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GLOBAL BIOFUEL POLICIES: A REVIEW

G.D. Sparks* and G.F. Ortman**

ABSTRACT

Global biofuel production has risen substantially in recent years, principally driven by government support for these industries. The stated motivations for these initiatives are numerous and have varied over time. This article presents a review of some important economic aspects of the most widely used biofuel and related policies around the world, and provides some theoretical and empirical evidence of these initiatives. The South African government's current biofuel policy stance is also evaluated, with concerns expressed over the fact that the commitment to the White Paper on Renewable Energy (DME, 2003) is not binding. Continued technological advancements, infrastructure development, and government interventions will be central to the future developments of biofuel industries, both locally and globally.

Keywords: biofuel production, policy, economic impacts

1 INTRODUCTION

Rajagopal and Zilberman (2007) point out that there has been an extensive history of dependence of alternative energy technologies on sustained governmental support in order to be competitive with fossil fuels in the marketplace. Biofuels are no exception, with government intervention in bioethanol markets dating back to 1978 in the United States (US) (Gardner, 2007; Tyner, 2007; Tyner & Taheripour, 2007, 2008b), in the form of subsidies, federally-funded research, and quantity mandates (Khanna *et al.*, 2008). Similarly, Brazil, now a well-established producer and consumer of bioethanol, promoted the development of its bioethanol industry through the National Alcohol Program (PROALCOOL) which was launched during the mid-1970s (Elobeid & Tokgoz, 2008). Sustained governmental support, therefore, has undoubtedly been an essential feature of the development of the biofuel industries in many of the present global market leaders in biofuel production (Coyle, 2007; Worldwatch Institute, 2007; Meyer *et al.*, 2008), particularly in the US, Brazil and the European Union (EU), where biofuel production has been most significant (Coyle, 2007; Worldwatch Institute, 2007).

* Master's candidate in Agricultural Economics, School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal, Pietermaritzburg. Email: sparks@tsb.co.za.

** Professor of Agricultural Economics, School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal, Pietermaritzburg. Email: ortmann@ukzn.ac.za.



The stated motivations for these legislative initiatives are numerous and have varied over time (Tyner, 2007; Worldwatch Institute, 2007). Among the most prominent of these are to address broad societal objectives, including concerns over energy security, goals to improve environmental quality, decreased traffic congestion, reductions in the tax costs of farm subsidy programmes, improving farm incomes and enhancing rural economic development (Coyle, 2007; Rajagopal & Zilberman, 2007; Tyner & Taheripour, 2007; Worldwatch Institute, 2007; Khanna *et al.*, 2008; De Gorter & Just, 2009a, 2009b).

Furthermore, Coyle (2007) suggests that governments tend to introduce supports to assist new and developing biofuel ventures in order to overcome both cost and scale disadvantages, as well as combating the inherent volatility in profits. This is essentially the “infant industry” justification for the use of subsidies. Martinez-Gonzalez *et al.* (2007) contend that since fossil fuel production is typically more price competitive than the production of biofuels, government intervention is necessary in order to compensate for this gap in price competitiveness. This is attributed to the fact that under current available technologies, the costs associated with producing crops and converting them to biofuels are too high for them to compete with fossil fuels on a commercial basis without active governmental support to promote both their development and use (FAO, 2008). US bioethanol policy in particular has stimulated considerable debate as to its effectiveness in solving the host of policy issues listed above (De Gorter & Just, 2008a, 2008b). It should also be noted that many countries intervene in both agricultural and energy markets (FAO, 2008).

The literature surrounding the potential implications of biofuel policies is still in its developmental stages (Rajagopal & Zilberman, 2007; Worldwatch Institute, 2007), with studies typically being either theoretical or simulation based, and usually concentrating on predicting the impact of reaching a particular biofuel target on a relatively small set of indicators (Rajagopal & Zilberman, 2007). Similarly, Banse *et al.* (2008) criticise that many models do not explicitly account for oil prices, restrict the policy measures to biofuel blend mandates, and often lack international trade considerations of biofuels. Rajagopal and Zilberman (2007) note further that there is a distinct lack of econometric evaluations of biofuel policies, and attribute this to problems, such as relatively short time-series data, and difficulties in determining causality and isolating the effects of individual policies. In a similar regard, Gardner (2007) notes that supply and demand parameters for bioethanol are difficult to estimate with precision since only a limited time period of market data are available, and these are under favourable structural conditions for bioethanol use (i.e., technology, institutions and regulations). A similar view is held by Elobeid and Tokgoz (2008).

The rapid growth of biofuel production in recent years has stimulated considerable and growing deliberations over how policy changes will continue to influence this emerging industry and associated spillover effects into other markets (Elobeid & Tokgoz, 2008). The importance of the correct set of biofuel policies has been noted by numerous authors, with the vast majority of published applications focusing specifically on the US bioethanol industry (Gardner & Tyner, 2007; Meyer *et al.*, 2008), very recent examples of which include De Gorter and Just (2009a, 2009b) and De Gorter *et al.* (2009). Similarly, De Gorter and Just (2008a) note that the potential misalignment of policy effects and stated objectives can pose serious difficulties for policy analysis, and emphasise the importance of the fundamental underlying economics of these policies. While numerous policy tools exist that could be used to achieve desired objectives, the cost effectiveness as well as the distributional implications of each will vary, creating both winners and losers among economic agents (Rajagopal & Zilberman, 2007). Accordingly, Parcell and Westhoff (2006) suggest that an understanding of how the economic costs and benefits from biofuel production are distributed is valuable when assessing future expansion of biofuel production, and establishing future biofuel policy.

The following section evaluates the rationale for government intervention in biofuel markets. In section 3, the economics of the more prominent global biofuel policies are discussed, with the subsequent section providing both theoretical and empirical implications of these initiatives. Thus, this article not only provides an analysis of various biofuel policy alternatives that are in effect around the world, but also strives to draw attention to their associated strengths and weaknesses, as well as the associated distributional effects. The article ends with a discussion and some conclusions. The primary objective of this article, however, is to provide a comprehensive and summarised compilation of economic literature surrounding the global biofuel policy spectrum.

2 THE RATIONALE FOR GOVERNMENT INTERVENTION IN BIOFUEL MARKETS

Rajagopal and Zilberman (2007) suggest that normative welfare analyses and political economic theory are the two most prominent methods used to explain the rationale for government intervention. The welfare maximisation argument, or alternatively the market failure hypothesis, is consistent with the view that government intervention can enhance allocative efficiency (Pasour & Rucker, 2005). Khanna *et al.* (2008) suggest that economists are typically in favour of government intervention in the market when there are market failures, such as those resulting from environmental externalities. Accordingly, Tyner (2007)

contends that biofuels present two forms of market failures, the first being that markets do not internalise the costs of energy security, and the second relating to environmental impacts of energy use, such as greenhouse gas emissions, which in turn are linked to concerns over global warming.

Additionally, Rajagopal and Zilberman (2007) suggest that market failure relating to biofuels may arise due to: (1) the generation of public goods, since research and development investments relating to the production and processing of biofuels may lead to knowledge spillovers, which are public goods, and subsequently result in an underinvestment by the private sector; (2) the protection of infant industries that are given special incentives and support to develop both skills and capacity; and (3) uncertainty, where investors may be inherently risk averse, while government may be risk neutral. Tyner (2007) postulates that in order to correct these market failures, government could introduce an additional, and substantially higher, tax on fossil fuels, subsidise alternatives to fossil fuels, or impose fuel standards that stipulate a minimum blend percentage of domestically produced alternatives to fossil fuels. Since the practicalities of an imposition of an increased tax regime are relatively complex (Owen, 2006), and are probably unlikely in many political contexts (Tyner, 2007), the focus of this article will primarily be on subsidies for alternative fuels and alternative fuel standards.

The second means to explain the rationale for government biofuel policy, as suggested by Rajagopal and Zilberman (2007), is from the political economic standpoint which proposes that public intervention is merely a demonstration of the rent-seeking behaviour of politicians, voters, lobbyists and bureaucrats. Environmental parties support biofuel use as a means of combating greenhouse gases; while venture capitalists, biofuel plant owners, manufacturers of biofuel processing equipment and plant facilities, crop farmers and their supporting agribusinesses all have large vested interests to protect, and potentially have a lot to gain from, a continued biofuel expansion and government protection (Herndon, 2008). With so many entrenched market participants, the removal of existing governmental support from biofuel markets could prove to be politically unpopular.

Rajagopal and Zilberman (2007) suggest that the market failure hypothesis, and associated social welfare arguments, implicitly assign equal weights for different economic groups. In this regard, however, Pasour and Rucker (2005) contend that the view that government initiatives can enhance efficiency is subjective and, therefore, economically indefensible as it would require making both value judgements and interpersonal utility comparisons. In contrast, Rajagopal and Zilberman (2007) suggest that the political economic approach typically assigns different weights to different economic groups. Subsequently, these authors advocate that the current set of biofuel related policies appear to be

designed to benefit political constituencies, rather than maximise welfare and/or environmental objectives. Similarly, De Gorter *et al.* (2009) propose that policies in the form of biofuel tax credits, biofuel import tariffs, and production subsidies exist primarily due to non-economic objectives.

Rajagopal and Zilberman (2007) conclude that irrespective of the underlying motivations for public intervention in biofuel markets, the existence of market failures in energy markets is indisputable; and the goal of an effective policy should be to fully internalise any externalities, whilst paying due consideration to distributional effects. Owen (2006) suggests that the internalisation of externalities is likely to result in an increase in the cost of power generation from the combustion of fossil fuels, and, therefore, a relative improvement in the competitive position of an increasing number of renewable energy technologies. Finally, Hochman *et al.* (2008) emphasise the need for government biofuel policy to account for interactions between farm policy and energy policy, since agricultural commodity and energy markets have converged.

3 THE BIOFUEL POLICY SPECTRUM AND RELATED IMPLICATIONS

A wide variety of policy tools are available for government intervention in biofuel markets, most of which are intended to encourage domestic production and stimulate demand for biofuels. Moreover, biofuel development is affected by numerous national policies in multiple sectors – including agriculture, energy, transport, environment, trade, and broader policies influencing the overall “enabling environment” for business and investments (FAO, 2008, p.27). However, no individual policy provides an optimum solution under all circumstances. For example, Lichtenberg and Zilberman (1986) note that the efficiency of any policy approach is dependent on the presence of pre-existing market distortions (possibly resulting from other forms of governmental intervention), as these distortions may have considerable effects on the allocation of scarce resources. Rajagopal and Zilberman (2007) add further that the actual choice of biofuel policy will likely be dependent on various factors, such as government budgets, resource availability, the accessibility and cost of information, transaction costs, and political economic considerations. Figure 1 exhibits the various points along the biofuel supply chain where direct and indirect policy measures can provide support for the biofuel industry.

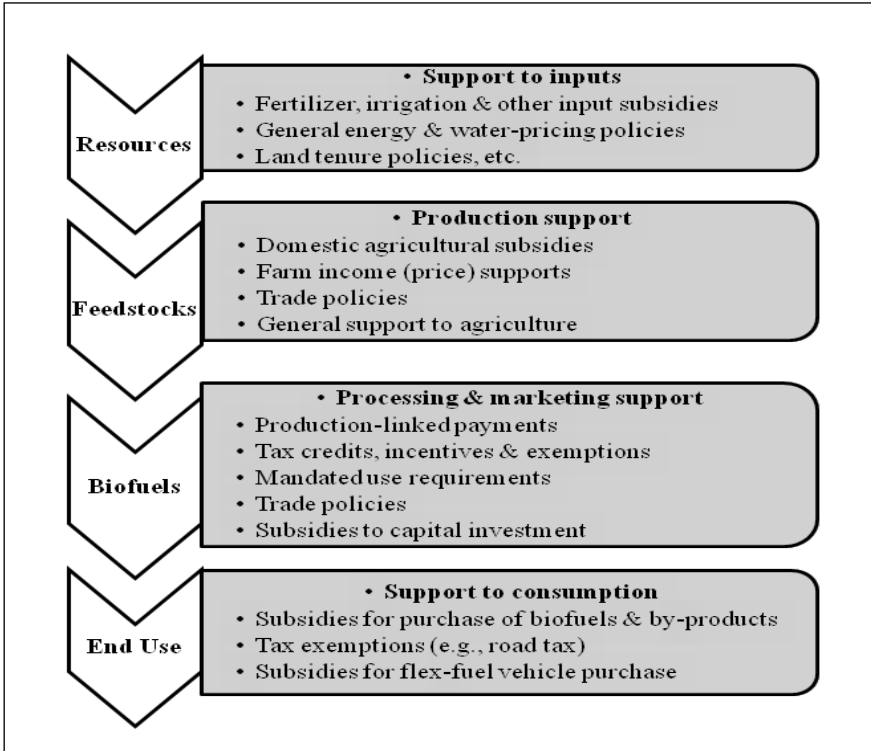


Figure 1: Government support at different points in the biofuel supply chain

Source: Adapted from FAO (2008, p.28)

Kojima *et al.* (2007, p.45) surmise that biofuel related policies around the world include the following:

- Fuel excise tax reductions or exemptions relative to taxes on fossil fuel products;
- Mandatory blending and/or consumption requirements;
- Import tariffs and/or quotas on biofuels, used in conjunction with preferential adjustments of tariffs and quotas for particular countries – primarily aimed at restricting access to benefits from biofuel promotion policies and favoured countries;
- Price supports intended to stimulate and increase biofuel production;
- Producer payments and tax credits linked to production;
- Investment incentives (e.g., grants, loans and loan guarantees), and tax-related incentives (e.g., tax holidays, accelerated depreciation and tax reductions);

- Grants and funding for research and development aimed at increasing the supply of biofuels;
- Downstream subsidies for vehicles designed to work using high-blend biofuels, and for storage facilities targeted at the infrastructural development of fuel production and consumption.

In the following sections, we evaluate the important characteristics of some widely used biofuel and related policies, of which excise tax credits, renewable fuel standards and mandatory blends appear to be most widely utilised. The implications that these policies have for economic welfare and, to a lesser extent, the environment are also evaluated.

3.1 Excise tax credit for biofuels

Most countries around the world levy a tax on the use of petroleum and diesel (Rajagopal & Zilberman, 2007). De Gorter and Just (2009b, p.738) define a biofuel tax credit as “a reduction (or elimination) of the fuel tax charged on sales based on the biofuel content”. A fuel tax reduction for biofuels, therefore, attempts to decrease the cost of biofuel relative to petroleum and/or diesel (Rajagopal & Zilberman, 2007). There appears to be consensus that reductions in fuel excise tax are currently the most direct and extensively used policy instrument to assist biofuels to compete with their fossil fuel counterparts (Kojima *et al.*, 2007; Rajagopal & Zilberman, 2007; De Gorter & Just, 2009a). According to De Gorter and Just (2009a), exempted or reduced biofuel excise taxes cover at least 65 per cent of total world consumption, and are known to be in effect in Argentina, Australia, Brazil, Canada, China, Columbia, the EU, Ghana, Honduras, India, Indonesia, Japan, Paraguay, Philippines, South Africa, Switzerland, Thailand, Uruguay and the US (DME, 2006, 2007; Kojima *et al.*, 2007; Rajagopal & Zilberman, 2007; De Gorter & Just, 2009a). However, the exact nature of these biofuel tax policies varies widely across countries (Rajagopal & Zilberman, 2007). Given the wide use of this policy instrument, De Gorter and Just (2009a) emphasise the importance of understanding the potential effects of such a policy on the markets for agricultural commodities, biofuels, fossil fuels, as well as the potential implications for economic welfare.

There also appears to be consensus that a biofuel tax credit alone essentially serves as a subsidy to biofuel producers (Rajagopal & Zilberman, 2007; De Gorter & Just, 2008a, 2008b), some of which may be passed on to the farmer (Rajagopal & Zilberman, 2007). De Gorter and Just (2008b, p.2) show that a “tax credit alone increases the market price of ethanol above the gasoline price by the level of the tax”; and serves as a taxpayer transfer to both domestic and foreign biofuel

producers. These authors further note that fuel consumers only indirectly benefit if oil prices decline with an increased supply of biofuels through the reduction in the average price of fuel. Thus, total fuel consumption may increase using this policy alternative. Schmitz *et al.* (2007) note that even a small decrease in the price of fuel translates into a large consumer gain because of the significant volume of fuel consumed. De Gorter and Just (2009a), however, suggest that the welfare effects of a tax credit depend on whether a given country is a large country importer or exporter in either the agricultural commodity used for biofuel production or fuel.

Biofuel excise tax credits may have adverse implications for government revenues, and the ability to use this policy instrument depends critically on both the presence and level of excise taxes levied on petroleum fuels (Kojima *et al.*, 2007; Rajagopal & Zilberman, 2007). Kojima *et al.* (2007) suggest that in countries where fuel taxes are relatively high, as they are in place primarily as a means to generate government revenue, a reduction in fuel taxes would likely have adverse effects on the fiscal situation. In this regard, Peters and Thielmann (2008) estimate that South Africa, among other countries, where between 20 and 25 per cent of total tax income originates from fuel taxation, could potentially lose in excess of 2 per cent of their national tax revenue if tax exempted biofuels were to displace 10 per cent of conventional fuels. Interestingly, Kojima *et al.* (2007) note that the tax rate levied on diesel is often comparatively lower than that of petroleum.

Tax subsidies are clearly effective in stimulating the production of biofuels, but fixed or unconditional tax subsidies have the risk of potentially transferring significant amounts of income to producers, particularly in the presence of high crude oil prices (Rajagopal & Zilberman, 2007; Tyner & Taheripour, 2008b). Tyner and Taheripour (2008b) highlight the possibility of introducing a variable biofuel subsidy that increases incrementally with corresponding decreases in the crude oil price. They estimate that under this regime biofuel production was markedly higher than under the fixed subsidy at relatively low crude oil prices. Similarly, Tyner and Taheripour (2007) analyse the possibility of implementing a two-part subsidy with a national security component (based on the energy content of the renewable fuel), and a component linked to the level of greenhouse gas emission reductions of the fuel. Rajagopal and Zilberman (2007, p.61) conclude that tax credits, which do not vary with changes in the crude oil price and do not have caps on production levels or “sunset clauses”, may result in a marked increase in the subsidy cost in the event that there is a structural break causing substantially lower oil prices or, alternatively, a large increase in biofuel production.

3.2 Renewable fuel standards and mandatory blending

While taxes and subsidies are essentially incentive-based approaches, numerous national and state governments exert a more direct control over fuel markets by

way of renewable fuel standards and mandatory blending requirements for biofuels (Rajagopal & Zilberman, 2007). Quantitative targets have typically been key drivers in the growth and development of most modern bioenergy systems (FAO, 2008). Thus, many governments around the world now require that a minimum percentage of transportation fuels sold should comprise biofuels (De Gorter & Just, 2009b). The exact nature of this requirement differs around the world with respect to the extent to which it is considered mandatory, the phase-in period, the amount or blend percentage mandated, and whether a national or regional strategy is implemented (Coyle, 2007). Winkler (2005) contends that governments' primary role should be to establish a quantitative target, and let the emerging renewable industry establish the most cost-effective way of meeting this objective.

Renewable fuel standards typically stipulate that the industry must acquire a certain percentage of its fuel from alternative domestic resources (Eidman, 2007; Tyner & Taheripour, 2007). These authors also suggest that the industry is required to purchase these alternative fuels irrespective of their cost in the market. As a result, the majority of these cost changes are passed on to consumers, by way of either cheaper or more expensive fuel at the pump. Therefore, unlike an excise tax credit, the effect of regulating the relative market shares by way of direct controls, such as mandatory blending policies and renewable fuel standards, are typically to increase the consumer price of fuel (Rajagopal & Zilberman, 2007; Banse *et al.*, 2008; De Gorter & Just, 2008a). The final fuel cost to the consumer is, therefore, dependent on the cost of the alternative fuel (Tyner & Taheripour, 2007).

Interestingly, De Gorter and Just (2009b) indicate that, with a fixed price of fuel, mandates increase the consumer price of fuel, which necessarily results in reduced fuel consumption compared to a biofuel tax credit that generates an equivalent level of biofuel consumption. However, with endogenous fuel prices they show that it is possible for the consumer price of fuel to decline under a mandate, depending on the relative supply elasticities of bioethanol and fuel. Rajagopal and Zilberman (2007), however, note that from the regulatory institution's perspective, mandatory blending requirements are revenue neutral, while producer surplus increases and consumer surpluses decrease. Thus, Tyner and Taheripour (2008a) surmise that a binding renewable fuel standard imposes an implicit tax on fuel consumption (through higher prices at the pump) and provides an implicit subsidy for biofuel producers.

Banse *et al.* (2008) contend that mandatory blending policies result in an increased demand for biofuel feedstock which raises its price relative to the crude oil price, and subsequently merely serves to augment the challenge of making biofuels competitive. Rajagopal and Zilberman (2007) and Tyner and Taheripour (2008b) conclude that while renewable fuel standards and mandatory blends are effective in stimulating the production of biofuels, they may be very inefficient in the presence of low crude oil prices.

3.3 Agricultural and trade policies

The active role governments play in allocating scarce resources between agriculture and the rest of the economy is indisputable (De Gorter & Swinnen, 2002). That said, the bulk of biofuel feedstock will likely come from the agricultural and forestry sectors (Walsh *et al.*, 2007). Since feedstock accounts for a significant proportion of biofuel production costs, agricultural and trade policies that influence the supply, demand and prices of various agricultural commodities can, therefore, be important determinants of biofuel economics (Rajagopal & Zilberman, 2007).

The stated objectives of agricultural policies are varied and typically include self sufficiency, balance of trade (payments), farm income and employment targets, secure supplies and low prices to consumers, as well as the stability of farm incomes, supplies, and prices (Winters, 1989). In contrast to energy policies, which have relied heavily on tax subsidies and mandates, agricultural policies have focused on either promoting or controlling product supply, through price supports, land-use acts, or regulation of import and export levels (Rajagopal & Zilberman, 2007). Historically, agricultural policies in industrial countries have protected domestic producers from imports from relatively lower-cost foreign producers, and in so doing have transferred income to domestic farmers, while agricultural policies in developing countries have typically taxed exports to generate government revenue (De Gorter & Swinnen, 2002; Karp & Perloff, 2002; Kojima *et al.*, 2007), and/or provide food for domestic consumers at relatively lower prices (De Gorter & Swinnen, 2002).

Pasour and Rucker (2005) demonstrate that price supports alone stimulate production. However, they invariably lead to surpluses and net costs to taxpayers, in the form of acquisition and possibly storage costs (these, however, do not include the deadweight and other opportunity costs associated with overproduction, such as a misallocation of scarce resources and reduced domestic consumption of the commodity; or the taxes necessary to run the programme), thereby creating an incentive for further government intervention in the market through programmes that regulate supply. Pasour and Rucker (2005) suggest further that product supply can be reduced by means of either restricting input use (particularly land), or by regulating output directly. To this end, these authors note that acreage allotments and marketing quotas have been used extensively in US farm price-support initiatives.

Prominent domestic agricultural policies in developed countries also include deficiency payments and other forms of direct producer subsidies (Karp & Perloff, 2002). Rajagopal and Zilberman (2007) suggest that price supports that are used in conjunction with deficiency payments have assisted in increasing production and lower market prices of commodities. In the US, government uses the deficiency payment method to support farmers of wheat, cotton, rice and feed grains (Pasour

& Rucker, 2005). The deficiency payment is the difference between a target price and the market price or loan rate, depending on which difference is smaller (Rajagopal & Zilberman, 2007). Tomek and Robinson (2003) note that this form of intervention can essentially subsidise both production and consumption, since producers receive above market equilibrium prices and consumers benefit from below market equilibrium prices. Rajagopal and Zilberman (2007) contend further that the effects of deficiency payments in biofuel markets are to reduce the cost of biofuel feedstock, and subsequently, the costs of biofuels and their by-products.

Trade policy has an extensive history as an important field of study in agricultural economics. Government intervention in agricultural sectors in both developed and developing nations has created significant distortions in international markets over the years, with explicit trade interventions typically including an assortment of tariffs, quotas, export subsidies and non-tariff barriers (Karp & Perloff, 2002). With specific reference to biofuel market intervention, Rajagopal and Zilberman (2007) note that governments around the world have imposed several forms of restrictions on the trade of both feedstock and biofuels; prominent examples of which include import tariffs, quotas, and export taxes, with preferential waivers for selected countries in some cases (see appendix A).

The predominant effects of import tariffs and quotas are to provide protection for domestic producers (Tomek & Robinson, 2003), as well as to restrict benefits to selected countries (Kojima *et al.*, 2007). Consumers, however, are unambiguously harmed by these policy measures, whilst governments generate revenue from import tariffs, and possibly quotas, depending on the method of allocation (Tomek & Robinson, 2003). Export taxes, in contrast, may be implemented to promote the export of value-added finished products rather than raw materials (e.g., promoting the export of biofuel rather than feedstock – see Argentina's policies in appendix A) (Rajagopal & Zilberman, 2007). In general, however, there has been a global shift towards the removal of barriers to trade in recent times. Accordingly, Rajagopal and Zilberman (2007) suggest that trade liberalisation in biofuel markets should serve to increase competition and lead to an improvement in average efficiency of production, ultimately translating into greater global welfare in the long run.

Agricultural policies undoubtedly have had significant implications for both agricultural trade and the geographic patterns of agricultural production at the international level and are, therefore, expected to have similar influences on the production of biofuels (FAO, 2008). For a comprehensive review of the economic costs, benefits and shortcomings of the above, and other, agricultural policies please refer to Pasour and Rucker (2005), while an extensive review of current biofuel trade policies around the world is contained in Kojima *et al.* (2007).

3.4 Other biofuel-related policy initiatives

There is evidently a wealth of available forms of government intervention in biofuel and related markets, the most prominent of which have already been discussed at some length. A brief overview of energy and carbon taxes is given by Rajagopal and Zilberman (2007); however, these policies do not appear to have been adopted widely to date, and are often regarded as being politically unpopular alternatives. Rajagopal and Zilberman (2007) note further that taxes increase the price of fuel (similar to the effects of fuel standards and blend mandates) and generate government revenue. Their distributional effects to producers and consumers, however, depend on the price elasticity of demand; Rajagopal and Zilberman (2007) suggest that in the event that demand is relatively price inelastic, producers pass the tax on to consumers.

Kojima *et al.* (2007) indicate that investment incentives (e.g., grants, loans and loan guarantees), and tax-related incentives (e.g., tax holidays, accelerated depreciation and tax reductions) are commonplace in biofuel and related markets around the world. Rajagopal and Zilberman (2007), however, note that policies, such as trading mechanisms, biofuel certification systems, and compensation schemes such as payments for environmental services, have yet to become well established in the context of biofuels. For example, the need to ensure that biofuels are produced in a sustainable manner has become increasingly controversial; and it has been suggested that establishing sustainability standards and certification schemes are possible strategies that could aid in ensuring that bioenergy crops are produced in a sustainable way (Schlegel & Kaphengst, 2007; Garcez & Vianna, 2009).

Research and development in bioenergy has typically been aimed at establishing technologies that enhance conversion efficiency, identifying sustainable feedstock, and, increasingly, developing cost-effective conversion methods for second and third generation biofuels (Rajagopal & Zilberman, 2007; FAO, 2008). Due to problems associated with knowledge spillovers (e.g., inventors may have difficulties in fully internalising the benefits of their innovations), it is often desirable for governments to provide support for research and development (Rajagopal & Zilberman, 2007). Subsequently, this form of intervention is not uncommon in biofuel-producing countries around the world (Rajagopal & Zilberman, 2007; FAO, 2008). An extensive history of, and explanations for, public funding in agricultural research and development is given by De Gorter and Swinnen (2002).

Flex-fuel vehicles, which are designed to use higher-percentage blends of biofuels than ordinary vehicles, are also actively promoted by many governments around the world; for example, by directly reducing registration fees, providing tax credits (e.g., on road taxes), and indirectly through energy-efficiency credits

to vehicle manufacturers (Kojima *et al.*, 2007; Rajagopal & Zilberman, 2007; FAO, 2008). State and federal policies in the US and Brazil, for example, give preference to alternative fuel vehicles (Rajagopal & Zilberman, 2007).

4 THEORETICAL AND EMPIRICAL LITERATURE OF POLICY IMPACTS

Generally, government policies and support that are directly linked to levels of production and consumption are regarded as causing the most significant market distortions, while those for research and development are arguably the least distorting (FAO, 2008). Kojima *et al.* (2007) note that some biofuel policies, such as mandates and fuel excise tax reductions that do not explicitly distinguish between domestically produced and imported biofuels, stimulate the consumption of biofuels and do not distort trade (except to the extent to which they may actually artificially stimulate it). However, other policy measures, in the form of import tariffs and/or producer subsidies (deficiency payments), provide clear protection and subsidisation of domestic production at the expense of foreign-produced biofuels.

By way of a social cost/benefit analysis, Gardner (2007) suggests that both subsidies and mandates for bioethanol are unlikely to generate net social gains. However, associated deadweight losses (e.g., misallocated scarce resources and reduced consumption) are expected to be relatively smaller in the short run, when both demand and supply responses are small, than in the long run, when both supply and demand are expected to be relatively more elastic and thus cause the deadweight losses to increase substantially. He notes further that for a given total subsidy cost, maize producers typically gain more from a deficiency payment subsidy than from a bioethanol subsidy. However, he concludes that although the primary beneficiaries of the bioethanol subsidy in the short run are bioethanol producers, the long-run beneficiaries are actually the maize producers. Babcock (2008) also finds significant welfare losses from US bioethanol policy, resulting in substantial transfers from taxpayers and non-ethanol maize users to maize growers, fuel blenders and bioethanol producers. He concludes that given the modest and relatively uncertain environmental benefits associated with bioethanol, it is unlikely that the associated public benefits outweigh the social welfare losses. In contrast, Wassell and Dittmer (2006) estimate that the external benefits associated with biodiesel production outweigh the required subsidies.

Many authors have evaluated the possible effects of trade liberalisation, specifically the removal of bioethanol import tariffs in the US, on biofuel markets and social welfare (Martinez-Gonzalez *et al.*, 2007; Rajagopal & Zilberman, 2007; De Gorter & Just, 2008b; Elobeid & Tokgoz, 2008; De Gorter *et al.*, 2009). These

authors note that such tariffs may actually contradict the objectives of improving the environment, reducing reliance on oil and diversifying energy sources, owing to the fact that maize-based bioethanol produced in the US contributes significantly less to the reduction of greenhouse gases than sugarcane-based bioethanol produced in Brazil.

Khanna *et al.* (2008) analyse US bioethanol policy initiatives from a potential environmental impact standpoint, and have a key focus on their ability to address negative externalities associated with vehicle emissions and traffic congestion. Interestingly, these authors demonstrate that a bioethanol subsidy has the potential to increase carbon emissions, increase congestion, and lower social welfare by inadvertently stimulating consumers to increase the distances they drive.

Table 1: Expected impacts of policies on selected economic and environmental indicators

Policy tool	Oil use reduction	GHG reduction	Farm income	Biofuel producers	Consumer surplus (Food)	Consumer surplus (Energy)	Government budget
Energy and fuel policies							
Biofuel Tax Credit	+	<>	+	+	-	<>	-
Biofuel Mandate	+	<>	+	+	-	-	<>
Carbon tax	+	+	<>	<>	<>	-	+
Efficiency standard	+	+	<>	<>	<>	+	<>
Vehicle subsidy	<>	<>	<>	<>	<>	<>	-
Agricultural and trade policies							
Price support	+	<>	+	<>	<>	+	-
Acreage Control	<>	<>	+	-	-	-	-
Import tariff	+	<>	+	+	+	-	+
Export subsidy	<>	<>	+	+	+	-	-
Export qouta	+	<>	-	+	+	+	<>
Where							
	+	Positive impact					
	<>	Uncertain impact					
	-	Negative impact					

Source: Adapted from Rajagopal and Zilberman (2007, p.106)

Numerous authors have estimated that net farm income increases substantially with a continued expansion of biofuel production, mostly as a result of higher crop prices and sustained government support (Gardner, 2007; Walsh *et al.*, 2007; Babcock, 2008; Gohin, 2008). Martinez-Gonzalez *et al.* (2007), however, stress

that an analysis of welfare effects derived from an individual biofuel industry, such as the US bioethanol market, is likely to underestimate the potential adverse impacts if it does not account for the deadweight losses that they may be generating in other markets. In this regard, many commentators have noted the potential adverse implications a continued biofuel expansion could have for livestock industries, by way of increased feed prices and other production costs, such as fuel and fertiliser (Walsh *et al.*, 2007; Elobeid & Tokgoz, 2008; Gohin, 2008; Herndon, 2008; Tokgoz *et al.*, 2008). Herndon (2008, p.412) contends that “unlike row crop farmers, these agricultural producers do not have the luxury of record-high prices for their livestock products to offset these drastically higher feed costs”. Table 1 provides a summary of the expected impacts of selected policies on various environmental and economic indicators.

Thus, Rajagopal and Zilberman (2007, p.68) surmise the following:

- Most policies reduce consumption of crude oil at the national level, owing either to an increased production of biofuel or a reduced demand for oil. Possible exceptions include acreage controls and export subsidies, which discourage domestic production and consumption, respectively. Export subsidies, however, may increase the global supply of biofuel, causing a global reduction in the demand for oil.
- The abilities of the majority of policies to reduce greenhouse gas emissions are largely uncertain, with the exception of policies that reduce the demand for oil (e.g., carbon taxes and efficiency standards). The uncertainty stems from the fact that emission reductions differ by crop, the intensity of input usage throughout the life cycle, and the nature of land-use changes etc. – all of which vary by location and with time.
- Policies that stimulate the production of biofuels typically have positive impacts on farm income.
- Biofuel producers are likely to gain or be unaffected by the majority of policies, with the exception of acreage controls which raise the costs of feedstock, and have negative impacts on producer surplus.
- Food and related markets are likely to be adversely affected due to rises in the prices of agricultural commodities associated with policies promoting the production of (first generation) biofuels.
- Impacts on consumer surplus are mixed. Taxes and mandates, which cause the overall price of energy to increase, reduce consumer surplus. The same is true for policies which restrict the production of feedstock. Efficiency standards, price supports for the production of biofuel crops, and export quotas raise consumer surplus by way of reducing the cost of energy service or by lowering the cost of biofuel feedstock. The impact of agricultural and trade policies on

consumer surplus for food are similar to the impacts of the policy on consumer surplus for energy.

- Taxes and tariffs generate revenue for government. In contrast, tax credits, price supports, acreage controls and trade subsidies result in reduced government revenue, or increased government spending.
- Generally, most agricultural and trade policies benefit farmers, while energy policies address the problems that result from oil consumption.

It is, however, important to emphasise that the above analyses are applicable only to the single isolated policy, and, therefore, do not necessarily hold true when there are multiple policies in effect simultaneously. Analysing the marginal and interaction effects between multiple policies is a complex task; recent studies of this nature include De Gorter and Just (2008a, 2008b, 2009a, 2009b) and De Gorter *et al.* (2009).

5 SOUTH AFRICAN BIOFUEL POLICY INITIATIVES AND PROPOSED TARGETS

The South African government has committed to comply with the framework of the White Paper on Renewable Energy (DME, 2003), which stipulates the production of renewable energy of 10 000 GWh (equivalent to 0.8 Mtoe)³ to be achieved by 2013 (DME, 2003), a portion of which has to come from the production of biofuels (Meyer *et al.*, 2008). This is approximately four per cent of the projected electricity demand for 2013 (DME, 2003). Currently, however, renewable energy contributes relatively little to energy levels in South Africa (DME, 2003; Winkler, 2005).

A brief overview of the current South African biofuels industrial strategy is provided by Funke *et al.* (2009). Key aspects include the targeted 2 per cent penetration level of biofuels in the national liquid fuel supply, equivalent to 400 million litres per annum, by 2013 (DME, 2007). Furthermore, the strategy recommends blending requirements of 2 and 8 per cent for biodiesel and bioethanol, respectively. These targets were proposed to be maintained until 2020. Additionally, the industrial strategy recommends that: (1) the current biodiesel fuel levy exemption be increased from 40 to 50 per cent; (2) the small-scale producer's threshold be raised from 300 000 to 1.2 million litres per annum (the South African Revenue Service (SARS) permits a 100 per cent exemption for these small producers); and (3) a 100 per cent fuel levy exemption for bioethanol be introduced (DME, 2007).

The DME (2007) contend that these goals can be achieved without jeopardising food security. They estimate further that only 1.4 per cent of arable land in South

Africa would be required and approximately 25 000 jobs would be created in meeting these objectives. Although job creation is a key focus of the revised strategy, these estimates may well be optimistic. For example, Gohin (2008) contends that only 43 000 jobs will be created by meeting the EU's biofuel target of 5.75 per cent of transport fuel by 2010. Interestingly, in the US, "small bioethanol and biodiesel producers" constitute plants producing less than 60 million gallons per annum. These producers are eligible for small producer excise tax credits, with a maximum credit of up to \$1.5 million per annum (Eidman, 2007).

However, there still appears to be a lack of a clear and comprehensive policy framework for the development of a South African biofuels industry, as none of the above *proposed initiatives* have been implemented to date. There are also concerns among stakeholders that government policy is taking too long to formulate, compounding existing uncertainty in the industry. These concerns appear to be further aggravated by the fact that South Africa's commitment to the framework of the White Paper on Renewable Energy (DME, 2003) is not binding. Therefore, if the targets for 2013 were not reached the government could simply "shift the goal posts" to a later target date. Thus, South Africa's biodiesel market is presently characterised by several small- and medium-scale producers (Amigun *et al.*, 2008), which may be of direct consequence to existing biofuel policy given that the most support currently exists for producers operating below the small-scale producer threshold of 300 000 litres per annum. Importantly, Funke *et al.* (2009) contend that the incentives and commitments as proposed by the South African biofuels industrial strategy (DME, 2007) are inadequate to both establish and sustain a domestic biofuel industry.

There is perhaps too much current emphasis placed on development-oriented small-scale biofuel production in the South African context, with the expected outcomes from such ventures potentially being relatively unrealistic. Therefore, there is a clear need for *objective* research that quantifies and qualifies the level of government support required to promote local biofuel initiatives – both at the commercial and smallholder level. However, the need for the government to play a proactive role in biofuel markets, at the very least through the provision of appropriate incentives, is clearly evident. The expected impacts of some additional biofuel policies that the government could consider for future biofuel promotion are summarised in Table 1.

6 DISCUSSION AND CONCLUSION

Historically, alternative energy technologies, including biofuels, have been dependent on sustained governmental support in order to be competitive with fossil fuels in the marketplace. While a significant driver of the recent increases in

biofuel production has been the rising real crude oil price, prolonged government intervention has undoubtedly been an essential feature of the development of the biofuel industries in many of the present global market leaders in biofuel production. Trends indicate that this will continue in the future. Biofuel development can be influenced by numerous national policies, in multiple sectors, at various stages in the supply chain – ultimately creating favourable market conditions for the production of biofuels. While a wide variety of policy tools are available for government intervention in biofuel markets, the cost effectiveness as well as the distributional implications of each will vary, creating both winners and losers among economic agents. This article evaluated the important characteristics of some widely used biofuel and related policies, of which excise tax credits, renewable fuel standards, and mandatory blends are most prominent.

In general, the majority of agricultural and trade policies provide net benefits for agricultural producers, while explicit energy policies strive to address the problems that result from oil consumption. Most explicit biofuel policies result in a reduction in the consumption of crude oil at the national level, owing to either increased production of biofuel or a reduced demand for oil. Furthermore, policies that stimulate the production of biofuels typically raise farm income. The majority of policies' abilities to reduce greenhouse gas emissions are largely uncertain, while their respective implications for consumer welfare and government revenue are mixed, and typically vary by policy. No individual policy, however, will provide an optimum solution under all circumstances. Continued research into dynamic policies that, for example, vary according to crude oil prices and account for both energy security and environmental impacts of biofuels, and build on the work of Tyner (2007) and Tyner and Taheripour (2007), could be very useful in years to come.

Government intervention in biofuel markets, at least in the developmental stages, appears to be essential. It is, therefore, recommended that South Africa hasten its attempts to finalise and implement a comprehensive, long-term, biofuel policy framework. Furthermore, since the vast majority of economic feasibility studies, irrespective of the scale of production, establish the need for governmental support in biofuel industries, it is suggested that the proposed South African biofuels industrial strategy, which advocates that only previously disadvantaged individuals producing biofuels in the former homelands will be eligible for government support, may need to be revised if South Africa is to have a realistic chance of achieving its proposed biofuel targets. There are, however, concerns that South Africa's commitment to the White Paper on Renewable Energy (DME, 2003) is not binding. Moreover, there may be concerns that the underlying calculations and conclusions drawn by the proposed South African biofuels industrial strategy may be overly optimistic, particularly those relating to job creation – which is one of the primary objectives of this revised strategy.

Bioethanol and biodiesel are the leading biofuel varieties produced worldwide. The most prominent contribution of these biofuels will likely be to augment the existing supply of fuels used in transportation sectors. However, under current production levels, biofuels contribution to global energy demand is modest. Therefore, despite the fact that global biofuel production levels are expected to continue to increase in the future, they are unlikely to be a panacea and should be used in conjunction with other renewable energy technologies, as outlined by the White Paper on Renewable Energy (DME, 2003). Nevertheless, continued technological advancements, infrastructure development and government interventions will certainly be central to the future developments of biofuel industries, both locally and globally.

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NOTES

- 1 Gigawatt hour (GWh) is an energy unit in which electricity consumption is measured (1 GWh = 3 600 GJ (Gigajoule); Joule is the unit of energy). Mtoe (million tons of oil equivalent) is a universal unit of comparison in which all energy can be measured (1 Toe = 42 GJ = 0.042 TJ = 0.012 GWh).

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APPENDIX A: CURRENT BIOFUEL PRODUCTION, FUTURE TARGETS AND POLICIES FOR SELECTED COUNTRIES

Country	Biofuel capacity	Future targets	Main sources of biofuel	Explicit biofuel policies	Main trade policy for biofuels
Australia	170 million litres of bioethanol	350 million litres of biofuel by 2010	Wheat and molasses	Producer subsidy, capital grants, vehicle standard	Import tariff of \$0.31/litre of both bioethanol & biodiesel
Argentina	204 million litres (2006)	5 % biofuels by 2010	Soybean	Excise tax credit, mandatory blending, export tax exemption on biofuel blends	Low export tax (5%) for soybean-based biodiesel compared to soybeans (23.5%) & soy oil cake (20%)
Brazil	17.5 billion litres (2006)	25% blending of bioethanol (has been in effect for a long time) & 5% biodiesel from 2013	Sugarcane & soybean	Mandatory blending, capital subsidies & vehicle subsidies	20% ad valorem import tariff on bioethanol (waived in case of domestic shortage)

Country	Biofuel capacity	Future targets	Main sources of biofuel	Explicit biofuel policies	Main trade policy for biofuels
Canada	240 million litres of bioethanol	5% bioethanol by 2010 & 2% biodiesel by 2012	Maize & wheat	Excise tax credit, mandatory blending, capital subsidies	Import tariff of \$0.1228 for bioethanol & \$0.11 for biodiesel (lower tariffs & exemptions for select countries)
China	1.2 billion litres of bioethanol (2006)	Data not available	Maize, cassava & sugarcane	Subsidies & tax breaks but only for non-grain feedstock	Import tariff of 30% on bioethanol
Colombia	400 million litres (2006)	10% bioethanol in cities exceeding 500000 people since 2006	Sugarcane & oil palm	Mandatory blending, tax breaks for sugarcane plantations, capital subsidies	Ad valorem import tariff of 15% on bioethanol & 10% on biodiesel
EU	3.6 billion litres of biodiesel (2005) & 1.6 billion litres of bioethanol (2006)	5.75% of transportation fuel on energy basis by 2010, & 10% by 2020	Rapeseed, sunflower, wheat, sugar beet & barley	Excise tax credit (is being phased out), carbon tax credit, mandatory blending, capital grants & funding for R&D	Ad valorem duty of 6.5% on biodiesel & import tariff of \$0.26/litre on bioethanol (latter is waived for some categories of countries)
Indonesia	340 million litres of biodiesel (2006)	10% bioethanol & 10% biodiesel effective April 2006	Oil palm	Mandatory blending & capital subsidies	Lower export tax for processed oils compared to crude palm oil
Japan	Insignificant	360 million litres by 2010 & 10% biofuel by 2030	Imported bioethanol	Excise tax credit	Ad valorem import duty of 23.8% on fuel bioethanol (to be lowered to 10% by 2010)
Malaysia	340 million litres of biodiesel (2006)	5% biodiesel since April 2007	Oil palm	Mandatory blending & capital subsidies	Lower export tax for processed oils compared to crude palm oil

Country	Biofuel capacity	Future targets	Main sources of biofuel	Explicit biofuel policies	Main trade policy for biofuels
South Africa	Insignificant	Proposed: 2% of national liquid fuel (400 million litres) by 2013 (until 2020), including 2% biodiesel & 8% bioethanol blends	Proposed: soybeans, canola, sunflower, sugarcane & sugar beet	Excise tax credit of 40% for biodiesel & 100% tax exemption for small-scale biodiesel producers (< 300 000 litres/annum)	N/A
Thailand	330 million litres of bioethanol (2006)	Data not available	Cassava, sugarcane, molasses	Price subsidy & capital subsidies	Import tariff of 2.5 baht/litre & ad valorem tariff of 5% on biodiesel
US	18.4 billion litres of bioethanol (2006) & 284 million litres of biodiesel (2005)	36 billion gallons of biofuels by 2022, with 15 billion gallons from maize-based bioethanol & 21 billion gallons of "advanced biofuels"	Maize, & in future cellulosic sources	Excise tax credit, mandatory blending, capital grants, vehicle subsidies	Import tariff of \$0.1427/litre of bioethanol plus ad valorem tariff with some exemption for Caribbean countries

Source: Adapted from Rajagopal and Zilberman (2007, p.106). Data on Brazil's future mandatory biodiesel blend from Pousa *et al.* (2007, p.5394); EU blend target for 2020 from Banse *et al.* (2008, p.119); US future targets from Senauer (2008, p.1227); Proposed South African data from DME (2006, 2007).