The Economic and Environmental Costs/Benefits of Green Fuel: The Case of the Chisumbanje Ethanol Plant

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AERC Special Paper 50
African Economic Research Consortium, Nairobi
May 2016

THIS RESEARCH STUDY was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are those of the author, however, and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

Contents

List of tables

Abstract

The study assesses the micro level benefits of a bioethanol plant in Zimbabwe. The study findings show that, besides producing cleaner fuel which is environmentally friendly, the Chisumbanje bioethanol plant provides a wide range of benefits to the country and the community in terms of import cost reduction and employment creation. The results demonstrate that, with just a 5% ethanol blend (E5), Zimbabwe has potential to reduce its gross fuel import bill by at least US$4.5 million per year, and this cost saving increases as higher blends are used. However, such projects have serious implications on government revenue. Government revenue from fuel import duties is reduced by at least US$0.30 per litre. The study also indicates that the country has capacity to increase the production of both sugar and alternative crops, hence no opportunity cost since production is inefficient. The findings further reveal that an industrial initiative such as the Chisumbanje project generates more utility for the youth who make the majority of the labour market as shown by the negative coefficient of age square.

Key words: *Economic benefits/costs, Green fuel, Zimbabwe*
JEL classifications: *Q16, Q42, Q55*

1. Introduction and background

The rising global temperatures, resulting from increased carbon dioxide (CO_2) emissions, require countries to critically examine the sources of these greenhouse gases. Fossil fuels contribute the largest proportion of greenhouse gases, responsible for 73% of the CO_2 production according to Balat et al. (2008). Several methods aiming at reducing greenhouse gases have been developed and applied in a number of countries; these methods include CO_2 sequestration, energy consumption reduction, replacing inefficient energy conversion sources, and making use of fuels with lower carbon content. While reduction in energy consumption is commendable for the control of greenhouse emissions, it has serious poverty implications in poor countries. Increasing efficiency in energy conversion requires advanced technologies, which are lacking in developing countries. As a result, developing countries find it difficult to use such methods of reducing greenhouse gases emissions. The state of poverty in developing countries makes it difficult for these countries to reduce energy consumption, especially from cheap sources such as coal and oil, leaving the switch to lower carbon content fuels the best option for them. In this regard, there has been mounting attention in biofuels in many developing countries as a means of providing cleaner liquid fuels while helping to address unemployment problems, imported inflation, energy security, and global warming concerns associated with fossil fuels. In Zimbabwe, the use of biofuels has greatly been driven by energy costs and security concerns.

Many Southern African countries, including Zimbabwe, import fossil fuels which have the potential to significantly increase greenhouse gases emissions. Hence biofuels can considerably reduce greenhouse gases emissions, import costs, and unemployment in these countries. The increased focus on biofuels is a cradle of investment opportunities for developing countries with appropriate land and water resources for raw material production. Most Southern African countries are net importers of energy in the form of fossil energies (Shumba et al., 2011). For this reason, the increased production of biofuels can potentially cut these countries' reliance on imported petroleum goods, lessen inflationary pressures, guarantee fuel security, support rural development and investment, lessen poverty, and create employment. However, with poor governance, biofuel development can also result in a number of problems, such as food shortages (Shumba et al., 2011). The sugar industry in Southern Africa has long been focusing on producing sugar for household consumption and exportation. Zimbabwe and Malawi started producing ethanol blended fuel in the 1960s, blending up to 18%. Despite the fact that blending has been traditionally done in Zimbabwe, little has been done in assessing the costs and benefits of biofuels in relation to imported fuels, government revenue, and opportunity costs. Moreover, the biofuel production can have both positive and negative consequences for local communities. For this reason, it is paramount to assess impacts of biofuel plants on communities in which they operate.

In 1965, Zimbabwe started producing petrol blend, a mixture of 15% ethanol and 85% imported petrol. Ethanol was produced from molasses extracted from sugar cane. Following shortages in animal feeds extracted from sugar cane residuals (molasses which were also used for ethanol production) and the emergence of markets for ethanol for beverages, Zimbabwe abandoned the blending programme in 1992, a year in which a severe drought also affected sugar cane production. By 2005, however, persistent fuel shortages, rising fossil fuel costs and environmental concerns revived interest in biofuels. The government erected two biofuel plants in Mutoko and Mt. Hampden with processing capacities of one million litres and 36 million litres per year, respectively. The feedstock in these two biodiesel plants was not sugar cane but jatropha crop. Following a good investment opportunity in 2009, the government (through Agricultural and Rural Development Authority) partnered a private company, Green Fuel Zimbabwe to relaunch a US$600 million bio-energy plant in the Eastern Chisumbanje district of Manicaland province which started full operation in November 2011. The Chisumbanje plant is the sole ethanol plant which also produces electricity for the community besides ethanol and other sugar cane products such as animal feeds. In addition to these direct benefits, the project may be associated with some opportunity costs in terms of the forgone sugar for consumption, ethanol for beverages, and land for producing other crops, if current production is efficient. The main question is; "what is the net benefit of the Chisumbanje ethanol production to the community?"

Since its inception in November 2011, Green Fuel Zimbabwe (the company operating the Chisumbanje ethanol plant) has been experiencing some problems in the demand and storage for its product. This has caused some stoppages in production. Most of the consumers of the blended fuel interviewed by the researchers on September 22, 2012 at Zuva filling station in Belvedere felt that the price charged per litre was too high for the product. But are the consumers' views justified? In response to the unresponsive demand for green fuel, the government has been advocating for mandatory blending. But is the policy of mandatory blending justified? Is there any cost savings from replacing gasoline with ethanol? Does the firm have the capacity to meet national ethanol demand under mandatory blending? What does the community benefit from increased ethanol production and what are the likely costs to the community and the government? Only a cost/benefit analysis could provide answers to these questions.

Despite the fact that there has been increased interest in bio-energy, there is still scanty literature on bio-energy in Africa. In Zimbabwe, no studies have statistically examined the costs and benefits of green fuel at both micro and macro levels. Ethanol has been produced in the country since the 1960s but no attempt has been made to model technically the costs and benefits of this biofuel production. This study, therefore, attempts to address the knowledge gap on this subject matter existing in the country. Furthermore, the study is of importance in enlightening the government and the public as to whether there are benefits/costs of mandatory blending, thereby helping them in making well-informed decisions when evaluating the policy. Besides informing policy makers in the Zimbabwean context, the study enlightens other African countries in the region which have not yet thought of such projects to either consider them or not consider them in their environmental policy. In general, the study examines the costs and benefits associated with the Chisumbanje ethanol plant in Zimbabwe. In addition, the study assesses the project's capacity to handle mandatory blending. In summary, the research attempts to determine the cost saving of replacing gasoline with ethanol, scrutinize the project's capacity to handle mandatory blending, evaluate its opportunity costs, and assess the community's perceptions about the project benefits and costs.

2. Literature review

While a number of studies on the economics of climate change (Gebregziaber et al., 2011; Bezabih, et al.,2010; Arndt, et al., 2010; Thurlow, et al., 2009; Reid, et al., 2008) have concentrated on the economic costs of climate change in Africa, very little effort has been applied in examining the economic benefits and costs of mitigation measures such as substituting green fuel for fossil fuel. But recent heightened interest in biofuels has aroused researchers to seriously consider modelling the costs and benefits of biofuels. A number of policy papers in the developed world, Asia and South America have tried to provide some literature on the benefits of moving from fossil fuel to biofuel (see Ahmad and May, 2009; Bang et al., 2009). Costs and benefits of biofuels have been evaluated using both microeconomic and macroeconomic models. Micro models involve models of technology adoption and resource allocation, and of cost-accounting. In these models, the economic costs and benefits of biofuels are estimated from the individual economic agent's perspective, the firm in this case. Some of the studies which applied cost-accounting methods include Haas et al. (2005), Johnson and Matsika (2006), Thomas and Kwong (2001), Amigun et al. (2006), and Balat et al. (2008), among others.

In terms of the cost-effectiveness of replacing leaded gasoline with ethanol-blended gasoline in Africa, Thomas and Kwong (2001) argue that in Africa, where lead additives are still heavily used, and where sugar cane production is high, ethanol can be a cheap source of octane. They found out that more than enough sugar cane is produced in Africa to replace all the gasoline used in Africa which would require Africa to produce about 20% of amount of ethanol produced in Brazil, and would require shift of some sugar production to ethanol production. However, they did not concentrate on individual countries and their study did not assess this cost-effectiveness at the micro level. Costs and benefits of ethanol production vary from one country to the other and from one type of feedstock to the other. For example, Johnson and Matsika (2006) established that Zimbabwe is amongst some of the developing countries which can produce ethanol from sugar cane more cheaply. Comparing Brazil, Malawi, Zambia, and Zimbabwe, Johnson and Matsika (2006) estimated ethanol production costs in these countries to be US$0.19-US$0.25, US$0.50-US$0.60, US$0.35-US$0.45, and US$0.25-US$0.40, respectively.

In the United States, Haas et al. (2005) assessed the costs of a biodiesel plant and found storage costs to be the main contributor to total equipment costs. In terms of input costs, feedstock accounted for 88% of the total production costs. The study further estimated the cost per litre of biodiesel production to be US$0.53. The feedstock (soybean oil) and the total production costs were found to be directly and linearly related. While Haas et al. (2005) estimated the cost of producing biodiesel using soybean oil in the US, in this study we attempt to evaluate the costs/benefits of the production of bioethanol, with the feedstock being sugar cane. The costs/benefits of bioethanol production might be largely explained by the availability and cost of sugar cane as established by Balat et al. (2008) that one major problem with bioethanol production is the availability of feedstocks.

More recently, researchers have begun to use macroeconomic models such as the sector and Computable General Equilibrium (CGE) models to analyse the economic costs/ benefits of biofuels. These models use aggregated data to model a whole sector and not only the situation of a single agent as in the cost-accounting models. Biofuel production is considered part of the agricultural sector, that is, biofuel demand is incorporated as an exogenous increase in the demand for feedstock (Rajagopal and Zilberman, 2007). Rajagopal and Zilberman argue that, macroeconomic models are more superior to microeconomic models in that the later are based on accounting principles rather than economic principles. So the distortions and externalities from public policies are not taken care of. The absence of good macroeconomic data and the fact that Chisumbanje is a small scale project make CGE modelling inappropriate in this case. Microeconomic models, therefore, are more appropriate since they are not as data-demanding as the macroeconomic models. In fact, they enable the researcher to concentrate on a smaller unit, thereby providing a detailed description of the costs/benefits of a given project.

The use of macro models, such as the CGE models in such cases, can provide misleading information and could underestimate the value of the project at micro or community level. The Chisumbanje project is tiny as a proportion of Zimbabwe's economy. Therefore, the use of CGE modelling can reduce the benefits of the project to zero despite the huge benefits that might be derived at the community level. There is, therefore, need to evaluate the community-level benefits and be able to recommend for the expansion of such projects countrywide.

3. Methodology

We apply a case study approach in this study or a microeconomic model, that is, we study the costs and benefits of ethanol production at Chisumbanje. First, the study indirectly estimates the cost savings of replacing lead with ethanol. Second, we assess the Chisumbanje plant's capability vis-à-vis vis-a-vis mandatory blending. Third, we examine the opportunity cost of ethanol production from sugar cane, that is, trade-off between sugar for ethanol and that for consumption and other uses. This opportunity cost is also assessed in terms of alternative uses for the land where sugar cane is grown. Last, we examine the perceived benefits of ethanol production to the Chisumbanje community (in terms of income changes resulting from changes in land use and employment patterns). In this regard, a different approach is applied to each research question.

The cost-effectiveness of replacing lead with ethanol is measured using Thomas and Kwong (2001) approach. Lead provides octane for gasoline; it is an additive. The amount of octane in a given amount of lead depends on the baseline characteristics of the gasoline (petrol) and the amount of lead that has already been added (Kwong and Thomas, 2001). The question is what is the cost of replacing the lead octane with the environmentally friendly octane from ethanol? Let the volume of ethanol required to replace the octane provided by the lead additive be given as:

$$Q_E = \frac{(O_{LG} - O_{UG})}{(\mathrm{O}_{LG} - \mathrm{O}_{UG})} \qquad (1)$$

where, O_{LG} is the octane number of the leaded petrol, O_{UG} is the octane number of the petrol without added lead, and O_E is the octane number of ethanol. So the net cost of substituting ethanol for lead is given as:

$$\Delta C = C_E Q_E - C_G Q_E - C_L L \qquad (2)$$

where, C_E, Q_E, C_G, C_L, and L are the ethanol cost, ethanol volume in litres, gasoline cost, lead cost and lead concentration, respectively. The first term of Equation 2 is the cost of ethanol, the second term is the cost savings for replaced gasoline, and the last term is the cost savings for the eliminated lead. In Zimbabwe, imported unleaded gasoline is blended with ethanol from Green Fuel Zimbabwe. In this view, we estimate the change in cost as:

$$C = C_E Q_E - C_{MP} Q_E \tag{3}$$

where, C_E , Q_E, and C_{MP} are, respectively, ethanol cost, ethanol volume, and imported unleaded petrol cost. If $C_E Q_E$, $< C_{MP} Q_E$, then blending will reduce costs.

In the second stage, we evaluate the firm's capacity vis-à-vis the national demand for petrol. The questions are; 1) in the case of mandatory blending, how much ethanol will be required to meet the country demand for gasoline? 2) how much sugar and land will be diverted from alternative uses? Fuel demand for the country is analysed through collecting secondary data from NOCZIM and some oil companies in Zimbabwe; and data on sugar cane quantities requirements can be provided by Green Fuel Zimbabwe. Third, we identify the alternative uses of ethanol and estimate the opportunity cost of using sugar for the production of bioethanol in terms of forgone sugar for consumption.

Lastly, we assess the perceived benefits and costs of ethanol production to the community. The perceived benefits to the community can be measured by utility derived from the project. As a result of the latent nature of the utility variable, we make use of the random utility model to assess whether the Chisumbanje community has benefited from the project or not. In this method, we let U^b and U^a be the individual's utility before and after the launch of the Chisumbanje ethanol plant, respectively. The two utilities cannot be observed but we can observe which period (before or after) provides greater utility or greater standards of living. Hence, we can say, the observed indicator equals one if welfare or utility is perceived to have been increased after the 2011 launch of the ethanol plant, that is if $U^a > U^b$, and equals zero if $U^a \leq U^b$. Following Greene (2003), we therefore formulate the linear random utility model as:

$$U^b = X'\beta_b + \varepsilon_b \text{ and } U^a = X'\beta_a + \varepsilon_a$$

where, X is a vector of explanatory variables or factors influencing individual's utility, β is a vector of the slope coefficients, and ε is the error term assumed to be identically and independently distributed, that is, $IID(0, \delta_\varepsilon^2)$. Consider B =1 to be the individual's preference of the period after the launch of the ethanol plant, then we have

$$\begin{aligned}
\Pr(B = 1 / X) &= \Pr(U^a > U^b) \\
&= \Pr(U^a - U^b > 0) \\
&= \Pr(X'\beta_a + \varepsilon_a - X'\beta_b - \varepsilon_b > 0) \\
&= \Pr\left[X'(\beta_a - \beta_b) + \varepsilon_a - \varepsilon_b > 0\right] \\
&= \Pr\left[X'\beta + \varepsilon > 0\right]
\end{aligned}$$

We assume that the utility function is well-behaved, that is, it satisfies the rationality assumptions. An individual, therefore, prefers *a* to *b* if and only if the utility derived from condition *a* is greater than that derived from condition *b*. The question is who benefited from the project? Did the project benefit all members of the Chisumbanje's Chechete community? To answer these questions, we model the determinants of the project's perceived benefit as:

$$B = X'\beta + \varepsilon \qquad (4)$$

where, *B* is a binary variable which takes a value of one if the individual perceives the project as beneficial or zero otherwise, *X* is a vector of individual characteristics which include age, education, employment status, participation in Green Fuel Zimbabwe activities, religion, and access to electricity. These characteristics have been used in a number of studies, for example, by Ezebilo et al. (2010). Changes in income and consumption are used to assess whether the project has benefited community members or not. The study avoids the use of actual income and consumption figures because of the difficulties in recalling accurate income and consumption figures. Since the project has been recently launched, people can easily recall their status of consumption or income just before the project launch. Education is defined in terms of years of schooling, and employment is a dummy variable which takes a value of one if the individual is permanently employed or zero otherwise. Religion and access to electricity are also dummy variables which take a value of one if the individual's religion is African tradition and has access to electricity, respectively or zero otherwise. We define participation as any kind of involvement in Green Fuel Zimbabwe activities, whether on full-time or part-time basis. Casual workers, permanent workers and contract farmers/out-growers are active participants of the project. The variable takes a value of one if one belongs to any one of these categories or zero otherwise. We expect age to have diminishing effects on the probability that one benefits from the project. As a result, we include age square as a variable capturing the diminishing effect of age. Variable coefficients are expected to be positive, except those of religion and age square, which are expected to be negative.

A survey was carried out in the Chisumbanje community eliciting information on residents' preferences between the period before and after the launch of the plant, age, years of education, employment status, religion, participation in any activity of Green Fuel Zimbabwe, and electricity accessibility. Residents of the Chechete communal area surrounding the location of the plant were interviewed using semi-structured questionnaires administered by the researchers. About 80 residents were interviewed over a 12-day period. The researchers walked from one end of the village to the other interviewing any resident of the village they met. Interviews were also done after working hours and during weekends in order to reduce selection bias associated with the likelihood of eliminating the working class from the sample. The process of interviewing people was purposive. Only residents of the area were selected.

4. Findings

Cost saving and mandatory blending

The consumer cost of pure ethanol per litre in Zimbabwe, including VAT, is about US$1; and a litre of imported unleaded petrol costs about US$1.51, including 15% VAT, ZINARA fuel levy of 1c per litre, NOCZIM debt redemption levy of 4c per litre, carbon tax of 6c per litre, petroleum importers levy of 0.04c per litre, excise tax or customs duty of 30c per litre, and a less than 1c NOCZIM strategic reserves tax. Bloch (2009) added these taxes per litre to obtain an approximate value of 58c per litre equivalent to 40% of the pump price in July 2009. Since taxes are transferred to consumers, we assume that the 40% will be maintained even if the fuel price changes. The maximum total tax paid per litre of petrol with a pump price of US$1.51 is US$0.61, and therefore the minimum price of imported petrol excluding taxes is US$0.90. Ethanol is exempted from carbon tax and all other import taxes. Considering VAT, fuel levy and redemption levy, the maximum price of a litre of ethanol excluding taxes is US$0.80. So the minimum import cost saving per litre of ethanol is given by Equation 3 as US$0.80 less US$0.90. In other words, the country saves a minimum of US$0.10 if one litre of imported unleaded gasoline is replaced by a litre of ethanol. Gasoline consumption in Zimbabwe has been a rising trend since 2009. It increased from an average of 500 million litres in 2009 to about 650 million litres in 2010, 732 million litres in 2011 and to about 900 million litres in 2012 (Ministry of Energy and Power Development, 2012). With 900 million litres of imported gasoline, a 20% replacement with ethanol will have a minimum cost saving of about at least $18m. Table 1 illustrates the approximate minimum cost savings resulting from ethanol blending for different levels of blends at a national gasoline consumption level of 900 million litres per year. These figures are approximations based on minimum cost saving.

However, government revenue from excise tax, carbon tax and petroleum importers' levy is transferred to consumers and producers. These levies make more than half of fuel levies, that is, the government transfers a minimum of US$0.30 per every litre replaced by ethanol. The higher the level of blend, the more revenue is lost by the government in terms of import taxes. The cost saving or benefits from gasoline replacement accrue to the consumers while the government loses import tax revenue, which could be avoided by imposing a special tax on ethanol. Overall, the loss in government revenue outweighs the benefit in import cost saving. This is, however, a transfer of revenue from the government to the consumers. There are also some government revenues which can be generated from the establishment of new biofuel firms such as corporate tax, PAYE, and others. The actual costs and benefits of replacing gasoline with ethanol is, therefore, complex and can be more clearly established through the use of complex macroeconomic models where sectoral impacts are taken into consideration.

In Zimbabwe, a 10% blend of ethanol reduces fuel prices by approximately US4-5 US cents per litre. The higher the proportion of ethanol in the blend, the larger is the cost saving, and the more revenue is lost by the government. Green Fuel Zimbabwe is currently producing ethanol at a cost of US$1.15 per litre inclusive of fixed capital costs, and this cost goes down to a maximum of U$0.80 excluding fixed costs and taxes. Per unit costs will go down after the initial capital outlay has been recouped. Increased volumes of ethanol production also reduce the cost per unit due to economies of scale. The plant which has a current capacity of producing more than 300,000 litres of ethanol per day was producing less than 150 litres per day in November 2012.

Table 1: Ethanol blends and cost savings at consumption level of 900 million litres per year

Blend level (%)	Max price per litre of petrol blend (US$)	Ethanol volumes required (million litres per year)	Approximate cost savings (US$ million per year)
0	0.90	0	0
5	0.88	45	4.5
10	0.87	90	9.0
20	0.85	180	18.0
85	0.81	765	76.5
100	0.80	900	90.0

Source: Ministry of Energy and Power Development, Zimbabwe.

In April 2012, the plant produced 10 million litres stored in the available storage tanks at the site and in Harare. The company can only store up to 10 million litres, implying that production is only dependent upon the consumption rate. The 10% blend level gives an approximate cost saving of about US$9 million if it becomes mandatory, while the 5% required by the government reduces costs by only about US$4.5 million. The results show that local ethanol production significantly decreases import costs of petrol if higher levels of petrol blends are used in Zimbabwe.

The capacities of ethanol producing plants in the country are not large enough to produce required ethanol volumes at higher blends such as 85% and 100%. Secondly, most vehicles in the country have engines not suitable for higher ethanol blends. The Chisumbanje ethanol plant can handle the legislated 5% mandatory blending which needs about 125,000 litres of ethanol per day at the current level of petrol consumption in the country. Since the plant has a capacity to produce 300,000 litres per day, the firm can also handle a 10% mandatory blending which requires an average of 250,000 litres per day. However, levels above 20% would require supplement in terms of imports since the current total domestic capacity is less than the required 500,000 litres of ethanol per day.

The opportunity cost of ethanol production at Chisumbanje

The main feedstock of ethanol production at the Chisumbanje ethanol plant is sugar cane. So the expansion of ethanol production requires taking land from other crops and allocating it for sugar cane production. Growing sugar cane has some opportunity costs in terms of the other forgone crops such as cereals. The main crop grown in the area besides sugar cane is maize; hence maize is the next best alternative crop. At Chisumbanje, where sugar cane is grown, maize yields are less than one tonne per hectare for un-irrigated land, and range between 2 tonnes and 6 tonnes per hectare for irrigated land. The 2012 maize price averaged between US$290 and US$300 per tonne, implying that, on average by using one hectare for maize production, the community can get less than US$300 for un-irrigated land before distribution costs and between US$580 and US$1,800 for irrigated land. On the other hand, sugar cane yields an average of 77.2 tonnes per hectare (see Table 2) of irrigated land producing at least 8,000 litres of ethanol or 10 tonnes of unrefined sugar equivalent to values of about US$8,000 and US$9,250, respectively.

The results indicate that sugar cane production at Chisumbanje is more viable as compared to other crops. In Zimbabwe, sugar cane is grown in drought prone semi-arid areas where staple maize performs poorly. At Chisumbanje, the total area earmarked for ethanol production is about 22,000 hectares with plant capacity of 120 million kilogrammes and producing 18 million litres per year at full capacity. The total area is only 0.5% of 4.2 million hectares of arable land in Zimbabwe. The Chisumbanje ethanol plant is located in Chipinge in the Middle Sabi region, a drought prone area in ecological farming region 5 where sugar cane production depends on irrigation water from Osborne dam. This makes ethanol production a non-threat to food security in Zimbabwe. Maize thrives best in natural farming regions 1 to 3 than in any of the other regions in Zimbabwe.

Table 2: Production data of sugar cane and sugar in Zimbabwe

Season	Area harvested (thousand ha)	Cane crushed (million tonnes)	Yield tonnes/ha	Sugar production (thousand tonnes)	Ethanol volume (million litres)	Cane sugar ratio	Ethanol cane ratio (litres/ton)
2008/09	35.3	2.6	68.8	297.9	10	8.67	80
2009/10	36.2	2.3	64.6	259.0	17	9.03	92
2010/11	35.3	2.7	76.4	332.0	18	8.12	88
2011/12	35.3	3.0	85.0	372.0	20	8.06	86
2012/13f	34.5	3.5	93.3	430.0	23	8.10	88

Source: Ministry of Industry and Commerce, Zimbabwe, 2012.
f means forecast.

In Zimbabwe, the main products from sugar cane are sugar for consumption and ethanol. The two plants using sugar cane as feedstock are the Chisumbanje ethanol plant and Triangle's Tongaat Hullet plant. At the Triangle plant, the main product of sugar cane is sugar for consumption; while at Chisumbanje, the main product is ethanol. Therefore, the main alternative use of sugar cane at Chisumbanje is sugar production. As explained in the preceding paragraph, a hectare of sugar cane for sugar is more valuable than a hectare of sugar cane for ethanol before distribution costs are considered. However, 40% of the country's sugar is exported making the distribution costs large. This leaves ethanol production a more viable project. The availability of under-utilized land and the simultaneous increase in the production of sugar and ethanol (Table 2) indicate that the country is inefficiently producing inside the sugar-ethanol production possibility boundary. The results from the survey, therefore, demonstrate that ethanol production at Chisumbanje has reduced opportunity cost since the project has improved productivity of the land. Even water harvesting has improved as a result of investments made by the private companies. More water is now available for the community as a result of these investments. The fact that there is capacity to increase both sugar production and ethanol production indicate an inefficient production.

Community benefits and costs

Generally, the Chisumbanje community benefits from the bioethanol project through employment creation, electricity generation, income from share cropping, banking services provided, and fertilizer which comes as a by-product from the ethanol plant. About 4,500 people are employed by Green Fuel Zimbabwe, of which 75% are from the local communities. The factory employs 240 workers and the rest of the workers are employed as farm workers. The plant also has a capacity to generate about 18MW of electricity, enough to power all the communities in the Chisumbanje area. The community had no electricity before the project, a problem resolved by the project. Communal farmers are given half hectares of irrigated land and fertilizer (a by-product from the plant) which enable them to produce enough food for their families. They can produce an average of six tonnes of maize per year, much larger than the less than a tonne produced before the project. In addition, communal farmers generate an average of about U$1,300 per year from share cropping with Green Fuel Zimbabwe.

However, the results from a survey in the Chechete community, a community in which the plant is located, indicate that even some of the community members not directly involved in Green Fuel Zimbabwe activities perceive their utility to have been increased by the project. There are also some community members who perceive their utility has deteriorated despite their direct participation in the project. Of the 80 individuals interviewed, 41 (61.2%) perceived the project as beneficial, while only 39 (38.8%) perceived it as disutility. About 40 (50%) of the interviewees were not directly involved in Green Fuel Zimbabwe activities. More than half of these (22 of the 40) argue that their utility has increased as a result of the project despite not being directly involved in the activities (see cross-tabulations in Appendix 1). Thirteen of the forty active participants of Green Fuel Zimbabwe activities had a perception that their utility decreased because of the project, mainly because their agricultural land had been taken. More than 50% of the employed saw the project to be a utility enhancer, while more than half of the unemployed saw it to be a utility reducer.

Equation 4 was estimated using the Maximum Likelihood – Quadratic hill climbing method, and the results indicate that, active participation in the project, employment status, and electricity availability, are not significant determinants of the probability that one has benefited from the project. In other words, the utility derived by community members from the project is perceived to be independent of a member's participation in the project, employment status, and electricity accessibility. However, the member's age, education, and religion increase the probability that the community member will perceive the project as beneficial. Education increases the probability that a member of the community will perceive the project as beneficial by between 19.7% (Probit) and 32.6% (Logit), while being a believer of African tradition reduces the probability that a member of the community will perceive the project as beneficial by between 1.23 (Probit) and 2.12 (Logit) units. The coefficient of the age square is negative, as expected, implying diminishing benefits from age. There is a maximum age at which a further increase in age will start to reduce the probability that a member of the community will perceive the project as a utility enhancer. Including the variable age, together with its square, makes the quadratic function nonsensical because it will imply a certain level of benefit perceived by the unborn. From the quadratic model in terms of age in Appendix 1, the age at which this maximum is attained is 29.4 years old. The results indicate that the perceived utility of old people (most of them African tradition followers) deteriorated as a result of the launch of the project. Whereas the perceived utility of the young people (the majority of the labour force) increased as a result of the project. The project is perceived to have benefited most of the youth who are active in the labour market at the expense of the few traditionalists who believe the project has interfered with their traditional systems of living.

Binary model specification tests in Appendix 3 indicate that the utility model is correctly specified and has a high predictive power. The expectation-prediction table demonstrates a high predictive accuracy of the model. About 82.5% is correctly classified with a sensitivity of about 93.9% and specificity of 64.5%. The Hosmer and Lemeshow goodness of fit test in Appendix 3 also provides no evidence of lack of fit of the model. Although the H-L statistic does not provide any information regarding the nature of the lack of fit observed, it detects incorrect model specification such as non-linearity in the predictors or missing predictors.

5. Conclusion and policy recommendations

The study indicates that bioethanol can greatly reduce the costs of importing petrol in Zimbabwe if higher levels of blends are implemented. However, the current plant capacity of ethanol production can only meet mandatory blend levels of not more than 20% in the country. Despite the current high costs of production, production of biofuels is economically attractive compared to imported gasoline in Zimbabwe. The production of biofuels will enhance rather than reduce food security. The country is inefficiently producing ethanol and sugar; there is capacity to increase both ethanol and sugar, implying that increases in ethanol production has no costs in terms of sugar for consumption given the available arable land. The study also established that the benefits of such projects are seen by the educated and the young who are active in the labour markets, while the majority of the elderly perceive the project as non-beneficial. Regardless of the old people's position, the Chisumbanje project has increased the average perceived utility of the communities surrounding the plant as the old are quite outnumbered by the young. It is such projects which drive industrialization in the rural areas, a prerequisite for economic development.

The production of biofuels in rural areas will also consequently serve to develop the hitherto disadvantaged rural areas through the out-growers scheme and provision of electricity produced from the ethanol plant. There is, however, need for government to come up with supporting policies for biofuels, which include mandates to guarantee known consumption volumes, subsidies to cushion biofuels industry in its infancy, tax incentives throughout the biofuels value chain to promote biofuels penetration, special funds for biofuels industry to minimize the cost of borrowed money, international biofuels standards to facilitate cross-border consumption, building capacity for biofuels governance and enhancing research and development.

However, mandatory blending has serious policy implications for the government in terms of revenue losses. Although there are cost savings in importation, more revenue is lost by the government. There is, therefore, need for future research to assess the economy-wide effects of producing more ethanol for gasoline. This study is only limited to a case since social accounting data for Zimbabwe is not available. Future studies should develop social accounting matrix (SAM) for the country first and then assess the full costs and benefits of the project. In the absence of a SAM, it is not easy to capture full costs and benefits of the project.

Notes

1. Ethanol blend is a mixture of ethanol and petrol, for example, E5 means 5% ethanol and 95% petrol.

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Appendix

Appendix 1: Cross-tabulations

Benefit * Employment status cross-tabulation

		Employment status		Total
		Otherwise	If employed permanently	
Benefit	no benefit	21	10	31
	benefit	20	29	49
Total	41	39	80	

Benefit * Religion cross-tabulation

		Religion		Total
		If Christianity or others	If African	
Benefit	no benefit	6	25	31
	benefit	31	18	49
Total	37	43	80	

Benefit * Electricity availability cross-tabulation

		Electricity availability		Total
		Otherwise	If an individual has electricity at the dwelling unit	
Benefit	no benefit	16	15	31
	benefit	12	37	49
Total	28	52	80	

Benefit * Participation in green fuel activities cross-tabulation

		Participation in green fuel activities		Total
		Otherwise	If one participates	
Benefit	no benefit	18	13	31
	benefit	22	27	49
Total	40	40	80	

Appendix 2: Regression results

Dependent Variable: BENEFIT
Method: ML - Binary Probit (Quadratic hill climbing)
Date: 12/28/12 Time: 10:33
Sample: 1 80
Included observations: 80
Convergence achieved after 5 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
EDUC	0.197298	0.056718	3.478608	0.0005
AGE*AGE	-0.000320	0.000107	-2.982346	0.0029
ELEC_AV	0.074254	0.416446	0.178304	0.8585
EMP_STATUS	-0.170416	0.455525	-0.374108	0.7083
GF_PART	0.116040	0.401528	0.288995	0.7726
RELIGION	-1.233690	0.403666	-3.056213	0.0022

Mean dependent var	0.612500	S.D. dependent var	0.490253
S.E. of regression	0.359192	Akaike info criterion	0.873815
Sum squared resid	9.547386	Schwarz criterion	1.052467
Log likelihood	-28.95258	Hannan-Quinn criter.	0.945441
Deviance	57.90517	Restr. deviance	106.8187
Avg. log likelihood	-0.361907		
Obs with Dep=0	31	Total obs	80
Obs with Dep=1	49		

Dependent Variable: BENEFIT
Method: ML - Binary Logit (Quadratic hill climbing)
Date: 12/28/12 Time: 10:35
Sample: 1 80
Included observations: 80
Convergence achieved after 5 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
EDUC	0.326107	0.102199	3.190906	0.0014
AGE*AGE	-0.000536	0.000188	-2.850224	0.0044
ELEC_AV	0.157915	0.727208	0.217152	0.8281
EMP_STATUS	-0.224814	0.803555	-0.279774	0.7797
GF_PART	0.258024	0.714523	0.361114	0.7180
RELIGION	-2.121958	0.726908	-2.919156	0.0035

Mean dependent var	0.612500	S.D. dependent var	0.490253
S.E. of regression	0.359367	Akaike info criterion	0.882586
Sum squared resid	9.556722	Schwarz criterion	1.061238
Log likelihood	-29.30345	Hannan-Quinn criter.	0.954213
Deviance	58.60690	Restr. deviance	106.8187
Avg. log likelihood	-0.366293		
Obs with Dep=0	31	Total obs	80
Obs with Dep=1	49		

Dependent Variable: BENEFIT
Method: ML - Binary Extreme Value (Quadratic hill climbing)
Date: 12/28/12 Time: 10:35
Sample: 1 80
Included observations: 80
Convergence achieved after 5 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
EDUC	0.297931	0.085591	3.480861	0.0005
AGE*AGE	-0.000344	0.000134	-2.573198	0.0101
ELEC_AV	0.056296	0.509477	0.110498	0.9120
EMP_STATUS	-0.417262	0.579838	-0.719618	0.4718
GF_PART	0.490440	0.514901	0.952495	0.3408
RELIGION	-1.672695	0.611478	-2.735494	0.0062
Mean dependent var	0.612500	S.D. dependent var		0.490253
S.E. of regression	0.352138	Akaike info criterion		0.850162
Sum squared resid	9.176112	Schwarz criterion		1.028814
Log likelihood	-28.00647	Hannan-Quinn criter.		0.921788
Deviance	56.01294	Restr. deviance		106.8187
Avg. log likelihood	-0.350081			
Obs with Dep=0	31	Total obs		80
Obs with Dep=1	49			

Dependent Variable: BENEFIT
Method: ML - Binary Probit (Quadratic hill climbing)
Date: 12/28/12 Time: 10:40
Sample: 1 80
Included observations: 80
Convergence achieved after 5 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.167858	0.658806	-0.254791	0.7989
AGE	0.075353	0.038385	1.963099	0.0496
AGE*AGE	-0.001281	0.000463	-2.766832	0.0057
McFadden R-squared	0.248139	Mean dependent var		0.612500
S.D. dependent var	0.490253	S.E. of regression		0.402226
Akaike info criterion	1.078910	Sum squared resid		12.45750
Schwarz criterion	1.168236	Log likelihood		-40.15640
Hannan-Quinn criter.	1.114723	Deviance		80.31279
Restr. deviance	106.8187	Restr. log likelihood		-53.40933
LR statistic	26.50587	Avg. log likelihood		-0.501955
Prob(LR statistic)	0.000002			
Obs with Dep=0	31	Total obs		80
Obs with Dep=1	49			

Appendix 3: Evaluation of binary specification

Expectation-Prediction Evaluation for Binary Specification
Equation: UNTITLED
Date: 05/10/13 Time: 15:19
Success cutoff: C = 0.5

	Estimated equation			Constant probability		
	Dep=0	Dep=1	Total	Dep=0	Dep=1	Total
P(Dep=1)<=C	20	3	23	0	0	0
P(Dep=1)>C	11	46	57	31	49	80
Total	31	49	80	31	49	80
Correct	20	46	66	0	49	49
% Correct	64.52	93.88	82.50	0.00	100.00	61.25
% Incorrect	35.48	6.12	17.50	100.00	0.00	38.75
Total Gain*	64.52	-6.12	21.25			
Percent Gain**	64.52	NA	54.84			

	Estimated equation			Constant probability		
	Dep=0	Dep=1	Total	Dep=0	Dep=1	Total
E(# of Dep=0)	20.88	8.32	29.20	12.01	18.99	31.00
E(# of Dep=1)	10.12	40.68	50.80	18.99	30.01	49.00
Total	31.00	49.00	80.00	31.00	49.00	80.00
Correct	20.88	40.68	61.55	12.01	30.01	42.03
% Correct	67.34	83.01	76.94	38.75	61.25	52.53
% Incorrect	32.66	16.99	23.06	61.25	38.75	47.47
Total Gain*	28.59	21.76	24.41			
Percent Gain**	46.68	56.16	51.42			

*Change in "% Correct" from default (constant probability) specification
**Percent of incorrect (default) prediction corrected by equation

Goodness-of-Fit Evaluation for Binary Specification
Hosmer-Lemeshow Test
Equation: UNTITLED
Date: 05/10/13 Time: 15:32
Grouping based upon predicted risk (randomize ties)

	Quantile of Risk		Dep=0		Dep=1		Total	H-L
	Low	High	Actual	Expect	Actual	Expect	Obs	Value
1	0.0007	0.0705	8	7.70940	0	0.29060	8	0.30155
2	0.0821	0.1596	8	7.08745	0	0.91255	8	1.03005
3	0.1647	0.5053	5	5.52605	3	2.47395	8	0.16193
4	0.5096	0.6529	4	3.43800	4	4.56200	8	0.16110
5	0.6717	0.7708	2	2.30295	6	5.69705	8	0.05596
6	0.7753	0.8313	3	1.58504	5	6.41496	8	1.57524
7	0.8338	0.9409	1	0.84179	7	7.15821	8	0.03323
8	0.9450	0.9652	0	0.39853	8	7.60147	8	0.41943
9	0.9662	0.9811	0	0.20452	8	7.79548	8	0.20988
10	0.9840	0.9910	0	0.10643	8	7.89357	8	0.10787
		Total	31	29.2002	49	50.7998	80	4.05626

H-L Statistic	4.0563	Prob. Chi-Sq(8)	0.8520

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