income groups. Second, the current literature is largely focused on developed economies; little is known and very few studies have been carried out in the context of Africa. Third, there are very few CGE models developed so far for Ethiopia. Moreover, these few CGE models have focused on other issues, including economic infrastructure, food aid, poverty reduction and livestock; none have looked into biofuels issues. Therefore, it is of interest to analyze the impact of investment in biofuels using a CGE model. Finally, this study will inform policy besides contributing to the literature.

The main objective of this study is to investigate the distributive effect and food security implications of biofuel investment in Ethiopia, using data obtained from biofuels firms on inputs and outputs in an economy-wide model. Specifically, this study assesses the effects of biofuels investment on food security in the country and examines the distributive effect in terms of the consequences for household welfare. We modify the Ethiopian SAM to include the biofuels sector, based on data collected from biofuels firms and NGOs involved in biofuels.

The rest of the paper is organized as follows. The next section presents a literature review. The section that follows presents the model, including the dynamic structure of the CGE model, and outlines data and context. The section after that presents simulations. Results are then discussed. The last section concludes and draws some policy implications.

Literature Review

Globally, only a few countries dominate the domestic use and export of biofuels. Ethanol, first produced in the 1970s, is still produced in much larger volumes than biodiesel, for which production started in the 1990s (Slater, 2007). The United States and Brazil are the largest producers of ethanol, accounting for over 80 percent of the world's total production. The EU, on the other hand, produces almost 80 percent of the world's biodiesel (FAPRI, 2010). Global production of biofuels has increased gradually over time. The largest future increases in production volumes are expected in Brazil, the United States, the EU, China, India, Indonesia, and Malaysia. By 2030, the total annual global production of biofuels is projected to increase to 92 Mtoe[2] under a reference scenario and to 147 Mtoe under an alternative policy scenario (IEA, 2006). Global biofuels consumption is projected to grow four-fold over the next two to three decades, accounting for 8% of transport fuel demand by 2035, up from 3% now (IEA, 2010).

[2] Mtoe stands for Metric ton of oil equivalent.

There have been continuing debates on the socioeconomic impacts of biofuel production. Proponents of biofuels production argue for the stabilizing effect that it might impose on the price of fossil fuels, its contribution to reduction of greenhouse gas emissions, and its income and growth effects in land-rich poor countries. The opponents argue that biofuel production competes with food production for land and labour and hence leads to rising food prices. Furthermore, there is concern that the increasing water demand by biofuel production might create additional pressure on already inadequate supplies of water. However, there are few studies conducted to assess these issues and quantify the impacts on growth and income distribution.

It is quite challenging to quantify the benefits of biofuels compared to oil fuels by assigning prices to effects such as climate benefits, air quality, human health, and sustainability of energy sources (World Watch Institute, 2007). The limited literature can be classified into three groups.

First, there are studies dealing with the effect of biofuel production on food prices (McNew and Griffith, 2005; Abbott et al., 2008; Chakravorty et al. 2009; Rosegrant, 2008; Mitchell, 2008; World Watch International, 2007 and Sourie et al., 2006). Competition imposed by biofuel production could result in significant rises in prices of agricultural products, including food crops. For instance, the OECD (2006, cited in World Watch Institute 2007), estimates significant rises in prices of sugar, vegetable oils, and cereals by 2014 resulting from increased use of biofuel. Hausman et al. (2012) use a structural vector auto-regression framework and find that increased corn ethanol production during the 2006/2007 production year explains about 27% of the experienced corn price rise. Roberts and Schenker (2010) provide a new framework to assess the impact of the current US ethanol mandate on world food commodity prices and global consumers' surplus. Specifically, they employ an econometric framework, i.e., an instrumental variable technique, to identify demand and supply elasticities of agricultural commodities using yield shocks - deviations from a time trend of output per area, which are predominantly caused by weather fluctuations. They then use their estimated elasticities to evaluate the impact of ethanol subsidies and mandates on world food commodity prices, quantities, and food consumers' surplus. They predicted world food prices to increase by about 30 percent and global consumer surplus from food consumption to decrease by 155 billion dollars annually as a result of the current US ethanol mandate. However, they also find that the predicted price increase scales back to 20 percent if a third of the biofuel calories are recycled as feedstock for livestock.

Continuing this line of research on food prices, Banse et al. (2008) analyze the trade impacts of an EU Biofuels Directive using a global CGE model, i.e., a modified version of the GTAP model. They find that cereal prices actually decline in the long-run, though less than they would without the directive. Using IFPRI's partial equilibrium model, Rosegrant finds that biofuels demand accounted for 39% of the increase in corn price from 2000 to 2007. Rajagopal et al. (2007) analyze the effect of the ethanol production tax credit on corn price, using a stylized partial equilibrium model. They find a 21% increase in corn price attributable to a $0.51 ethanol production tax credit in the US in 2006. The US Congressional Budget Office (CBO) estimates also suggest that about 10 to 15 percent of the rise in food prices between April 2007 and April 2008 is attributable to the increased use of ethanol (CBO, 2009). However, Chakravorty et al. (2011) show that about two-thirds of the increase in food prices can be attributed to changes in consumption patterns and only one-third to biofuels mandates.

Second, some work has been conducted on the effect of biofuel production on farm jobs and income (Treguer and Sourie, 2006; World Watch Institute, 2007). For instance, Treguer and Sourie (2006) estimate the effect of the massive biofuel production decision of France in order to meet the European energy directives of 2003. Using a partial equilibrium model (the OSCAR model), their results indicate that production of biofuel crops increases farm jobs and farm income. However, some argue that whether this effect leads to net welfare gain or loss for poor farm households depends on two opposing forces (World Watch Institute, 2007). One, farm households in poor countries will receive higher prices for their agricultural products due to increased global prices resulting from the competition for resources between agriculture-based energy production and other agricultural products. Two, as discussed above, poor households dependent on imported food will face higher food prices and hence become poorer.

The third type of research attempts to analyse the impact of biofuel production on global trade, growth, income distribution, and poverty (Arndt et al., 2009, 2010; Peskett et al., 2007; Ugarte et al., 2007; Dufey, 2006; and Birur, 2008). Arndt et al. (2009) might be the only research work that quantitatively estimated the effect of biofuel investments on food security, poverty, and growth in the context of Africa, using a dynamic computable general equilibrium for Mozambique. This research indicated that biofuel investment can increase growth and reduce poverty, depending on the type of technology used in production, amid some displacement of food crops by biofuels. They find that, depending on the production technology, biofuel investment increases Mozambique's annual economic growth by about 0.6 percentage points and reduces the incidence of poverty by about six percentage points, over a 12-year phase-in period.

They see the out-growers[3] approach to producing biofuels to be more pro-poor, due to the greater use of unskilled labor and accrual of land rents to smallholders, as compared with the more capital-intensive plantation approach. The out-grower production technology has more effect on growth and poverty reduction because it increases the income of small land holders and increases the rental value of their land. The results did not favor unrestrained biofuels development, but suggested that a carefully designed and managed biofuels policy holds the potential for substantial gains.Similarly, Arndt et al. (2010), for the case of Tanzania, showed that biofuels investment contributes positively to poverty reduction. They also argue that any trade-offs that do exist between biofuels and food production are likely to be smaller when feedstocks are produced by larger-scale farmers, because of higher yield per hectare.

There are few CGE models developed so far for Ethiopia. These include World Bank(2004), Gelan (2007), Diao et al.(2005) and Dorosh and Thurlow(2012. World Bank (2004) investigates how public investment can contribute to stimulate growth on a balanced path, using the economic potential of rural areas and their linkages with urban development. The paper argues that more balanced and sustained growth could be achieved by increasing economic infrastructure in high potential zones and sectors through public investment and by reducing market distortions (including food aid effects) and factor market limitations due to property rights regimes. The results of that paper imply a reorientation of the growth strategy that is on course in Ethiopia toward high potential zones and sectors, commercial farming, and fewer food aid based projects.

Gelan (2007) examined impacts of food aid on domestic food production, employing a CGE model and using data from Ethiopia. His simulation experiments show that food aid has unambiguous disincentive effects on domestic food production. That is, the removal of food aid caused a modest increase in food prices but this stimulated food production. The employment and income generation effects of the removal of food aid also outweighed the adverse effect of the status quo. Overall, the removal of food aid led to improvements in aggregate household welfare. Moreover, his simulation experiments also suggest that, in reality, poor rural households and urban wage earners are the ones who benefit most in the absence of food aid, unlike the concerns observed in the food aid literature that any reduction in food aid would hurt the poor. Entrepreneurs, on the other hand, are more likely to encounter a marginal welfare decline.

[3] An out-growers scheme is a contract farming arrangement in which a firm enters into a binding agreement with individual or groups of farmers to grow a certain crop and through which the firm ensures its supply of agricultural products (Felgenhauer and Wolter, 2008).

Diao and Pratt (2007),using a spatially disaggregated economy-wide model, assess which agricultural subsectors have the strongest capacity to drive economic growth and poverty reduction in Ethiopia, and what kind of agricultural and nonagricultural growth is needed to achieve the millennium development goal of halving the 1990 poverty rate by 2015. Their study reveals that agriculture, primarily through growth in staple crops and livestock, has the potential to play a central role in alleviating poverty and increasing growth in Ethiopia. However, they also find that similar rates of agricultural growth have different effects on poverty, necessitating regionally based strategies for growth and poverty reduction at the subnational level. Their findings also imply that agricultural growth requires concurrent investments in roads and other market conditions.

Using a new CGE model for Ethiopia based on data from the EDRI 2005/06 Ethiopia SAM (Tebkew et al., 2009), Dorosh and Thurlow (2012) analyze agricultural growth options that can support high levels of agricultural development in the context of CAADP (Comprehensive Africa Agriculture Development Programme), which Ethiopia is in the process of implementing, together with other African governments. As part of CAADP, Ethiopia has committed itself to meeting targets of devoting at least 10 percent of public expenditures to agriculture and to achieving a 6 percent growth rate in agricultural GDP. The CGE model results indicated that it is possible to reach and sustain the six percent agricultural growth target during the period 2006-2015 if Ethiopia can meet its targets for crop yields and livestock productivity. Results also suggest that achieving six percent per year of agricultural growth would reduce national poverty to 18.4 percent by 2015, thereby lifting an additional 3.7 million people out of poverty compared to a base simulation using medium term growth rates.

Gelan et al. (2012) extend the Dorosh and Thurlow (2012) dynamic CGE model to integrate livestock in the CAADP framework and assess the role of livestock in rural poverty reduction. Their results reveal the important role of the livestock sector in enhancing various measures of GDP and combatting food insecurity. They find that, unlike previously held views, agricultural GDP and overall GDP growth levels resulting from livestock total factor productivity (TFP) shocks are very similar to those resulting from cereal TFP shocks. They also find that livestock sector productivity growth leads to greater factor income, particularly labor income. Their results also imply that strategies focusing on development of the cereal sector alone might be inefficient.

This paper builds on these GGE models to help resolve questions about biofuels' effect on food security and poverty.

The Model

This paper uses a dynamic CGE model to simulate the impact of investment in biofuels. CGE models are applied to income distribution, trade strategy, and structural change in developing countries, where such models have features that make them suitable for such analysis. First of all, these models can simulate the functioning of a market economy, including markets for labour, capital and commodities, as well as the transmission of changes in economic conditions through prices and markets. Second, the structural nature of these models allows consideration of new economic activities such as biofuels. Third, these models are specified so that all economy-wide constraints are respected. For instance, investments in biofuels may generate substantial foreign exchange earnings needed by the country in question. These investments may use a large quantity of land and demand a large amount of labour. Therefore, the models consider the balance of payments and the supply of useable land and labour. Fourth, these models provide detailed sectoral breakdowns and permit a 'simulation laboratory' to quantitatively investigate how various impact channels and feedback effects influence the structure and performances of the economy through time. Last, these models provide a theoretically consistent framework for welfare and distributional analysis.

In CGE models, economic decisions are the outcome of decentralized optimization by both producers and consumers within a coherent economy-wide framework. They include a number of substitution possibilities in response to variations in relative prices. Examples include substitution between various labour types; between capital and labour; between exports and domestic sales; and between imports and domestic goods. Market imperfections and institutional rigidities are captured by exogenously imposing immobile sector capital stocks, labour market segmentation, and home consumption. These features allow a more realistic application of these models to developing countries.

Structure and Assumptions of the Dynamic CGE Model

Structure of the Dynamic CGE Model

The impacts of biofuels investment are generally economy-wide in nature and lead to strong general equilibrium feedback effects. Hence, they are amenable to CGE analysis. Moreover, shocks related to biofuels investment and production might lead to differential effects being experienced by different groups of households. Therefore, we employ a modified version of the standard CGE model for Ethiopia based on the 2005/2006 Social Accounting Matrix

(SAM) of Ethiopia developed by the Ethiopian Development Research Institute (EDRI). The basic structure of the CGE framework mimics the generic IFPRI model.[4]The IFPRI standard CGE model explains all of the payments recorded in the SAM. The model essentially follows the SAM disaggregation of factors, activities, commodities, and institutions. The model is specified as a set of simultaneous equations, most of which are nonlinear, and there is no objective function. The equations define the behaviour of the different actors. For production and consumption decisions, behaviour is captured by nonlinear, first-order optimality conditions. That is, production and consumption decisions are driven by the maximization of profits and utility, respectively. The equations also include a set of constraints such as markets (for factors and commodities) and macroeconomic aggregates (balances for Savings-Investment, the government, and the current account of the rest of the world). These have to be satisfied by the system as a whole but are not necessarily considered by any individual actor.

Each producer (represented by an activity) is assumed to maximize profits, defined as the difference between revenue earned and the cost of factors and intermediate inputs. Profits are maximized subject to a production technology. The technology is specified by a constant elasticity of substitution (CES) function of the quantities of value added and a Leontief function of aggregate intermediate inputs. Each activity produces one or more commodities according to fixed yield coefficients. In addition, a commodity may be produced by more than one activity. The revenue of an activity is defined by the level of the activity, yields, and commodity prices at the producer level. As part of its profit- maximizing decision, each activity uses a set of factors up to the point where the marginal revenue product of each factor is equal to its wage (also called factor price or rent). Factor market closures are according to equilibrating supplies and demands in each factor market, with the quantity supplied of each factor fixed at the observed level. An economy-wide wage variable is free to vary to ensure that the sum of demands from all activities equals the quantity supplied. Each activity pays an activity-specific wage that is the product of the economy-wide wage and an activity-specific wage (distortion) term; these also are fixed.

In the model, institutions are represented by households, enterprises, the government, and the rest of the world. Households (disaggregated as in the SAM) receive income from the factors of production (directly or indirectly via the enterprises) and transfers from other institutions. Transfers from the rest of the world to households are fixed in foreign currency, as is the case for all transfers between the rest of the world and domestic institutions and factors. Households use

[4] See Lofgren et al. (2002) for a detailed description.

their income to pay direct taxes, save, consume, and make transfers to other institutions. The direct taxes and transfers to other domestic institutions are defined as fixed shares of household income, whereas the savings share is flexible for selected households. Household consumption covers marketed commodities, purchased at market prices that include commodity taxes and transaction costs, and home commodities, which are valued at activity-specific producer prices. Household consumption is allocated across different commodities (both market and home commodities) according to linear expenditure system (LES) demand functions, derived from maximization of a Stone-Geary utility function. Enterprises may also receive transfers from other institutions. Enterprise incomes are allocated to direct taxes, savings, and transfers to other institutions. Enterprises do not consume. Government collects taxes at fixed *ad valorem* rates and receives transfers from other institutions. Government uses this income to purchase commodities for its consumption and for transfers to other institutions. Government consumption is fixed in real (quantity) terms, whereas government transfers to domestic institutions (households and enterprises) are CPI-indexed. Government savings, i.e., the difference between government income and spending, is a flexible residual. The final institution is the rest of the world. Transfer payments between the rest of the world and domestic institutions and factors are all fixed in foreign currency. Foreign savings or the current account deficit is the difference between foreign currency spending and receipts.

Key Assumptions of the Model

In the current account, a flexible exchange rate is assumed, so that it adjusts in order to maintain a fixed level of foreign savings (i.e., the external balance is held fixed in foreign currency terms).

In this model, labour is assumed to be mobile across sectors and fully employed, which is a strong assumption. For instance, if biofuels production results in higher employment, then the tradeoffs between biofuels and food production are less pronounced, as the GDP gains from the biofuels production would be larger. Full employment closure implies that expanding biofuels production reduces use of labor elsewhere in the economy.This is consistent with widespread evidence that, while relatively few people have formal jobs, a large proportion of the working age population engages in productive activities that contribute to GDP. Therefore, employing this working age population in biofuels production has an opportunity cost. According to the 2005 National Labor Force Survey (CSA, 2006), the country’s total unemployment rate was 5.0%, with male and female unemployment rates of 2.5% and 7.8%, respectively. The urban unemployment rate of the country was 20.6% while the unemployment rate in rural areas was

2.6%. The rural unemployment rate is low because family members work on family farms when they don't have formal jobs.

The consumer price index is taken as the model's numeraire. Trade elasticities are taken from GTAP (Global Trade Analysis Project) (Diamaranan, 2006). The model is calibrated in such a way that the initial equilibrium reproduces the base-year value from the SAM.

The features of the model described so far apply to a single-period static CGE model. However, as investments in biofuels unfold over a dozen years or more, the model is made capable of producing forward-looking growth trajectories. The model is dynamized by building a set of capital accumulation and updating rules for capital stock, labour force growth by skill category, and productivity growth. In addition, a simple adaptive expectation formation is specified whereby investment is allocated according to current relative prices. This implies that investors expect current price ratios to prevail indefinitely. Crowding-in of private investment in non-biofuel sectors is not explicitly modeled, though suggested by Hausmann (2007). We opted instead to focus on the direct impact of biofuels, though we considered the potential technology spillovers.

A set of dynamic equations update various parameter values and variables from one year to another. Growth in total supply of each labour category and land is specified exogenously. In addition, growth in land supply by agro-ecological zones to biofuels sectors is specified exogenously. Sector capital stocks are adjusted each year based on investment, net of depreciation. Factor returns adjust in such a way that factor supply equals demand. This model adopts a 'putty-clay' formulation such that new investments can be directed to any sector in response to differential rates of return (Arndt et al., 2010). However, installed equipment remains immobile. Sector-specific factor productivity growth is specified exogenously. Based on these simple relationships to update key variables, we generated a serious of growth trajectories for different biofuels investment scenarios.

In the modeling, we focus on the differential impacts of various biofuels production scenarios on a baseline scenario that excludes biofuels investments. Comparison with the baseline helps us evaluate whether the biofuels scenarios are reasonable. Examining the differences between the biofuels scenarios and the baseline scenario allows us to isolate the impacts of biofuels investments, thus providing clear and analytically tractable comparisons.

Data

The SAM

The SAM used in the Ethiopian CGE model contains 60 activities, including 41 agricultural and 5 non-agricultural sectors. The 2005/06 Macro-SAM of Ethiopia is presented in Table A1 in the Appendices. A total of 14 agricultural and non-agricultural commodities are distinguished. The main feature of the model is that activities are classified according to agro-ecological zones (AEZs); see EDRI (2009) for details on AEZs.[5] Of the factors of production, there are three categories of labour (skilled, semiskilled, and unskilled labour types). The model also identified agricultural capital and land, categorized in five agro-ecological zones, and non-agricultural capital. The model also distinguishes 14 household types. Rural households are classified according to their poverty status (poor and non-poor) and location (AEZs), resulting in 10 rural household types. Urban households are based on urban size and poverty status, resulting in 4 urban household types. The details in the 2005/06 SAM captures Ethiopia's economic structure and influence model results. Biofuels are expected either to be exported or used to substitute for fuel imports. As a result, a substantial increase in the quantity of biofuels will have implications for trade and foreign exchange availability. Availability of foreign exchange enables the country to import more and reduce exports of other products. As a result, one would expect that sectors with high trade share, where trade share might be taken to represent sectors with a large proportion of production exported or a high degree of import competition, will be more affected compared to non-traded sectors.

Table 1 provides the basic features of the Ethiopian economy in 2005/06, which is the base year for the dynamic CGE model. Agriculture generates a little less than half of the national gross domestic product (GDP) and three-fourths of total employment. The manufacturing sector, by contrast, accounts for only 13 and 7% of total GDP and employment, respectively. The country depends heavily on imported industrial products, accounting for 71% of total imports, while industrial exports accounted for a fifth of total exports. Note that fuel imports are quite considerable, accounting for about 12% of total imports and 18% of total industrial imports in 2005/06. The country imports more fuel than agricultural products. For example, cereals accounted for 3.5% of total imports over the same period.

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[5]The five AEZs include: moisture-reliable humid lowlands, (AEZ1); moisture-sufficient highlands (cereal-based systems) (AEZ2); moisture-sufficient highlands (enset-based systems), (AEZ3); drought-prone (AEZ4); and pastoralist (AEZ5).

With various incentives provided by the Ethiopian government, currently there are biofuel investment activities in different parts the country aimed at the production of ethanol and biodiesel. This policy addresses the problem that Ethiopia's fossil fuel demand is entirely satisfied through imports, so that the country is significantly exposed to the shocks associated with fluctuations in fossil fuel prices. The biofuel sector not only seems promising in addressing the energy security issue but is also expected to create more jobs and income, promoting the country's goal of poverty reduction. Reports indicate that over 500,000 hectares of land have already been offered by regions to national and transnational companies for biofuels investment (ABN, 2007; Lashitew, 2008). Jatropha, castor bean, and palm (for oil) are the main biofuel crops that are being developed, particularly for biodiesel. Both foreign and domestic companies are involved (Lakew and Shiferaw, 2008). In the case of ethanol production, the feedstock comes primarily from large-scale sugarcane plantations. Currently, the sugar byproduct molasses is the most favorable feedstock for large-scale ethanol production. The country has four sugar factories, namely Wonji-Shoa, Metahara, Fincha, and Tendaho; three of these are publicly owned. Metahara and Fincha, which are publicly owned, currently have ethanol production plants. However, the government has plans to establish a new sugar factory with a production capacity of 106,000 tons of sugar per annum and has commissioned the expansion of the existing factories to include ethanol production plants. This was projected to raise the country's ethanol production to 80,000 cubic meters by the year 2011 from the earlier level of 8,000 cubic meters (Gebremeskel and Tesfaye, 2008).

Biofuel activities vary across AEZs. For instance, while sugarcane plantation is undertaken in moisture-sufficient highlands (AEZ2), palm oil activity is mainly undertaken in moisture-reliable humid lowlands areas (AEZ1) (Table 2).Note that small scale sugarcane production is also undertaken by smallholders in the other AEZs.[6] Jatropha and castor bean activities are produced mainly in moisture-sufficient highlands (*enset*[7]-based systems), drought-prone, and pastoralist zones: AEZ 3 & 4 for jatropha and AEZ 4 & 5 for castor bean.This disaggregation captures some of the diversity in economic structure and potential across regions.

[6] See, for instance, agriculture sample survey of CSA (Central Statistical Agency) (various issues).

[7] *Enset* (i.e., *Enset ventricosum*) is an edible crop (plant). It is the edible species of a separate genus of the banana family, thus named 'false banana', but the *Enset* fruit is not edible. The plant is cut before flowering, the pseudostem (false stem) and leaf midribs are scraped, the pulp is fermented for 10-15 days and finally steam-baked flat-bread is prepared out of it and used as food (Shank and Ertiro, 1996).

Survey (Data Collection)

A survey was conducted on biofuels investment in Ethiopia. The purpose of the survey was to generate sector and crop-specific primary data to calculate the **input-outputcoefficients** in relation to the biofuels sector for the CGE analysis. A structured instrument/questionnaire was developed to collect the relevant data. The instrument covered questions related to time elapsed in the investment process from application and registration through land acquisition; feedstock production and utilization, including purchase price of feedstock offered to out-growers, labor and capital inputs to feedstock production, and related expenses; investment in plant and equipment and plant capacity; biofuels (ethanol and biodiesel) extraction (processing) and sales; as well as assessment of environmental and social issues. A list of over 45 companies with investment permits for biofuels was obtained from the Ethiopian Investment Agency. Then, 15 biofuels companies and 2 NGOs involved in biofuels were approached to fill out the structured questionnaire. There were 6 non-responses. In fact, the data collection wasn't easy and it involved a lot of diplomacy and a number of revisits. Besides its use in calculating the input-output coefficients, the survey also helped to characterize the biofuels sector in Ethiopia. Table 3 provides an overview of this sector from the survey results. The survey revealed that there is one company that started exporting biodiesel and two companies that are at the product testing stage. The survey also determined information on complementary local innovations going on in the biofuels sector, including the invention of biodiesel stoves, processors/ distilleries, and biogas driven vehicles. All these suggest that the sector requires policy attention and could possibly be an avenue to reducing poverty and enhancing growth. However, we also found that the sector suffers from lack of appropriate institutional setup in terms of better regulatory framework and follow up, particularly at the regional level.

As for production characteristics, while large scale sugarcane is mainly plantation-based, jatropha and castor bean production activities are undertaken by a combination of plantation-based and smallholder production through the out-growers scheme. In addition, jatropha and castor bean production activities are labour-intensive, as they require more labour per land compared with sugar cane (Table 4). According to this recent biofuels investment survey, sugar cane accounted for a larger share of the total land allocated to biofuel crops (Figure 1). However, it is important to note that a small proportion of the total land allotted to biofuels production was utilized in 2007. For instance, while a fifth of the total land allocated for biofuelsis utilized in castor bean, the figures for jatropha and palm oil are very small, i.e., 1.5% and 0.8, respectively, in 2009 (Figure 2). A little more than half of the total land allotted to sugarcane has been utilized over the same period. This suggests that there is a room for further expansion of production by bringing more land into cultivation; it is unlikely that smallholders will be displaced in the short- and medium-term, until full-scale operation is reached.

Biofuels development in Ethiopia is unique in two important respects. First, the biofuels sector in Ethiopia is characterized by a diversity of biofuels crops (jatropha, castor bean, sugarcane, and palm oil, including indigenous trees). Second generation biofuels, i.e., byproducts such as molasses, are used for ethanol production. There are also intercropping options in the case of castor beans. Secondly, the biofuels business model includes a mix of plantations, out-growers schemes, and community development models. For example, REST in Tigrai and ORDA in the Amhara region are involved in biofuels under a community development model.[8] The modeling has captured these features as much as possible.

Simulations

Scenarios

First, we produce a **baseline scenario** or growth path, which assumes that the economy continues to grow during 2003–2020 in line with its recent growth trajectory. For each year, we update the model to reflect changes in population, supply of labour and land, and factor productivity (see Table 5). Ethiopia could be considered a land-abundant country, as the proportion of land under cultivation is relatively small compared to the potential cultivable land. As a result, we assumed that the land supply grows at 3.2% on average in all agro-ecological zones, which is the same as the rate of cropped area expansion over the past decade. Population is assumed to grow at 2.5%, which is the same as the average rate of population growth from 1994 to 2007 (CSA, 2008). Rising skill intensity in the labour force is captured by assuming the supply and productivity of skilled and semiskilled labour force to grow faster than unskilled labour.[9] It is also assumed that there is an unbiased technological change, which shifts the

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[8] REST is an abbreviation for "Relief Society of Tigrai" and ORDA is an abbreviation for "Organization for Rehabilitation and Development of Amhara."

[9] Skilled labour of youth and adults is assumed to grow at a rate of 7.9% per year, which is consistent with expansion of higher education in the country. While semi-skilled labour is assumed to grow at the rate of 5% per year, unskilled labour is assumed to grow at 4.4% per year, a little more slowly than the rate at which semi-skilled is assumed to grow. According to data from national labour force surveys, labour force grows faster than the rate of population growth. The most recent Population Census (CSA, 2007) indicates that the age composition of the population is skewed towards the young and adult population, suggesting that the labour force grows faster than the population growth rate.

parameter on the production function (total factor productivity parameter) to grow at the rate of 2.5% in livestock and sectors that produce cereals and cash crops.

Similarly, total factor productivity in all other non-agricultural activities is assumed to grow at the rate of 2.9%. These estimates of TFP are obtained from previous studies on growth accounting in the country (e.g. Prat and Yu, 2008; World Bank, 2009). The rate of total factor productivity growth in sugarcane activity is assumed to be 5%, which is consistent with the expansion in the sector. The total factor productivity in jatropha producing activity grows at the rate of 3%, while that of castor bean producing activity is assumed to grow at the rate of 3.5%. The results of these scenarios are compared with the biofuels scenarios in order to isolate the effects of biofuels investment from the effect of other factors. Given that there exists a diversity of biofuels options for Ethiopia, we considered seven **biofuels scenarios** (see Table 6), the details of which are elaborated bellow.

The sugarcane scenario, scenario 1 (S1), assumes expansion of sugarcane production through extensive cultivation, i.e. by allocating more land to sugarcane production. Specifically, we increase land allocated to sugarcane by 5,116.44 hectares per year over the 2020 period.[10]

In the jatropha scenario, scenario 2 (S2), we keep increasing jatropha production by bringing more land into cultivation. Land allotted to this crop increases by 2,153.62 hectares per year. Given that a large proportion of land allocated to this crop is not utilized, we assume that expansion of jatropha will not affect smallholders in terms of land displacement.

In scenario3 (S3), the castor bean scenario, castor bean production is expanded by increasing the quantity of land, which is assumed to grow by about 2,033.33 hectares per year. Notice that further expansion of land beyond this magnitude can come at the expense of smallholders, i.e. smallholder land will be reduced by the amount of land allotted to castor bean production.

Scenario 4 (S4), the palm oil scenario, assumes expansion in palm oil production by increasing the quantity of land, which is assumed to grow by 2,000.00 hectares per year.

Scenario 5 (S5) includes S2 (jatropha) with improved productivity of the smallholder crop sector. This scenario intends to capture the spillover effect of biofuel technology on

[10]The recent biofuel investment survey indicates that, of the total land allocated to sugarcane, jatropha , caster bean, and palm oil, about 34,058.42, 31,804.33, 24,500 and 29,775 hectares of land are not utilized, in that order. In the biofuel scenarios, we evenly distribute this unutilized land over the 15 periods, which implies no displacement of smallholders.

smallholder agriculture. Such an effect can arise, for instance, through improved farming practices or access to other agricultural inputs (e.g. chemical fertilizer, improved seeds, insecticides, etc). Productivity growth in the cereals sector increased from 2.5 to 5% per year.

Scenario 6 (S6) is S3 (castor bean) with spillover effects of biofuel technology on smallholder crop agriculture. This induces improved productivity of the smallholder crop sector.

The last scenario, scenario 7 (S7), captures the combined effect of all biofuel interventions on the structure of the economy.

Discussion of Results

Biofuels and Food Security

Tables 7 and 8 presents the sectoral effects of biofuel expansion in Ethiopia, with particular attention to food security.[11] In general, in terms of sectoral effects, cereals (food) benefited most, especially in zones where biofuel investment is located. In particular, the jatropha and castor bean scenarios that involved spillover effects affected cereal production, with the effect being variable across regions. For example, under the jatropha with spillover scenario, cereal production in z3 and z4 (AEZ 3 & 4) increased by 4.3 percent; it decreased by 1.6 percent in z1 and z2 and by 1.5 percent in z5. Similarly, under the castor bean with spillover scenario, cereal production in z4 and z5 respectively increased by 4.6 and 4.7 percent but decreased by 1.2 percent elsewhere.

Moreover, the effect on cereal production (food security) of the jatropha and castor bean scenarios that involved spillover effects is larger when land is fully employed but mobile (Table 8). This might be because the forward and backward linkages between cereals production and biofuels investment are stronger than the linkages between biofuels and the other-agriculture sector. Smallholders in regions where biofuels crops are located can benefit from biofuel expansion in different ways, including wage employment, improved farm practices (e.g. technology transfer), and infrastructure (e.g. roads, markets), etc.,The spillover effects of these biofuels crops on cereal production are significant in magnitude, even though these biofuels crops are located in AEZs where there is very minimal cereal production (e.g. AEZs 3 and 4 for

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[11]Notice that we make use of Table 2 in introducing biofuel shocks. In other words, in the sugar cane scenario, we expand land area in all zones, as this crop is grown by small holders, as indicated in the EDRI SAM. In the palm scenario, land expansion occurs in AEZ 1 only. We expand land for biofuel crops in the jatropha and caster bean scenarios in AEZ 3 & 4 and AEZ 4 & 5, respectively.

jatropha and AEZs 4 and 5 for castor bean). However, there are negative effects on cereal (food) production elsewhere. These negative effects might be due to the price-reducing effect of increased cereal (food) production in the biofuels regions.

When the spillover effects are not included, jatropha, castor bean, and palm oil scenarios are found to have no effect on cereals. The effect of the sugarcane scenario is positive, even without including spillover effects, however, at only .1 percentage point, especially in AEZ4 and AEZ5. Unlike the jatropha and castor bean scenarios that involved spillover effects, the sugarcane scenario has no impact elsewhere.

Similarly, the combined scenario, which includes spillover effects for some biofuel crops, has a positive effect on cereals, especially in AEZ4 and AEZ5, but at a small magnitude of1 percentage point.

The effect of biofuels investment on cash crops also turns out to be either neutral or mild and positive. However, the effect of biofuels investment on livestock is found to be neutral or negative, perhaps because biofuel crops compete for land with livestock to some extent. For example, whereas the sugarcane, palm oil and combined scenarios negatively affect livestock, the jatropha and castor bean scenarios involving spillover effects, as well as the other scenarios, (jatropha, castor bean, and palm oil scenarios without spillover effects) are found to have no effect on livestock. Moreover, the effect of biofuels expansion on other agriculture is found to be either neutral or positive.

Only the jatropha and castor bean scenarios that involved spillover effects have any effect in the simulations where land is assumed to be fully employed but mobile. The effect on cereal (food) production of these two scenarios is variable across regions (Table 8). Moreover, the effect is relatively larger in magnitude as compared to the simulations where land is fully employed but activity-specific. Furthermore, except for livestock, the effects on cash crop production and other agriculture are also mixed or variable across regions. Table 9 also shows the trade-off or the difference between the two simulations, i.e., when land is assumed to be fully employed but mobile and fully employed but activity-specific.

Overall, contrary to the notion that increased biofuels production might undermine the food security objectives of developing countries, our simulations suggest they can have some positive effects -or the opposite - depending on the region. In fact, production in both cereals (food) and cash crops increases in four of the seven scenarios, with some negative effects in two of the four scenarios. Biofuels expansion also enhances other agriculture, although the effects tend to be mild. However, the effects of biofuels on cereals (food) varied by regions. Moreover, results also varied depending on whether land is activity-specific or is allowed to be mobile. This suggests that biofuel investment initiatives can have a ‘win-win’ outcome that can improve smallholder productivity and increase cereals production depending on the region.

In general, biofuel expansion complements the growth of the agriculture sector, with important linkages to other sectors. That is, a big rise in agricultural income implies that demand for local manufactures goes up (Adelman and Robinson, 1978). Note that this result is based on the assumption that there is no displacement of smallholders, i.e., that biofuels investments take place on unutilized land that is not occupied by smallholders. Given the government’s huge investment in road infrastructure in the country (see MoFED, 2010), access to unused land will no longer be constrained by inadequate road infrastructure. Therefore, further biofuel investment is likely to be undertaken on unoccupied lands, at least in the short-to medium-term.

Another important observation from the results in Tables 7 and 8 is that the different biofuels crops tend to compete with each other for the available land. The degree of competition tends to be strong, especially in the case of the sugarcane and combined scenarios. Note also that, because a significant proportion of land is utilized in sugarcane production, there is less scope for sugarcane production to increase through land expansion, in comparison to the opportunity for land expansion of other biofuels crops. That explains the higher degree of competition in the sugarcane and combined scenarios. In addition, only the combined scenario and the sugarcane scenario significantly increase the production of biodiesel and ethanol, respectively.

The paper also assesses the impact of biofuels investment on the price of cereals for the two different simulations. The spillover scenarios, with higher productivity growth in cereals, result in much less effect on cereal prices when land is fully employed but activity-specific. The other biofuel scenarios do not have any impact on cereals prices and the price paths follow the price path of the base scenario (Figure 3). On the other hand, when land is fully employed but mobile, the sugarcane scenario results in less effect on cereal prices. The spillover scenarios, with higher productivity growth in cereals, result in significant fall in cereal prices. The other biofuel scenarios do not have any impact on cereals prices and the price paths follow the price path of the base scenario (Figure 4)

Welfare (Distributive) Effects of Biofuel Investment

We also examine welfare and distributive effect of biofuels investment. The results are presented in Table 10. Note that the effects on household welfare are measured in terms of changes in equivalent variation (EV). The EV captures what income change at the current price would be equivalent to the proposed change in terms of its impact on utility (welfare), using the current prices as the base. As can be seen, in the case of the simulation results where land is assumed to be fully employed but activity-specific (see Table 10), the sugarcane and combined scenarios, as well as the jatropha and castor bean scenarios that involved spillover effects, affect both poor and non-poor households in both rural and urban areas.

In the case of the sugarcane and combined scenarios, most of the rural poor gain some benefits, but the urban households benefit most. Except for those residing in AEZs 1, 2 and 5, the welfare of rural non-poor households elsewhere is negatively affected under both scenarios. Factor returns is one of the transmission mechanisms through which the benefits of biofuel investment can affect household welfare. Returns to factors depend, among other things, on the rate of return to labour, which in turn depends on factors such as human capital, physical assets, natural capital such as land, and other factors (Osmani, 2005). This means that the urban households are better able than rural households to exploit opportunities created by biofuels investments, due to either a greater quantity of employment or greater earnings per unit of employment (or both) compared to rural households. In addition, the welfare effect is greater for urban households compared with poor rural households under both the sugarcane and combined scenarios. This may be because of differences in both quality and quantity of factor endowments between the two groups of households. The impact on the welfare of rural households also varies by agro-ecology in both cases.

The combined scenario, i.e., when all biofuels investments are undertaken simultaneously, has more or less the same effect on household welfare as the sugarcane scenario. However, the welfare effects, as measured by changes in the equivalent variation,tend to be stronger in the biofuels scenarios involving spillover effects, because of the lower cereal prices that these scenarios generate.

The jatropha, castor bean, and palm oil scenarios without spillover effects turn out to have no significant effects on the welfare of households, unlike the sugarcane and combined scenarios. On the other hand, the jatropha and castor bean scenarios involving spillover effects have a significant positive effect on the welfare of all households involved.

Finally, in the case of simulations where land is fully employed but mobile, only the jatropa and castor bean scenarios involving spillover effects affect household welfare. Both scenarios affect household welfare positively everywhere (Table 11).

Conclusion and Policy Implications

This study provides empirical evidence regarding the economy-wide effects of biofuel investment in Ethiopia. Specifically, this study investigates the distributive effect and food security implications of biofuel investment in Ethiopia using an economy-wide CGE model. One of the key features of the study is that it captures the impact of biofuels investment by agro-ecology zones. Another feature is its use of data from firms and NGOs involved in biofuels production.

The model results indicate that biofuels can provide the country with an opportunity to accelerate economic growth and improve household welfare. Two important conclusions can be drawn. One, biofuels can provide an opportunity to accelerate agricultural growth and enhance food security. In particular, in the sugarcane scenario and the jatropha and castor bean scenarios with spillover effects, as well as the combined scenario, production activities are projected to increase overall agriculture production and food security. Two, biofuels expansion can improve household welfare. Moreover, the benefits of biofuels investment are magnified if such investment is accompanied by technology spillovers to other agricultural crops such as cereals. This suggests that biofuel investment complements the growth of the agriculture sector. Rural households tend to be the main beneficiaries of such investment, particularly in the case of the scenarios that involved spillover effect. Urban households benefited most in the case the sugarcane and the combined scenarios.

Contrary to the notion that increased biofuel production runs counter to the food security objectives of developing countries, our simulations suggest the opposite. In fact, both cereals and cash crops production increase in all scenarios. As long as such schemes are undertaken in unutilized land, biofuel investment initiatives can have a ‘win-win’ outcome that can improve smallholder productivity and increase food crop production. Assuming that government investments in road infrastructure in Ethiopia will continue in the years to come, access to unused land will no longer be constrained by inadequate road infrastructure, and further biofuel investment will be undertaken on unoccupied lands, at least in the short-to medium-term.

An important implication is that, to maximize the benefits of biofuel investment, it is important to expand infrastructure. This will help expand and attract biofuel investment in areas not occupied by smallholders. This approach will not only improve food security and enhance household welfare but also help to stabilize the macroeconomy.

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Tables and Figures

Table 1. Structure of Ethiopia's Economy in 2005/06

	Share of total (%)				Export Intensity[a] (%)	Import penetration[a] (%)
	GDP	Employment	Exports	Imports		
Total	100.00	100.00	100.00	100.00	8.96	21.88
Agriculture	48.14	73.54	42.23	4.69	11.18	3.39
Cereal crops	13.83	23.02	0.00	3.49	0.00	7.23
Cash Crops	7.05	8.83	25.01	0.16	53.77	1.24
Sugar Cane	0.32	0.46	0.00	0.00	0.00	0.00
Jatropha	0.00	0.00	0.00	0.00	0.00	0.00
Castor Bean	0.00	0.00	0.00	0.00	0.00	0.00
Palm Oil	0.00	0.00	0.00	0.00	0.00	0.00
Livestock	14.39	20.08	4.51	0.00	4.99	0.00
Other Agriculture	7.80	12.49	12.71	1.05	16.82	3.73
Forestry and Fisheries	4.75	8.66	0.00	0.00	0.00	0.00
Non-Agriculture	51.86	26.46	57.77	95.31	7.82	28.51
Industry	11.72	7.62	17.56	70.99	6.60	41.25
Electricity	0.92	0.14	0.00	0.00	0.00	0.00
Food processing	2.30	1.66	3.01	2.42	10.53	14.92
Biofuel processing	0.00	0.00	0.00	0.00	0.00	0.00
Ethanol processing	0.00	0.00	0.00	0.00	0.00	0.00
Other industrial processing	8.49	5.81	14.56	56.40	6.38	41.58
Services	40.15	18.84	40.2	24.3	6.4	13.6

Note: [a] "Export intensity" is the share of exports in domestic output. "Import penetration" is the share of imports in total domestic demand. Sums of shares in this table and subsequent tables may not equal to 100 due to rounding.

Source: Ethiopia's 2005/06 social accounting matrix (SAM).

Table 2. Biofuel Investment by Agroecology

Agro-ecological zone	Type of feed stock used for the production of biofuel			
	Jatropha fruit	Castor bean seed	Palm oil	Sugar cane
AEZ 1			Yes	
AEZ 2				Yes
AEZ 3	Yes			
AEZ 4	Yes	Yes		
AEZ 5		Yes		

Source: Biofuel investment survey, 2010

Table 3. Overview of the Biofuels Sector in Ethiopia

Indicator	Number / description
No. of firms/companies	>15 (incl. NGOs)
No. of firms already at production stage	2
No. of firms that started export	1
No. of firms at production test stage	2
Total investment (capital)	Multimillion >1.3 b ETB (>0.1 billion USD)
Investment (type)	Largely foreign but also domestic
Land (000' ha)	>308 (currently operated); >101 (additional)
Year in operation	Since 2005
Installed plant capacity	492 to 28,800 liters/day
Employment opportunities.	>17,714 (Temp), >236 (Perm)
Crop types	Sugarcane, jatropha, castor bean, palm oil
Technology	Plantation, out-growers, and community development
Regions	All regions, Oromiya, SNNPR, Amhara, etc.

Source: Results of biofuels investment survey 2010.

Table 4. Biofuel production characteristics/technical coefficients

	Sugarcane and ethanol	Jatropha/castorbean diesel
Land employed (ha)	11,248.00	3,284.00
Biofuel crop production (tons)	569,168.00	200.00
Farm workers employed (in number)	5,365.00	4,384.00
Land yield	50.60	0.06
Farm labour yield	106.09	0.05
Land per capita	2.10	0.75
Capital per hectare	16.46	0.00
Labour-capital ratio	0.029	0.00
Biofuel produced (liters)	5,323,866.05	2,880.69
Processing workers employed	27	0.00
Feedstock yield (L/ton)	9.35	14.40
Processing labour yield	197,180.22	

Source: Biofuel investment survey, 2010

Table 5. Core Macroeconomic Assumptions of the Dynamic CGE Model

	Initial (2005)	Baseline scenario (growth rates)
Population (in thousands)	70,167	2.5
GDP	100.0	2.54
Labour supply	40,479.4	7.0
Skilled labour	7.9	7.9
Professional labour-rural	5.0	5.0
Administrative labour-urban	5.0	5.0
Unskilled labour-urban	4.4	4.4
Agricultural labour-rural	4.4	4.4
Capital stock	56,455.9	10
Land supply	3.2	3.2

Table 6. Scenarios for Biofuel Simulation

Scenarios	Technology	
	Plantation(Capital intensive)	Outgrower (labour intensive)
(i) S1: Sugarcane	S1	
(ii) S2: Jatropha		S2
(iii) S3: Castor bean		S3
(iv) S4: Palm oil	S4	
(v) S5: Spillover effect		S2+ improvements in smallholder productivity
(vi) S6: Spillover effect		S3+ improvements in smallholder productivity
(vii) S7: Combined (i-vi)	S1+S2+S3+S4+S5+S6	

Table 7. Sectoral Effects (Average Yearly Growth of GDP at Factor Cost Per Sector by Region) When Land Is Assumed To Be Fully Employed and Activity-Specific

		Change from (relative to) the baseline growth rate (2005-2020) (%)						
	base	sugarcane	jatropha	castorbean	Palmoil	Jatropa +spillover	Castor bear + spillover	Combined
GDP	9.1	0	0	0	0	0.1	0.1	0
acr-z1	7.4	0	0	0	0	-1.6	-1.2	0
acr-z2	7.6	0	0	0	0	-1.6	-1.2	0
acr-z3	7.6	0	0	0	0	4.3	-1.2	0
acr-z4	7.5	0.1	0	0	0	4.3	4.6	0.1
acr-z5	7.4	0.1	0	0	0	-1.5	4.7	0.1
acc-z1	8	0.1	0	0	0	0.1	0.1	0.1
acc-z2	8.1	0	0	0	0	0	0	0
acc-z3	7.9	0.1	0	0	0	0	0	0.1
acc-z4	8.1	0	0	0	0	0	0	0
acc-z5	7.9	0.1	0	0	0	0.1	0	0.1
asc-z1	13.2	29.3	0	0	0	0	0	29.3
asc-z2	15.4	-5.1	0	0	0	0.2	0.2	-5.1
asc-z3	15.2	-3.9	0	0	0	0.1	0.1	-3.9
asc-z4	14.2	8.5	0	0	0	0.1	0.1	8.5
asc-z5	12.3	35	0	0	0	0	0	35
aj-z3	12.1	0	1.5	-0.8	-0.2	1.5	-0.8	0.4
aj-z4	12.1	0	1.5	-0.8	-0.2	1.5	-0.8	0.4
acb-z4	13.6	0	-0.6	1.6	-0.3	-0.5	1.6	0.8
acb-z5	13.6	0	-0.5	1.6	-0.2	-0.5	1.6	0.8
apo-z1	11.5	0	-0.6	-0.8	1.7	-0.6	-0.8	0.2
alv-z1	7.4	-0.1	0	0	-0.1	0	0	-0.1
alv-z2	7.3	0	0	0	0	0	0	0
alv-z3	7.4	-0.1	0	0	0	0	0	-0.1
alv-z4	7.3	0	0	0	0	0	0	0
alv-z5	7.3	0	0	0	0	0	0	0
aoa-z1	8.6	0.1	0	0	0	0.1	0.1	0.1
aoa-z2	8.5	0	0	0	0	0	0	0
aoa-z3	8.7	0.1	0	0	0	0.1	0.1	0.1
aoa-z4	8.6	0.1	0	0	0	0.1	0	0.1
aoa-z5	8.3	0	0	0	0	0	0	0
afrfs	12.7	0	0	0	0	0	0	0
afr_energ	10.7	0	0	0	0	0.1	0.1	0
aelect	7.9	0	0	0	0	0	0	0
afood	8.5	0.9	0	0	0	0.2	0.2	0.9
abdcj	11.1	0	1.5	-0.8	-0.2	1.5	-0.8	0.4

abdccb	13	0	-0.5	1.6	-0.2	-0.5	1.6	0.8
abdcpo	10.5	-0.1	-0.6	-0.9	1.6	-0.6	-0.9	0.2
Aeth	6.1	6.5	0	0	0	-0.1	-0.1	6.5
Aoip	12	-0.1	0	0	0	0	0	-0.1
Aser	9.3	0	0	0	0	0	0	0
Total	9.1	0	0	0	0	0.1	0.1	0

Table 8. Sectoral Effects (Average Yearly Growth of GDP at Factor Cost Per Sector by Region) When Land Is Assumed To Be Fully Employed and Mobile

		Change from (relative to) the baseline growth rate (2005-2020) (%)						
	base	sugarcane	jatropha	castorbean	palmoil	Jatso	castbso	combined
acr-z1	7.3	0	0	0	0	-3.6	-2.8	0
acr-z2	7.6	0	0	0	0	-3.5	-2.8	0
acr-z3	7.5	0	0	0	0	6.4	-3.3	0
acr-z4	7.5	0	0	0	0	6.1	6.7	0
acr-z5	7.3	0	0	0	0	-4.1	7.2	0
acc-z1	7.9	0	0	0	0	0.8	0.7	0
acc-z2	8.3	0	0	0	0	1.6	1.3	0
acc-z3	7.6	0	0	0	0	-0.6	0.4	0
acc-z4	8	0	0	0	0	-1.6	-2	0
acc-z5	8.1	0	0	0	0	1.2	-2.7	0
asc-z1	12.8	0	0	0	0	1.5	1.4	0
asc-z2	12.6	0	0	0	0	1.5	1.3	0
asc-z3	12.1	0	0	0	0	0.2	0.7	0
asc-z4	12.6	0	0	0	0	-1.1	-1.5	0
asc-z5	11.9	0	0	0	0	2.5	-4.2	0
aj-z3	12	0	0	0	0	-0.1	0.2	0
aj-z4	12	0	0	0	0	-0.1	-0.3	0
acb-z4	13.8	0	0	0	0	0	0.2	0
acb-z5	13.8	0	0	0	0	-0.1	-0.3	0
apo-z1	11.3	0	0	0	0	0.4	0.2	0
alv-z1	7.3	0	0	0	0	0	0.1	0
alv-z2	7.3	0	0	0	0	0	0	0
alv-z3	7.3	0	0	0	0	0	0	0
alv-z4	7.3	0	0	0	0	0	0	0
alv-z5	7.3	0	0	0	0	0	0	0
aoa-z1	8.7	0	0	0	0	0.7	0.6	0
aoa-z2	8.4	0	0	0	0	0.9	0.8	0
aoa-z3	8.9	0	0	0	0	-0.5	0.2	0
aoa-z4	8.7	0	0	0	0	-1	-1.3	0
aoa-z5	7.9	0	0	0	0	0.3	-0.8	0
afrfs	12.7	0	0	0	0	0	0	0
afr_energ	10.7	0	0	0	0	0.1	0.1	0
aelect	7.9	0	0	0	0	0	0	0
afood	9	0	0	0	0	0.2	0.2	0
abdcj	11.2	0	0	0	0	-0.1	-0.1	0
abdccb	13.5	0	0	0	0	0	0	0

abdcpo	10.4	0	0	0	0	0.4	0.3	0
aeth	8.8	0	0	0	0	-0.1	-0.1	0
aoip	12	0	0	0	0	0	0	0
aser	9.3	0	0	0	0	0	0	0
total	9.1	0	0	0	0	0.2	0.2	0

Table 9. Trade Off (Difference in Average Yearly Growth of GDP at Factor Cost Per Sector When Land Is Assumed To Be Fully Employed and Mobile, and Fully Employed and Activity- Specific).

	base	sugarcane	jatropha	castorbean	palmoil	Jatso	castbso	combined
acr-z1	-0.09	-0.04	0.00	0.00	0.00	-2.00	-1.60	-0.04
acr-z2	0.08	-0.04	0.00	0.00	0.00	-2.04	-1.64	-0.04
acr-z3	-0.08	-0.04	0.00	0.00	0.00	2.12	-2.04	-0.04
acr-z4	-0.03	-0.04	0.00	0.00	0.00	1.75	2.16	-0.04
acr-z5	-0.09	-0.04	0.00	0.00	0.00	-2.54	2.54	-0.04
acc-z1	-0.09	-0.06	0.00	0.00	0.00	0.70	0.60	-0.06
acc-z2	0.20	-0.06	0.00	0.00	0.00	1.58	1.33	-0.06
acc-z3	-0.28	-0.06	0.00	0.00	0.00	-0.70	0.35	-0.06
acc-z4	-0.03	-0.03	0.00	0.00	0.00	-1.61	-2.02	-0.03
acc-z5	0.19	-0.06	0.00	0.00	0.00	1.15	-2.76	-0.06
asc-z1	-0.40	-29.31	0.00	0.00	0.00	1.50	1.36	-29.31
asc-z2	-2.87	5.15	0.00	0.00	0.00	1.35	1.21	5.15
asc-z3	-3.04	3.90	0.00	0.00	0.00	0.00	0.57	3.90
asc-z4	-1.66	-8.48	0.00	0.00	0.00	-1.12	-1.50	-8.48
asc-z5	-0.35	-34.98	0.00	0.00	0.00	2.45	-4.29	-34.98
aj-z3	-0.16	0.02	-1.44	0.84	0.27	-1.49	1.09	-0.34
aj-z4	-0.12	0.02	-1.45	0.84	0.27	-1.60	0.47	-0.35
acb-z4	0.18	0.02	0.57	-1.56	0.26	0.53	-1.31	-0.78
acb-z5	0.22	0.02	0.57	-1.57	0.26	0.43	-1.94	-0.78
apo-z1	-0.21	0.02	0.58	0.82	-1.66	0.98	1.08	-0.21
alv-z1	-0.01	0.01	0.00	-0.01	0.01	-0.02	-0.02	0.01
alv-z2	-0.02	0.02	0.00	0.00	0.00	-0.01	-0.01	0.02
alv-z3	-0.02	0.02	0.00	0.00	0.00	-0.01	-0.01	0.02
alv-z4	-0.02	0.01	0.00	0.00	0.00	-0.01	-0.01	0.01
alv-z5	-0.02	0.02	0.00	0.00	0.00	-0.01	-0.01	0.02
aoa-z1	0.10	-0.04	0.00	0.00	0.00	0.65	0.51	-0.04
aoa-z2	-0.06	-0.04	0.00	0.00	0.00	0.89	0.71	-0.04
aoa-z3	0.18	-0.04	0.00	0.00	0.00	-0.53	0.22	-0.04
aoa-z4	0.09	-0.04	0.00	0.00	0.00	-1.07	-1.37	-0.04
aoa-z5	-0.34	-0.05	0.00	0.00	0.00	0.28	-0.86	-0.05
Afrfs	-0.03	0.04	0.00	0.00	0.00	-0.01	-0.01	0.04
afr_energ	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	0.00
aelect	0.06	-0.06	0.00	0.00	0.00	0.01	0.01	-0.06
Afood	0.44	-0.83	0.00	0.00	0.00	0.06	0.05	-0.83
Abdcj	0.03	0.02	-1.43	0.83	0.27	-1.53	0.78	-0.34
abdccb	0.48	0.02	0.57	-1.56	0.26	0.48	-1.62	-0.78
abdcpo	-0.06	0.02	0.58	0.83	-1.67	0.99	1.09	-0.21

Aeth	2.66	-6.52	0.00	0.00	0.00	0.06	0.03	-6.52
Aoip	-0.02	0.09	0.00	0.00	0.00	-0.01	-0.01	0.09
Aser	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Total	0.01	-0.05	0.00	0.00	0.00	0.05	0.05	-0.05

Table 10. Effects of Biofuel Investment on Household Welfare (Income) When Land Is Fully Employed but Activity-Specific (in %)

	Initial spending (2005/06)	base	sugarcane	jatropha	castorbean	palmoil	jatso	castbso	combined
rural poor-z1	480.81	1.42	0.10	0.01	0.01	0.01	1.78	1.41	0.11
rural poor-z2	9,584.28	27.33	-0.01	0.00	0.00	0.00	2.28	1.79	-0.01
rural poor-z3	4,436.87	12.81	0.26	0.00	0.00	0.00	2.88	1.21	0.27
rural poor-z4	8,349.40	22.87	0.24	0.00	0.00	0.00	4.31	3.93	0.24
rural poor-z5	1,304.67	3.26	1.25	0.00	0.00	0.00	2.91	3.27	1.25
rural nonpoor-z1	583.15	2.07	0.47	0.00	0.00	-0.01	1.41	1.12	0.47
rural nonpoor-z2	31,003.13	95.42	0.12	0.00	0.00	0.00	1.08	0.81	0.12
rural nonpoor-z3	12,536.06	39.82	-0.09	0.00	0.00	0.00	2.59	0.91	-0.09
rural nonpoor-z4	24,150.76	70.55	-0.01	0.00	0.00	0.00	4.53	4.38	-0.01
rural nonpoor-z5	3,079.40	8.88	0.87	0.00	0.00	0.00	2.49	2.17	0.87
urban poor-s	2,549.88	12.60	0.96	0.00	0.00	0.00	1.83	1.45	0.97
urban poor-b	1,694.07	5.46	1.36	0.00	0.00	0.00	1.49	1.17	1.36
urban nonpoor-s	12,611.32	50.52	0.98	0.00	0.00	0.00	1.04	0.82	0.98
urban nonpoor-b	11,057.75	29.91	1.25	0.00	0.00	0.00	0.58	0.45	1.25

Note: z stand for AEZs; s stands for small; and b stands for big

Source: CGE simulation results

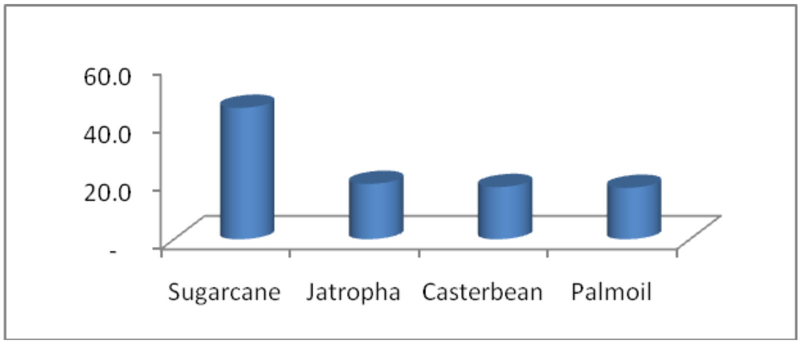
Table 11. Effects of Biofuel Investment on Household Welfare (Income) When Land Is Fully Employed but Mobile (in %)

	base	sugarcane	jatropha	castorbean	palmoil	jatso	castbso	combined
hhd-pz1-r	1.42	0.00	0.00	0.00	0.00	1.99	1.59	0.00
hhd-pz2-r	27.33	0.00	0.00	0.00	0.00	2.46	1.94	0.00
hhd-pz3-r	12.81	0.00	0.00	0.00	0.00	3.90	1.26	0.00
hhd-pz4-r	22.87	0.00	0.00	0.00	0.00	5.50	5.34	0.00
hhd-pz5-r	3.27	0.00	0.00	0.00	0.00	3.34	3.47	0.00
hhd-npz1-r	2.08	0.00	0.00	0.00	0.00	2.02	1.64	0.00
hhd-npz2-r	95.65	0.00	0.00	0.00	0.00	1.90	1.48	0.00
hhd-npz3-r	39.61	0.00	0.00	0.00	0.00	2.24	1.35	0.00
hhd-npz4-r	70.59	0.00	0.00	0.00	0.00	4.07	3.80	0.00
hhd-npz5-r	8.90	0.00	0.00	0.00	0.00	2.80	2.36	0.00
hhd-sp-u	12.65	0.00	0.00	0.00	0.00	2.02	1.63	0.00
hhd-bp-u	5.48	0.00	0.00	0.00	0.00	1.66	1.33	0.00
hhd-snp-u	50.72	0.00	0.00	0.00	0.00	1.15	0.93	0.00
hhd-bnp-u	30.01	0.00	0.00	0.00	0.00	0.65	0.52	0.00

Table 12. Trade-off (Difference between the Simulations)

	base	sugarcane	jatropha	castorbean	palmoil	jatso	castbso	combined
hhd-pz1-r	0.00	-0.10	-0.01	-0.01	-0.01	0.21	0.18	-0.11
hhd-pz2-r	0.00	0.01	0.00	0.00	0.00	0.17	0.15	0.01
hhd-pz3-r	-0.01	-0.26	0.00	0.00	0.00	1.02	0.05	-0.27
hhd-pz4-r	0.00	-0.24	0.00	0.00	0.00	1.19	1.41	-0.24
hhd-pz5-r	0.01	-1.25	0.00	0.00	0.00	0.43	0.20	-1.25
hhd-npz1-r	0.00	-0.47	0.00	0.00	0.01	0.60	0.52	-0.47
hhd-npz2-r	0.22	-0.12	0.00	0.00	0.00	0.82	0.67	-0.12
hhd-npz3-r	-0.21	0.09	0.00	0.00	0.00	-0.35	0.43	0.09
hhd-npz4-r	0.03	0.01	0.00	0.00	0.00	-0.46	-0.58	0.01
hhd-npz5-r	0.03	-0.87	0.00	0.00	0.00	0.31	0.19	-0.87
hhd-sp-u	0.05	-0.96	0.00	0.00	0.00	0.19	0.18	-0.97
hhd-bp-u	0.02	-1.36	0.00	0.00	0.00	0.17	0.16	-1.36
hhd-snp-u	0.20	-0.98	0.00	0.00	0.00	0.11	0.11	-0.98
hhd-bnp-u	0.10	-1.25	0.00	0.00	0.00	0.07	0.07	-1.25

Figure 1. Share in Total Biofuel Crop Land by Biofuel Crop Type (%)



Source: Biofuel investment survey, 2010

Figure 2. Ratio of Utilized Land to Total Land Allocated to Each Biofuel Crop (%)

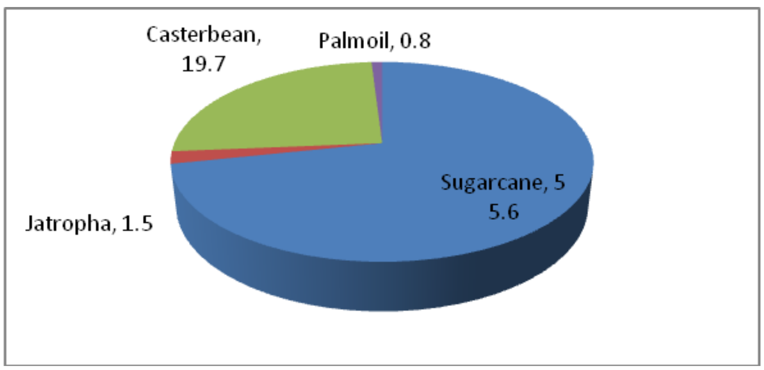


Figure 3. Impact on Prices of Cereals When Land Is Fully Employed but Activity-specific

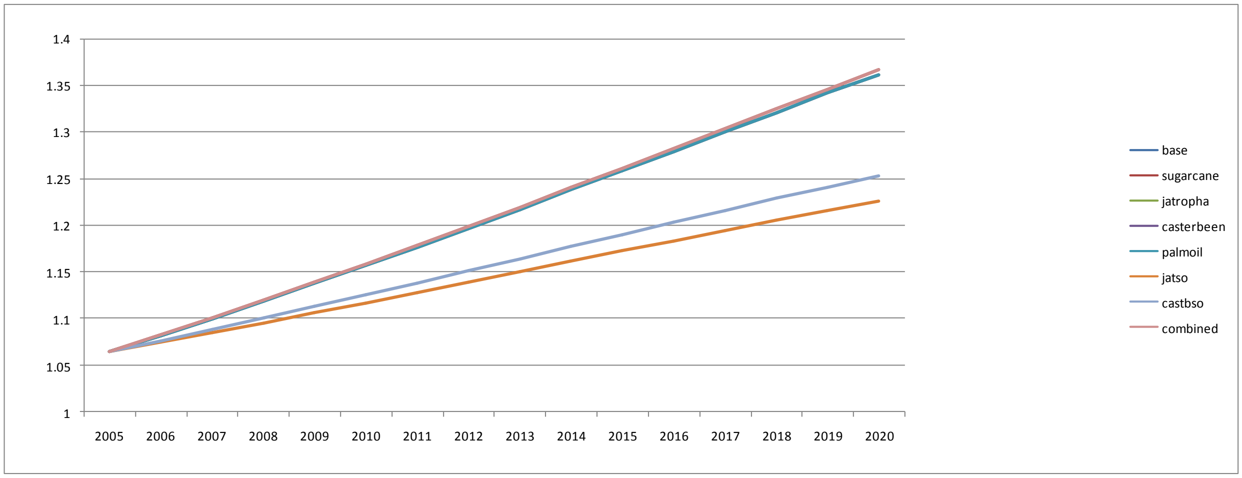
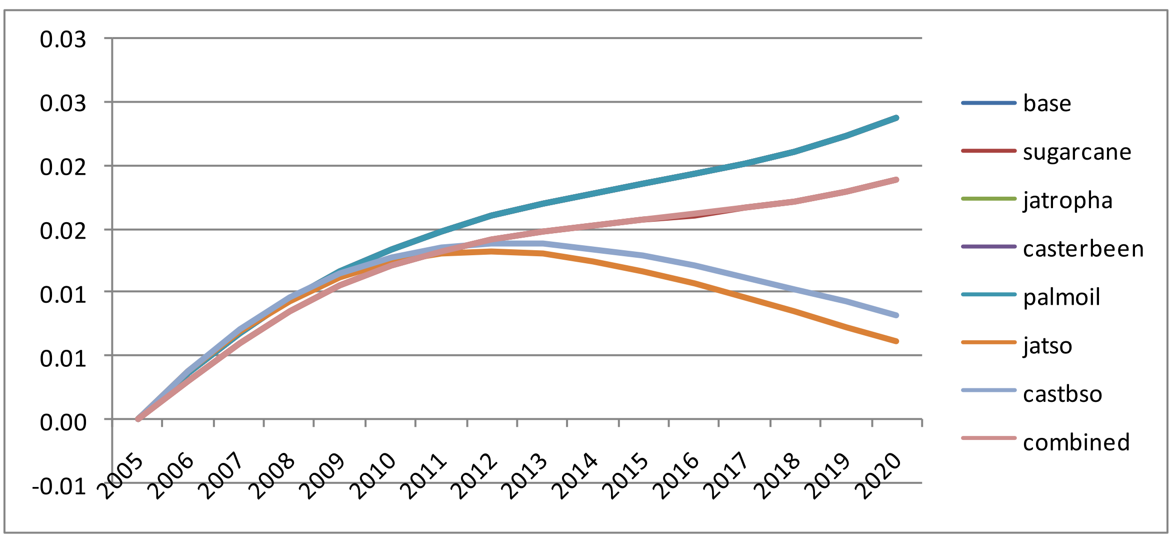


Figure 4. Impact on Prices of Cereals When Land Is Fully Employed but Mobile



Appendices

Table A1. The 2005/06 Macro-SAM for Ethiopia (billion ETB)

	ACT	COM	LAB	CAP	ENT	HHD	GOV	DTAX	MTAX	STAX	S-I	ROW	TOTAL
ACT		187.3											187.3
COM	65.1	46.2				114.8	15.9				31.8	16.8	290.5
LAB	68.8												68.8
CAP	53.5												53.5
ENT				48.2			-5.4						42.9
HHD			68.8	5.5	41.5		1.5					15.7	133.0
GOV								4.1	7.0	3.1		3.3	17.5
DTAX					1.3	2.7							4.1
MTAX		7.0											7.0
STAX		3.1											3.1
S-I						15.5	5.4				3.6	10.9	35.5
ROW		46.9		-0.2									46.7
TOTAL	187.3	290.5	68.8	53.5	42.9	133.0	17.5	4.1	7.0	3.1	35.5	46.7	

Source: Tebkew et al. (2009).

Table A2. Household Income Distribution

	Share (%)						Total (%)
	Labor	Land	Livestock	Capital	Gov't	ROW	
All groups	44.4	5.0	3.3	30.4	1.5	15.4	100.0
Rural	46.8	8.6	5.6	32.6	0.6	5.7	100.0
Poor	66.4	3.6	7.3	15.1	1.2	6.4	100.0
Non-poor	40.2	10.3	5.0	38.5	0.4	5.5	100.0
Urban	41.0			27.3	2.7	29.0	100.0
Poor	62.8			8.0	3.9	25.3	100.0
Non-poor	37.4			30.5	2.5	29.6	100.0
Poor	65.8	3.0	6.1	14.0	1.6	9.5	100.0
Non-poor	39.4	7.3	3.5	36.2	1.0	12.5	100.0

Source: Ethiopia SAM 2005/06