

3. Economic and policy drivers of liquid biofuels

Agriculture both supplies and demands energy; hence, markets in both sectors have always been linked. The nature and strength of these linkages have changed over the years, but agricultural and energy markets have always adjusted to each other, with output and consumption rising or falling in response to changing relative prices. Rapidly increasing demand for liquid biofuels is now tying agriculture and energy more closely than ever. However, policy plays an influential role in defining the linkages between them. Many countries intervene in both markets through a range of policy measures aimed at addressing a diverse range of goals. This chapter addresses the fundamental economic relationships among agriculture, energy and biofuels. It also reviews the policies being pursued to promote biofuels and discusses the way in which they affect the relationship between agricultural and energy markets.

Biofuel markets and policies

A discussion of the economics of liquid biofuels must start from the allocation of resources among competing uses in the energy and agriculture sectors. This competition occurs at several levels. In energy markets, liquid biofuels such as ethanol and biodiesel are direct competitors with petroleum-based petrol and diesel. Policies such as mandated blending of biofuels with petrol and diesel, subsidies and tax incentives can encourage biofuel use, while technical constraints such as a lack of vehicles that run on biofuel blends can discourage their use. Leaving aside such factors for the moment, biofuels and fossil fuels compete on the basis of their energy content, and their prices generally move together.

In agricultural markets, biofuel processors compete directly with food processors and animal-feeding operations for commodities.

From the point of view of an individual farmer, it is unimportant what end use a prospective buyer has in mind for the crop. Farmers will sell to an ethanol or biodiesel processor if the price they receive is higher than they could obtain from a food processor or a feeding operation. If the price of biofuels is high enough, it will bid agricultural commodities away from other uses. Because energy markets are large relative to agricultural markets, a small change in energy demand can imply a large change in demand for agricultural feedstocks. Therefore crude oil prices will drive biofuel prices and, in turn, influence agricultural commodity prices.

The close link between crude oil prices and agricultural prices, mediated by biofuel demand, in fact establishes a floor and a ceiling for prices of agricultural commodities – determined by crude oil prices (FAO, 2006a). When fossil fuel prices reach or exceed the cost of producing substitute biofuels, the energy market creates demand for agricultural products. If the demand for energy is high relative to markets for agricultural commodities and agricultural biofuel feedstocks are competitive in the energy market, this will create a floor price effect for agricultural products determined by fossil fuel prices. At the same time, however, agricultural prices cannot increase faster than energy prices or they will price themselves out of the energy market. Thus, as energy markets are very large compared with agricultural markets, agricultural prices will tend to be driven by energy prices.

In practice, the link between energy and agricultural commodity prices may be less close and immediate than in theory, at least until biofuel markets become sufficiently developed. In the short run, a number of constraints limit the capacity of the biofuel sector to respond to changes in relative prices of fossil fuels and agricultural commodities, for example bottlenecks in distribution, technical problems in

BOX 3 Biofuel policies in Brazil

Around 45 percent of all energy consumed in Brazil comes from renewable sources, reflecting the combined use of hydroelectricity (14.5 percent) and biomass (30.1 percent); the use of sugar cane in the internal renewable energy supply in 2006 represented 32.2 percent of renewable energy and 14.5 percent of total internal energy supply (GBEP, 2007).

Brazil has been a pioneer in national regulatory efforts for the bioenergy sector and has accumulated significant experience and expertise in the area of biofuels, particularly concerning the use of ethanol as a transport fuel. The Brazilian experience of using ethanol as a petrol additive dates back to the 1920s, but it was only in 1931 that fuel produced from sugar cane officially began to be blended with petrol. In 1975, following the first oil crisis, the Government launched the National Ethanol Programme (ProAlcool), creating the conditions for large-scale development of the sugar and ethanol industry. The programme was aimed at reducing energy imports and fostering energy independence. Its main goals were to introduce into the market a mixture of petrol and anhydrous ethanol and to provide incentives for the development of vehicles that were fuelled exclusively with hydrated ethanol. Following the second major oil shock, in 1979, a more ambitious and comprehensive programme was implemented, promoting the

development of new plantations and a fleet of purely ethanol-fuelled vehicles. A series of tax and financial incentives was introduced. The programme induced a strong response, with ethanol production rising rapidly along with the number of vehicles running exclusively on ethanol.

Subsidies provided through the programme were intended to be temporary, as high oil prices were expected to make ethanol competitive with petrol in the long run. However, as international oil prices fell in 1986, the elimination of subsidies became problematic. In addition, rising sugar prices led to scarcity of ethanol, and in 1989 severe shortages in some of the main consuming centres undermined the credibility of the programme.

The period from 1989 to 2000 was characterized by the dismantling of the set of government economic incentives for the programme as part of a broader deregulation that affected Brazil's entire fuel supply system. In 1990, the Sugar and Ethanol Institute, which had regulated the Brazilian sugar and ethanol industry for over six decades, was extinguished, and the planning and implementation of the industry's production, distribution and sales activities were gradually transferred to the private sector. With the end of the subsidies, the use of hydrated ethanol as fuel diminished drastically. However, the mixture of anhydrous ethanol with petrol

transportation and blending systems or inadequate plant capacity for conversion of feedstocks. The more flexibly demand and supply can respond to changing price signals, the more closely prices on energy and agricultural markets will be linked. Today, the Brazilian sugar-cane ethanol market is the most developed and most closely integrated with energy markets. Contributory factors include the existence of a large number of sugar mills able to produce either sugar or ethanol, highly efficient energy conversion systems with co-generation of ethanol and electricity, a large share of flex-fuel vehicles

capable of running on ethanol-petrol blends and a national distribution network for ethanol (FAO, 2006a).

While agricultural feedstocks compete with fossil fuels on the energy market, agricultural crops also compete with each other for productive resources. For example, a given plot of land can be used to grow maize for ethanol or wheat for bread. When biofuel demand bids up the prices of commodities used as biofuel feedstock, this tends to bid up the prices of all agricultural commodities that rely on the same resource base. For this reason, producing biofuels from non-

was boosted with the introduction in 1993 of a mandated blending requirement specifying that 22 percent of anhydrous ethanol must be added to all petrol distributed at retail petrol stations. The blending requirement is still in place today, with the Inter-Ministerial Board for Sugar and Ethanol establishing the required percentage, which can range from 20 to 25 percent.

The most recent phase of the Brazilian ethanol experience began in 2000 with the revitalization of ethanol fuel and was marked by the liberalization of prices in the industry in 2002. Ethanol exports increased further as a result of high oil prices in the world market. The dynamics of the sugar and ethanol industry began to depend much more on market mechanisms, particularly in the international markets. The industry has made significant investments, expanding production and modernizing technologies. An important factor in domestic market development in recent years has been the investment of the automobile industry in bi-fuel or dual-fuel alcohol-petrol cars, also referred to as flex-fuel vehicles, which are able to run on a blend of petrol and ethanol.

Biodiesel, by contrast, is still an infant industry in Brazil, and biodiesel policies are much more recent. The biodiesel law of 2005 established minimum blending requirements of 2 percent and 5 percent

to be accomplished by 2008 and 2013, respectively. Reflecting social inclusion and regional development concerns, a system of tax incentives was established for the production of raw materials for biodiesel on small family farms in the north and northeast regions of Brazil. Under a special scheme, the "Social Fuel Seal" (*Selo Combustível Social*) programme, biodiesel producers who buy feedstocks from small family farms in poor regions pay less federal income tax and can access finance from the Brazilian Development Bank. The farmers are organized into cooperatives and receive training from extension workers.

Current bioenergy policies in Brazil are guided by the Federal Government's *Agroenergy Policy Guidelines*, prepared by an interministerial team. Linked to the overall policy of the Federal Government, the Ministry of Agriculture, Livestock and Food Supply has prepared a programme to meet the bioenergy needs of the country. The goal of the Brazilian Agroenergy Plan 2006–2011 is to ensure the competitiveness of Brazilian agribusiness and support specific public policies, such as social inclusion, regional development and environmental sustainability.

Sources: based on GBEP, 2007, and Buarque de Hollanda and Poole, 2001.

food crops will not necessarily eliminate the competition between food and fuel; if the same land and other resources are needed for both food and biofuel feedstock crops, their prices will move together even if the feedstock crop cannot be used for food.

Given current technologies, the costs of producing crops and converting them to ethanol or biodiesel are too high in many locations for biofuels to compete with fossil fuels on a commercial basis without active government support to promote their development and subsidize their use. Many countries – including a growing number

of developing countries – are promoting biofuels for three main reasons: strategic concerns over energy security and energy prices, concerns over climate change, and agricultural support considerations.

One justification made for providing policy support to a new sector is that it is needed to overcome the initial costs of technological innovation and market development required to enable a sector to become competitive. This is the "infant industry" argument for subsidies. But subsidies for a sector that cannot ultimately achieve economic viability are not sustainable and

may serve simply to transfer wealth from one group to another while imposing costs on the economy as a whole.

Subsidies can also be justified when the social benefits of developing a sector outweigh the private economic costs. This may be the case, for example, if liquid biofuels generate social benefits in the form of lower carbon emissions, greater energy security or revitalized rural areas. Such policy interventions entail costs, however, and their consequences are not always as intended. These costs include the direct budgetary costs, borne by taxpayers, and market costs, borne by consumers, and involve the redistribution of resources towards the favoured sector. Distributional effects can extend beyond the country implementing the policy to have an international dimension – just as the agricultural support and protection policies of many OECD countries have complex impacts on producers and consumers in other countries. In addition, because policy interventions divert resources from other social and private investments, they often have indirect opportunity costs. In some cases, other policy interventions that target the stated objectives of the biofuel policies more directly could be less costly and more effective.

Underlying objectives of biofuel policies

As noted above, several countries have introduced policies promoting the development of liquid biofuels. High and volatile petroleum prices, increased awareness of fossil fuels' contribution to global climate change and the desire to promote economic revitalization in rural areas are the most commonly expressed reasons underlying these policies (FAO, 2007b).

Secure access to energy supplies is a longstanding concern in many countries. Reducing vulnerability to price volatility and supply disruptions has been an objective behind the energy policies of many OECD countries for several decades, and many developing countries are equally concerned about their dependence on imported sources of energy. The recent increases in prices, mainly of oil, have strengthened

the incentive to identify and promote alternative sources of energy for transport, heating and power generation. Strong demand from rapidly growing developing countries – especially China and India – is adding to concerns over future energy prices and supplies. Bioenergy is seen as one means of diversifying sources of energy supply and reducing dependency on a small number of exporters. Liquid biofuels represent the main alternative source that can supply the transport sector, which is overwhelmingly dependent on oil, without more radical changes to current transport technologies and policies.

The second important factor driving bioenergy policies is the increasing concern about human-induced climate change, as the evidence of rising temperatures and their anthropic origin becomes ever more compelling. Few now dispute the need to take action to reduce greenhouse gas emissions, and many countries are incorporating bioenergy as a key element in their efforts to mitigate climate change. Bioenergy has been perceived as offering significant potential for emission reductions, relative to petroleum-based fuels, in electricity, heating and transportation, although actual net impacts on greenhouse gas emissions may vary significantly depending on factors such as land-use change, feedstock type and related agricultural practices, conversion technology and end use. Indeed, recent analyses suggest that large-scale expansion of biofuel production could cause a net increase in emissions.

While climate-change concerns have been among the strongest incentives for promoting bioenergy development, other environmental concerns have also played a role – not least the wish to reduce urban air pollution. Burning biomass using modern technologies or using liquid biofuels in engines may reduce emissions of regulated air pollutants relative to fossil fuel use. Also, the generation of energy from residues and wastes, such as the biodegradable parts of municipal solid waste, represents an environmentally friendly means for their disposal. The implications of liquid biofuel production and use for the environment, including greenhouse gas emissions, are discussed further in Chapter 5.

Supporting the farm sector and farm incomes has been a key – if not the most important – driving factor behind biofuel policies in several developed countries. In countries with heavily subsidized farm sectors, the revitalization of agriculture through its role as provider of bioenergy feedstocks has been widely viewed as a solution to the twin problems of oversupply of agricultural produce and declining global market opportunities. The possibility of boosting farm incomes while reducing income support and subsidies has considerable appeal for policy-makers (although the latter part of this strategy has been difficult to achieve). While several OECD countries, particularly in Europe and North America, have long embraced the potential of biofuels to support agriculture, an increasing number of developing countries also claim rural development – along with energy security – objectives for their biofuel policies (FAO, 2007b).

Policy measures affecting biofuel development

Biofuel development is influenced by a wide range of national policies in multiple sectors, including agriculture, energy, transport, environment and trade, as well as broader policies affecting the overall “enabling environment” for business and investment. Policies applied to bioenergy, particularly liquid biofuels, significantly influence the profitability of biofuel production. Identifying the relevant policies and quantifying their impact in specific cases is difficult because of the variety of policy instruments and ways they are applied; however, they have generally translated into (sometimes very significant) subsidies aimed at supporting biofuels and influencing the financial attractiveness of their production, trade and use.

Subsidies can affect the sector at different stages. Figure 8, adapted from the Global Subsidies Initiative (Steenblik, 2007), shows the various points in the biofuel supply chain where direct and indirect policy measures can provide support for the sector. Some of these factors are interrelated, and assigning policies to one category or another may be somewhat artificial in practice. Different

policy instruments and types of related support applied at different stages may have very different market impacts. Generally, policies and support directly linked to levels of production and consumption are considered as having the most significant market-distorting effects, while support to research and development is likely to be the least distorting.

Agricultural policies

Agricultural and forestry policies that predate the liquid biofuels era have had a strong influence on the bioenergy industry. Indeed, agricultural subsidies and price support mechanisms directly affect both production levels and prices of first-generation biofuel feedstocks and feedstock production systems and methods. Most OECD countries have applied policies of subsidization and protection in agriculture, which international trade negotiations within the framework of the World Trade Organization (WTO) have not succeeded in eliminating, although some discipline on agricultural policies and agricultural protection has been introduced. Such policies have had significant implications for agricultural trade and geographic patterns of agricultural production at the international level, as they will for the production of biofuel feedstocks.

Blending mandates

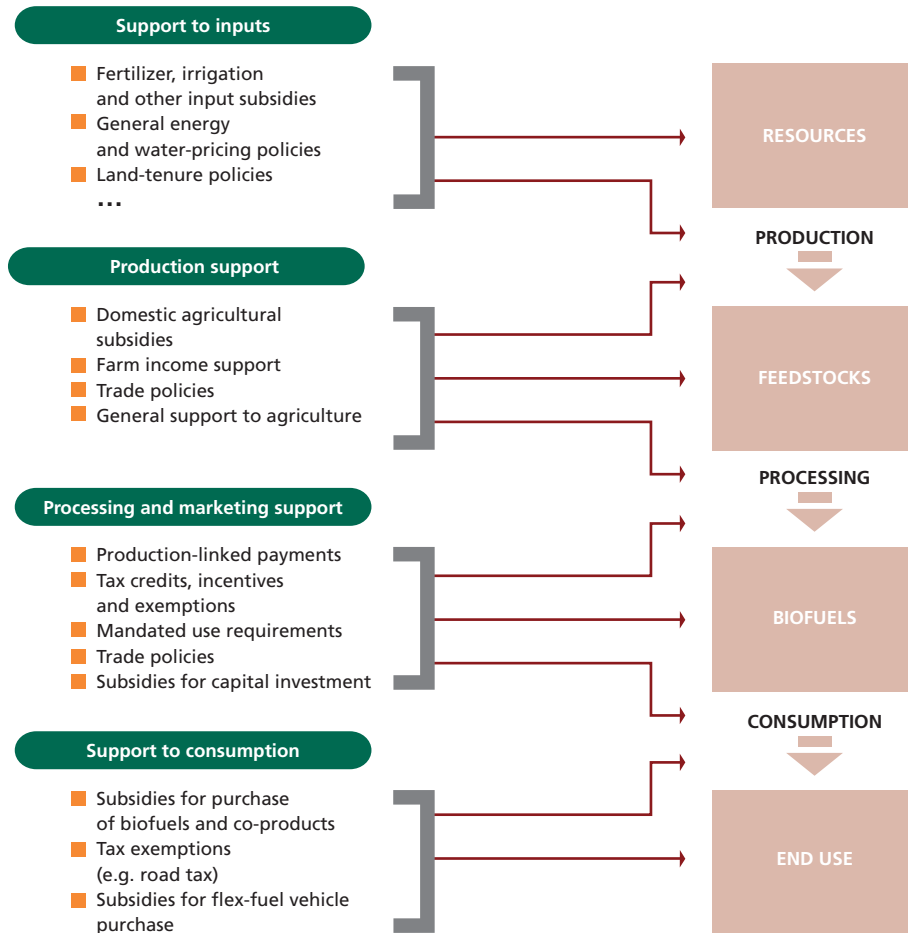
Quantitative targets are key drivers in the development and growth of most modern bioenergy industries, especially liquid biofuels for transport, where blending mandates are increasingly imposed. Table 4 summarizes the current voluntary and mandatory blending requirements for liquid biofuels in the G8+5 countries,⁶ although it should be noted that policies in this area are in rapid evolution.

Subsidies and support

Support to distribution and use are key policy components in most countries that promote the use of biofuels. Several countries are subsidizing or mandating investments in infrastructure for biofuel storage,

⁶ The G8+5 group comprises the G8 countries (Canada, France, Germany, Italy, Japan, the Russian Federation, the United Kingdom and the United States of America), plus the five major emerging economies (Brazil, China, India, Mexico and South Africa).

FIGURE 8
Support provided at different points in the biofuel supply chain



Source: adapted from Steenblik, 2007.

transportation and use, most of it directed towards ethanol, which normally requires major investments in equipment. Such support is often justified on the grounds that greater use of ethanol and expansion of the market for it will not occur until sufficient distribution infrastructure and sales points are in place. Flex-fuel vehicles, designed to use higher-percentage blends of ethanol and petrol than ordinary vehicles, are also actively promoted by many governments, for example through reduced registration fees and road taxes. While most petrol-powered cars built in the OECD countries can run on blends with an ethanol content of up to 10 percent, and some up to 20 percent, flex-fuel vehicles can use any blend up to 85 percent of ethanol.

Tariffs

Tariffs on biofuels are widely used to protect domestic agriculture and biofuel industries, support domestic prices of biofuels and provide an incentive for domestic production. The major ethanol producers, with the exception of Brazil, apply significant MFN (most-favoured nation) tariffs (see Table 5). However, there are several exceptions to the MFN rates and tariff quotas in place. Generally, lower tariff rates tend to apply to biodiesel.

Tax incentives

While tariffs are used to stimulate domestic production and protect domestic producers, tax exemptions represent a means for stimulating demand for biofuels. Tax

TABLE 4
Voluntary and mandatory bioenergy targets for transport fuels in G8+5 countries

COUNTRY/COUNTRY GROUPING	TARGETS ¹
Brazil	Mandatory blend of 20–25 percent anhydrous ethanol with petrol; minimum blending of 3 percent biodiesel to diesel by July 2008 and 5 percent (B5) by end of 2010
Canada	5 percent renewable content in petrol by 2010 and 2 percent renewable content in diesel fuel by 2012
China	15 percent of transport energy needs through use of biofuels by 2020
France	5.75 percent by 2008, 7 percent by 2010, 10 percent by 2015 (V), 10 percent by 2020 (M = EU target)
Germany	6.75 percent by 2010, set to rise to 8 percent by 2015, 10 percent by 2020 (M = EU target)
India	Proposed blending mandates of 5–10 percent for ethanol and 20 percent for biodiesel
Italy	5.75 percent by 2010 (M), 10 percent by 2020 (M = EU target)
Japan	500 000 kilolitres, as converted to crude oil, by 2010 (V)
Mexico	Targets under consideration
Russian Federation	No targets
South Africa	Up to 8 percent by 2006 (V) (10 percent target under consideration)
United Kingdom	5 percent biofuels by 2010 (M), 10 percent by 2020 (M = EU target)
United States of America	9 billion gallons by 2008, rising to 36 billion by 2022 (M). Of the 36 billion gallons, 21 billion to be from advanced biofuels (of which 16 billion from cellulosic biofuels)
European Union	10 percent by 2020 (M proposed by EU Commission in January 2008)

¹ M = mandatory; V = voluntary.

Sources: GBEP, 2007, updated with information from the United States Department of Agriculture (USDA, 2008a), the Renewable Fuels Association (RFA, 2008) and written communication from the EU Commission and Professor Ricardo Abramovay, University of São Paulo, Brazil.

TABLE 5
Applied tariffs on ethanol in selected countries

Country/Country grouping	Applied MFN tariff	At pre-tariff unit value of US\$0.50/litre		Exceptions/Comments	
		Local currency or ad valorem rate	Ad valorem equivalent (Percentage)		Specific-rate equivalent (US\$/litre)
Australia	5 percent + A\$0.38143/litre		51	0.34	United States of America, New Zealand
Brazil	0 percent		0	0.00	From 20 percent in March 2006
Canada	Can\$0.0492/litre		9	0.047	FTA partners
Switzerland	SwF35/100 kg		46	0.232	EU, GSP
United States of America	2.5 percent + US\$0.54/gallon		28	0.138	FTA partners, CBI partners
European Union	€0.192/litre		52	0.26	EFTA, GSP

Notes: Ethanol is classified for trade purposes as HS 2207.10, undenatured ethyl alcohol.

Tariffs indicated are rates as of 1 January 2007.

MFN = most-favoured nation; FTA = Free Trade Association; EFTA = European Free Trade Association; GSP = Generalised System of Preferences; CBI = Caribbean Basin Initiative.

Source: Steenblik, 2007.

BOX 4

Biofuel policies in the United States of America

The production of ethanol from maize currently dominates United States biofuel production, with production levels of 30 billion litres in 2007, followed by biodiesel from soybean, which reached 2 billion litres. The United States of America is also devoting significant resources towards developing and implementing next-generation biofuel technologies.

A range of policies are currently being implemented to promote bioenergy, including the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, the 2002 Farm Bill and the Biomass Research and Development Act of 2000. Several of these affect liquid biofuels for transport.

Financial incentives to biofuels began during the Carter Administration with the 1978 Energy Tax Act, following the oil price shocks of the 1970s. The Act provided an excise tax exemption for alcohol fuel blends at 100 percent of the petrol tax, which at the time was 4 cents per gallon. More recently, the American Jobs Creation Act of 2004 introduced

the Volumetric Ethanol Excise Tax Credit (VEETC), a tax credit of 51 cents per gallon of ethanol for blenders and retailers. The VEETC was extended by the 2005 Energy Policy Act through to 2010, and was expanded to include biodiesel. Biodiesel producers who use agricultural feedstocks are eligible for a tax credit of US\$1.00 per gallon, while producers of waste-grease biodiesel can receive a credit of 50 cents per gallon. Several states also offer some form of excise tax exemptions. VEETC is applied to biofuels regardless of their country of origin. However, a 54 cents/gallon and 2.5 percent ad valorem tariff is imposed on imported ethanol.

The Energy Policy Act of 2005 introduced quantitative targets for renewable fuels. Indeed, the Renewable Fuels Standard (RFS), established by the Act, mandated that all motor petrol sold in the United States of America must have reached a renewable fuel content of 7.5 billion gallons (1 gallon = 3.785 litres) by 2012; after 2012, the percentage content was to be maintained at the level of 2012. Several states have also

incentives or penalties are among the most widely used instruments and can dramatically affect the competitiveness of biofuels *vis-à-vis* other energy sources and thus their commercial viability. The United States of America was among the first of the OECD countries to implement biofuel tax exemptions with the 1978 Energy Tax Act, following the oil price shocks of the 1970s. The Act provided an excise tax exemption for alcohol fuel blends. In 2004, the tax exemption was replaced by an income tax credit for producers. Other countries have since implemented different forms of excise tax exemptions.

Research and development

Most biofuel-producing countries conduct or fund research and development at various stages of the biofuel production process, ranging from agronomy to combustion.

Bioenergy research and development has generally been aimed at developing technologies for improving conversion efficiency, identifying sustainable feedstock and developing cost-effective conversion methods for advanced fuels. Current patterns of funding in developed countries suggest that an increasing proportion of public research and development funding is directed towards second-generation biofuels, in particular cellulosic ethanol and biomass-derived alternatives to petroleum-based diesel.

Economic costs of biofuel policies

The Global Subsidies Initiative (Steenblik, 2007) has prepared estimates of subsidies to the biofuel sector in selected OECD economies, presented in Table 6. These

implemented, or plan to implement, their own renewable fuels standards.

The 2005 Act also continued funding for the Biomass Program, providing more than US\$500 million to promote use of biotechnology and other advanced processes to make biofuels from cellulosic feedstocks cost-competitive with petrol and diesel, to increase the production of bioproducts that reduce the use of fossil fuels in manufacturing facilities and to demonstrate the commercial application of integrated bio-refineries that use cellulosic feedstocks to produce liquid transport fuels, high-value chemicals, electricity and heat.

The Energy Independence and Security Act of 2007 established more ambitious quantitative targets, stipulating a volume for 2008 of 9 billion gallons of renewable fuels and a phased increase to 36 billion gallons by 2022. Of the latter, 21 billion gallons should be covered by advanced biofuels (of which 16 billion from cellulosic biofuels and 5 billion from undifferentiated advanced biofuels).

In terms of grants, the 2007 Energy Independence and Security Act authorized US\$500 million annually for the fiscal years 2008–15 for the production of advanced biofuels with at least an 80 percent reduction in life-cycle greenhouse gas emissions relative to current fuels. It likewise foresaw a US\$200 million grant programme for the installation of refuelling infrastructure for ethanol-85.

The 2002 Farm Bill had included several provisions to promote the development of bio-refineries, to provide incentives to feedstock producers and to realize education programmes for farmers, local authorities and civil society promoting the benefits of biofuel production and utilization. The 2007 Farm Bill, voted by Congress in May 2008, reduced the tax credit for maize-based ethanol from 51 to 45 cents per gallon and introduced a tax credit of US\$1.01 per gallon for cellulose-based ethanol.

Sources: based on GBEP, 2007, and information from USDA, 2008a, and RFA, 2008.

estimates give a rough idea of the magnitude of transfers supporting biofuels in the countries covered, although they probably tend to underestimate the total value of investment incentives, for which information is difficult to obtain. The estimates do not consider potential market-distorting impacts of the different policies.

The total support estimates (TSE) calculate the total value of all government support to the biofuels industry including, among others, consumption mandates, tax credits, import barriers, investment subsidies and general support to the sector such as public research investment. They are analogous to the TSE calculated for agriculture by the OECD. As such, they include measures deemed to be directly tied to production levels and less-distorting supports that are not directly linked to output. They do not include support to agricultural feedstock

production, which is calculated separately in the TSE for agriculture.

Table 6 confirms that biofuel subsidies are already relatively costly for taxpayers and consumers in the OECD economies, with United States processors and growers receiving support worth just over US\$6 billion per year, and those in the EU receiving almost US\$5 billion per year. The table also provides estimates of the share of TSE that varies according to the level of production. This provides an indication of how the total would change with increasing output, such as that implied by the consumption targets in place in the EU and the United States of America. EU ethanol subsidies are almost completely variable with output and so would increase in line with mandated increases in output. The table also suggests that OECD biofuel subsidies are likely to become much larger as mandated consumption increases.

BOX 5 Biofuel policies in the European Union

Over the past decade, the production and use of biofuels has increased substantially in the European Union (EU). In 2007, 9 billion litres of biofuel were produced, dominated by biodiesel (6 billion litres). The sector has undergone very rapid growth, with Germany accounting for more than half of EU biodiesel production. The main feedstock used is rapeseed (about 80 percent), with sunflower oil and soybean oil making up most of the rest. The EU industry has been slower to invest in ethanol production, which totalled almost 3 billion litres in 2007. The main ethanol feedstocks are sugar beet and cereals.

EU biofuel legislation consists of three main Directives. The first pillar is Directive 2003/30/EC for promotion of a biofuels market in the EU. To encourage biofuel use, in competition with less costly fossil fuels, the Directive sets a voluntary "reference target" of 2 percent biofuel consumption (on the basis of energy content) by 2005 and 5.75 percent by 31 December 2010. It obliges Member

States to set national indicative targets for the share of biofuels, in line with reference percentages of the Directive, although it leaves them free to choose a strategy to achieve these targets.

The second pillar is Directive 2003/96/EC, which allows for the application of tax incentives for biofuels. Taxation not being within the sphere of action of the European Community, each Member State can decide on a level of taxation for fossil fuels and biofuels. However, these tax exemptions are considered as environmental state aid and therefore their implementation by Member States requires authorization from the European Commission in order to avoid undue distortions of competition.

The third pillar of the EU biofuel legislation concerns environmental specifications for fuels indicated in Directive 98/70/EC amended by Directive 2003/17/EC. The Directive contains a 5 percent limit on ethanol blending for environmental reasons. The Commission

TABLE 6
Total support estimates for biofuels in selected OECD economies in 2006

OECD economy	ETHANOL		BIODIESEL		TOTAL LIQUID BIOFUELS	
	TSE (Billion US\$)	Variable share ¹ (Percentage)	TSE (Billion US\$)	Variable share ¹ (Percentage)	TSE (Billion US\$)	Variable share ¹ (Percentage)
United States of America²	5.8	93	0.53	89	6.33	93
European Union³	1.6	98	3.1	90	4.7	93
Canada⁴	0.15	70	0.013	55	0.163	69
Australia⁵	0.043	60	0.032	75	0.075	66
Switzerland	0.001	94	0.009	94	0.01	94
Total	7.6	93	3.7	90	11.3	92

¹ The percentage of support that varies with increasing production or consumption, and includes market-price support, production payments or tax credits, fuel-excite tax credits and subsidies to variable inputs.

² Lower bound of the reported range.

³ Total for the 25 Member States of the European Union in 2006.

⁴ Provisional estimates.

⁵ Data refer to the fiscal year beginning 1 July 2006.

Sources: Steenblik, 2007; Koplou, 2007; Quirke, Steenblik and Warner, 2008.

has proposed an amendment that includes a 10 percent blend for ethanol.

Bioenergy support has also been introduced as part of the Common Agricultural Policy, especially following its reform in 2003. By cutting the link between payments made to farmers and the specific crops they produce, the reform allowed them to take advantage of new market opportunities such as those offered by biofuels. A special aid of €45 per hectare is available for energy crops grown on non-set-aside land (traditional food crop areas). In addition, while farmers cannot cultivate food crops on set-aside land, they can use this land for non-food crops, including biofuels, and are eligible to receive compensatory payments per hectare.

Support to bioenergy comes also from the new EU rural development policy, which includes measures to support renewable energies, such as grants and capital costs for setting up biomass production.

In March 2007, the European Council, based on the Commission's

Communication *An energy policy for Europe*, endorsed a binding target of a 20 percent share of renewable energies in overall EU energy consumption by 2020, as well as a 10 percent binding minimum target for the share of biofuels in overall EU petrol and diesel consumption for transport by 2020. The latter target is subject to production being sustainable, second-generation biofuels becoming commercially available and the fuel-quality Directive being amended to allow for adequate levels of blending (Council of the European Union, 2007). A proposal for a renewable energy Directive including both these targets and sustainability criteria for biofuels was put forward by the European Commission to the Council and the European Parliament on 23 January 2008.

Sources: based on GBEP, 2007, and information from the Web site of the European Commission.

To provide some perspective on the relative importance of these biofuel subsidies, Table 7 shows them on a per-litre basis. Ethanol subsidies range from about US\$0.30 to US\$1.00 per litre, while the range of biodiesel subsidies is wider. The table reveals that although some countries' total support expenditures are relatively modest, they can be substantial on a per-litre basis. Again, the variable portion of support provides an indication of the scope for increases in expenditures as output grows, although some subsidies are budget-limited, especially at the state or provincial levels.

Economic viability of biofuels

The biofuel policies discussed above are shaping the global agricultural economy in ways that may have unintended consequences for the countries implementing the policies and for the rest of the world. All countries

are affected, whether or not they produce biofuels. The mandates, subsidies and incentives being implemented by various countries have created a major new source of demand for agricultural commodities. As a consequence, the historic linkages between agriculture and the energy sector are becoming stronger and are changing in character. Biofuel policies have important implications for farm output and incomes, commodity prices and food availability, returns to land and other resources, rural employment and energy markets.

An individual farmer will produce feedstock for biofuels if the net revenue he or she earns is greater than for alternative crops or uses. The decision-making process for a biofuel crop is the same as for any other crop. Farmers choose what to produce on the basis of expected net revenues and perceptions of risk and may use formal models, experience, tradition or a combination of the three in making their

choice. The calculus will differ from farm to farm and season to season, depending on the prevailing market and agronomic conditions.

Within the prevailing policy and market context, the price a farmer receives for a biofuel crop depends primarily on the energy potential of the crop, conversion costs, transportation costs and the value of co-products. As discussed in Chapter 2, crops differ in their physical energy potential, which is a function of biomass feedstock yields per hectare and the efficiency with which the feedstock is converted to biofuels. Yields vary from crop to crop, depending on cultivars, agronomic practices, soil quality and weather.

Global average crop yields for first-generation ethanol feedstocks range from 1.3 tonnes per hectare for sweet sorghum to 65 tonnes for sugar cane (see Table 2 on page 16). Similarly, conversion efficiency ranges from 70 litres of ethanol per tonne for sugar cane to 430 litres for rice. In terms of land intensity (litres/hectare), sugar beet and sugar cane are the most productive first-generation crops. Economic efficiency may differ markedly, however, because the costs of production vary widely by crop and location.

Budgeting models can be used to evaluate the financial performance of biofuel processing firms. Tiffany and Eidman (2003) calculated the performance of a dry-mill ethanol plant based on a range of maize prices, ethanol prices, prices of co-products, natural gas prices and interest rates relative to alternative investments. This model found that ethanol plants had experienced great volatility in net returns over the preceding decade and that net returns were highly sensitive to changes in price for maize, ethanol and natural gas. These price changes, together with variations in ethanol yields, could thus have a marked effect on net margins for ethanol plants.

Yu and Tao (2008) provide a simulation of three ethanol projects in different regions of China based on different feedstocks: cassava, wheat and maize. They took into consideration the variability of feedstock and petroleum prices and calculated the expected net present value (NPV) and internal rate of return (IRR) of investments of the three projects under a range of price conditions. They found that the cassava project had a positive expected NPV and an IRR exceeding 12 percent under most scenarios and thus was likely to be economically competitive,

TABLE 7
Approximate average and variable rates of support per litre of biofuel
in selected OECD economies

OECD economy	ETHANOL		BIODIESEL	
	Average (US\$/litre) ¹	Variable (US\$/litre) ¹	Average (US\$/litre) ¹	Variable (US\$/litre) ¹
United States of America²	0.28	Federal: 0.15 States: 0.00–0.26	0.55	Federal: 0.26 States: 0.00–26
European Union³	1.00	0.00–0.90	0.70	0.00–0.50
Canada⁴	0.40	Federal: up to 0.10 Provinces: 0.00–0.20	0.20	Federal: up to 0.20 Provinces: 0.00–0.14
Australia⁵	0.36	0.32	0.35	0.32
Switzerland⁶	0.60	0.60	1.00	0.60–2.00

Notes:

¹ Values (except in the case of the United States of America and Australia) are rounded to the nearest US\$0.10.

² Lower bound of reported range. Some payments are budget-limited.

³ Refers to support provided by Member States.

⁴ Provisional estimates; includes incentives introduced on 1 April 2008.

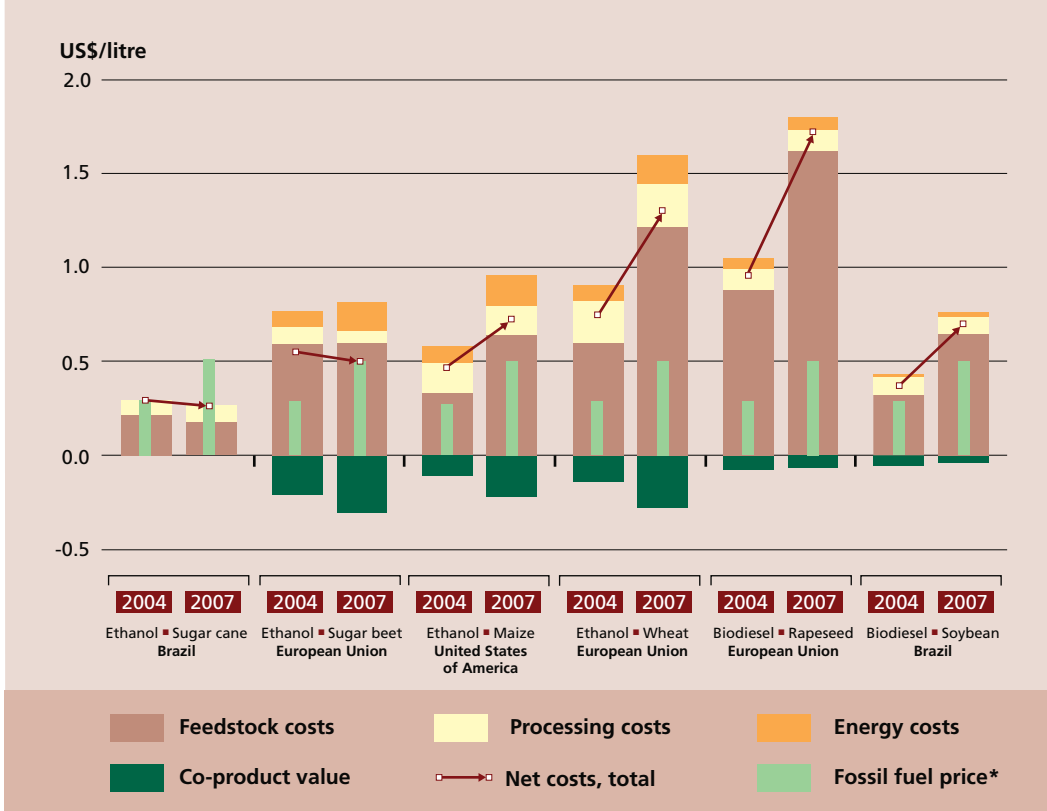
Federal and most provincial supports are budget-limited.

⁵ Data refer to the fiscal year beginning 1 July 2006. Payments are not budget-limited.

⁶ Range for biodiesel depends on source and type of feedstock. Some payments are limited to a fixed number of litres.

Source: Steenblik, 2007, p. 39.

FIGURE 9
Biofuel production costs in selected countries, 2004 and 2007



*Net price of petrol or diesel in national markets.

Source: OECD-FAO, 2008.

although with a 25 percent probability of less favourable returns. The maize and wheat projects had very low or negative NPVs and thus would not be economically viable without subsidies. The relatively poor performance of the wheat and maize projects was attributable primarily to higher feedstock costs, which exceeded 75 percent of total production costs.

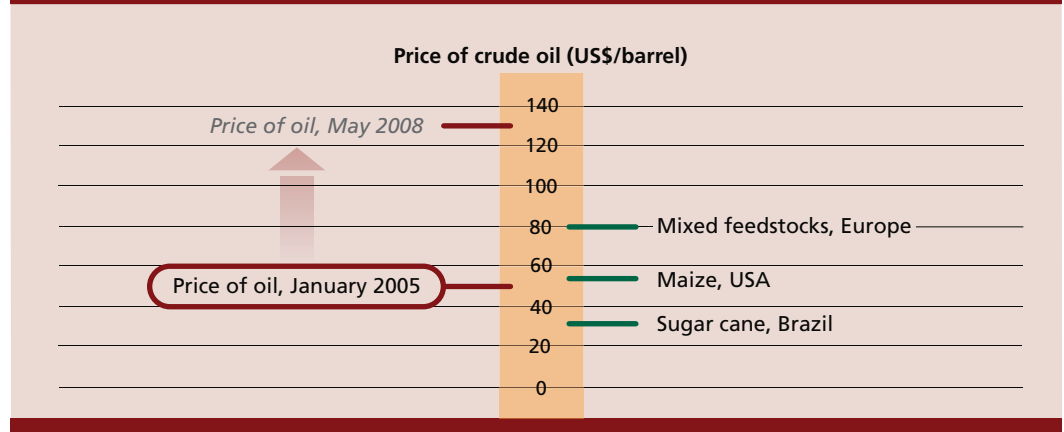
OECD-FAO (2008) estimated average biofuel production costs in selected countries for alternative feedstocks, shown in Figure 9. Costs are broken down by feedstock, processing and energy costs. The value of co-products is deducted and net costs are indicated in the chart by a square dot. The market price of the nearest equivalent fossil fuel (petrol or diesel) is indicated for each fuel by a green bar.

By far the lowest total costs are for Brazilian sugar-cane ethanol. In all cases for which data are reported, the commodity feedstock accounts for the largest share of total costs. Energy costs for ethanol

production in Brazil are negligible because bagasse, the major co-product of sugar-cane processing, is burned for fuel. In contrast, European and United States processors typically pay for fuel, but sell co-products from the ethanol and biodiesel production processes, usually for animal feed.

After subtracting the value of co-products, the resulting net production costs, on a per litre basis, are also lowest for Brazilian sugar-cane ethanol – the only biofuel that is consistently priced below its fossil-fuel equivalent. Brazilian biodiesel from soybean and United States ethanol from maize have the next lowest net production costs, but in both cases costs exceed the market price of fossil fuels. European biodiesel production costs are more than double those for Brazilian ethanol, reflecting higher feedstock and processing costs. Feedstock costs for maize, wheat, rapeseed and soybean rose sharply between 2004 and 2007, and future profitability will depend on how they

FIGURE 10
Breakeven prices for crude oil and selected feedstocks in 2005



Source: based on data from FAO, 2006a.

continue to evolve in relation to petroleum prices.

A 2006 FAO study calculated the points at which ethanol from various feedstocks and farming production systems would be competitive with fossil fuels, based on average feedstock prices prior to 2006 (FAO, 2006a) (see Figure 10). The findings reveal a wide variation in the ability of different systems to deliver biofuels on an economically competitive basis and are consistent with those of the OECD in that Brazilian sugar cane was found to be competitive at much lower crude oil prices than other feedstocks and production locations. Based on maize prices prior to 2006, United States maize ethanol was found to be competitive at crude oil prices of around US\$58/barrel, but it is important to note that this breakeven point will change as feedstock prices change. Indeed, sharp rises in maize prices (partly due to demand for biofuels) and reductions in sugar prices since this analysis was conducted suggest that the competitive advantage of Brazilian sugar-cane ethanol over United States maize ethanol may have widened.

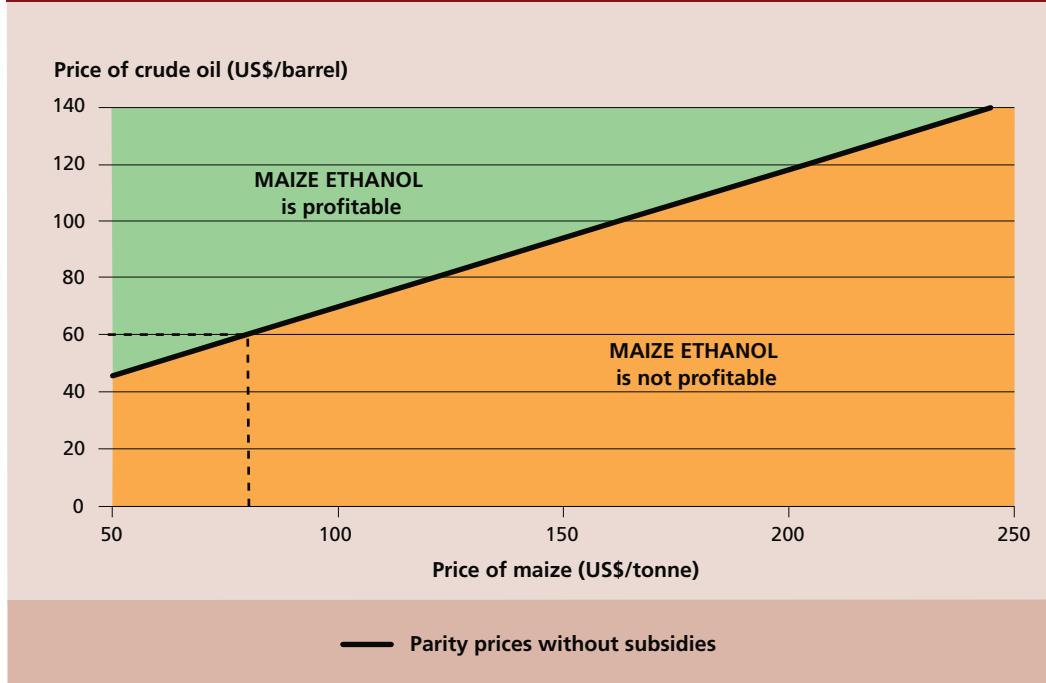
Tyner and Taheripour (2007) took the dynamic nature of commodity prices into account and calculated the breakeven points – without tax credits and incentives – for various combinations of maize-based ethanol and crude oil prices in the United States of America, given existing technologies (Figure 11). Their analysis of a single feedstock reveals the importance of

relative feedstock and crude oil prices for the economic viability of the system. For example, at a crude oil price of US\$60.00/barrel, ethanol processors could pay up to US\$79.52/tonne for maize and remain profitable. Similarly, at crude oil prices of US\$100.00/barrel, processors could pay up to US\$162.98/tonne. The solid black line traces out the various parity prices or breakeven points for ethanol-based maize in the United States of America. At price combinations located above and to the left of the parity price line, maize ethanol is profitable; at lower crude oil prices or higher maize prices (combinations below and to the right of the solid line), maize ethanol is not profitable.

Similar analyses could be performed for other feedstocks and production locations. The results would differ according to the technical efficiency of feedstock production and biofuel conversion in the particular setting. The parity price line for lower-cost producers would intersect the vertical axis at a lower point. The slope of the parity price line would depend on the ease with which producers can expand feedstock production and biofuel processing in response to price changes. A country's parity price line could also shift over time in response to technological progress, improvements in infrastructure or institutional innovations.

Tyner and Taheripour (2007) also took into consideration the influence of policy interventions on economic viability. They estimated that the United States renewable fuel standard, tax credits and tariff barriers

FIGURE 11
Breakeven prices for maize and crude oil in the United States of America



Source: based on Tyner and Taheripour, 2007.

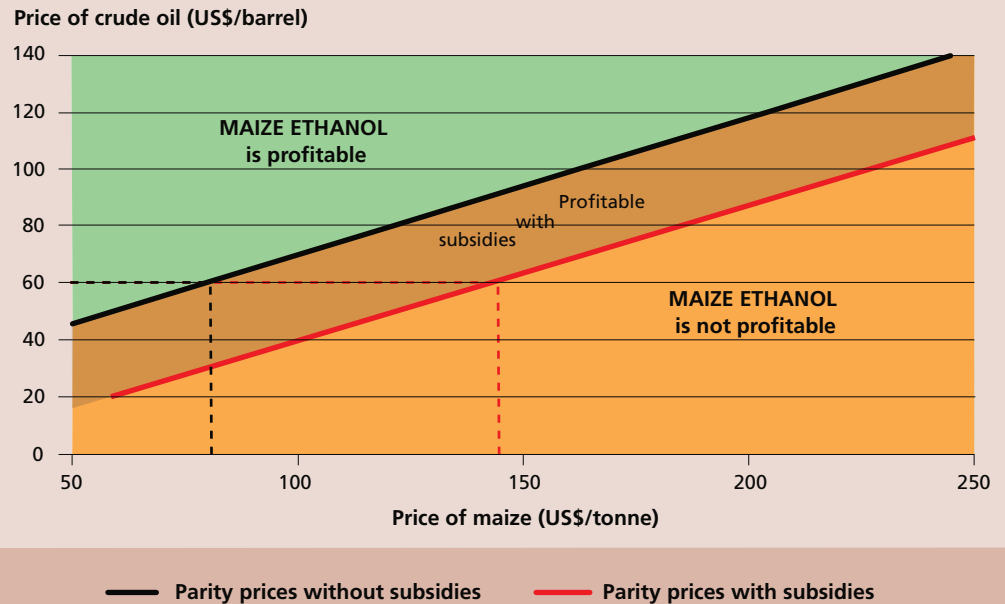
(see Box 4 on United States biofuel policies) represent a combined subsidy of about US\$1.60/bushel (US\$63.00/tonne) for maize used in ethanol production. Figure 12 shows the breakeven prices for maize at various crude oil prices, both on the basis of the energy content of ethanol and also including the value of the existing subsidies. The red line takes into account the value of United States mandates and subsidies for ethanol. This line is below and to the right of the black line, indicating that for a given crude oil price, ethanol processors can pay a higher price for maize and remain profitable. The value of the mandates and subsidies raises the breakeven price for maize by about US\$63.00/tonne for any given level of petroleum prices. As shown above, for a crude oil price of US\$60/barrel, maize ethanol would be competitive on an energy basis as long as the market price for maize remained below US\$79.52/tonne, but the subsidies enable processors to pay up to US\$142.51/tonne and still remain profitable.

Figure 13 superimposes observed monthly maize and crude oil prices from June 2003 through April 2008 on top of Tyner and Taheripour's parity price lines. The data

points show that the relative maize/crude oil prices generally lie to the right of the black line, indicating that the maize price is higher than the breakeven point for ethanol on an energy basis and that United States maize ethanol is not competitive with fossil fuels without subsidies. The price pairs typically lie between the two lines, indicating that subsidies are often, but not always, enough to make maize ethanol competitive.

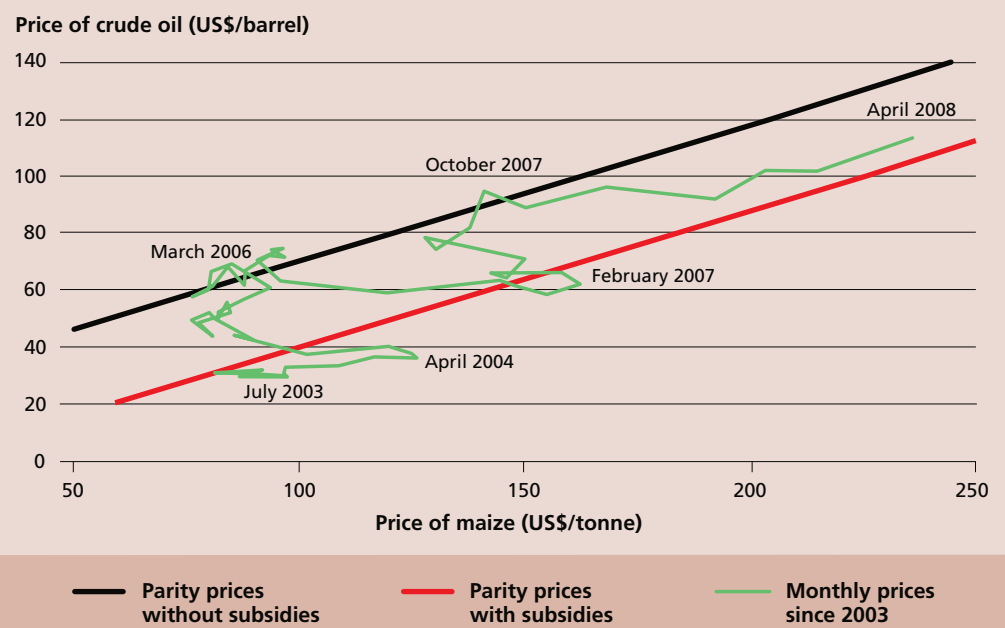
Looking at the data over time reveals a stepwise relationship, in which the price of crude oil seems to pull up maize prices as ethanol production expands. Before mid-2004, crude oil prices were so low that maize could not compete as an ethanol feedstock even with the available subsidies. Crude oil prices began to rise in mid-2004, at a time when maize prices were still quite low. By early 2005, crude prices had exceeded US\$60/barrel and maize was almost competitive even without subsidies. The United States Energy Policy Act of 2005 established the Renewable Fuel Standard starting at 4 billion gallons in 2006 and rising to 7.5 billion in 2012. A rush of ethanol plant construction ensued, and the demand for maize as a feedstock for ethanol expanded rapidly.

FIGURE 12
Breakeven prices for maize and crude oil with and without subsidies



Source: based on Tyner and Taheripour, 2007.

FIGURE 13
Maize and crude oil breakeven prices and observed prices, 2003–08



Sources: adapted from Tyner and Taheripour, 2007. Crude oil prices: Brent crude, Chicago Board of Trade (US\$/barrel). Maize prices: US Yellow No. 2, Chicago Board of Trade (US\$/tonne). Prices downloaded from the Commodity Research Bureau Web site (<http://www.crbrtrader.com/crbindex/>) on 10 June 2008.

The price of maize rose steadily throughout 2006, partly in response to ethanol demand, although other market factors were also involved, while the price of crude oil remained close to US\$60/barrel. During this period, the competitiveness of maize as an ethanol feedstock fell sharply even with the subsidies, and many ethanol plants began to operate at a loss. Crude oil prices began rising sharply again in mid-2007, reaching US\$135/barrel by mid-2008. Maize thus regained its competitiveness, albeit with subsidies, after mid-2007.⁷ Biofuel policies themselves influence the price of agricultural commodities and hence partially determine their competitiveness as feedstocks for biofuel production. The role of policies in shaping biofuel markets is explored more fully in Chapter 4.

The analysis suggests that, given current technology, United States maize ethanol can rarely and only briefly achieve market viability before the price of maize is bid up to the point that it again becomes uncompetitive as a feedstock. Current subsidies and trade barriers offset part of this disadvantage, but do not guarantee competitiveness.

The analysis also illustrates the close link between crude oil prices and prices of agricultural feedstocks. The pattern revealed is consistent with the argument presented at the beginning of this chapter that, because energy markets are large relative to agricultural markets, crude oil prices will drive agricultural prices. It further underlines the role played by government support policies in shaping the relationship between prices in the two sectors.

While similar breakeven point analysis has not been conducted for other biofuel feedstocks and other countries, an examination of the crude oil–commodity price pairs suggests that similar patterns hold for most feedstocks. Figure 14 shows the monthly price pairs for petroleum and rapeseed, palm oil, soybean and sugar. With the exception of sugar, they exhibit the

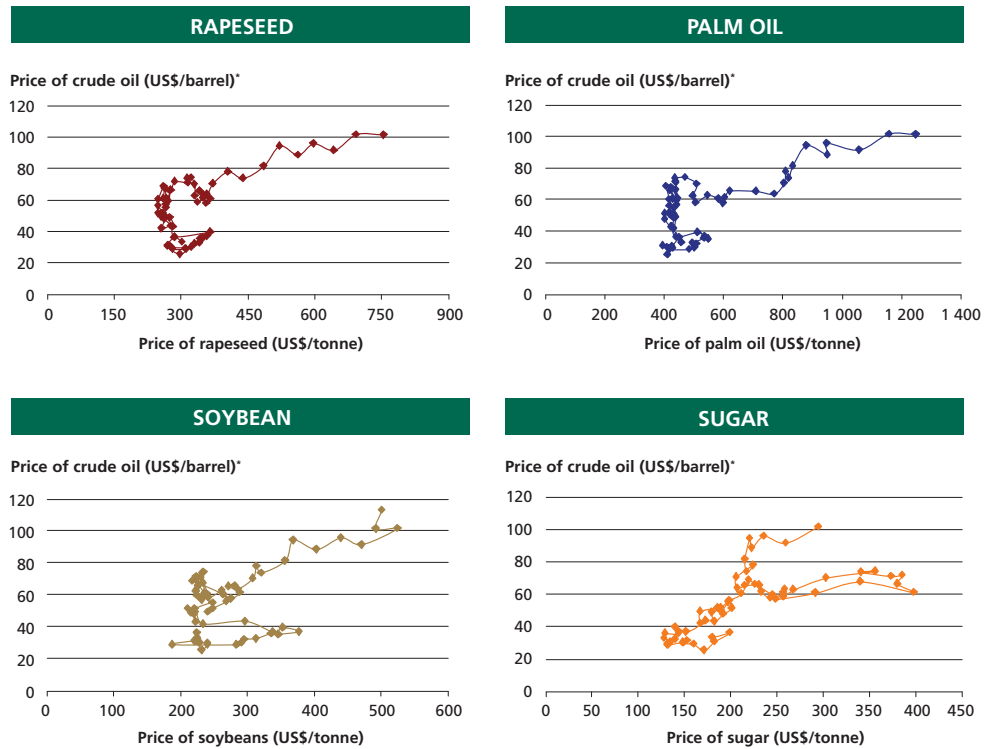
same general pattern in relation to oil prices as in the case of maize. Sugar prices, in contrast, have been declining in recent years, serving to enhance the profitability of sugar cane as an ethanol feedstock.

Key messages of the chapter

- Liquid biofuels such as bioethanol and biodiesel compete directly with petroleum-based petrol and diesel. Because energy markets are large compared with agricultural markets, energy prices will tend to drive the prices of biofuels and their agricultural feedstocks.
- Biofuel feedstocks also compete with other agricultural crops for productive resources; therefore energy prices will tend to affect prices of all agricultural commodities that rely on the same resource base. For the same reason, producing biofuels from non-food crops will not necessarily eliminate competition between food and fuel.
- For given technologies, the competitiveness of biofuels will depend on the relative prices of agricultural feedstocks and fossil fuels. The relationship will differ among crops, countries, locations and technologies used in biofuel production.
- With the important exception of ethanol produced from sugar cane in Brazil, which has the lowest production costs among the large-scale biofuel-producing countries, biofuels are not generally competitive with fossil fuels without subsidies, even at current high crude oil prices. However, competitiveness can change in line with changes in feedstock and energy prices and developments in technology. Competitiveness is also influenced directly by policies.
- Biofuel development in OECD countries has been promoted and supported by governments through a wide array of policy instruments; a growing number of developing countries are also beginning to introduce policies to promote biofuels. Common policy instruments include mandated blending of biofuels with petroleum-based fuels, subsidies

⁷ An additional factor stimulating ethanol demand in the United States of America has been the ban in California – effective from January 2004 – on the use of methyl tertiary butyl ether (MTBE). MTBE is a petrol additive used to improve the clean burning of engines, but with suspected adverse impacts on water quality, that can be replaced by ethanol.

FIGURE 14
Price relationships between crude oil and other biofuel feedstocks, 2003–08



* Monthly prices since 2003.

Sources: Crude oil prices: Brent crude, Chicago Board of Trade (US\$ per barrel), downloaded from the Commodity Research Bureau Web site (<http://www.crbtrader.com/crbindex/>) on 10 June 2008. Commodity prices from FAO international commodity price database.

to production and distribution, and tax incentives. Tariff barriers for biofuels are also widely used to protect domestic producers. These policies have decisively affected the profitability of biofuel production, which in many cases would otherwise not have been commercially viable.

- The main drivers behind government support for the sector have been concerns over climate change and energy security as well as the desire to support the farm sector through increased demand for agricultural

products. Although seemingly effective in supporting domestic farmers, the effectiveness of biofuel policies in reaching the climate-change and energy-security objectives is coming under increasing scrutiny.

- In most cases, these policies have been costly and have tended to introduce new distortions to already severely distorted and protected agricultural markets – at the domestic and global levels. This has not tended to favour an efficient international production pattern for biofuels and biofuel feedstocks.