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Review

Industrial biotechnology for developing countries: The case for genetically modified biofuels in Kenya

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Attempts to diversify the energy portfolios of developed countries with green technologies have brought competition between food and fuel for crop production resources to the forefront of public policy debates. Biofuel policies in the European Union (EU) and the United States (US) mandate the long-term use of renewable energy in transportation, independent of production capacity and technical feasibility. Both the US and EU policies explicitly allow for biofuel imports and, hence, have the potential to provide developing countries with export opportunities. For example, the EU is seen as a market that could be supplied with biofuels produced in Kenya. As a result, contentious land acquisitions have been made in Kenya to make way for sugar cane and jatropha cultivation for biofuel production. One potential means of improving the efficiency of Kenya's agricultural sector is the application of transgenic technologies. The objective of this article is to assess whether a biofuel industry could be developed in Kenya, based on the use of genetically modified (GM) feedstocks to supply the EU demand for biofuel. This article concludes that GM agriculture will improve the economic returns for those Kenyan farmers willing to engage in the production of GM biofuel crops.

Key words: Barriers to trade, energy policy, genetically modified (GM) crops, international trade, land-use policy.

INTRODUCTION

Interest in producing biofuels has risen significantly in recent years in response to increased instability in international oil supplies, the environmental degradation associated with greenhouse gas (GHG) emissions and government policies which support the development of energy alternatives to fossil fuels. The desire to find alternative sources of energy, particularly for transportation purposes, has resulted in large scale government investments in, and support for, the biofuel industry. The United States (US), the European Union (EU) and a number of other countries, including developing countries, have encouraged the development of renewable energy in an attempt to enhance energy security and to mitigate the negative effects arising from GHG emissions (Viju and Kerr, 2013). The EU and US policies mandate significant domestic use of biofuels, in spite of capacity constraints in the EU and technical limitations in the US.

These industry support measures, which artificially boosts demand for biofuels, create potential beneficial opportunities for developing countries endowed with large amounts of land suitable for growing biomass. The potential for genetically modified (GM) crops to support biofuel production in developing countries exists as observed, for example, in Brazil and Argentina. However, diversifying the energy mix with biofuel production may result in a loss of natural capital, (defined as the stock of natural resources, environmental and ecosystem resources used as inputs in the production of goods and services in addition to being enjoyed for its own sake) (Olewiler, 2004) including biodiversity. The EU's Renewable Energy Directive (RED) (2009) imposes regulatory constraints on

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those seeking to contribute to the mandated ten percent minimum of biofuels in transportation. In the US, the Energy Independence Security Act (2007) limits the type of land that can be used to produce inputs slated for biofuel production. These restrictions apply regardless of whether suppliers are domestic or foreign. The EU and US provisions may thwart attainment of the potential biofuel benefits by developing countries. The EU RED offers a premium to second generation biofuels derived from cellulosic conversion relative to first generation technologies as the latter are believed to significantly impact agricultural markets and exacerbate food insecurity (first generation technology refers to fuels derived from starch, sugar, animal fats and vegetable oils and second generation technology refers to non-food sources such as cellulose and waste).

The International Energy Agency (IEA, 2010) reported that Africa has the potential to be a significant producer of second generation biofuels, provided the appropriate technology and requisite infrastructure are available. Smeets et al. (2007) support this view and suggest that 104 to 717 million hectares of surplus agricultural land in sub-Saharan Africa could be available if agricultural efficiency improves significantly. One mechanism that improves agricultural efficiency is the application of transgenic technologies. The appropriate technology and infrastructure may involve non-food crops developed through biotechnology. In Kenya, contentious land acquisitions have occurred in the Tana Delta to make way for sugar cane and jatropha cultivation as inputs into biofuel production (http://www.guardian.co.uk/world/2011/jul/02/biofuelsland-grab-kenya-delta). These acquisitions have raised concerns because of the threat to wetland habitats populated with rare and spectacular birds. The cultivation of marginal lands such as those in the Tana Delta, suggests there is little productive crop land available that can be utilized for biomass production. Improving yields through GM crops may allow Kenya to produce food and energy crops with little to no negative social and/or environmental displacements. Van Kooten (2011) argues that GM crops offer the ability to increase output while reducing farming impact on the environment.

The application of biotechnology in agricultural production on a commercial scale on the African continent is limited to Egypt, Burkina Faso, Sudan and South Africa (James, 2013), although African countries have the greatest need to exploit the power of modern biology to ensure food security (Van Kooten, 2011). An example of this need was found in Kenya, when the Government of Kenya passed the Biosafety Act of 2009 which became operational in the summer of 2011, allowing the production and importation of GM crops to address food shortages (Reuters, 2011). Thus, a potential opportunity may exist for widespread adoption of GM agriculture in Africa, as a means of achieving both food security and energy diversification. The adoption of GM crops offers Kenya and other countries the opportunity to further extract benefit from strong traditional export markets such as the EU. The objective of this article is to analyze Kenya's biofuel export potential specifically for the EU market demonstrating the potential for GM crops to boost economic returns for African farmers (given strong existing trade relationships between the EU and Kenya, the EU market is the focus of this article; there may well be other markets with considerable potential for biofuels produced in Kenya).

BACKGROUND

The biofuel policies of industrialized nations offer developing countries potential opportunities to foster rural development through increased biofuel exports. Countries such as India, China, Brazil, Indonesia and Argentina are adopters of traits that are used, or available for use, in biofuel production to some degree. Pray et al. (2006) argue that India and China have the most developed regulatory and biosafety systems in the developing world. The demand for biofuel feedstocks would encourage producers to increase output by bringing 'idle' land into production, especially if the traits of GM biofuel feedstock crops increased productivity. Potential traits such as drought tolerance or increased salinity tolerance provide such potential. As observed by Smyth et al. (2011) 41% of GM canola in Western Canada is produced on erodible land. Agronomically, perennial crops, such as switchgrass and miscanthus that can be used for biofuel production, have the potential to improve environmental quality (Scheffran and BenDor, 2009).

Competition over land resources used to produce energy and food crops has led to policy revisions in both the EU and US. The amended biofuel policies contain sustainability provisions to mitigate any negative externalities that may occur from biofuel production, notably, food insecurity and environmental degradation, such as deforestation. Sustainability provisions contained in developed country legislation includes GHG emission savings requirements and capacity constraints in terms of land use. These requirements arose out of the food versus fuel debate as competition over resources to produce crops for biofuel production was an important contributing factor to the spike in food prices that occurred in 2008 (Hailu and Weersink, 2010). Given the food price increases brought about by higher biofuel production, policy makers in the EU and US revised their biofuel policies to be 'food friendly' (Williams and Kerr, 2011).

The Roundtable on Sustainable Biofuels (RSB) is a multi-stakeholder organization hosted by the Swiss Federal Institute of Technologies in Lausanne (EPFL) that provides and promotes a global standard and certification scheme for socially, environmentally and economically sustainable production of biomass and biofuels. The certification issued by the RSB satisfies the requirements of the EU RED. As a result, its principles can be used as a guide or proxy for sustainable conversion of biomass, particularly, land use. The 12^{th} Principle of the RSB states that biofuel operations shall respect land rights and land use rights. The need to secure or bolster these rights stems from the likelihood of capacity expansion through infringement of the rights of other users, especially in jurisdictions with weak institutions. An example of the expansion of biofuel crop capacity infringing on land rights is illustrated by the case of Kenya's Tana Delta. According to the United Kingdom's Royal Society for the Protection of Birds, the delta is home to 350 species of birds, including the globally threatened Basra reed warbler and the Tana River cisticola. The area also hosts lions, hippopotami, elephants, rare sharks and reptiles including the Tana writhing skink, as well as endangered primate species. Therefore, the introduction of biofuel crop production into the delta may put these wildlife population, some of which are already considered endangered, at risk. The production of biofuel in Kenya is encouraged by the incentives arising from the policies of developed countries such as the EU and US, which have imposed consumption mandates on their respective markets. Williams (2011) shows that the import potential in the EU and US arising from their biofuel policies amounts to 24.6 and 79 billion litres (bl), respectively. These large quantities suggest expanded export opportunities for developing countries, provided they are able to satisfy the sustainability conditions specified in the policies, including those for land use.

The adoption of GM crops on a large scale in Africa offers the continent the opportunity to be an important player in the international trade of biofuel. Novy et al. (2011) argue that multiple factors influence adoption by African countries. The factors include wealth, organic agri cultural area, colonial ties, (the EU which includes all the former African colonial powers in its membership is a major trading partner for Africa stemming from free trade agreements that arose from colonial era trading patterns and commercial ties; the EU has, for the most part rejected the use of biotechnology in agriculture and bans the importation of GM crops that have not been approved in the EU) (Viju et al., 2012) past rejection of GM technology and the percentage of the country under land protection. Through ordinary least squares (OLS) regression and correlation analysis, the authors show organic agriculture and GM agriculture are able to coexist within African countries such as South Africa. De Groote et al. (2004) show that the lack of adoption on a large scale in countries such as Kenya is based on environmental concerns, human safety and commercial feasibility, especially in periods of low grain prices. The EU is a major trading partner for Kenya through EC Regulation 1528 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2007R1528:20081209:EN:PDF).

Kenya, for the most part, exports agricultural commodities such as, fruits, vegetables and cut flowers to the EU. These products account for 90% of the value of exports (http://www.kenyabrussels.com/index.php?menu=6&leftmenu=87&page=91.). The main driver of exports to the EU is the horticultural sub-sector, with overall exports valued at US$1.3 billion in 2008 (Kenya, Ministry of Trade, 2012). European Commission (EC) Regulation 1528 exempts Kenya's exports to the EU from tariff and Tariff Rate Quota restrictions making the EU the second largest export market after the Common Market for Eastern and Southern Africa (COMESA) (Kimbugwe et al., 2012). Swinbank (2009) argues that most ethanol is imported at a zero tariff rate from developing countries due to the super-Generalised System of Preferences. As such, the strong trading relationship between Kenya and the EU makes large scale adoption of GM food crops economically unattractive given the EU's resistance to GM products.

A study by Constant (2011), examines the effects of jatropha production on food security in Mali. Constant argues that jatropha biofuel production can have positive and negative impacts on agriculture in major potential production areas in Mali due to agricultural inputs competing and complementing each other. The competition for land is likely to result in higher production costs and threaten food security. The complementariness is expressed in job creation and carbon sequestration. Therefore, capacity improvements arising from GM crops affords African countries the ability to reap the benefits from biofuel policies such as the EU RED; a policy that creates a demand for their product that is unlikely to exist otherwise but imposes capacity constraints in the form of land use restrictions on producers both within and outside the EU.

Consumer attitudes have been the driving force behind the EU's stance on GM products (Gaisford and Kerr, 2001). Friends of the Earth Europe have challenged the appropriateness of GM crops on the grounds that they threaten ecological farming and 'quality food' production (Friends of the Earth Europe, 2006). Scientific and policy debates on GM crops in the EU have focused on speculative risks and less on the possible positive agronomic and economic impacts on farmers (Phillips et al. 2006; Gómez-Barbero et al., 2008). These authors consider GM crops to be an insurance against crop damage. Finger et al. (2011) showed that *Bacillus thuringiensis* crops result in yield gains due to reduction of agronomic stresses, such as insect pressures. Although *B. thuringiensis* crops may improve the welfare of farmers by mitigating crop losses, opponents to GM agriculture base their position on speculative risks pertaining to human health, herbicide and pesticide resistant weeds that endanger biodiversity. With regards to risks of biodiversity, the benefit of yield increases would enhance biodiversity in the case of Kenya's Tana Delta as GM crops could reduce biofuel production in the Tana Delta. Biofuel crops are unlikely to face human safety concerns given that they do not enter the food supply chain. Therefore, the EU's stance on biotechnology-based biofuels from an agricultural trading partner would likely rest on environmental concerns; that is, the product satisfies the sustainability criteria, and provenance of coexistence (coexistence is the premise that the production of conventional, genetically modified and organic crops can be done in such a manner that the sales opportunities for the respective farmers are not affect; that is, coexistence is capable of managing, or minimizing, the likelihood of variety/product comingling); the absence or acceptable presence of unauthorized GM crops destined for the European food supply chain.

REGULATORY AND BIOFUEL LANDSCAPE

Kenya's Energy Act (2006) promotes the development of renewable energy technologies including biofuels. The strategy includes expanding domestic capacity through the use of waste and cellulosic conversion. The Biosafety Act of 2009 provides the legal and institutional frameworks for governing modern biotechnology in Kenya. Specifically, the Act aims to accomplish the following:

1. Facilitate responsible research and minimize potential risks that may be posed by modern biotechnology activeties including GMOs.
2. Ensure an adequate level of protection in the field of safe transfer, handling and use of GMO's that may have an adverse effect on human health and environment.
3. Establish a transparent science-based and predictable process to review and make decisions on modern biotechnology activities.

The current regulatory framework and trade opportunities that exist in traditional export markets, such as the EU, provide potential advantages for Kenyan biofuel stakeholders.

The two major biofuels currently produced commercially are ethanol and biodiesel. These fuels are derived from biomass or waste. The conversion of these raw materials requires technologies which are currently commercial infeasible on a large scale given the significant costs attached, especially for developing countries. Therefore, given current technology, the main biofuels produced and consumed are food-derived, such that sugar and corn are the main inputs for the production of ethanol while vegetable oils derived from sunflowers and soybeans are used for producing biodiesel.

The Kenya Economic Review of Agriculture (2010) reports a six percent increase in sugarcane production for 2009. However, the report indicates that production costs are among the highest on the African continent, posing a barrier for developing the domestic biofuel industry. If Kenya is able to lower its sugarcane production costs, sugarcane derived ethanol offers some benefits as has been demonstrated by Brazil.

Brazil is the second largest producer of sugar cane ethanol. With regards to GM crops, Brazil is an adopter of GM corn and soybeans, and Brazilian soybean production meets the EU sustainability criteria pertaining to GHG emissions (Lendel and Schaus, 2010). India and China are primarily producers of ethanol by using alternative inputs such as corn, cassava and molasses, a by-product of sugarcane. For these developing countries with large populations, the threat to food security associated with advances in biofuel production is a credible concern. As a consequence, the approach to further developing the biofuel industry involves commercialization of second and third generation biotechnologies. These technologies are currently used in production at a very small scale, demonstrating that economies of scale are not currently present.

In 2011, the International Energy Agency (IEA) reported that while advances have been made with second generation cellulosic ethanol technology, given the first large-scale, plants are now coming into production; however, none are at a commercial scale. By 2012, the situation had changed somewhat with both Iogen (Iogen press announcement:http://www.iogen.ca/news_events/press_releases/2012_04_30_refocus.pdf.) and British Petroleum (BP press announcement: http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7079431) announcing plans to cancel the construction of large-scale cellulosic ethanol plants in North America. With regards to biodiesel, hydrotreated vegetable oil is produced by hydrogenating vegetable oils or animal fats. The first large-scale plants have been opened in Finland and Singapore, but the process has not yet been fully commercialized (Bacovsky et al., 2010). Third generation biofuels derived from algae, in the long term, may prove to be a competitive biomass alternative, given the potential benefits of high productivity per hectare (Darzins et al., 2010). However, these technologies are far from large-scale commercial production. Thus, in the long-term, these 'food friendly' technologies may prove a worthwhile alternative but in the short to medium-term, first generation technologies will likely remain the most commercially viable of the three.

In the case of Kenya's corn production, one of the main food crops for producing ethanol, output increased by 3.1%, but with lower average yields of 1.63 tonnes per hectare (ha) in 2009. Table 1 shows Kenyan corn production for the years 2005 to 2009. Although, the production area has remained relatively constant for this period, yields have decreased significantly with yields declining by 26% in 2008. Smale and Olwande (2011) showed that from 1990 to 2009, the growth rate of production decreased to 0.845 due to a negative growth rate in yield, which was partially offset by an expansion in crop area. These compare unfavourably with a growth rate of 3.3% (44 percent of the growth attributed to yield as compared to expansion in area) for the 1965 to 1980 period. Therefore, it is expected that limited opportunities to expand productive areas may be offset by a positive growth in yield from GM crops.

It is clear that Kenya's yields are significantly lower than those typical in the US and Canada, which are both producers of corn-based biofuel and users of transgenic technologies. The pest problem of stem borers is a major

Table 1. Kenyan corn production, 2005-2009.

Year	2005	2006	2007	2008	2009
Area(ha)	1,760,618	1,888,185	1,615,304	1,793,757	1,885,071
Production (tonne)	2,964,984	3,299,893	2,975,791	2,407,593	2,482,022
Average yield (tonne/ha)	2.0	2.1	2.3	1.7	1.6

Source: Kenya Economic Review of Agriculture, 2010.

constraint to higher corn production in Kenya as losses due to stem borers represent approximately 13% of potential yield (De Groote, 2002). One approach Kenya could pursue to increase production of biofuel crops is to bring 'idle' lands into production, although this is constrained by the amount of land available. A viable alternative would be to increase yield through the application of biotechnology. Genetically modified crops are dominated by two traits, insect resistance and herbicide tolerance. The direct impact of GM crops on yields has been thoroughly assessed. In a meta-analysis of 203 publications, Finger et al. (2011) argued that GM seeds do not increase yield *per se* because insect and herbicide traits are not designed to increase crop yield potential, but actually reduces the loss in potential yield caused by pest damage. Therefore, yield improvement will depend on the level of crop management practiced and prevailing pest pressure. Kenya's yields are inhibited due to poor pest control, making the benefits of adoption higher than in a country with better pest control. In essence, higher yields will result from using GM seeds but the magnitude of the yield improvements will vary.

The cost to acquire GM seeds may also be an adoption barrier if it results in commercial infeasibility due to unprofitability. Gómez-Barbero et al. (2008) suggested that the economic impact of higher yields plus small pest control cost savings is sometimes offset by higher GM seed prices. However, using the GM crop for energy purposes may not suffer from infeasibility given the high prices for biofuels arising from the mandate policies of the EU and US. The likely differential is narrowed by the expected higher price for crops, especially if high oil prices prevail. In addition, a positive externality of GM derived biofuel is the release of land resources for production of food, which would have been otherwise used for the production of perennial crops such as switchgrass as biofuel inputs. An export market such as the EU provides a premium for second generation biofuel; that is, biofuels made from wastes, residues, non-food cellulosic material and lignocelluolosic material, which provides farmers an incentive to adopt GM non-food crops.

The European Union's renewable energy directive

Although, the EU is the leading producer of biodiesel in the world, the opportunity may arise for exporters to supply the EU market due to the capacity constraints of some member states. However, the EU RED provisions relating to land use and GHG emissions must be satisfied in order for the biofuel to be counted towards the mandate, whether produced from GM crops or non-GM crops.

The EU RED requires that 20% of overall EU energy consumption be sourced from renewables and a mandatory ten percent minimum target for all member states for the consumption share of renewable energy in transportation. The EU mandate is a target, which is expected to reach 40.2 million tonnes of oil equivalent (MTOE), of which 23 MTOE will likely be met through imports (Williams, 2011). Paragraph 18 of RED defines the ten percent target as that share of final energy consumed in transport, which is to be achieved from renewable sources as a whole, and not solely from biofuels. In addition, second generation biofuels contribution to the target is twice that made by other biofuels (Article 21(2)).

The sustainability criteria for biofuels are laid out in Article 17 of the RED and discussed below. However, biofuels produced from waste and residues, other than agriculture, fisheries and forestry residues only need to satisfy sustainability criterion A (Article 17). The sustainability criteria that apply to EU produced renewable energy and imports are set out as follows: A. GHG saving (see Annex V of the RED for typical and default GHG saving values by production pathway if no net carbon emissions is from land use change) is at least 35%, increasing to 50%, effective January 1 2017 and further increasing to 60%, effective January 1 2018 (Paragraph 2). Biofuels produced by 'installations' that were in operation as of 23 January 2008 are exempted from complying with this criterion until April 1 2013. In the case of a production pathway with a typical (a typical value means an estimate of the representative GHG savings for a particular biofuel production pathway (Article 2(n))) or default (default value means a value derived from a typical value by the application of pre-determined factors and that may, in circumstances be specified in the Directive, be used in place of an actual value (Article 2 (O)), GHG saving value below the minimum GHG emission saving rate, producers may calculate the actual value (Lendle and Schaus, 2010). If the actual value is at least the required saving rate, this type of biofuel would have satisfied the GHG emissions savings of the sustainability criteria B. Are not produced from raw materials obtained from land with high biodiversity value (a draft consultation document on the criteria and geographic ranges to determine which grassland can be considered to be highly biodiverse grassland is available at http://ec.europa.eu/energy/renewables/consultations/doc/2010) and high carbon stock (Paragraphs 3 and 4).

C. Are not produced from raw materials on peatland in January 2008 unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil (Paragraph 5).

The exceptions to the land use criteria B and C allow the extraction of raw materials from wetlands as long as the status of the land is unchanged and the soil was completely drained in January 2008 or has not been drained since January 2008 in the case of peatland (Sec 4 2010/C160/02) (Communication from the Commission on the practical implementation of the EU biofuels and bioliquids sustainability scheme and counting rules for biofuels.). The criteria restrict production and processing methods by imposing land specificity requirements for biofuel production but the criteria do not restrict the production of biomass through GM methods. Therefore, authorized GM varieties for feed and food may be used to produce biofuels. In addition, suppliers of unauthorized GM varieties or GM varieties that are expected to go through a protracted regulatory approval process in the EU for human consumption may be used to produce biofuel as a circumvention measure by GM firms given that the EU policy for GMOs is only applied to food and feed. For example, Brazil was able to circumvent the US tariff of $0.54 by up to seven percent of US production and gain greater market access by using Caribbean Basin Initiative (The Caribbean Basin Initiative allows duty-free access to US market for a number of Caribbean countries products including fuel ethanol under certain conditions. Ethanol produced from at least 50% local feedstocks may be imported duty-free. If the local feedstock content is lower, limitations apply on the quantity of duty-free ethanol. In the case where 100% foreign feedstock is used, duty free access of ethanol produced from the feedstock is allowed up to 7 percent of US production. (http://www.nationalaglawcenter.org/assets/crs/RS21930.pdf) countries such as Jamaica as an intermediate destination for the refining of ethanol destined for the US. Applying this example to Kenya, would then mean that if a particular GM crop is restricted from the EU food/feed market but the same crop can be used to produce biofuels (EU GM policy does not restrict GMO use in producing biofuels), then a possible strategy would be to divert the crop to the fuel market away from the food/feed market. On this note, a brief review of the EU policy on genetically modified organisms (GMOs) is provided given the fact that Africa is an agricultural import market for the EU and the potential risk of comingling GM presence in food and feed as a result of using GM crops for fuel purposes.

European Union's policy on GMOs

The EU GM policy regulates GMOs for food and feed use, food and feed containing GMOs and food and feed produced from or containing ingredients produced from GMOs. Regulations 1829/2003 and amendments 2006 and 2008 set out the EU's framework for GM food and feed. These regulations provide a centralized procedure for authorization of GM food and feed, rules for the labelling of GM food and feed and a threshold for the presence of GM material that is adventitious or technically unavoidable (Dayananda, 2011). The threshold for adventitious or technically unavoidable presence of approved GMOs in food and feed is 0.9%, which requires that food and feed with more than 0.9% of approved GM material must be labeled GM (European Commission, 2006). The EU has a zero tolerance policy on unapproved GM varieties in food and 0.1% tolerance threshold for feed, provided the feed variety has been submitted to the EU for variety approval. The European Commission (EC) must authorize a particular GM variety for food or feed use before it can be sold or introduced in the domestic market (Article 4(2) and Article 15(2), Regulation EC 1829/2003). The cultivation of GM crops within the EU on a commercial level is observable in a few member states including Spain and Portugal. Therefore, given that it has been established that both the EU biofuel and GM policies do not limit the use of transgenic technologies in biofuel production, the trading of GM biofuels between the Kenya and the EU is discussed below.

Only biofuels that meet the sustainability criteria will be counted for the ten percent mandate for the use of biofuels in transportation. Furthermore, the premium for sustainable biofuels (Williams, 2011) encourages international trade in the long run as foreign firms seek to benefit from the inflated price of biofuels in the European market.

Trade in biofuels

The increased demand for renewable fuels in the EU arising from the RED provides an opportunity for its existing trade partners, particularly Africa. The EU renewable energy market is dominated by biodiesel production and consumption. As discussed above, Brazil, Argentina, China and India are developing countries which have made noteworthy investments in developing domestic biofuel Industries. Olz and Beerepoot (2010) argued that favourable conditions for biomass cultivation, along with economic and social factors, are expected to boost biofuel production in Southeast Asian countries such as Indonesia. The EU is a major market for Argentina and Indonesia produced biodiesel. Indonesia experienced a boom in biodiesel (derived from palm oil) exports to the EU with a reported 1,225 million liters in 2011 as compared to 563 million liters in 2010 (USDA, 2012). For China and India, the food insecurity risk posed by higher levels of biofuel production, and hence constraints on output, restricts these countries potential impact on international markets, especially that for biodiesel. In the case of Brazil, production is skewed towards ethanol destined for the US, a market that is receptive to GMOs.

Increased competition in the EU from foreign biodiesel would be expected to provoke resistance from vested interests. This response would most likely arise from erosion of EU biodiesel crop producers' market share, causing them to raise concerns about the authenticity of sustainable land use and coexistence regimes in developing countries. In Kenya's case, production of crops to be used as biofuels may threaten other agricultural exports if concerns regarding coexistence and the comingling of unauthorized GM crops in non-GM exports are not satisfactorily addressed. Vested interests in the EU may use imported biofuels as a means to protect the agricultural sector by claiming possible contagion of food crops due to the production of biofuels in the country of origin. For example, in a public consultation on biofuel policy in the EU, Friend of the Earth Europe (2007: 2) stated that GM crops should not be permitted in the production of biomass due to "unacceptable health and environmental concerns as well as lead to the further intensification of agriculture and increase corporate control of agriculture" (there is no reference to a peer-reviewed publication that supports these claims in this document from Friends of the Earth). This type of approach alludes to the 'precautionary principle', defined as "those specific circumstances where scientific evidence is insufficient, inconclusive or uncertain and there are indications through preliminary objective scientific evaluation that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be inconsistent with the chosen level of protection" (European Commission, 2000: 10). Although, the 'precautionary principle' requires some scientific evidence or evaluation, Dayananda (2011) argues that the EU can still consider that the existing evidence is not sufficient, inconclusive or uncertain, raising the issue of a threshold for scientific evidence. Hence, the 'precautionary princeple' increases the risk for firms considering the EU as an export market for biofuel and they should be cognizant of such a possibility.

Although the US biofuel policy provides export opportunities in alternative energy for developing countries, Williams (2011) shows that the blend wall, which is a technical constraint on demand known as E15, reduces the potential of trade opportunities for developing countries and, rather, may provide export opportunities for US producers. Furthermore, it is unlikely that the blend wall will be lifted/removed in the short run given the lag in putting in place capacity to produce new automobile engines compatible with higher levels of ethanol content in gasoline (Williams and Kerr, 2011). Therefore, the adoption of GM crops for energy purposes is ideal if producers are faced with 'limited capacity' and increasing demand for their product both domestically and internationally; arising from the EU biofuel policy–a value of trade estimated to be US$16.5 billion (Williams, 2011).

ANALYTICAL FRAMEWORK AND DISCUSSION

This section discusses a partial equilibrium model of potential biofuel trade between the EU and Kenya facilitated by GM adoption. The US demand for foreign biofuels is constrained by the blend wall (BW). The US and EU markets are the largest for ethanol and biodiesel, respectively, by virtue of the biofuel mandates. The US embraces GMOs exhibiting wide-scale adoption, while the EU aversion to GM crops is well documented. Therefore, our model explores the application of GM crops in biofuel production in a developing country (Kenya) and the export potential to the EU given the strong trading relationship. The left hand side partial-equilibrium diagram in Figure 1 illustrates the EU market for transportation fuel with a ten percent biofuel blending mandate and the right side represents the supply of biodiesel in Kenya meeting the sustainability criteria of RED. In building the model, a number of assumptions were made:

Assumptions

1. The model focuses on biodiesel satisfying the renewable fuel share in transportation of ten percent by 2020.
2. The price of biodiesel in the EU is higher than the world price of diesel due to compliance costs (Williams, 2011).
3. Biodiesel is a substitute for petroleum-based diesel.
4. The cost to produce biodiesel from GM crops is profitable. Hence, it is commercially viable to produce biodiesel derived from GM crops.
5. Coexistence regimes in Kenya meet EU standards. Hence, the EU recognizes the coexistence regime as one that satisfactorily segregates GM crops for the fuel supply chain and non-GM crops and/or approved GM crops for the food supply chain. Therefore, Kenya can successfully trade both agricultural and food-based energy products with the EU.
6. Supply of diesel is elastic. Suppliers will be able to meet an increase in demand for diesel by using oil in the short run and the EU can easily import more oil to satisfy increased diesel demand.
7. Imports are expected to supplement domestic production required to meet the blending mandate, that is, no waiver of the mandate will be granted due to shortfall in production by member states.

Figure 1 shows the potential impact of increased imports on the EU domestic industry as a result of Kenya's biodiesel export potential supported by the adoption of GM crops. The demand curve is Dd for pure and/or blended diesel as biodiesel and petroleum-based diesel are substitutes for each other. Sd is the supply of pure and/or blended diesel as biodiesel and petroleum-based diesel are fuel substitutes. At the intersection of Dd and Sd is the quantity of diesel consumed, Qd and the price of diesel in the EU is Pwd.

In Panel A of Figure 1, Sbd is the supply of biodiesel, which meets the sustainability criteria, that is produced within the EU. At Pa, the mandate is met domestically thus resulting in autarky as foreign producers are unable to supply the EU market due to compliance costs resulting

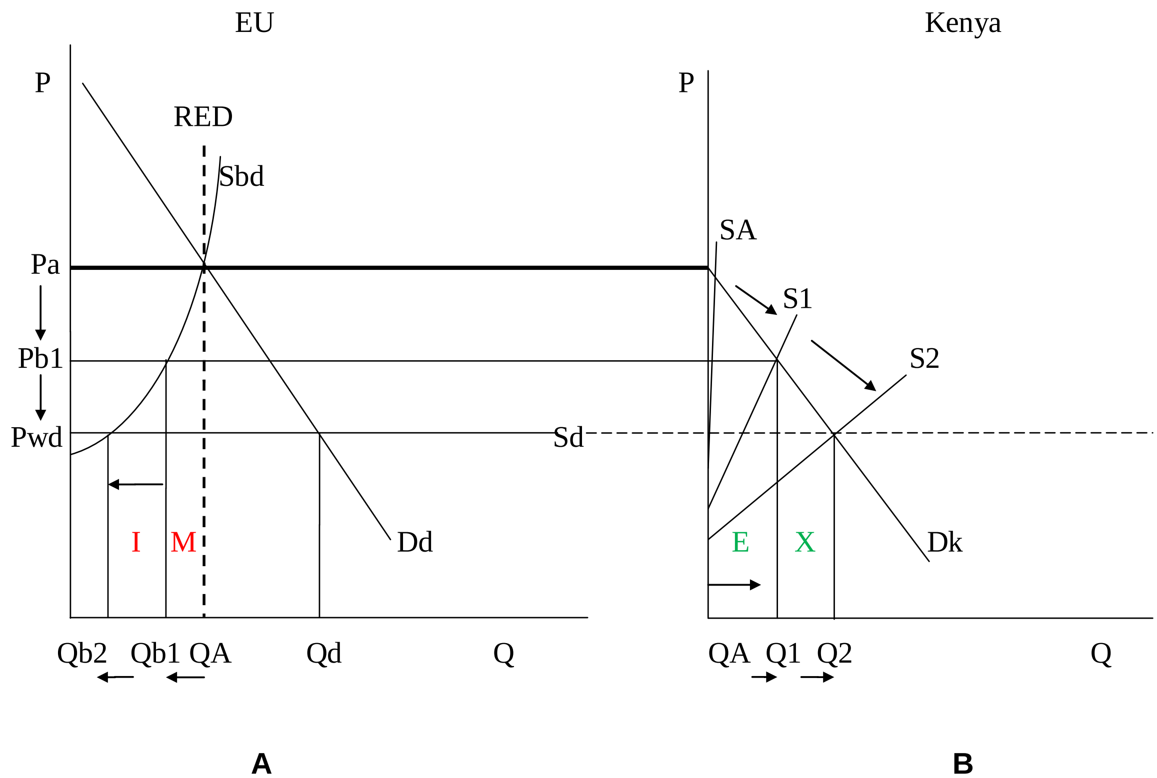

Figure 1. Impact of foreign biodiesel on EU market for transportation fuel.

resulting in a decrease in supply, thus, raising the price of biodiesel higher than the price for diesel (Williams, 2011). At pb1, the mandate is met through a combination of domestically produced biodiesel, Qb1 and imports given the ability of some foreign producers to supply the EU market regardless of compliance costs. Therefore, area M represents the imports needed to satisfy the ten percent mandate at pb1.

In Panel B of Figure 1, SA represents the export supply curve of Kenya to the EU when producers in the EU can completely meet the mandate at Pa. As QA = 0, Kenya does not supply the EU given that compliance costs have the potential to be effective trade barriers. However, the adoption of GM biofuel crops by Kenyan producers that are able to absorb compliance costs and supply (export) biodiesel to the EU are represented by S1 due to the lower production costs arising from the use of GM crops.

The demand for Kenya's biodiesel by the EU is represented by Dk. Domestically produced biodiesel competing with foreign produced alternatives (Q1) places downward pressure on the price of biodiesel in the EU, as illustrated at Pb1. As the competition intensifies between domestic and foreign sources of biofuel (in 2011, the European Biodiesel Board reported that EU production decreased for the first time in history. The Board credits the decline to increased imports from Argentina, Indonesia and North America. Source: http://www.ebb-eu.org/pressdl/BlackSeaGrain%20Oct 2011.pdf) given the benefit of supplying the EU exceeds the cost for Kenyan producers, the supply curve shifts further right to S2 (higher GM adoption) and the quantity supplied by Kenya is Q2. As exports increase to Q2, the price of biodiesel in the EU approaches the world price for diesel, pwd and the RED is a no longer a binding mandate. At pwd, EU consumers benefit by lower prices for fuel but domestic production is reduced due to the inability of some EU producers to compete at pwd; at Qb2.

The model shows the likely effects of successful marketing of biofuels by Kenyan biofuel exporters in the EU market. For EU consumers, an increase in consumer surplus and a decrease in producer surplus are observed. As increasing compliance costs lead to a binding mandate; the price of biodiesel is higher than the price for diesel, increased exports by Kenya supported by the GM adoption place downward pressure or narrows the gap between the two prices.

The degree of successful adoption depends on the ability of producers in African countries to convince the EU that they are able to manage coexistence satisfactorily. It is expected that the proof of coexistence and segregation costs may very well result in biotech based biofuel being commercially infeasible. Nevertheless, the prospect for foreign producers to benefit from RED is enhanced by the inability of producers in the EU to compete with increased supplies of more cost effective biofuels, notably biodiesel.

CONCLUSION

A key point made by this article is that even though biofuel policies create significant demand for green technology, the EU RED simultaneously limits the way this demand can be met. Constraints on supply require improvements in the efficiency of current production resources. One approach to improving the efficiency of the agricultural sector is the application of GM crops.

Williams (2011) shows that countries with abundant land may have a competitive advantage due to the EU RED capacity constraints. Nonetheless, developing countries such as Kenya may have abundant land but are unable to exploit this competitive advantage due to food security concerns arising from the competition between food and fuel over crop production resources. Furthermore, the competition is intensified if a significant portion of the ‘abundant land’ is disqualified from growing biofuel inputs by virtue of the capacity constraints found in the EU RED. Therefore, countries facing this dilemma can still be competitive in the biofuel export market by adopting transgenic technologies which proffer to increase crop yield, thus, increasing supply without an expansion in production areas. Hence, it is argued that prospective biofuel suppliers in Kenya can improve efficiency through transgenic technologies in order to be competitive in the biofuel market and mitigate the negative social and/or environmental effects resulting from the intensified competition between food and fuel for scarce crop production resources.

For developing countries, the positive outcomes of adopting GM technologies involve benefitting from a trade estimated at US$16.5 billion (2010 dollars) and the multiplier effects of advancing rural development as well as a vibrant domestic biofuel industry. A negative outcome is the potential closure of borders by, for example, Germany and France; the two largest biodiesel producers in the EU and main export markets for Kenya’s agricultural products, including horticulture valued at US$1.3 billion in 2008, due to the comingling of GM material in food or feed in contravention of the EU GM policy. In essence, the likely outcome for Kenya rests on the level of infrastructural and technological investments, including those into transgenic crops for agriculture and the biofuel Industry, as well as EU recognition of its coexistence regime.

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