The South African Bio ethanol blend mandate and its implications on regional agricultural markets and welfare

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Abstract

The paper aims to analyse the potential impact of South African Biothanol Blend mandate on SACU region's maize and sugar production (referred to as bioethanol crops commodities), trade and overall welfare outcomes. The study has been necessitated by the importance of maize as a staple food for the Southern African region and the importance of sugar to some of the SACU countries' economies especially that of Swaziland. The simulation experiment has been an artificial decrease in cereal and sugar cane output in South Africa due to their diversion to bioethanol production, with a corresponding increase in petroleum output by a factor proportional to the blend mandate in place. This simulation has been undertaken using the GTAP7 model and database. Simulations results show that South African production of bioethanol and its blending to fuel will not result in major negative welfare changes in South Africa. However, production of bieothanol from maize negatively affects the rest of SACU member states in terms of welfare outcome and cereal prices. On the other hand, South Africa experience the most welfare benefits from maize based bioethanol. Production of bioethanol from sugar cane improves welfare in the rest of SACU region, such welfare envisaged to accumulate more to Swaziland, one of the region's major low cost sugar producer and exporter. Bioethanol crops commodities industry output and trade changes for the rest of SACU member states trend with the level of commitment of that commodity in the South African bioethanol production and blending programme as expected.

Key Words: Bioethanol Blend Mandate, GTAP 7, Welfare Outcomes
JEL Classification: Q1, Q13, Q130

1. Introduction

Biofuel production has been gaining popularity around the world because of the unpredictable and sometimes high prices of fossil fuels, most notably the oil crisis of the 1970s. More recently biofuels are being promoted due to global warming and the need for cleaner energy. Fossil fuels have been identified as having a negative environmental impact due to the emissions of Green House Gases (GHG) that contribute to global warming and climate change. Dutta (1999) equated environmental pollution to the tragedy of the commons. Another reason for promoting biofuels is to improve and diversify farm incomes where their production is supported by policies that protect local producers.

One important global attempt to reduce GHG emission was the signing of the Kyoto protocol in 1997. Under this protocol industrialized nations committed themselves to reducing their GHG emission by 5.2% below 1990 levels for the years 2008–2012. GHG under the Kyoto protocol refer to carbondioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Perflurocarbons (PFCs), Hydroflurocarbons (HFCs) and Sulphur Hexaflouride (SF_6). GHG are measured in CO_2 equivalent and the carbon footprints refer to their total amount emitted into the atmosphere by individuals. This definition therefore result in climate change discussions centering around carbon thus giving rise to terms like carbon policies, carbon tax and carbon trading.[1]

Biofuels primarily refer to bioethanol and biodiesel. Biodiesel is produced mainly from vegetable and animal oils/fats by a process called transesterification while bioethanol is produced mainly from sugar crops (e.g. sugar cane and sugar beet) and grain crops (e.g. corn, wheat, barley and rye) by a process of fermentation. This means that bioethanol is produced from commodities that have direct impact on food security. For this reason, this study will focus on bioethanol (as opposed to biodiesel) production and its use as a blended transport fuel.

Bioethanol and biodiesel are considered renewable substitutes to fossil based gasoline and diesel. Because its primary feedstock is a vegetable oil or animal fat, biodiesel is generally considered to be renewable and since the carbon in the oil or fat originate mostly from CO_2 in the air, biodiesel is considered to contribute much less to global warming than fossil fuels (Van Gerpen, 2004). Bioethanol, since it is produced from renewable feedstock is also considered a renewable fuel. Bioethanol usually forms 10% (E10) of the blend fuel mixture or up to 85% (E85) as is used in flexi fuel vehicles (FFV) that can use both ethanol and gasoline as fuel. Despite its lower energy content than traditional fossil fuels (bioethanol contains 68% of the energy in a litre of petrol) bioethanol improves the fuel combustion in vehicles, thereby reducing the emission of carbon monoxide, unburned hydrocarbons and carcinogens (Nigam and Singh, 2010). Whitten (2004) reported a reduction in CO_2 emission by up to 30 % when using 10% bioethanol blended with petrol due to the higher oxygen content of bioethanol of about 35%w/w. Moreover, the higher octane number (a measure of fuel tendency to burn more efficiently) of bioethanol has been cited as one further advantage of its use as a transport fuel (Balat and Balat, 2008; Dodic´ et al, 2009; Costa and Sodré, 2010).

However, controversies on the role that biofuels play in reducing GHG emissions and their overall environmental benefits have come up especially in the area of life cycle analysis which has been extensively studied. Life-cycle assessment approach is defined as a methodology for the comprehensive assessment of the impact that a product has on the environment throughout its

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[1] CO_2 equivalents is a metric measure used to compare the emissions from various GHG based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalents ($MMTCO_2$ Eq)." The carbon dioxide equivalent for a gas is derived by multiplying the tons of the gas by the associated GWP. $MMTCO_2$ Eq = (million metric tons of a gas) * (GWP of the gas) – (http://www.epa.gov/climatechange/glossary.html)

life-cycle on a ‘‘from cradle to grave’’ analysis (ISO 14040, 2006). Life-cycle assessment outcomes of the environmental benefits of biofuels vary widely mainly depending on the feedstock analysed, location of the study, method of analysis used and the parameters analysed.

In his study on the use of bioethanol as E10 and E85 blend, Niven (2004) concluded that E10 is of debatable air pollution merit, offers little advantage in terms of GHG emissions, energy efficiency or environmental sustainability; and will significantly increase both the risk and severity of soil and groundwater contamination. He further concluded that E85 offers significant GHG benefits but will however produce significant air pollution and involve substantial risks to biodiversity with largely unknown overall sustainability. Puppan (2002) on the other hand analysed the benefits of using E5 produced from sugar beet, winter wheat and potatoes in Germany. The study concluded that E5 fuel has lower impacts on depletion of abiotic resources and climate change, but higher impacts on stratospheric ozone depletion with acidification and human toxicity impacts remaining unchanged.

Besides the controversies of the benefits of biofuels in reducing GHG emissions, their criticism has centered on their competition with food production. Various studies have been undertaken on the controversy surrounding the effects of biofuels production on food production and therefore on food prices. Globally, the most serious concerns about biofuel expansion focus on the potential impact on global food prices and thereby poverty. At the global level, the immediate net effect of higher food prices on food security is likely to be negative (FAO 2008).

A World Bank report (2008) noted that the price of corn rose by 23% in 2006 and by 60% in 2007/08 due to the bioethanol production programme in the USA. There has been other studies as well that have linked increase biofuel production especially bioethanol to increased food prices (Perini, 2008; Von Braun, 2008; Alexandratos, 2008; Aman and Chad, 2007). These studies mostly analyse the effect of the USA bioethanol production programme from corn and conclude that increase bioethanol production is responsible for the upward pressure on global food prices especially the sharp increase observed in 2008. Michell (2008) identified the USA and EU bioethanol production as the cause of rising food prices.

Despite the global controversies of biofuels, South Africa is one of the countries that are promoting their production and use in transport fuel in a blend mandate format. This blending target is supported by the regulations regarding the mandatory blending of biofuels with petrol and diesel, which amends the petroleum Act 120 of 1977. The regulation sets a minimum concentration of blending of 5% biodiesel blending on a volume by volume basis as opposed to energy equivalence values and also sets a minimum of 2% to 10% maximum blending of bioethanol with petrol also on a volume by volume basis. Setting blend mandates is a common method of promoting uptake of biofuels. Table 1 summarizes biofuel production by the leading global producers, together with the blend mandates and production incentives in place.

Table 1: Biofuel Policies in Major Producing Countries

Country	Current Production	Mandate or Target	Production Incentive	Trade Policy
USA	49.2 Bnl ethanol 3.7 Bnl biodiesel	Mandate: 36 billion gallons of biofuels by 2022, of which no more of 15 billion gallons come from conventional sources and no less of 16 billion gallons come from cellulosic ethanol.	Tax credit of US$0.45/gallon ($0.12/litre) for ethanol blenders and US$1.00/gallon ($0.26/litre) for biodiesel blenders from agricultural feedstocks.	Ethanol tariff of US$.54/ gallon ($0.143/litre) plus ad valorem duty of 2.5 %. Ad valorem duty of 1.9 % on biodiesel
European Union	7.2 Bnl ethanol 10.9 Bnl biodiesel	Mandate: minimum of 10% of transport fuel from renewable fuels by 2020.	Member States can apply tax reductions on biofuels as well as provide production incentives.	Specific tariff of €0.192/litre of under-natured ethanol and €0.102/litre of denatured ethanol. Ad valorem duty of 6.5 % on biodiesel.
Brazil	22.7 Bnl ethanol (sugar cane) 2.5 Bnl biodiesel (soya)	Blending mandate for ethanol of 20–25%. Biodiesel use mandate set at 5% (B5) since 2010 (proposal to increase to up to 10% by 2020.	Tax incentives on fuel ethanol and biodiesel. Tax incentives on flex-fuel vehicles	Ad valorem duty of 20% on ethanol imported from outside the Mercosur area (temporarily in the list of exceptions). Ad valorem duty of 14% for biodiesel.
India	1.08 Bnl of Ethanol (molasses). 0.24 Bnl of biodiesel (Jatropha).	Indicative 20% target for blending for both ethanol and biodiesel by 2017	Minimum price mechanisms for feedstocks Tax incentives for ethanol or biodiesel.	Ad valorem duty of 28.6% both on ethanol and biodiesel.
China	2.3 Bnl ethanol [corn and wheat]. 0.6 Bnl biodiesel [waste and residues].	E10 for 2020 (12.7 Bnl ethanol) Target of 2.3 Bnl biodiesel consumption in 2020 Target of 15 percent of fuel consumption to be non-fossil fuel by 2020	Production subsidies on ethanol and biodiesel	Ad valorem duty of 5% on denatured ethanol (30% until 2009) and 40% on undenatured ethanol
Thailand	0.5 Bnl ethanol [sugar cane,] 0.7 Bnl biodiesel [palm oil]	Ethanol: E20 mandatory since 2008. Biodiesel: B2 mandatory since 2008 and B5 since 2012.	Tax exemption for ethanol. Investments subsidies for ethanol plants. Soft loans for biodiesel	No export duties on processed palm oil or biodiesel

Source: Adapted from Diop et al (2013: 21)

There is a paucity of studies on the potential effects of bioethanol production on food markets in the Southern African region. The impact of the proposed South African bioethanol blend mandate policy on food production and trade in the Southern African region has also not been studied. Most studies on the South African, and African bioethanol programmes in general, are not empirical and do not analyze the effect of the proposed biofuel blend mandate on South African neighboring states. Soumonni and Cozzens (2008) analysed the potential for biofuel use in Africa and concluded that most of the African region's push towards biofuels does not yet follow a sustainable path. They also observed that most government-run programs appear to be motivated by economic growth for their countries to the exclusion of some of the other issues that are central to the well-being of the affected communities and to the ecosystem.

Nolte (2008) analysed the commercial feasibility of biodiesel in South Africa and concluded that the potential market size for biodiesel in South Africa is about 1 billion litres if it is to replace 10% of its diesel consumption by 2010. He further noted that producing 10% of South Africa's diesel using oilseeds would require a major production increase and that land availability for such a production increase would not be a problem. This means that the agricultural resources and potential market are available to produce and absorb 10% of the countries diesel in the form of biodiesel.

Makenete et al. (2008) studied the impact of bioethanol production on food security with particular emphasis on Maize-to-Ethanol production and concluded that a multi-feedstock approach (including using maize) is crucial for sustainable biofuel production in South Africa. He cited that this approach this will enable producers to select crops best suited to the agro-climate of the regions where their plants are situated and to minimize logistic costs by sourcing crops grown closest to their plants.

Von Maltitz et al (2009) analysed the opportunities for biofuel production in sub-Saharan Africa. The key conclusions they drew from their study was that Africa has land available to support biofuel production but that issues of land rights, biodiversity, de-forestation and land cap measures for biofuel production need to be addressed.

Johnson and Matsika (2006) studied the bio-ethanol trade and developments in Southern Africa and concluded that transportation costs appear to be small compared to production costs, although the higher cost of shipment by land implies a need for regional coordination strategies.

Diop et al. (2013) assessed the impact of biofuels production in developing countries from the point of view of policy coherence for development. This study concluded that in relation to the 2010/11 food crisis in the Sub-Saharan Africa (SSA) region for example, low and declining productivity of agriculture, coupled with exceptionally unfavourable weather conditions and rising international oil prices, seem to be more prominent drivers behind rising food prices than the current biofuel production level.

From the studies undertaken on the South African biofuel blending programme, our study aims to fill the gap in empirical studies of the blend mandate by analyzing it potential impact on regional maize and sugar markets. The South African blend mandate strategy prohibits the use of maize for ethanol production on the grounds that this would contribute to food insecurity in the country. Although this prohibition is in place, it is interest to know the potential effect of maize based production of bioethanol in South Africa and the SACU region with which South Africa share a free trade agreement.

The rest of the paper is organized as follows: section 2 outlines the modelling approach used in this study, section 3 discusses the GTAP model, section 4 is narrates the experimental simulates, section 5 presents and discusses the results while section 6 is the conclusion.

2. Modelling approach

Modelling the South African biofuel blend mandate will use the Global Trade Analysis Project (GTAP) model, which is an example of a CGE model. Partial equilibrium models, as opposed to general equilibrium models, are informative, detailed and easy to model for a small-scale market simulation of a policy change but they are generally not convenient to study global or international spillover effects of a policy change.

CGE modelling, as first conceptualised by Walrus (1834-1910), has its underpinnings on a system of equations based on the assumption of an economy in perfect competition where firms maximise profits subject to their production function and consumers maximise their utility subject to a budget constraint. In this case then there are various economic agents and the sum of excess demand across markets must be equal to zero. CGE models are therefore based on a general equilibrium approach where economic agents are represented by a set of equations that describe their optimisation behaviour. The modeler specifies the equations that describe the agent behaviour and how these various economic agents are related to each other.

CGE modelling, as its name suggests, aims to determine a point in a market where supply equals demand i.e. Walrasian equilibrium. At this equilibrium point markets clear, households maximise utility under a budget constraint and firms maximise profits, which are driven down to zero. The aim of CGE modelling then is to solve for prices and quantities that will prevail at the equilibrium point. In the Walrasian equilibrium model the flexible price vector determines the equilibrium while in the Keynesian equilibrium model in the short-run the quantities vary while the price remain fixed (Khan, 2004). CGE models are based on cross-sectional data at a given point in time. The database and its size depend on the economy under analysis. Experiments are designed by manipulating certain key variables in a balanced dataset and analysing the resulting changes in variables specified as endogenous. Such models have been used in a wide range of studies and in various fields of economic and environmental policy analysis. For example, CGE modelling techniques have been used to analyse taxes and international trade (Shoven and Whalley ,1984), in the study of developing economies (Decaluwé and Martens, 1988), to analyse energy and the environment (Bhattacharyya, 1996) and in analysis of benefits and losses resulting from free trade agreements (Loyd and MacLafren, 2004).

The advantage of CGE models is that they take a holistic view of the entire economy under analysis and consider the interrelationships between the various economic agents across a given economy. In this way, they offer useful insights on possible economic impacts of changes in key variables and this makes them informative. They also integrate many aspects of economic theory and the basic assumption of agent behaviour can be manipulated by the modeler to suite the economy under analysis. As noted by Kretschmer and Peterson (2009) GE models are able to capture macro-economic and international feedback effects through changes in relative prices of inputs and outputs.

Their major drawback is that they are static and cannot predict outcome in a time-series manner. This makes them unsuitable for forecasting. Another disadvantage is that the assumptions made by the model are sometimes not realistic and can affect simulation outcomes. They also generally need a lot of data from various sources and some of the data may not be accurate, which may result in misleading experimental outcomes. Further, CGE models tend to be large and as such they cannot relate results or outcomes accurately to a specific cause or shock in the database. As noted by Wing (2004) CGE models are viewed with suspicion in economics and policy analysis communities as a "black box", whose results cannot be meaningfully traced to any particular features of their database or input parameters, algebraic structure or method of solution. However, for empirical studies of policies with global spillovers they remain the methods of choice.

General equilibrium models have been used to explore the impact of different mandatory blending policies on world agricultural production. Whereas some models focus on the impacts of the European Directive on the world agricultural markets (Banse et al. 2008), others explore the consequences of the implementation of both E.U. and U.S. biofuels policies (Birur et al. 2008, Hertel et al. 2009b). Other CGE models that have been used especially to analyse energy markets in European and US markets include USAGE (Dixon et al., 2007), a GTAP-E version modified at LEI Institute (Banse et al., 2008), WorldScan (Boeters et al., 2008), DART (Kretschmer et al, 2008), EPPA (Reilly and Paltsev, 2007; Gurgel et al., 2007; Melillo et al., 2009) and augmented versions of GTAP (Birur et al., 2008; Hertel et al., 2008; Keeney and Hertel, 2008).

3. The GTAP Model

The GTAP model is an example of a CGE model as discussed above. The standard GTAP model is a widely used static, multi sector, multi region applied general equilibrium model developed by Hertel in 1997. It is based on a detailed database with a broad coverage of trade distortions and explicit statistics on transport margins. Firms use constant-returns-to-scale technologies except for the resource supply sectors with an upward-sloping supply function where a fixed factor is included in the production technology to construct a diminishing-returns-to-scale technology. Import demand is modeled through the Armington assumption of imperfect substitutability between domestic and imported goods and between imported goods from different regions.

The GTAP 7 data base consists of 57 commodities and 113 regions. The GTAP 7 database is based on 2004 international trade data. The 113 regions are defined as aggregates of 226 countries using the GTAP standard country list. The Alpha-3 codes defined by the International Organization for Standardization (ISO) are used as country codes for the GTAP primary regions.

In the sectoral definitions used in the GTAP 7 Database GTAP agricultural and food processing sectors are defined by reference to the Central Product Classification (CPC). The other GTAP sectors are defined by reference to the International Standard Industry Classification (ISIC) since this is the reference classification point for I-O statistics tables where the GTAP data is sourced. The CPC was developed by the statistical office of the United Nations (UN) and serves as a bridge between the ISIC and other sectoral classifications (Narayanan et al 2008).

Since quantities and prices are endogenous in the GTAP model, the simulation of production changes is through altering the output tax rate. Manipulation of the tax rates is the standard procedure used in the GTAP model to obtain regional elasticities of various commodities. This is done by altering the output tax by enough to raise the market price by 1%, one commodity and one region at a time. The percentage reduction in output is then recorded and the own price elasticity of demand determined.

4. Experimental Simulation

The simulation of a South African blend mandate will be through the artificial decrease in bioethanol crops commodities production in South Africa. This artificial decrease in bioethanol crops commodities output will be equivalent to their diversion to bioethanol production as per the blending percentage in place. As such, this artificial output decrease will be by a bioethanol crops commodities equivalent amount as would be demanded at 2% and 10% volumetric equivalent blending of gasoline with biofuel. This decrease in South African bioethanol crops commodities output, which simulates the blend mandate policy is analysed with emphasis given on its effects on SACU bioethanol crops commodities production and trade and welfare outcomes. For the analysis of the South African bioethanol policy, six experiments will be conducted differentiated by the blending percentage and the bioethanol source as follows,

- 2% Blend Mandate - 50% Maize : 50% Sugar Cane based bioethanol;

- 2% Blend Mandate – 100% Maize based bioethanol;
- 2% Blend Mandate –100% Sugar Cane based bioethanol;
- 10% Blend Mandate – 50% Maize, 50% Sugar Cane based bioethanol;
- 10% Blend Mandate – 100% Maize based bioethanol;
- 10% Blend Mandate –100% Sugar Cane based bioethanol.

The steps in the modeling approach are therefore as follows:

- Determine annual South African gasoline demand
- From the South African Gasoline demand we calculate the equivalent ethanol demand at 2% and 10% blend mandate using the simple identity as shown below:

$$Q_{e,t} = Q_{g,t}.M$$

Where M is the blend mandate share ϵ [0, 1]

From the equation above the derived demand for bioethanol in South Africa with a binding mandate at any time t ($Q_{e,t}$) is simply the demand for gasoline at any time t ($Q_{g,t}$) multiplied by the % blend ratio M in volumetric equivalence.

- From the bioethanol demand calculated above, the equivalent bioethanol crop commodities (i.e. maize and sugar cane) in tonnes required to produce the demanded bioethanol is then calculated using the crop commodities bioethanol production efficiencies. These crops commodities equivalent in tonnes are then transferred into the GTAP model as percentage artificial decrease in their output as a result of their diversion to production of bioethanol. This artificial percentage decrease in bioethanol crops commodities output uses the 2004 South African production level of these commodities. This is because the GTAP 7 database used in our study is based on 2004 international trade data. For this reason, the South African bioethanol crops commodities production levels is vital in our simulation.

Table 2 below shows sugar cane and cereal production in South Africa from 2004 to 2012. These production statistics, especially the 2004 production levels will be useful in calculating the required percentage decrease in their output to simulate the effect of the South African bioethanol blend mandate.

Table 2: South African Production of Barley, Oats, Rye in Thousand of Tonnes

Commodity	2004	2005	2006	2007	2008	2009	2010	2011	2012
Sugar Cane	19,094	21,265	20,275	19,724	19,255	18,655	16,015	16,800	17,278
Maize	9,710	11,715	6,935	7,125	12,700	12,050	12,815	10,360	11,830
Barley	185	225	236	222.5	192	216	194	312	296
Oats	37	34	43.5	42	27	37	34	57	60
Rye	0.62	1.4	3	3.1	3	2	2	1.9	2

Source: FAOSTAT (2014)

- The simulation hinges on the assumption that South Africa produces all the bioethanol as will be required by the blend mandates from "current" production level of bioethanol crops commodities, i.e. sugar cane and maize or cereals. In this way, our analysis of the blend mandate will have no impact on land use and analyses the blend mandate as an "upper bound" worse possible scenario where the country does not expand production of bioethanol crops commodities but merely diverts "current" production level from food production to bioethanol production. This worst case scenario is reasonable since it sets an upper benchmark or worse possible outcome of the South African blend mandate on bioethanol crops commodities or food markets in the SACU region.

- Similarly, the simulation of the effect of the blend mandate on transport fuel in South Africa is via the artificial percentage increase in output of fuel production in the country by an equivalent amount required by the bioethanol blend mandate.

The gasoline and equivalent derived bioethanol demand in South Africa from 2004 is calculated and shown in Table 3 below:

Table 3: South African Annual Motor Gasoline Consumption (Millions of Barrels) and the bio ethanol Equivalent of the Blend Mandate

Year	Gasoline Demand (miilion barrels per year)	Bioethanol Equivalent (million barrels per year)	
		2% Blend Mandate	10% Blend Mandate
2004	70.82314	1.416463	7.082314
2005	69.272255	1.385445	6.927226
2006	69.4595	1.38919	6.94595
2007	71.248	1.42496	7.1248
2008	68.2185	1.36437	6.82185
2009	75.044	1.50088	7.5044
2010	74.2775	1.48555	7.42775

Source: EIA and calculated by author

From 2004 gasoline consumption statistics, 1.4 million barrels of bioethanol equates to 225.2 Million litres at 2% blend mandate. At 10% blend mandate 7.08 Million barrels of bioethanol equates to 1126 Million litres.[2] The annual demand for biothanol in South Africa at 10% blend mandate compares favourably to that determined by Nolte (2008) of 1 billion litres of biodiesel demand in 2010 at 10% blend mandate.

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[2] This calculation is based on the conversion of 1 barrel (oil, petroleum)=158.99L

These litres of bioethanol are then converted to the sugar cane and maize equivalence using the crops production efficiencies.[3] These results are shown in Table 4 below:

Table 4: Bioethanol demand at various blend mandates, bioethanol crop commodities equivalent and as a % of 2004 South African bioethanol crops commodities production

	2% Blend Mandate – 50% Maize, 50% Sugar Cane	2% Blend Mandate – 100% Maize	2% Blend Mandate – 100% Sugar Cane	10% Blend Mandate – 50% Maize, 50% Sugar Cane	10% Blend Mandate – 100% Maize	10% Blend Mandate – 100% Sugar Cane
Millions Liters of Bioethanol Required/Year	225.20	225.20	225.20	1126.02	1126.02	1126.02
Maize Equivalence in Million Tonnes/Year	0.23	0.46	0	1.16	2.31	0
Sugar Cane Equivalence in Million Tonnes/Year	1.6	0	3.2	8.04	0	16.09
% of 2004 Sugar Cane Production	8.4	0	16.8	42.1	0	84.2
% of 2004 Cereal Production	2.3	4.6	0	11.7	23.3	0

These percentages bioethanol crop commodities demand as shown in Table 3 are then used to artificially depress cereal and sugar cane production in the GTAP model database. In the GTAP model sectors database, it is not been possible in the database to separate the bioethanol grain crops i.e. maize, barley and rye into their respective component commodities. Only wheat is disaggregated in the model database and the rest of the bioethanol crops commodities are aggregated into cereals sector which include maize, barley, rye, oats and other cereals in the original GTAP7 sector aggregation. For this reason, these commodities are analysed as an aggregated commodity. Only

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[3] Maize produces 486.8 litres of bioethanol per tonne using dry milling while 1 tonne of sugar cane produces 17.8 gallons (~70 Litres) of ethanol.

sugar cane and sugar have therefore been disaggregated amongst the bio ethanol crop commodities of interest in this study.

It is expected that the diversion sugar and maize to bioethanol production in South Africa will increase (decrease) their import (export). It is this fall in South African maize production, most of which is exported to the rest of the SACU member states, that will need to be analysed because it has important food security implications in the lesser economies of SACU. Increase use of sugar cane to produce bioethanol is expected to have less negative welfare effects since sugar is a not a main food component like maize. In particular, maize is the staple food for most of the region and forms a major share of household budget, given that poorer people spend a substantial share of their income of food.

The effect of the blend mandate on the South African transport fuel market is modelled into the GTAP by altering the petroleum products sector of the model. In the model, this sector is aggregated and consists of the manufacture of coke oven products, refined petroleum products (which include petrol and diesel) and the processing of nuclear fuels. Petrol and diesel production are not isolated out in the model and thus it is not possible to analyse accurately changes that affect these commodities. The method of analysing the effect of the South African blend mandate on transport fuel is through artificially increasing industry output of these products by an equivalent bioethanol amounts as will be demanded at 2% and 10% blend mandate.

As calculate previously and recorded in Table 3, the 2004 gasoline consumption statistics equates to 225.2 Million litres and 1126 Million litres of bioethanol per year at 2% and 10% blend mandate respectively. The EIA estimated that the manufacture of total petroleum products in South Africa, which includes motor gasoline, jet fuel, kerosene, distillate fuel oil, residual fuel oil and liquefied petrol gases, amounted to 690.54 thousand barrels per day. This equates to 40072.97 million litres of total petroleum products manufacture per year. Injection of 225.2 million litres of bioethanol to this output is equivalent to a 0.56% increase while 1126 million litres of bioethanol equatets to 2.8 percent increase in total petroleum products output in South Africa. To model the effect of the blend mandate on transport fuel, the amount of petroleum products output is South Africa is therefore increased by these percentages. This approach is inaccurate and cannot specifically determine the effect of the blend mandate on transport fuel but in the absence of disaggregated gasoline in the model, this offers the best approximation.

These calculated percentage changes are then transmitted to the GTAP model as shocks to the respective commodities output as a way of simulating the South African bioethanol blend mandate. The approach used in this study is not unique in that many analyses have been done with partial equilibrium models where the existing models of the agricultural sector receive an exogenous increase in demand for feedstock used in biofuel production (e.g. maize, sugar cane, wheat, sugar beet, oilseeds, etc.) to determine the changes in long-run equilibrium prices and the implications for welfare (OECD, 2006; European Commission, 2007b).

For simulating these shocks therefore, the original 57 GTAP sectors are aggregated as follows:

I. sugar cane
II. sugar
III. cereals
IV. grain crops
V. rest of crops
VI. petroleum products - manufacture of refined petroleum products (which is a sector that is part of manufacture of coke oven products, refined petroleum products and processing of nuclear fuel)
VII. livestock products
VIII. rest of commodities

The countries are aggregated as follows: South Africa, Rest of SACU region (which includes Botswana, Lesotho, Namibia and Swaziland) and the Rest of World (ROW).

The aggregation of the database for the study use the complete GTAPAgg software licensed to the author. Simulation experiments are done using RunGTAP, which is a graphical user environment developed by Mark Horridge of the Centre of Policy Studies at Monash University.

We apply the Standard GTAP closure rules for this simulation experiment. In this closure rule, the price of composite capital good supplied to savers by global bank varies by region; and the World price index of primary factors is the numeraire variable. The solution method applied in the analysis is the Johansen method.

5. Results and Discussion

The analysis of the South African bioethanol blend mandate effect in South Africa and the rest of SACU member states will be based on welfare outcomes per capita, bioethanol crop commodities industry output, trade balance and prices changes as result of the policy.

In the GTAP model, welfare effects are composed of endowment contribution, technical efficiency, allocative efficiency, investment/savings effects and terms of trade changes. Endowment contribution arises from changes in the availability of primary factors of production while technical efficiency arises from changes in the use of factors of production. Allocative efficiency is a result of changes in the allocation of resources relative to pre-existing distortions and investment/savings contribution is because of changes in household investment/savings patterns. Terms of trade effects are due to the difference between the value of the initial vector of net exports at new and initial vector of world prices and if this difference is positive, the country experiences a welfare gain (Pant et al, 2000).

The equivalent variation outcomes as a result of the South African bioethanol blend mandate are reported in Table 5 below:

Table 5: Equivalent Variation Outcome per Capita (US$ Million)

	South Africa	**Rest of SACU**
2% Blend Mandate – 50% Maize, 50% Sugar Cane	0.20	0.43
2% Blend Mandate – 100% Maize	0.39	-0.66
2% Blend Mandate –100% Sugar Cane	0.01	1.54
10% Blend Mandate – 50% Maize, 50% Sugar Cane	0.98	2.21
10% Blend Mandate – 100% Maize	1.90	-3.19
10% Blend Mandate –100% Sugar Cane	0.06	7.60

The equivalent variation per capita welfare outcomes as a result of the South African bioethanol blend mandate shows a clear trend that increased commitment of maize into the production of bioethanol result in increasing welfare loss for the rest of the SACU member states. For example, producing bioethanol solely from maize result in welfare loss of US$ 0.66 per capita at 2% blend mandate while this figure increases to US$ 3.19 per capita for 100% maize based bioethanol at 10% blend mandate for the rest of SACU member states. However, a sugar cane based South African bioethanol production programme result in welfare gain for the rest of the SACU member states. This welfare gain increases with increasing sugar cane commitment and also outweighs the welfare loss as a result of maize based bioethanol production. For example, at 2% bioethanol blend mandate and a 50:50 sugar cane and maize based bioethanol, SACU member states experience a welfare gain of US$ 1.54 per capita. This value increases to US$ 2.20 per capita at 10% blend mandate. This welfare gain can be attributed mostly to Swaziland, who is a known efficient producer of sugar cane. Indeed, welfare gain for the rest of the SACU member states is highest at US$ 7.6 per capita for 100% sugar cane based bioethanol at 10% blend mandate as expected from the trend.

For the poorer SACU member states, the welfare loss as result of increasing commitment of maize to bioethanol production is because maize is a staple food in these countries. These countries are also net importers of maize. Using maize for bioethanol production will increase its demand and therefore its price. This will affect household income and result in welfare loss.

South Africa on the other hand experiences a welfare gain in all cases of bioethanol production regimes. These South African welfare gains are higher for maize based bioethanol than for sugar cane based bioethanol. This means that South Africa is a better producer of maize than sugar cane. For example, South African welfare gain is highest (US$ 1.90 per capita) at a 10% blend mandate and 100% maize based bioethanol. It is lowest at 2% blend mandate and 100 % sugar cane based bioethanol production.

The effect of the South African bioethanol blend mandate on bioethanol crops commodities production or output is shown in Table 6 below:

Table 6: Bioethanol crops commodities output changes due to the South African bioethanol blend mandate

	South Africa		Rest of SACU	
	Cereals	**Sugar**	**Cereals**	**Sugar**
2% Blend Mandate – 50% Maize, 50% Sugar Cane	-3.06	-7.53	2.13	6.89
2% Blend Mandate – 100% Maize	-6.19	0.05	4.35	-0.13
2% Blend Mandate – 100% Sugar Cane	0.07	-15.11	-0.1	13.9
10% Blend Mandate – 50% Maize, 50% Sugar Cane	-14.91	-37.66	10.37	34.45
10% Blend Mandate – 100% Maize	-30.15	0.22	21.22	-0.61
10% Blend Mandate –100% Sugar Cane	0.34	-75.54	-0.48	69.51

Table 6 above show that industry output for the bioethanol crops commodities go down in South Africa as a result of the bioethanol blend mandate as per our ‘shock’ simulation. This is due to the diversion of these bioethanol crop commodities from food production to bioethanol production. This simulation results in increased bioethanol crops commodities production in the rest of the SACU member states in trend with the amount diverted to bioethanol production. For example, a 10 % blend mandate with 50:50 sugar cane maize share depress cereal output in South Africa by almost 15% and sugar output by almost 38%. It increases cereal output in the rest of the SACU region by 10.4 % and sugar output by 34.5 %. A 10% blend mandate and 100% maize based bioethanol expand cereal production by 21.22 % in the rest of SACU region and depress sugar production by 0.61%. A 10% blend mandate and 100% sugar cane based bioethanol expand sugar production by 69.51 % in the rest of SACU region and depress cereal production by 0.48 %. This observation is in line with expectations that increased demand for bioethanol crops commodities in South Africa will stimulate their production and trade in the rest of SACU countries. Increase output of one crop commodity will be at the expense of the other crops, which will be competed away and therefore result in their depressed output as the results show.

Trade balance outcomes as a result of the South African bioethanol blend mandate policy is shown in Table 7 below:

Table 7: Bioethanol crop commodities trade balance outcomes of the South African bioethanol blend mandate

	South Africa		**Rest of SACU**	
	Cereals	**Sugar**	**Cereals**	**Sugar**
2% Blend Mandate – 50% Maize, 50% Sugar Cane	-20.01	-80.63	-0.63	19.34
2% Blend Mandate – 100% Maize	-40.71	0.44	-1.13	-0.27
2% Blend Mandate –100% Sugar Cane	0.72	-161.69	-0.13	38.95
10% Blend Mandate – 50% Maize, 50% Sugar Cane	-97.43	-403.15	-3.08	96.72
10% Blend Mandate – 100% Maize	-198.42	2.15	-5.52	-1.3
10% Blend Mandate –100% Sugar Cane	3.58	-808.45	-0.65	194.74

Trade balance analysis reveals that South Africa experience a negative trade balance in the bioethanol crops commodities as expected as a result of their increased commitment to bioethanol production. However, an interesting finding is that the rest of SACU member states experience a negative trade balance in cereals at all levels of blend mandate and crops shares used for bioethanol production in South Africa. This means that as net cereal importers mainly from South Africa, the negative cereal trade balance of the rest of the SACU member states will worsen as South Africa use maize to produce biothethanol.

Table 8 below presents the changes in prices as a result of the South African bioethanol blend mandate policy.

Table 8: Changes in bioethanol crop commodities prices due to the South African bioethanol blend mandate

	South Africa		Rest of SACU	
	Cereal	**Sugar**	**Cereal**	**Sugar**
2% Blend Mandate – 50% Maize, 50% Sugar Cane	7.72	6.37	0.43	0.09
2% Blend Mandate – 100% Maize	15.6	-0.03	0.77	0.03
2% Blend Mandate – 100% Sugar Cane	-0.17	12.77	0.1	0.14
10% Blend Mandate – 50% Maize, 50% Sugar Cane	37.61	31.85	2.12	0.43
10% Blend Mandate – 100% Maize	76.04	-0.15	3.73	0.14
10% Blend Mandate –100% Sugar Cane	-0.83	63.84	0.51	0.72

Changes in prices are as expected. Increased demand for sugar cane and maize in South Africa increase cereals and sugar domestic prices. This price increase is also experienced in the rest of the SACU member states but only modestly. This means there is evidence of little price transmission to the rest of the SACU member states due to a South African Bioethanol Blend Mandate. However, it is the increase in prices of cereals, which is the main food source for the poorer rest of SACU member states that contributes to the observed welfare loss.

6. Conclusion

This analysis reveals that a South African sugar cane based bioethanol production programme will mostly benefit the rest of SACU member states with modest welfare benefits to South Africa. On the other hand, a maize based South African bioethanol production programme will be beneficial mostly to South Africa but will harm the rest of the SACU member states. It is therefore reasonable that South Africa pursues a sugar cane based bioethanol production programme as this option will likely lead to win-win outcomes for South Africa and the rest of the SACU member states.

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