Annex 5

The role of demand for biofuel in the agricultural commodity price spikes of 2007/08

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Executive Summary

- Demand for feedstocks used directly in *biofuel production has dramatically increased over the last decade*. For example, the proportion of maize used for bioethanol increased from 4% in 2001/02 to 12% in 2007/08. Still, in terms of global commodity markets, food and feed uses dominate.

- This surge in biofuel demand has likely been *primarily driven by government policies* rather than by 'organic' demand from rising crude oil prices during the past few years. Indeed, higher oil prices alone do not drive commercial incentives to produce biofuels; rather, it is the ratio of the oil price to feedstock prices which matters. In the US maize market, the viability of maize-ethanol production has been *mostly* uneconomic in recent years, even during the large rise seen in the oil price during 2007/08. Were it not for public policy, biofuel demand is very unlikely to have increased as it did.

- The primary impact of high oil prices on agricultural commodities seems still to be *through the supply-side*, via increased costs of production, rather than the emerging demand-side channel of biofuels. Fuel and fertiliser account for over half of operating costs of crop farms but many commentators have ignored oil's ongoing importance as an input into agricultural production.

- Medium-term economic models agree that biofuel demand has and will *put upward pressure on prices for those agricultural commodities* used in biofuels production.

- However, available evidence suggests that biofuels had a relatively *small contribution* to the 2008 spike in agricultural commodity prices where its impact was largely limited to the maize market with some knock-on effects on soybean prices. By way of contrast, the price of wheat increased before maize and to a higher peak, moving the ratio of wheat to maize prices higher than the recent past and suggesting that incentives for any demand-side substitution were actually away from wheat.

- Studies which have found a large biofuel impact across agricultural commodities have often considered too few variables, relied on statistical associations or made unrealistic or inconsistent assumptions.

- A significant feedstock for biofuel use, sugar, did not see a large rise in price during the spike period but increased significantly in 2009 when other commodity prices had fallen back from their peaks.

- Whilst commodity prices have fallen steeply from their peaks in 2008 biofuel demand has remained steady – indicating that the causal link from biofuel demand to short-term crop prices is still relatively weak.

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Areas for future research

- A closer examination of the biodiesel and agricultural markets and prices.

- Developing models of short-term (i.e. within year) price movements rather than the reliance on medium-term models.

- Further understand the role of oil as an input to food commodity production and how this has changed over time.

- Fuller appraisal of the different types of biofuels policies and their impact on agricultural markets is required, in particular the impact of inflexible quantitative targets for biofuel consumption.

Introduction

This paper is part of a larger body of work that aims to shed more light on what led to the high agricultural commodity prices in 2008. The paper first looks at of some of the specifics of agricultural markets and the changes over the last few years in those markets due to biofuels (bioethanol and biodiesel). It goes on to give a brief overview of biofuel policies in the main producer countries. It examines the links between agricultural and energy markets, including economic modelling of the medium-term relationship between the two, and it evaluates the economic viability of biofuel production in the US, taking a case study approach to a specific commodity, namely sugar. The second part of the paper looks at the 2008 price spike including a literature review of biofuel's impact on the recent agricultural price increases and draws conclusions based on the arguments surrounding biofuel's contribution to the price spike in 2008.

Specifically this paper sets out to address the following question:

- To what extent did the use of grains/oilseeds for biofuel production (policy driven or not) play a role in the price spikes of 2008?

But will also cover the following:

- What has been driving biofuel production in recent years, policy or changing energy prices?

- What are the implications of any new links between energy and agricultural markets through biofuels for the level and volatility of agricultural prices in the medium term?

We start with an outline of the key foodstocks used for biofuels.

Agricultural commodity markets and production

There are two main types of liquid biofuels produced from land-based energy crops:

- bioethanol is an alcohol that can be derived from sugar or starch crops (e.g. sugar or maize[1]) by fermentation;

- biodiesel can be derived from vegetable oils (e.g. rapeseed oil, soy or palm oil) by reaction of the oil with methanol.

Table 1 shows production in 2008 by the main biofuels producing countries for biodiesel and bioethanol (those countries where production exceeds 100 million litres).

Table 1: Biofuel production in main biofuels producer countries in 2008

Bioethanol production in 2008 (million litres)		Biodiesel production in 2008 (million litres)	
United States	36,300	Germany	3,180
Brazil	24,497	United States	2,650
China	2,448	Netherlands	1,372
Canada	870	France	991
Germany	730	Spain	926
France	578	United Kingdom	347
Spain	578	Australia	260
Australia	164	Austria	252
United Kingdom	153	Portugal	227
		Sweden	127
		Brazil	110
		Belgium	108
		Denmark	103
		Canada	100

Source: Bacovsky et al., 2009

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[1] Maize is known as corn in the United States. Although the two terms are interchangeable we use maize for consistency throughout this paper, with the exception of direct quotes.

Table 2 and Figure 1 give the contribution of agricultural feedstocks to biofuel production in specific countries as well as globally. By far the most important feedstock in tonnage terms is Brazilian sugarcane, followed by US grains (namely maize). In Europe the most important feedstocks are vegetable oils and sugar beet.

Table 2: World feedstock use for bioethanol and biodiesel in 2008 ('000 tonnes)

2008	Total Grains	Sugar beet	Sugarcane	Total Vegetable oils
EU-27	3,925	6,756	0	6,630
Brazil	0	0	302,500	830
Canada	2,250	0	0	44
US	87,420	0	0	1,852
China	4,309	0	0	0
World	98,133	6,756	305,936	11,525

Source: F.O Licht

Figure 1 shows the importance of the different feedstock in the ethanol market.

Figure 1: Share of world ethanol production by feedstock in 2008
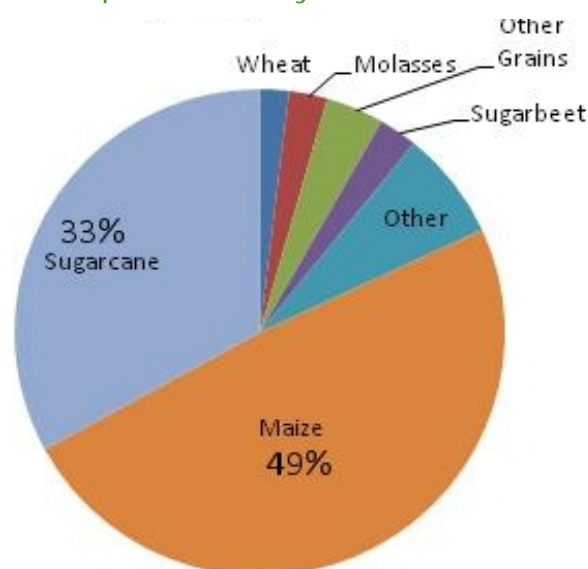
Source: OECD

Concentration of production is high in the world biofuel market – globally, the US accounts for 90% of grain used for bioethanol production whilst Brazil accounts for 99% of sugarcane used for bioethanol production. The EU accounts for 58% of vegetable oil used for biodiesel.

At the outset of any analysis of the impact of biofuels on agricultural commodity markets, it is useful to look at some statistics on world cereal markets. Cereals are produced across the world and a significant fraction of production is traded across regions (around 15-20 percent). Exports are dominated by the five major exporters, which are Argentina, Australia, Canada, the EU and the US. Key statistics in marketing years[2] are given in Table 3.

Table 3: Key world grain statistics

Wheat (million tons)					
	2004/05	2005/06	2006/07	2007/08	**2008/09 (est)**
Production	628	621	598	609	**687**
Consumption	614	625	611	614	**639**
Trade	110	110	111	110	**136**
5 Major Exporters	86	80	81	79	**92**
Maize (million tons)					
	2004/05	2005/06	2006/07	2007/08	**2008/09 (est)**
Production	713	698	709	795	**790**
Consumption	686	701	725	775	**778**
Trade	76	79	87	101	**82**
US Exports	47	51	56	62	**46**
Total Grains* (million tons)					
	2004/05	2005/06	2006/07	2007/08	**2008/09 (est)**
Production	1,647	1,606	1,588	1,697	**1,793**
Consumption	1,597	1,619	1,629	1,687	**1,723**
Trade	212	215	222	239	**247**
5 Major Exporters	165	162	165	181	**170**

*Includes wheat, maize and other coarse grains but excludes rice

Source: International Grains Council (IGC) (2009), November Grain Market Report

Turning to biofuels demand, using crops for fuel is not new. However, as Table 4 shows, the rate of increase in the use of cereals for ethanol has been significant since the turn of the millennium.

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[2]   We refer throughout to marketing years unless otherwise stated

Table 4: Annual percentage change in global wheat and maize use (million tonnes)

	Wheat annual % change in			Maize annual % change in		
	total use	industrial use[1]	use for ethanol[2]	total use	industrial use[1]	use for ethanol[2]
2001/02	0%	9%		2%	5%	
2002/03	3%	8%		0%	11%	30%
2003/04	-1%	1%	250%	3%	12%	15%
2004/05	3%	5%	86%	6%	10%	13%
2005/06	2%	14%	85%	2%	12%	27%
2006/07	-2%	6%	13%	3%	17%	29%
2007/08	1%	2%	26%	7%	21%	36%
2008/09 (est)	4%	5%	47%	0%	10%	21%

[1] includes all industrial use, of which some is ethanol for fuel and non-fuel use

[2] includes fuel and non-fuel use

Source: IGC website

Table 4 could be misinterpreted to suggest that biofuel production has led to significant additional demand for both wheat and maize. However, one has to be cautious when interpreting percentage changes as Table 5 and Figure 2 show.

Table 5: Proportion of wheat and maize for industrial use and ethanol

	Wheat		Maize	
	Industrial use as % of total use[1]	Ethanol use as % of total use[2]	Industrial use as % of total use[1]	Ethanol use as % of total use[2]
2001/02	1.8%		13%	4%
2002/03	1.9%	0.0%	14%	5%
2003/04	2.0%	0.1%	15%	6%
2004/05	2.0%	0.2%	16%	6%
2005/06	2.2%	0.4%	17%	7%
2006/07	2.4%	0.4%	19%	9%
2007/08	3.0%	0.6%	22%	12%
2008/09 (est)	2.5%	0.8%	24%	14%

[1] includes all industrial use, of which some is ethanol for fuel and non-fuel use

[2] includes fuel and non-fuel use

Source: IGC website

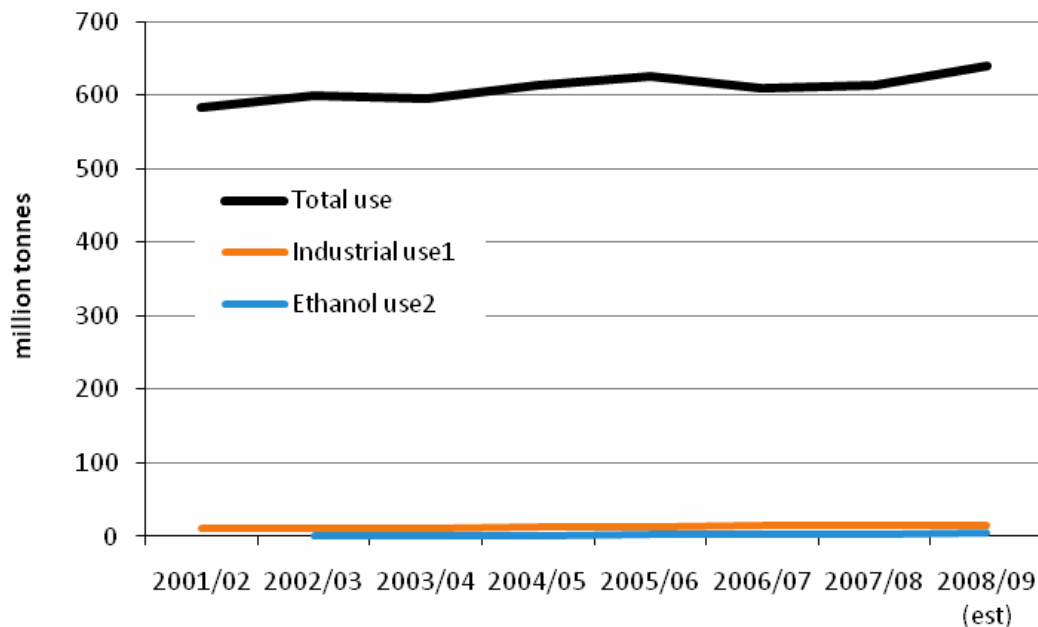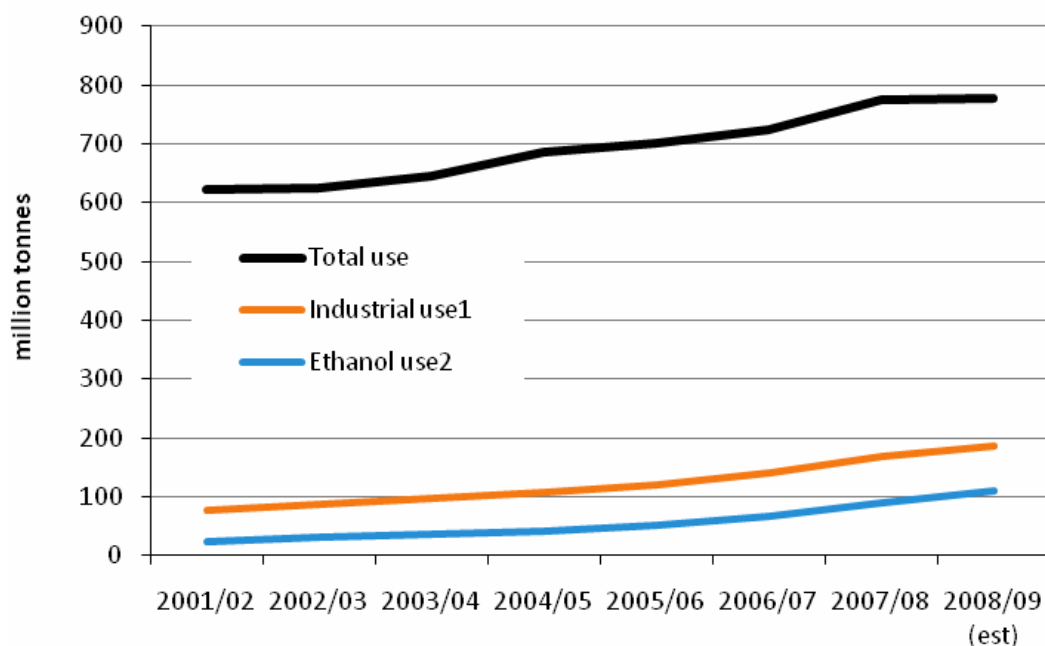## Figure 2: Global wheat and maize use 2000/01 to 2008/09

Wheat

Maize

[1] includes all industrial use, of which some is ethanol for fuel and non-fuel use [2] includes fuel and non-fuel use

Source: IGC website

Given the very low proportion of wheat used for ethanol, wheat-based ethanol production cannot have had a major direct impact on the wheat price rise in 2008. For maize though, the proportion is much higher. **Therefore, the focus of this analysis will be on the impacts of maize-based ethanol production on agricultural commodity markets**. This includes analysing possible indirect effects on other agricultural commodities, such as wheat and soybeans, through substitution effects.

Biodiesel production has also increased over the last few years. The feedstock for biodiesel is vegetable oil. Figure 3 shows the share of vegetable oil consumption used for biofuels between 2005 and 2008.

Figure 3: Share of vegetable oil consumption used for biodiesel production in selected countries
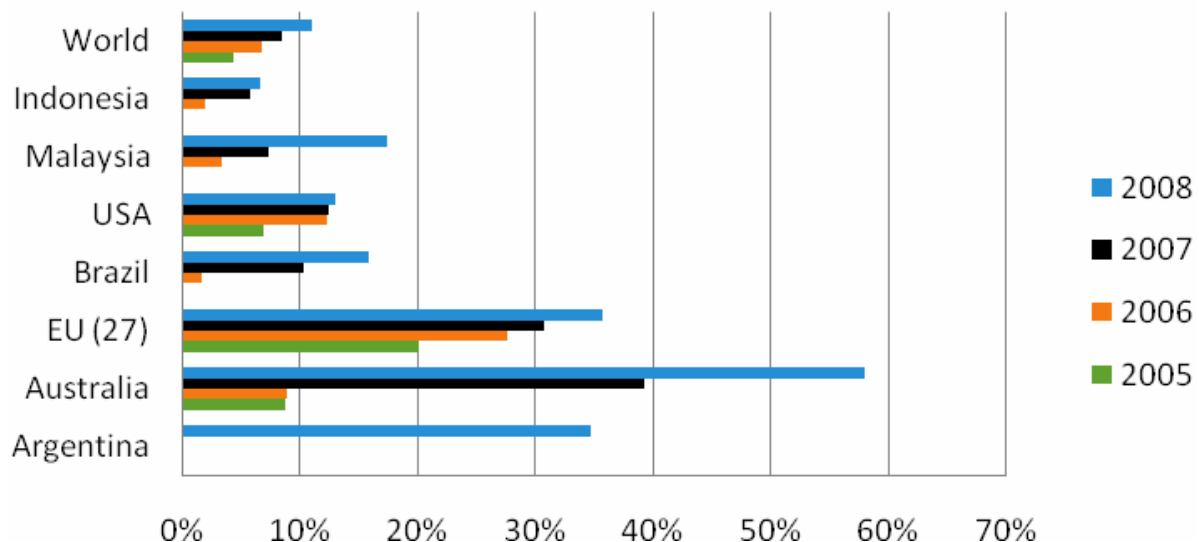
Source: FAO and OECD Secretariats (2009a)

The vegetable oil market is very complex. Vegetable oil is produced from palm oil as well as from a number of other oilseeds. The oilseed market is driven by both the vegetable oil market and the animal feed market. The profitability and the supply of oilseeds depend on the specifics of both the vegetable oil and the oilseed meal markets.

Although the use of vegetable oil for biodiesel is a non-negligible proportion of the vegetable oil market, this paper will not analyse the vegetable oil market in much detail because the main focus of the 2007/08 price spikes was on the cereals market (United Nations in China, 2008). However, we recommend further research is undertaken to address these issues.

An overview of biofuel policies

Biofuel production is supported by a number of different policies with primary aims ranging from reducing climate change from traditional fuel use (for example in the EU) to increasing energy security (in the Americas). This section outlines the main biofuels policies in each of the major biofuel-producing regions: the US; EU; Brazil and then goes on to consider policies in other countries.

United States

US biofuel policy is set out in the US Energy Independence and Security Act (EISA). Amongst other things the act amends the Renewable Fuel Standard (RFS) which calls for US biofuel use to grow to a minimum of 36 billion gallons per annum or 136 billion litres per annum by 2022. According to the OECD's 2008 Outlook, maize-based ethanol is scheduled to grow to reach 15 billion gallons per annum (57 billion litres (bnl) per annum) until 2015 and then remain at that level; biofuel from cellulosic materials are scheduled to begin production in 2010 and by 2022 will represent a significant share of biofuel use (16 billion gallons per annum) (OECD-FAO, 2008a). According to the OECD's 2009 Outlook (OECD-FAO, 2009b), ethanol use – predominantly for fuel – is bound to expand rapidly and to exceed 70 bnl by 2018, doubling the 2008 volume, but still below the original mandate of almost 95 bnl for that year. This is partially based on the assumption that cellulosic ethanol will provide some 5.5 bnl by 2018, a major achievement but falling short of the envisaged 26.5 bnl target.

Figure 4: Effect of mandates in the EISA 2007 on the consumption of biofuels
(Billions of gallons)
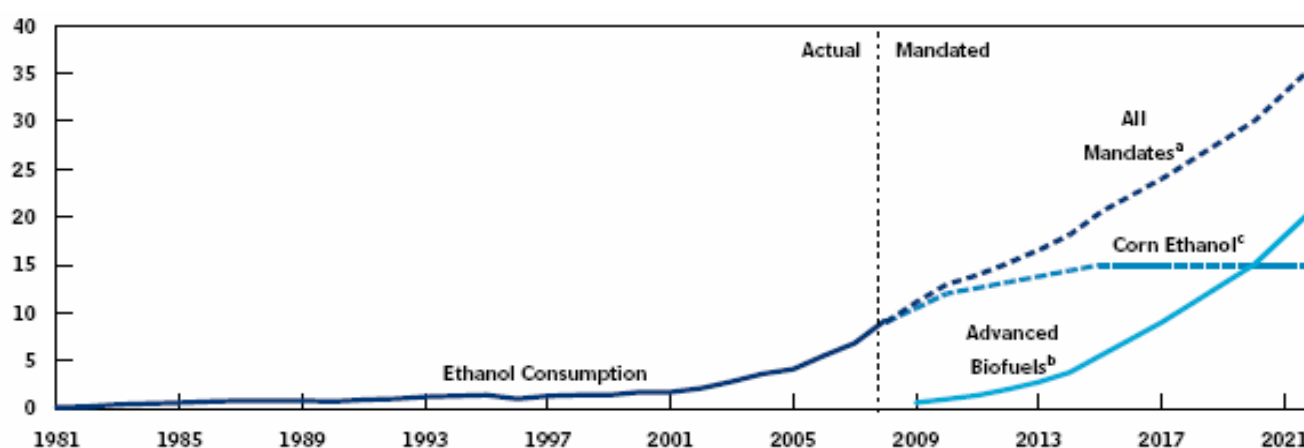
Source: Congressional Budget Office based on data from the Energy Information Administration.

a. The mandates enacted in the Energy Independence and Security Act of 2007, or EISA (Public Law 110-140), require that by 2022, a total of 36 billion gallons of renewable biofuels (fuels made from biological raw materials) be consumed annually. The law also requires that corn ethanol make up no more than 15 billion gallons of that total.

b. Advanced biofuels are renewable fuels not made from cornstarch that reduce greenhouse-gas emissions over the "life cycle" of the fuel (its production, distribution, and use) by at least 50 percent relative to emissions from gasoline.

c. The Energy Information Administration estimates that annual corn ethanol usage will be 15 billion gallons between 2015 and 2022.

The US is the only important producer of maize-based-ethanol and as such the maize-based ethanol consumption mandate acts as an effective US production mandate. Considerable attention is paid to studying the impacts on sectors of the economy, including food production and prices, as a result of complying with the new RFS legislation. The EISA07 also contains several economic and environmental safeguards (e.g. RFS waivers and suspensions[3]) should the government feel the need to reduce the RFS requirement based on their requirements to continually study the impact of increased ethanol/cellulose/renewable fuel production and use.

Aside from these biofuel consumption mandates, US biofuel policy also includes:

- The Blenders' tax credit (formally, the Volumetric Ethanol Excise Tax Credit (VEETC)) provides oil companies with an economic incentive to blend gasoline with ethanol. As of January 1, 2009, the original tax credit totalling 51 cents per gallon on pure ethanol was reduced to 45 cents per gallon. The tax credit for biodiesel is $1.00 per gallon. This is simply a subsidy to ethanol and biodiesel consumption.

- Tariffs on imported ethanol. U.S. ethanol imports are subject to a 2.5 percent ad valorem tariff, which is modest compared to the tariffs that other countries impose. For example, Brazil levies a 20 percent ad valorem tariff on ethanol imports. All ethanol blended with gasoline in the U.S. qualifies for the blenders' credit, no matter the country of origin of the fuel ethanol. To offset this fact, U.S. ethanol imports from non-Caribbean Basin countries are subject to a 54 cent per gallon secondary tariff. Thus, the total import tariff for imports from non-Caribbean Basin countries is a volumetric import tariff of 54 cents per gallon plus a 2.5% ad valorem tariff.

- Research and infrastructure grants and subsidies.

- Elimination of MTBE (methyl tertiary-butyl ether) as an oxygenate[4] from 2005 onwards with ethanol the only economically feasible alternative.

European Union/UK

In the EU biodiesel produced from oilseeds is the major source of biofuels – indeed the EU is the largest biodiesel market in the world accounting for more than half of global biodiesel use.

Policy in the EU is mainly driven by concerns over climate change and the environmental impacts of fossil fuel use. Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport set national indicative targets for the proportion of renewable transport fuels. The targets were set at 2% by energy content by the end of 2005 and 5.575% by energy content by the

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[3] The Administrator of the Environmental Protection Agency (EPA) can waive the Renewable Fuel Standard mandates if implementation of the requirements would severely harm the economy or environment of a state, a region, or the United States, or if EPA determines that there is inadequate domestic supply of renewable fuel. The request for a waiver can be made the by US States and refiners and blenders. The EPA Administrator can also initiate the waiver without receiving a request. There are also provisions for regular reviews of the impact of the mandates.

[4] Oxygenates are additives to petrol to make it burn more cleanly and reduce pollution.

end of 2010. Biofuels use remained significantly below the target in most Member States. Directive 2009/28/EC, also known as the Renewable Energy Directive (RED), repealed the 2003 directive and obliges a **10%** share of renewable energy in the transport fuel mix by 2020 subject to the 'sustainability' of production and commercial availability of second-generation biofuels. It introduces mandatory sustainability requirements. It is up to EU member states themselves to select instruments to meet the obligation. The Commission are required by the RED to produce a report on indirect land use change (ILUC) by the end of 2010 at the latest. By the end of 2014 the Commission will undertake a review of, amongst other things the cost-efficiency of the measures to be implemented to achieve the target, the feasibility of meeting the target sustainably and the impact of the target on the availability of foodstuffs at affordable prices. On the basis of that report, the Commission shall submit, if appropriate, proposals to the European Parliament and the Council, addressing the above elements.

The existing EU Fuel Quality Directive (FQD) also has an impact on the biofuels markets in the EU. It was amended in 2009 and now sets a target of a minimum 6% reduction in GHG emissions from road transport.

The EU also imposes import tariffs on biofuels. The EU import tariff on bioethanol is 10.2 Euro cents per litre for denatured ethanol (unfit for human consumption) and 19.2 Euro cents per litre[5] on undenatured ethanol. The EU import tariffs on biodiesel is an ad valorem tariff of 6.5%.

In the UK, the 2003 Directive has resulted in the Renewable Transport Fuels Obligation (RTFO). The RTFO places an obligation on fuel suppliers to ensure that a certain percentage of their aggregate sales are made up of sustainable renewable fuels. The effect of this will be to require **5%** of all UK fuel sold on UK forecourts to come from a renewable source by 2013/4. The UK Government has committed to producing an implementation plan for the 2009 Renewable Energy Directive in 2010. The 2009 Renewable Energy Directive must be transposed into UK law by 5 December 2010. The UK Government has set up a stakeholder panel to help advise on the implementation of the RED.

Brazil

Brazilian ethanol is produced from sugarcane. Brazil is the second largest producer and leading exporter of ethanol. As a consequence of the 1973 oil crisis and concerns over energy security, Brazil developed the world's largest bioethanol market. The 1975 National Alcohol Program required Petrobras (Brazil's major oil company) to purchase a set quantity of ethanol; provided subsidies to keep the price of ethanol at the forecourt below the gasoline price and set blending mandates for bioethanol (Hayes et al., 2009). The ethanol market was deregulated in 2000. The fossil fuel market remains highly regulated though with state oil company Petrobras regulating prices. However, a number of policy measures remain in place (Moreira, 2007). Biofuel policy mandates that all gasoline must contain between **20% and 25%** of anhydrous ethanol. Currently, the mandate is **23%** (**5%** biodiesel in **2010).**

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[5]   This represents 34% ad valorem assuming an ethanol price of 0.7 $/l at an exchange rate of 1.25 $/EUR (UNCTAD, 2006).

Figure 5: Brazilian ethanol balance 2005/06 to 2008/09
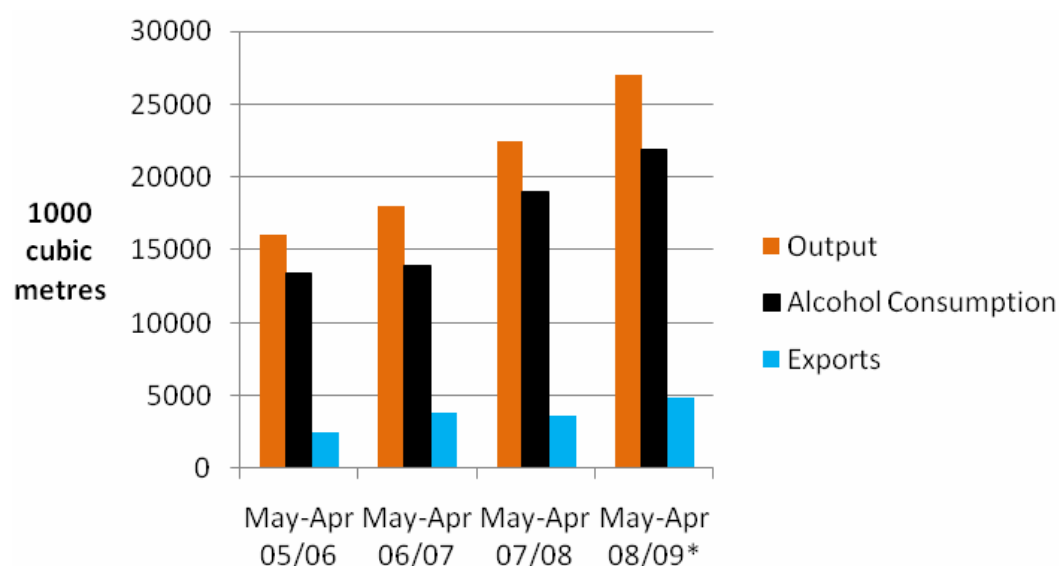
In addition to these biofuel mandates Brazil offers various tax incentives to ethanol production. For example the CIDE tax introduced in 2001, essentially a fossil fuel tax, is currently applied at a rate of R$0.23/litre on gasoline whilst the rate is set at zero for ethanol (the tax is charged to the manufacturer on sale to the distributor). The rate was reduced from R$0.28 to R$0.18 per litre in May 2008 to keep petrol prices at the pump stable but was increased again in 2009 to R$0.23. Ethanol imports are subject to a 20% ad valorem tariff. Other measures which have an impact on ethanol consumption are a ban on diesel-powered personal vehicles and a requirement that all government entities have to buy 100 percent hydrated alcohol-fuelled vehicles.

Other countries

Many of the biofuel policies in place take the form of mandatory targets – either blending obligations or quantitative targets in gallons or litres of biofuel production/consumption. Such mandates are often complemented with tax incentives to ethanol producers (as is the case in the US). Economically speaking mandates can be thought of as undesirable because they do not explicitly take into account the costs of production (or economic viability). The impact of mandates on the shape of the demand curve is discussed in the Annex 1. The discussion highlights that mandates can increase price volatility arising from supply shocks in agricultural markets under certain circumstances. Put simply this is because mandates have to be met 'no matter what' i.e. irrespective of economic circumstances and prices. As a consequence, a proportion of total crop demand – biofuel demand – becomes unresponsive to crop (and oil) prices.

The following table gives details of targets and policies currently in place in other countries around the globe.

Table 6: Targets for renewable energy and fuels in 2010 for selected countries

Countries	% of RES in total primary energy	% fuels from RES[6]
EU-27	12%	5.75%
Austria		Mandatory target of 5.75%
Belgium		5.75%
Cyprus 2, 3	9%	5.75%
Czech Republic	5-6%	5.55%
Denmark	20% in 2011	5.75%
Estonia	13%	5.75%
Finland		Mandatory target of 5.75%
France	10% in 2010	7% (2010), 10% (2015)
Germany	4%	Mandatory target of 5.75%
Greece		5.75%
Hungary		5.75%
Italy		2.50%
Ireland		NA
Latvia	6%	5.75%
Lithuania	12%	5.75%
Luxembourg		5.75%
Malta		NA
Netherlands	10% by 2020	Mandatory target of 5.75%
Poland	7.5% by 2010 14% by 2020	5.75%
Portugal		5.75%
Slovak Republic		5.75%
Slovenia		Mandatory target of 5%
Spain	12.10%	Mandatory target of 5.83% in 2010
Sweden		5.75%
United Kingdom		Mandatory target of 5% of transport fuel sales by 2013/14
Other OECD Countries		
Australia		350 million litres
Canada		5% renewable content in gasoline by 2010
Japan		50 million litres of biofuels by 2011(domestic production)
Norway		No
New Zealand	90% of total electricity	Mandatory target of 3.4% of total transport fuel sales by 2012
United States		36 billion US gallons by 2022

Source: OECD (2008b)

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[6]   RES refers to renewable energy supply

New linkages between agricultural commodities and oil

This section examines the traditional linkage between the price of oil as a key input and how developments in biofuels technology and policy have introduced a new link between the oil price and demand for agricultural commodities. The linkages are explored in a more theoretical framework in Appendix 2 where we show the impact of oil price shocks on agricultural markets, given the new demand-side link.

a) Economic theory and the growth in biofuel production

Economic theory is clear that biofuels demand will lead to higher prices in some agricultural commodities

Other things being equal, additional demand for biofuels can be expected to put upward pressures on the prices of the soft commodities that are used to make them. In this section very simplified charts are used to explain the impact of biofuels in theory under different assumptions. The charts are meant as illustrations only.

Figure 6 shows how new biofuel demand[7] will shift the total demand curve outwards, resulting in higher output but also higher prices. Biofuel demand in this most basic scenario is linear. The scale of the change in both price and output does not only depend on the shift in the demand curve but also depends on the shape of the supply curve. The magnitude of the change in the quantity produced and the price depends on how elastic supply is.

Figure 6: Supply and demand of cereals including demand for biofuels

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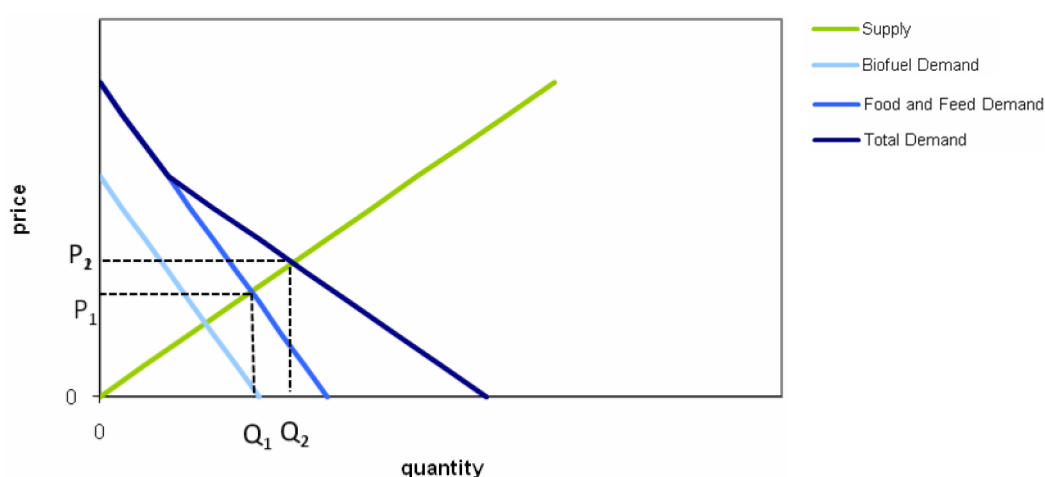
[7]   In the charts and sometimes in the text, demand for cereals for biofuel is shortened to 'biofuel demand'.

In the very short term, supply is almost perfectly inelastic. However, in the medium to longer term, many economic models assume an almost perfectly elastic supply curve – in this case any increase in demand – be it for food, feed or industrial uses – has little long-run impact on price; the additional demand results only in an additional quantity supplied. Figure 7 illustrates these points.

Figure 7: The impact of the supply elasticity on price and quantity
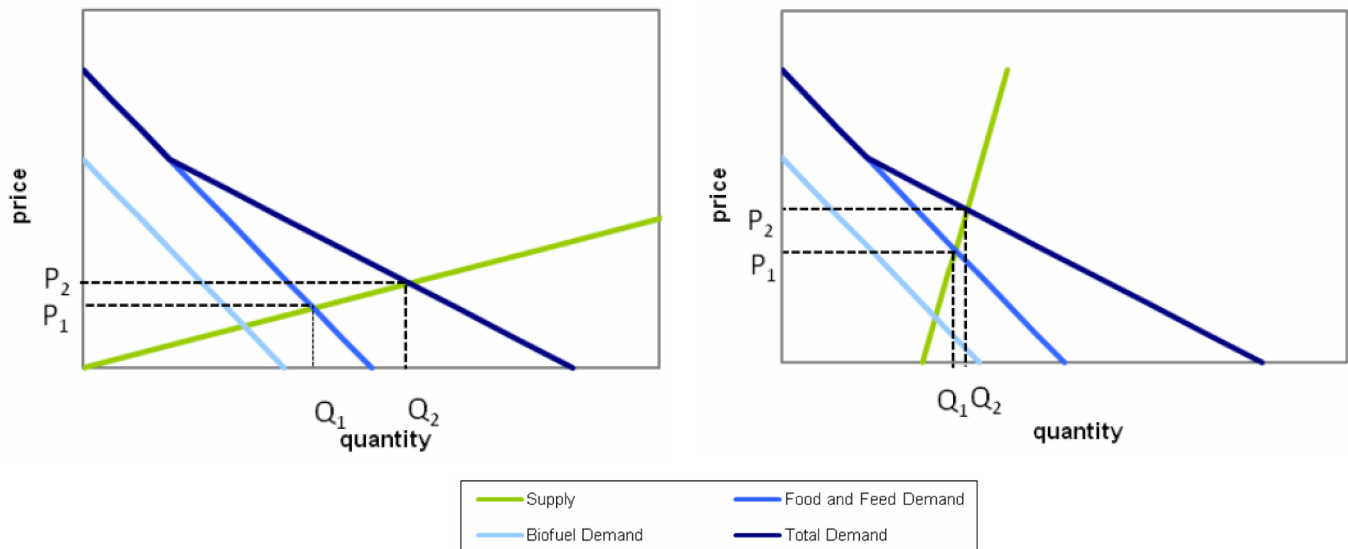
In addition to adjustments along the supply curve, the supply curve itself is not static but will shift over time with technological change and as land and other factors of productions become available. Marked shifts in the supply curve often occur after episodes of high prices as one-off costs, such as those of converting land and technical investment, are borne. These permanently shift the supply curve.

In reality the demand curves are not linear. The shape of the demand curve for biofuel demand, and thus total demand, depends on the policies that are implemented to support biofuel production and consumption. As has been explained above, different countries have different types of policies in place. However, mandate/obligation type policies have become more widespread over the last few years. For a fuller discussion of these issues and their impact on the shape of the demand curve, see appendix 1.

b) Key role of oil as an input to agricultural goods

Historically crude oil and agricultural commodity prices have "spiked" together – circa 1973, 1979 and 2008

Figure 8: Real prices of agricultural commodities and crude oil (index 2000=100)
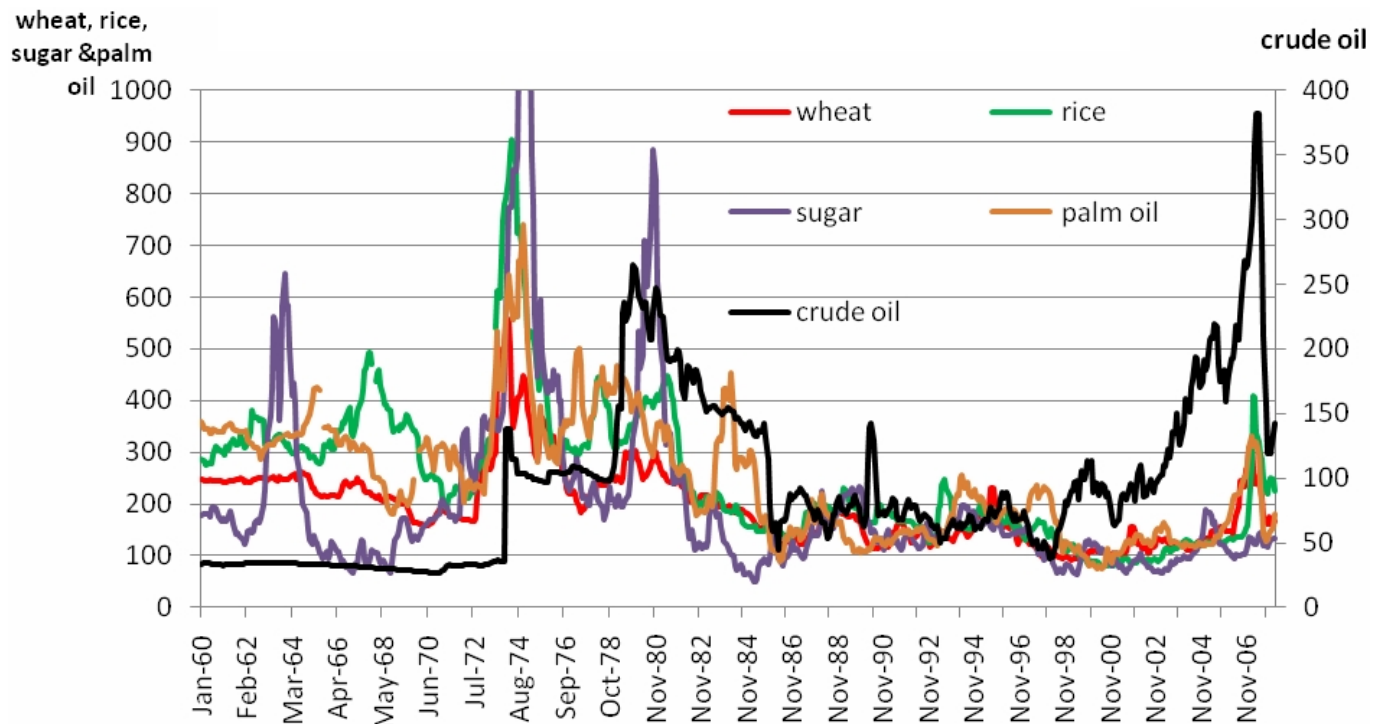
Source: UNCTAD, BEA

Oil and fuel have always been an important input to agricultural production

Exposure to energy market developments is not new in agricultural markets, given energy's role as an input into the production process. Fertilisers derived from natural gas and pesticides are particularly sensitive to energy prices, whilst fuel and heating are also important farm production costs. Volatile energy prices have shifted agricultural production costs and hence supply curves in the past and will continue to do so in the future. Impacts are not always immediate as it takes time for some of the impacts to work their way through the production chains.

The following table shows the importance of energy in farm production costs in the US and gives an indication of energy's role by crop. Energy is relatively more important in the production of maize and wheat than in soybeans (and to a lesser extent barley).

Table 7: Energy-related costs for major field crops in the US in 2009

US major field crops	Energy-related costs 2009 (forecasts)		total operating costs ($/acre)	total production costs ($/acre)	Energy related costs as a proportion of total operating costs	Energy related costs as a proportion of total production costs
	fertiliser ($/acre)	fuel, lube and electricity ($/acre)				
Maize	135.86	28.66	292.27	535.77	56%	31%
Soybeans	24.57	13.82	134.42	398.15	29%	10%
Wheat	51.54	17.94	115.23	273.55	60%	25%
Rice	110.71	95.83	454.17	828.35	45%	25%
Barley	51.29	19.44	129.86	341.99	54%	21%

Source: USDA ERS (2009) available at http://www.ers.usda.gov/Data/CostsAndReturns/data/Forecast/cop_forecast.xls

In the case of maize, wheat and barley production energy related costs represent over half of all operating costs. Operating costs rather than total production costs determine the supply curve for agricultural goods in the short term, implying that oil price shocks in the short term will have significant impacts on agricultural supply by increasing marginal costs for producers.

Biofuel production has introduced new demand-side links

The growth of biofuels production has strengthened the demand side transmission mechanism in agricultural markets. That is to say that increased demand for biofuels derived from agricultural products increases the linkage between agricultural and energy markets. A rise in the price of energy increases the demand for biofuels since they are a substitute for other forms of energy and hence shifts the agricultural demand curve as well as the supply curve. However, recent analysis by OECD and FAO (2009b) suggests that the supply side link through production costs remains stronger than the demand side link despite the recent growth in biofuels production. What should also be borne in mind is that much of the increase in demand for biofuels seen over recent years is policy-driven rather than market-driven (i.e. government policies rather than oil or energy prices have shifted the demand curve. The impacts are also dependent on how the policies are implemented, whether in the form of one or more of quantitative blending mandates, import tariffs, subsidies or tax incentives to producers.

c)   Economic models of biofuel demand, oil and agricultural prices

Economic models can be used to consider the medium-term impact of biofuels policy on food commodity prices under different oil and policy scenarios. These models rely on their assumptions which are usually based on past relationships and as such results need to be treated with caution. Despite this, we have used the OECD-FAO AGLINK-COSIMO model (2008 version) to project the medium-term impacts of biofuel policies on world agricultural commodity prices (see Table 8). AGLINK-COSIMO is a partial equilibrium model of domestic and international markets for major temperate-zone agricultural commodities. It includes detailed representations of policies affecting these markets and covers all major producer and consumer countries (in total more than 40 countries and regions).

In 2008, for the first time, a biofuel module was incorporated representing the production of biofuels, the production and use of by-products and the use of biofuels for transport. For more information on the model, see OECD (2008b).

EU biofuel policies will increase agricultural prices – but have little bearing on the sensitivity to oil price

Table 8 presents scenarios using the AGLINK-COSIMO model, surrounding oil prices and EU blending targets and their impact on agricultural prices. Both scenarios include impacts of the US Energy Independence and Security Act.

Table 8: World commodity price projections for 2% and 14% blending target in the EU (US$/tonne)

	EU blending target 2%			EU blending target 14%		
	low oil price	high oil price	% change	low oil price	high oil price	% change
Oilseeds	365	530	**45**	386	552	**43**
Maize	130	185	**42**	134	190	**42**
Wheat	194	248	**28**	200	258	**29**

Source: Own calculations using OECD-FAO's Aglink-Cosimo model

The low oil price scenario assumes that the average oil price in 2009 will be $48 per barrel increasing gradually to $58 per barrel. The high oil price scenario assumes an oil price of $92 in 2009 per barrel increasing over the period to reach $145 in 2017.

The two scenarios of 2% blending target and 14% blending target represent the situation in the EU in 2006 (the last year for which data was available when the modelling was carried out) and the Renewable Energy Directive mandatory target for 2020. The 2020 target is specified as a percentage of energy content (10%), whilst in the model targets and mandates are specified as a percentage of the volume of fuel. A mandatory target of 10% in energy terms is equivalent to a 14% target in volume terms.

The impacts on commodity prices from an increase in the oil price do not differ significantly between the 2% and 14% blending scenarios (the column with the percentage changes in table 8). Hence, the model suggests that increasing the EU blending target from 2% to 14% **does not significantly increase the sensitivity of agricultural commodity prices to energy prices** (noting that we have not modelled the impacts of changes in US biofuel policy here). This is essentially because the model assumes that the EU biofuel production is almost entirely driven by policies. However, we can see that the impact of the oil price increase is relatively strong – oilseed prices are between 43-45% higher in the high oil price scenario compared with the low oil price scenario (dependent on blending targets); maize prices are around 42% higher and wheat prices approximately 28% higher.

In their latest Agricultural Outlook OECD-FAO (2009b) examine the sensitivity of their agricultural price projections to the crude oil prices. The Outlook acknowledges that an additional link between crude oil and agricultural markets is strengthening through the demand for biofuel feedstock commodities and their close substitutes. However "due to the increasingly mandate-driven dynamics of the biofuel sectors of many countries, this element is less pronounced than would be the case under more market-driven conditions." The Outlook concludes "Despite higher biofuel use and production particularly in the short term, the major link driving up crop prices remains production costs." A significant caveat to this discussion is that **these are model results based on certain assumptions**; these need to be understood and limitations of modelling exercises of this nature need to be taken into account. It should also be noted that the model does not model within year changes and that it models medium and not short-term impacts.

But US policies to mandate production do not bind under the models assumptions

It would have been more interesting to assess a change in the US mandate. The US mandate only becomes binding when the tax policy does not achieve the required consumption. However, under the model's assumptions about the oil price and other factors that influence the maize markets, the mandate does not bind and so it is the tax policy and not the mandate that drives maize-based ethanol production. In reality, the two are of course linked. The tax policy is an instrument to achieve the mandate. In the time available for this paper, it was not possible to make further changes to the model to consider this.

The impact of biofuels production on agricultural price volatility depends on how policies are implemented

As mentioned before, inflexibly quantitative mandates make demand inelastic and have the potential to increase price volatility. However, if the legislation allows for mandates to be adjusted, they can contribute to a reduction in volatility. In Brazil, the mandate is adjusted depending, among other things, on sugar production and the sugar price. In the US, the legislation also provides the possibility to adjust policy. The effects of such adjustments could be significant,

In the US, the EISA07 includes safeguards that provide for an administrative decision to reduce or suspend the mandate for any year if domestic supply is inadequate or if the mandate is deemed to cause severe harm to the environment or the economy.

A simulation was run on the OECD Aglink-Cosimo model to analyse the strength of the relationship between the maize-ethanol production mandate and agricultural commodity prices – specifically maize, soybeans and wheat as shown in Table 9. It assumed a one-off severe drought in 2010 for the Corn Belt of the United States causing significantly lower maize yields and supply. The supply of soybeans and wheat were not affected- the only factor changed was the maize yield. The model suggests a substantial increase in maize prices, with a significant spill-over effect into the soybean price and a relatively limited increase in the wheat market through animal feed substitution. When the simulation was rerun with a 50% reduction in the mandate, to take into account a possible change in legislation, the price increases were dampened significantly. The same scenarios were run again for a drought occurring in 2015 i.e. a severe drought reduces maize yield by the same percentage and mandates are cut by 50%. The dampening effect in 2015 is greater than in 2010 due to increased size of the mandate in 2015 compared to 2010.

Table 9: Price projections for drought and mandate waiver scenarios

	2010			2015		
	Price Impact		Waiver Mitigation	Price Impact		Waiver Mitigation
	Drought plus Mandate	Drought plus Waiver		Drought plus Mandate	Drought plus Waiver	
Maize	45%	19%	58%	47%	16%	66%
Soybean	28%	23%	18%	25%	20%	23%
Wheat	12%	5%	60%	13%	4%	66%

Source: Own calculation using OECD-FAO's Aglink-Cosimo model

And biofuel production by-products dampen the price impact of cereal use for biofuels

By-products from biofuel production can be used as animal feed. Therefore, the impact on the availability for feed is less than the volume of maize used for ethanol. For every tonne of maize entering an ethanol plant, one-third of a tonne of Distillers Drain Grains (DDG) is produced. However, co-products of bioethanol production are not a straightforward replacement for feed grains. They are a high protein feed, and as such replace to some degree oilmeal consumption. In order to assess the overall impact of the replacement, the impacts on the soybean market needs to be considered both on the demand and supply side. Nevertheless, even without a detailed analysis, one can conclude that the availability of by-products which can be used as substitutes for other feeds dampens the price effect of increased demand for biofuels to some degree. Many but not all studies or models take this effect into account.

It is important to note that although medium-term models have been improved to include the biofuels market in recent years, biofuel related modules and additions are still very recent and are work in progress.

d) Viability of commercial biofuel production

Commercial biofuel production depends on the ratio of oil to the relevant agricultural prices

A paper by the US Congressional Budget Office (2009) sheds some light on the US policy impact. It estimates that the break-even ratio of the price per gallon of retail gasoline to the price per bushel of maize is currently 0.9 in the absence of subsidies and given current technologies (we assume the ratio was higher in the past as technological improvements have allowed the ratio to decline over time). This means that when the price of gasoline is greater than 90 percent of the price of a bushel of maize, ethanol production becomes profitable. Ratios above 0.9 raise incentives for firms to invest in new production capacity, whilst ratios lower than 0.9 mean that ethanol would not be produced in the absence of government subsidies. A time series of this ratio is given in Figure 9.

Figure 9: Economic viability of maize ethanol production in the US
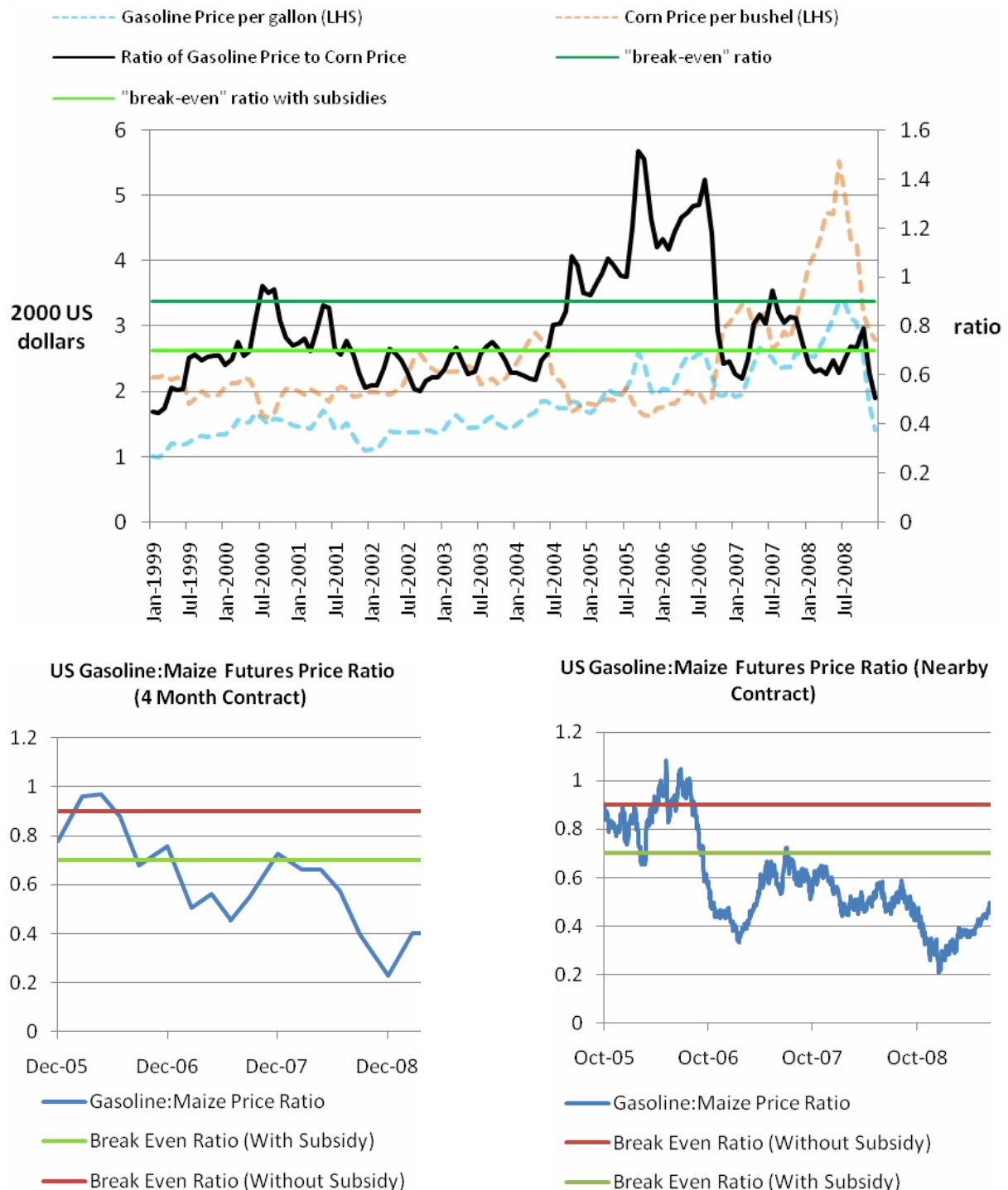
It is likely that in the majority of the last ten years, maize ethanol production in the US has not been economically viable – the ratio of gasoline to maize prices lies below the "break-even" ratio estimated by the Congressional Budget Office (CBO) – and that for much of this period bioethanol production would not have increased were it not for government support. However for approximately 18 months

between January 2005 and summer 2006 the ratio based on spot prices climbed above the "break-even" level, indicating that even if there were no subsidies in place there would have been an economic incentive to expand maize ethanol production. However when using futures prices, this ratio becomes lower during this period meaning that futures prices would have provided little economic incentive to expand bioethanol production.

And despite significant subsidies, that ratio has typically been unfavourable

The US tax credit policy effectively lowers the price of maize and therefore effectively shifts down the break-even ratio. The light green line in Figure 9 gives CBO's estimate of the "break-even" ratio at the current subsidy of 45 cents per gallon, indicating that economic incentives to expand bioethanol production throughout 2007 were the result of the subsidies in place rather than any market-incentives driven by changes in the relative price of fuel to maize – if these subsidies had not been in place, maize ethanol would have remained economically unviable.

Suggesting that 'market' demand had a limited role in expanding production during 2008

On this evidence, there is little to suggest that market-driven bioethanol production would have materially risen during 2008, even in the presence of the US tax credit policy. The outlook for ethanol production will depend to some degree on which policy instrument is seen as the binding one in the longer term i.e. if the mandate is not likely to be met will the tax credit be changed or the mandate adjusted. Also, would the tax credit be reduced if the mandate is exceeded?

Observers suggest biofuel demand will create a 'price-floor' for some agricultural commodities

Some commentators have contended that the emergence of biofuels as a source of extra demand in agricultural crop markets puts an effective price floor beneath grain and oilseed prices – that is, the oil price will ensure agricultural commodity prices will not fall below a certain level because, below that price, biofuel demand would expand significantly. Indeed a recent paper from CARD (Hayes et al., 2009) supports this view. The paper examines the impact of the biofuel sector on world agricultural markets under a range of US biofuel policy scenarios. The model used to simulate these scenarios is the FAPRI partial equilibrium model of the world agricultural sector. One of the main conclusions of the paper is:

"..the ethanol blenders' credit and the biofuel consumption mandate offer a very effective support to the corn ethanol sector. When energy prices are high such that the RFS[8] is exceeded, then corn ethanol expands to higher energy prices; when energy prices are low then corn ethanol production

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[8]   The Renewable Fuel Standard (RFS) establishes targets for US biofuel use of which up to 15 billion gallons can be met by conventional biofuels by 2015. RFS also mandates 1 billion gallons of biodiesel by 2012.

responds to corn ethanol mandates. The combination of these **two supports effectively provides a price floor for ethanol and for corn**"

Although this suggests it is biofuels *policy*, rather than organic demand, that might put a floor in agricultural markets, the paper goes on to add:

"Finally, this study shows strong evidence of the increasingly tight linkage between the energy and agricultural sectors as a result of the expanding biofuel sector. That is, to a large degree, **energy price determines biofuel price and thus the prices of agricultural commodities as well**"

But this under-plays the role of agricultural prices in their own right

However, as can be seen from the previous charts, the rise in the ratio and hence economic viability of production in 05/06 was *not only* driven by higher oil/gasoline prices in this period but also because maize prices were relatively low at the time too (see orange series in chart) – making the maize a relatively attractive feedstock for biofuel purposes. It is the relative price of energy to crops which provides economic incentives for maize ethanol production, not the raw cost of energy or oil alone – it is incorrect to assume that higher oil and energy prices alone would provide sufficient economic incentive to expand bioethanol production, as highlighted by the OECD recently.

"The sometimes predicted improved economic viability of biofuel production and use associated with higher crude oil prices so far has not materialised in many countries. Most production chains for biofuels have costs per unit of fuel energy significantly above those for the fossil fuels they aim to replace. Despite the rapid and substantial increase in crude oil prices and hence in the costs for gasoline and fossil diesel, <u>the cost disadvantage of biofuels has widened in the past two years as agricultural commodity prices soared and thereby feedstock costs increased</u>." (OECD, 2008).

And only sustained price differentials will drive investment and increased production

It is important to note the difference between the short and the longer term here. In the short term, production can only expand until all production capacity is fully used. There is therefore a limit to the additional production that can be switched on in the short term. For the petrol-maize price ratio to provide strong incentives for producers to expand bioethanol output in the medium term above policy driven levels, the ratio would need to be expected to remain above the "break-even" level for some time; the fact that the ratio is so volatile makes forecasting the ratio into the future difficult and acts as a disincentive to make the necessary medium to long-term investment in production capacity above the policy determined level. If, as OECD-FAO (2009b) have noted, the feedstock prices have a tendency to move in the same direction as the oil price, then the additional link is likely to be fairly weak. In addition, there are limits on the demand side as well, with blending limits for conventional cars and infrastructure.

e) Demand side obstacles to further rapid bioethanol expansion

Looking forward, there are significant obstacles to further ethanol expansion in the US which could constrain biofuel demand

A recent paper by Tyner (2009) highlights the fact that the US ethanol industry is producing at close to its theoretical short-term maximum. This is because the US is fast approaching the so-called "blending wall". In the US the E10 (10% ethanol, 90% gasoline) blend completely dominates the market. According to Tyner (2009) the US consumes 140 billion gallons of gasoline annually which sets the maximum amount of E10 ethanol at 14 billion gallons (although practicalities around infrastructure etc. set the limit lower at 12 billion gallons – see Tyner, Dooley et al 2008). Planned or existing capacity for ethanol production stands at around 13 billion gallons. Once the E10 blend wall is reached Tyner (2009) contends that the "link" between US maize and crude oil prices will be substantially weakened as biofuel demand will be unable to respond to higher energy prices.

The following table is taken from Westcott (2009, ERS USDA) and sets out the targets contained in the EISA2007. Conventional biofuel refers to ethanol produced from maize starch. As is evident, after 2010 the blending wall could become a major constraint as the mandate rises above 12 billion gallons.

Table 10: US blending mandates for conventional and non-advanced bioethanol from 2008 to 2022

| Calendar year	Conventional and non-advanced biofuel, bn gallons
2008	9
2009	10.5
2010	12
2011	12.6
2012	13.2
2013	13.8
2014	14.4
2015	15
2016	15
2017	15
2018	15
2019	15
2020	15
2021	15
2022	15

Westcott (2009, ERS USDA) makes a similar argument around the E10 blend wall and highlights the fact that increasing fuel efficiency will accentuate these issues because the mandates are set in volume terms and not by the biofuel share in the overall fuel market.

The E85 market is currently very small and there are concerns around the impact of higher blends on the fuel systems of the current vehicle fleet as well as issues around infrastructure at petrol stations for supplying blends such as E85. Midlevel blends between E10 and E85 are generally not legally permitted in the US (except for special use in flex-fuel vehicles); vehicle warranties often do not cover these higher blends because of concerns over the corrosive impact of higher ethanol concentrations. As a consequence there are considerable barriers to large increases in US ethanol production in the near-future.

f)   Sugar as a biofuel and links with the oil price

To conclude this section, we examine the case of the sugar market.

Figure 10: Sugar-based ethanol production in Brazil and world sugar price from 2001 to 2008
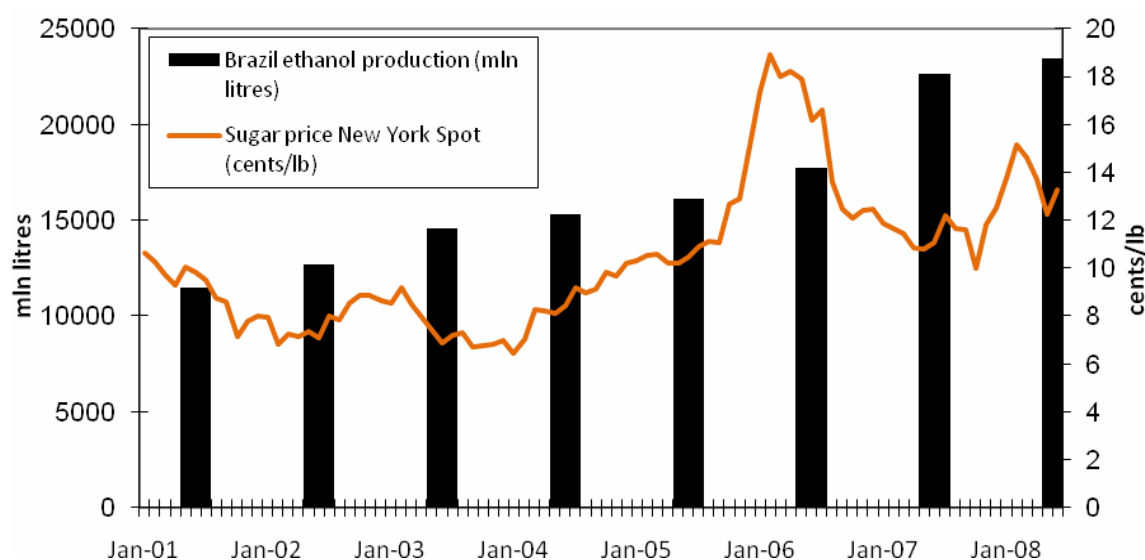

Source: OECD/FAO Agricultural Outlook database (2009a) for ethanol production, available at http://www.agri-outlook.org

Since sugar-based ethanol production has a much longer history, longer data series are available that show the relationship between ethanol production and the feedstock price. As can be seen from Figure 10, there is no close relationship between the ethanol production and the sugar price. The sugar price peaked in 2005/06 when ethanol production increased only modestly. In 2007 and 2008, when ethanol production increased more rapidly, the price of sugar decreased – implying that a straightforward correlation between sugar prices and ethanol production doesn't really exist. There are similarities between the US maize and Brazilian sugar markets and their link to the ethanol

market. For example, Brazil is the largest sugar exporter and the US is the largest maize exporter. In Brazil, more than half of all sugar cane grown is destined for the production of fuel alcohol. In the US a high percentage of maize (around a third) was used for ethanol production in 2008. However, there are also important differences. Nevertheless the example of the sugar market shows that the situation is more complex and attributing all price changes to ethanol production is too simplistic.

Brazilian sugar based ethanol dominated the market up until 2005. In 2007 Brazil accounted for 36 percent of world ethanol production (down from 42 percent the previous year) and for more than half of global trade in ethanol (OECD, 2008b). Sugar cane based ethanol is currently the only competitive alternative to petrol and Brazil is the largest exporter of sugar and the largest producer of sugar cane based ethanol. One might assume that the correlation with the crude oil price should be relatively strong in the case of sugar. Indeed this was the perceived "wisdom" for some time. It is also important to note however that the price of petrol in Brazil does not move with the world price of crude oil.

Figure 11: Relationship between raw sugar and crude oil prices 2000 to 2009
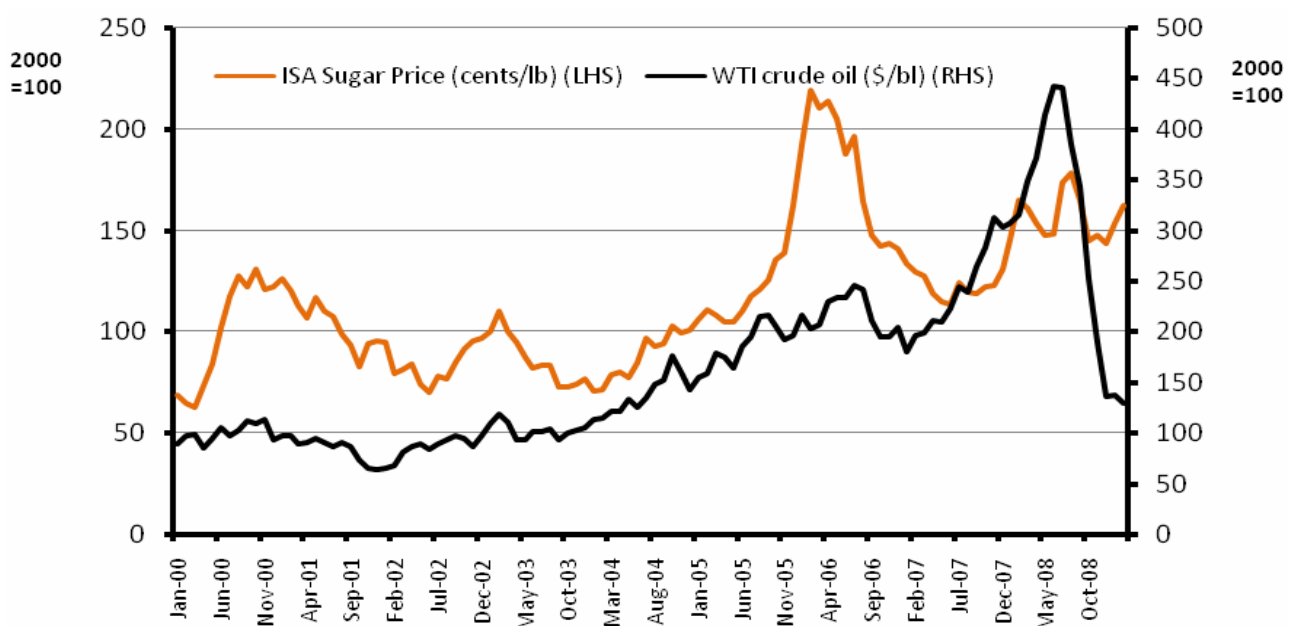
Source: UNCTAD, EIA

Between 2000 and 2005/06 there seems to be a degree of correlation between sugar prices and crude oil prices. One would expect a degree of correlation irrespective of biofuel considerations given the role of crude oil in the agricultural production process. From end 2005, the 'relationship' seems to have weakened. Oil prices continued their moderate upward trend but sugar prices rose more sharply than over the previous years. In early 2006, oil prices continued on their upward trend but sugar prices declined sharply before rebounding slightly in summer 2007. More recently crude oil prices collapsed by 70% from July 2008 to Feb 2009, whilst sugar prices have remained relatively stable.

The sugar market highlights the danger of assuming that, as an increasing percentage of a given commodity is used in the production of biofuel, it will necessarily follow the price of crude oil. Feed and food uses still dominate cereals, sugar and oilseed markets and there are too many factors affecting agricultural and soft commodities in the short and medium term to make this such a close relationship.

Literature review of estimates of biofuel impact

This section considers the main studies examining the impact of biofuels on commodity prices; economic models that consider the interactions between biofuel, oil and agricultural commodities and an appraisal of these models, especially with respect to their ability to assess the impact of biofuels on short-term prices.

a) Studies considering biofuels and their contribution to agricultural price increases

A number of studies have attempted to consider this topic and some have attached shares in the price increase to each of the drivers mentioned above, that is to say they have quantified the contribution of factors such as biofuels. In addition, some studies have explicitly considered the 2008 price spike.

The following table is not exhaustive but gives broad coverage to a number of studies looking at the role of biofuels in agricultural price rises.

Table 11: Overview of studies on the role of biofuels in agricultural price rises

Organisation/ Researcher	View on Biofuels	Impacts on agricultural markets	Quantified	Focus on price spike?
OECD-FAO (2008a)	Added demand pressure but biofuel demand driven primarily by mandates and policies rather than markets and prices	One of many contributing factors to the price rises seen last year	No but have conducted primary research on biofuel demand	n/a
Mitchell (2008)	Biofuels directly and indirectly responsible for low grain stocks, large land use shifts, export bans and speculative activity. In the absence of biofuel production these factors would not have had an impact on global food prices	Impacts across all commodities, biofuel has been the most important factor in the food price rise from 2002 to 2008	No, not in the final version of the paper. The final version of the paper states that biofuel production was the most important factor in the price spike without further quantifying its contribution.[9]	No but time period considered includes spike
IMF (Lipsky, 2008)	Biofuels policies in some advanced economies are spilling over to the price of key food items	One of many contributing factors to the price rises seen last year; impacts concentrated in maize and soybean markets	IMF estimates suggest that increased demand for biofuels accounts for 70 percent of the increase in maize prices and 40 percent of the increase in soybean prices	Yes
IFPRI (Rosegrant, Von Braun 2008)	Increased demand substantial, but policy rather than market driven	Biofuels, amongst other factors, have been a trigger for higher food prices	Yes. 12% increase in the aggregate real grain price from *2000 to 2007* attributable to biofuels which equates to 30% of the price increase seen between 2000 and 2007 (to note pre-peak levels)	No

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[9] In an initial, and frequently quoted, version of his paper, Mitchell attributed three-quarters of the 140% price increase to the direct and indirect impact of biofuels.

Organisation/ Researcher	View on Biofuels	Impacts on agricultural markets	Quantified	Focus on price spike?
US Federal Reserve (Baier et al., 2009)	New demand factor in specific crop markets	Increase in biofuel production from 2006 to 2008 had a sizeable impact on maize, soybeans, wheat and barley prices, but a much smaller impact on global food prices	Yes. Increase in world biofuel production accounts for 12% of the rise in IMF food price index from June 2006 to June 2008. US biofuel policy accounts for 60 percent of this effect, Brazil accounts for 14 percent and the EU accounts for 15 percent	Yes
US Congressional Budget Office (2009)	New demand factor in specific crop markets	Significant factor in driving US maize market; also impacts on livestock through feed channel but not only driver behind increased maize demand	Yes. Between 28% and 47% of the increase in US maize prices between April 2007 and April 2008 attributable to biofuels	Yes but only maize prices during the spike period
CARD, Iowa (Hayes et al., 2009)	Significant demand side factor in feedstock markets. With high energy prices, maize ethanol production expands accordingly. When energy prices are low, maize ethanol production responds to mandates. Little discussion of biofuels role in the price spike of 2008.	US policies provide a price floor for ethanol and maize. Increasingly tight linkage between energy and agricultural sectors. "That is, to a large degree, energy price determines biofuel price and thus the prices of agricultural commodities as well"	Given current policies and a crude oil price of $105/bl, maize price rises by 20% due to biofuel channel. Soybean prices rise by 9% (as soybean area diverted to maize). Removal of US biofuel support and low energy prices ($75/bl) leads to a fall in maize price of 18%	No

Organisation/ Researcher	View on Biofuels	Impacts on agricultural markets	Quantified	Focus on price spike?
Abbott, Hurt and Tyner (2008)	Biofuel demand has been primarily driven by higher crude oil prices rather than policies. The primary impact of crude oil on commodity prices is now through the biofuel channel (rather than any supply-side/production cost impacts)	Biofuel demand for maize was a major driver of the decline in global maize stocks. Increased Maize area displaced Soybean area. Hence biofuels are identified as 1 of 3 major factors explaining prices rises, including 2008 spike (alongside dollar depreciation and low stocks)	No. Impossible to attribute quantified impacts to each causal factor	Yes, qualitatively
Saunders, C., Kaye-Blake, W. and Cagatay, S. (2009)	Demand for energy and rising energy prices has driven demand for commodities used as biofuel feedstocks	Depends on the crop. Maize, oilseeds and sugar most affected by biofuels	Yes but the period studied excludes the price spike of 2008	No
Gilbert (2008, 2009)	Agricultural price booms are better explained by common factors than by market-specific factors such as supply shocks. Biofuel demand is a common demand shock to some agricultural markets	Not large. The attribution of prices rises to biofuel demand is a residual argument reflecting a lack of other available explanations. Dollar depreciation and monetary factors have been more important in explaining prices rises.	Biofuels impact not quantified explicitly.	Yes, focus on 2006 to 2008

Organisation/ Researcher	View on Biofuels	Impacts on agricultural markets	Quantified	Focus on price spike?
Trostle (USDA, 2008)	Biofuels significant new source of demand, driven both by policy and higher crude oil prices	Between 2002 and 2007 maize for ethanol accounted for 30 percent of the global growth in wheat and feed grains use. Since US is world's largest maize exporter, higher prices resulting from increased US biofuel demand spilled over onto world markets. Global biofuel demand played role in stock drawdowns, contributing to spike	No	Not explicitly
Timmer (ADB, 2008)	see biofuels as a significant demand driver, but uncertain as to whether this policy or crude oil price induced	Inter-commodity linkages in both supply & demand give agricultural prices a floor established by their potential conversion into biofuel.	No. Author's view that is near impossible to quantify impacts due to model limitations	Yes but qualitatively

Table 11 illustrates the lack of consensus within the literature on the role played by biofuel demand in recent agricultural price increases. It also demonstrates that estimated impacts are highly dependent on:

- The choice of the price index used. The analysis should be clear about whether the index refers to specific markets or a general food index;

- The baseline scenario against which impacts are measured;

- Which other factors are included in the analysis and the estimates of the role played by other contributing factors; and

- Assumptions surrounding elasticities (the short-term, medium-term or long-term) and the degree of crop substitution.

However there is broad agreement that biofuel demand did lead to some increases in prices in specific agricultural commodity markets, for example maize, especially over the medium term. There is some disagreement over whether this demand has been driven by policies or by increasing crude oil prices.

Several researchers also emphasise that quantifying impacts on other commodities through substitution impacts is extremely difficult. With respect to the price spike, some authors highlight a myriad of contributing factors and conclude that assessing the relative importance of each is not feasible (Timmer 2008; Abbott, Hurt and Tyner 2008). This paper now examines more closely those studies focussing on the 2008 price spike.

b) Modelling results and the 2007/08 price spikes

This section draws out the findings of the above literature review with particular reference to the 2008 price spike and then goes on to discuss the general limitations of using medium-term economic models for examining a short-term episode of price increase.

As indicated in Table 11, the degree of focus on the price spike is varied with very few studies focussing explicitly on the causes of the spike but several studies including the relevant period in their analysis. We focus on those studies making explicit reference to the causes of the 2008 price spike.

Modelling results seemed to suggest that biofuels played an important role in agricultural price rises

Mitchell (2008) does not use a model explicitly, but follows the dynamics behind the actual food price data. He identifies biofuels as the major driver behind the price rises. The price index used is an export value weighted dollar index of developing countries prices of export food crops. The index rose by

140% between January 2002 and February 2008. According to the Center for Development Research at the University of Bonn (Gerber et al., 2008) the paper attributes a maximum contribution of 15% to increased energy prices and 20% from a weaker dollar. These figures are produced by rather back-of-the-envelope calculations which we will not go into here. This leaves a 105% increase in the price index unaccounted for. Mitchell (2008) , without quantifying the contribution of biofuel production to the remaining 105% price increase, states that biofuel production was the most important factor in the price spike.

Rosegrant (2008) looked at the real price of grains between 2000 and 2007 and compared these to prices simulated by the IFPRI model over the same period under different scenarios. The real grain price here is a production-weighted average of rice, wheat, maize and other coarse grains. It seems to make little sense to include rice in this grain aggregate as rice is not linked with the biofuel market in any country. The study compares the actual grain prices realised over the period against a baseline scenario which holds biofuel demand growth at its 1990 to 2000 trend. The study estimated that policy-driven biofuel demand accounted for an increase of 12% in the real grain price over this period, which equates to less than 2% per annum from 2000 to 2007. Alternatively biofuel demand accounted for 30% of the total increase in real grain prices over the period. The Rosegrant (2008) study does *not include* any data from 2008 and so does not consider the 'peak' in agricultural crop prices which characterised the spring/summer of that year.

Saunders et al. (2009) use a multi-country, multi-commodity partial equilibrium model to investigate three factors commonly thought to have contributed to the price rises – weather shocks, strong growth in highly populated countries and increased biofuels production. Their findings show that the significance of each factor varies by crop; however for maize, sugar and oilseeds increased production of biofuels has the largest impact on world prices. Changes in prices in these markets likely spilled over into dairy and poultry markets. We evaluate this study further in the following section.

FAO (2009) also use a partial equilibrium model to emphasise the significance of biofuels production in determining world crop prices. Their modelling relates to projections of future prices rather than an analytical assessment of the factors behind the agricultural price spike of 2008; however some analysts have taken this as evidence of a significant biofuel impact on agricultural prices. Explicitly, the FAO (2009) states "For coarse grains and vegetable oil, the price outlook would be most affected if biofuels production were to remain constant at 2007 levels. Holding biofuels production constant at its 2007 level results in a 12 percent decline in the 2017 projected prices for coarse grains and around 15 percent in the projected price of vegetable oil."

The US Congressional Budget Office (CBO) (2009) estimated the impact of ethanol demand on maize prices but does not give significant detail on the methodology used in its calculation to warrant significant attention here. The CBO used a range of estimates from the economics literature about the elasticity of the supply of maize to increases in its price. Once this is estimated one can derive the

impact of the demand 'shock' on prices (because the elasticity is *related* to the slope of the supply curve, although the two are not the same). The rise in the demand for maize to be used in producing domestic ethanol raised the commodity's price, according to the paper, by between 50 cents and 80 cents per bushel between April 2007 and April 2008. That range is equivalent to between 28 percent and 47 percent of the increase in the price of maize over the period.

A further contribution comes from Gilbert (2008, 2009), who argues that agricultural price booms are better explained by common factors rather than by commodity-specific factors. This argument maintains that commodity-specific explanations require too much coincidence in order to generate the sorts of price rises across agricultural commodities that were seen from 2006 to 2008; in the case of biofuels this would refer to large substitution effects on the supply side. Gilbert identifies biofuel demand as a factor relating to demand growth in agricultural commodities during this period, alongside futures activity and dollar depreciation. Gilbert estimates a regression model which does not explicitly include biofuel demand, the biofuel variable is included in the 'residual' i.e. the variation in agricultural prices that cannot be explained by the explanatory factors Gilbert considers explicitly – futures activity, dollar depreciation and oil prices. Gilbert's regression results imply that biofuel demand growth was not a major factor in driving the price spike.

Timmer (2008) maintains that is near impossible to attribute quantified impacts to specific factors, but argues that "the trigger for the higher prices depends on individual commodities but significant depreciation of the US dollar, high oil prices *and demand for biofuels have been the main drivers*".

In summary then, only the US Congressional Budget Office (CBO) and (2008, 2009) focus their analysis on the period of the price spike. The CBO take a necessarily simplified approach in doing so. They find biofuels demand between April 2007 and April 2008 contributed between 50 and 80 cents per bushel (between 28 and 47 per cent increase in the *maize* price). Other studies have quantified the contribution of biofuels to prices over a longer period often using economic models whose time horizon is up to 10-15 years. These estimates agree that the steep increase in biofuel demand since the turn of the century led to agricultural prices rising above where they would otherwise have been.

c) The relevance of partial and general equilibrium models in evaluating price spikes

Partial and general equilibrium models using annual data are useful tools to understand price formation in agricultural markets but we see in the above section that the results are also used liberally in interpreting short-term price increases. This section considers the appropriateness of this approach and suggests future model developments.

Economic models are designed around annual data

Annual models can only ever explain annual variation in prices. However when explaining price spikes one needs to explain monthly, weekly or even daily variations in prices. The following chart highlights this.

Figure 12: Weekly and annual wheat prices 2004 to 2009
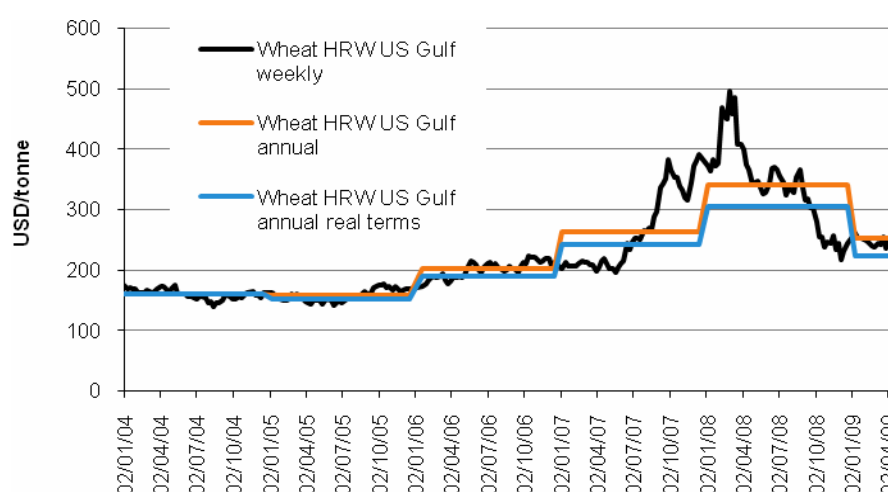
Source: HGCA website

Annual models do not distinguish between the pink line and the blue line in Figure 12 – thus can at most explain the increase to average annual price to just under $350/tonnes in 2008 but cannot explain within year changes and the weekly price reaching almost $500/tonne in March 2008. When prices are fairly stable as they were between 2004 and 2006, there isn't much difference between weekly and average annual prices and there is less of a question about the an annual model's ability to shed light on weekly price movements.

Partial equilibrium models give medium-term answers to the question of how agricultural prices are formed and are primarily intended to be used for medium-term projections and policy simulation. Crucially, partial equilibrium models do not incorporate the volatility that is observed in some commodity markets and assume equilibrium situations. (Benjamin et al., 2009)

Time-frame is also key for elasticity assumptions

These models generally use estimates of medium-term elasticities and are therefore more suitable to assess medium-term changes in markets, such as planned expansion of biofuel production, than short-term supply shocks, such as a bad harvest. The model assumes that supply can respond to both these changes in the same manner. This is not the case. Figure 7 illustrates the impact of different assumptions about supply elasticities.

Some studies are only cover a sub-set of potential drivers

Saunders et al (2009), for example, find that based on their provisional results 'the modelling suggests that the most important factor behind the price rise depends on the commodity, with maize, oilseeds and sugar most affected by biofuels, while some meats and dairy products are more affected by income growth' and 'weather was the most important factor for wheat prices, and contributed to rice and oilseed price changes'. In order to understand the relevance of these results for the 2008 price spike, it is important to understand the assumptions and limitations of the model. In the model only three factors were studied, weather, income growth and biofuels. The impact of other factors were not studied. Also, the period covered is 2004 to 2007, so excluding the price spike in 2008. And finally, as the authors point out, the model output did not replicate the actual price changes: the modelled increase in maize was twice the actual price and the sugar price rise modelled was 2.8 percent while its actual price rise was 40 percent.

Other studies that tried to quantify the impact, such as Mitchell in an earlier draft of his paper, also only looked at three factors and attributed all the rest to biofuels. Such an approach has obvious limitations and the discussion above has illustrated that it is too simplistic to assume that most changes in agricultural crop markets over the last few years can be attributed to biofuels.

In order to get a large impact of biofuels one needs to assume inelastic supply and demand and large indirect effects

Price and volume changes balance markets after shocks, such as a large increase in demand. If demand and supply are elastic, the balancing will occur mainly through changes in the quantity. This limits the price effect. In order to get a large price effect, one needs to assume that the quantities change little. In the case of an increase in demand for crops for biofuel production, the assumption that is required to get a large price effect would be that supply changes little in face of the increased demand and that substitution on the demand side is also limited. In this case, one would expect to find little change in the production of maize and thus little impact on the supply of other crops. A large price increase would also assume that there is limited substitution on the demand side. If there was easy substitution on the demand side then the demand for non-biofuel use would be diverted to other crops and the price increase would be limited. Given inelastic supply and demand in the maize market, price impacts could be large. However, this also means that there are small spill-over effects to other markets. If maize production does not expand and there is little substitution of maize for other uses, then other crop markets cannot be affected much by changes in the maize market.

Baier et al (2009) show that a large impact of biofuel on agricultural commodity prices in 2008 can only be generated by assuming inelastic supply *and* large indirect effects. As these two assumptions are inconsistent, they conclude that these studies are misleading.

Baier et al (2009) conclude in their paper that "In summary, there are many studies with very different estimates of the impact of biofuels on crop and global food prices. Various assumptions are being made to these estimates – some of which are economically reasonable and feasible, while others seem a bit unrealistic. Unfortunately, most media attention has been given to the extreme estimates without much consideration for the economic assumptions that must be made to generate these results. Once we look at the underlying assumptions, we see that these eye-popping estimates are unrealistic".

As well as the obvious conclusions around treating model results with caution, there may be a case for developing models that have a shorter timeframe and which are more able to consider the (lower) supply and demand elasticities that apply within the harvest year which would be valuable in considering the causes and consequences of demand and supply shocks. This is the main recommendation for further research. In addition, if a commodity has an inelastic supply curve, this implies it has no close substitutes on the supply side. Thus, models can be inconsistent in that they combine assumptions of inelastic supply curves with a high level of commodity substitutability.

Role of biofuel demand in the 2007/08 price spikes

Previous sections have confirmed a significant expansion in biofuels production in recent years, and the consensus that this increase in demand has and will contribute to prices that are higher than would otherwise have been the case for some agricultural commodities over the medium term. This section is concerned with whether biofuels demand played a key role in the 2008 price spike with a focus on maize and it's most immediate substitutes – soybeans and wheat. The structure of this section is as follows:

• Biofuel demand in and before 2008;

• Substitution effects and timing of price increases;

• Biofuels contribution to grain stock levels; and

• What has happened since the 2008 price peak.

a) Biofuel demand in and before 2008

Biofuel demand increased steeply in the last decade

The increase in demand for ethanol was much higher than the increase in demand for feed and food. The following chart gives global maize utilisation from 00/01 to 08/09.

Figure 13: Global maize utilisation for different end uses 2000/01 to 2008/09
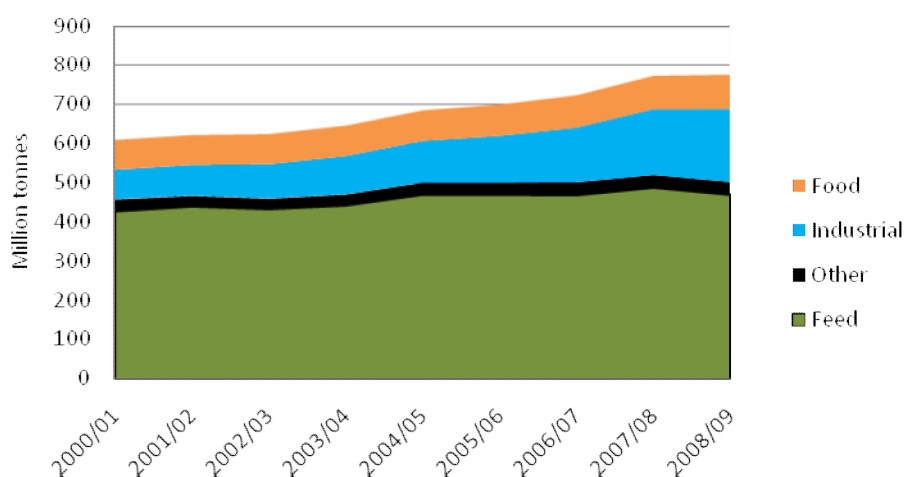
Source: IGC website

Whilst total use has been rising at approximately 3% per annum over this period, maize use for industrial processing has been rising at 12 % per annum, mainly driven by use for fuel ethanol. Some have argued that the more rapid rise in maize for ethanol use has been a significant driver behind price rises, not just in maize but across agricultural markets.

This increase in demand was particularly pronounced between September 2006 and September 2008 where bioethanol production in the US doubled to 20m barrels and accounted for roughly a third of total US maize production.

Figure 14: US monthly fuel ethanol production from 1999 to 2009 (thousand barrels)

Source: EIA (2009), Monthly Energy Review available at http://www.eia.doe.gov/emeu/mer/renew.html
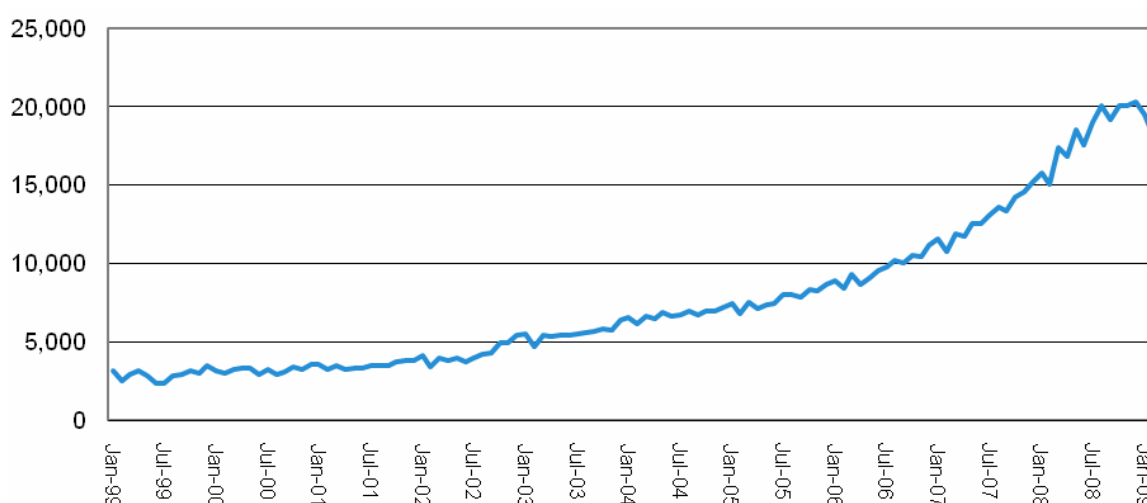
As noted in the section reviewing biofuels policy, this was primarily driven by policy, rather than any organic demand based on substituting away from oil.

Clearly, in the case of US demand for maize, there was a dramatic and arguably exogenous increase in the demand for the production of biofuels in the period leading up to 2008. If this increase in demand for biofuel production came at the expense of supplying maize, or close substitutes, to food markets then we could expect an important contribution to price increases (including in those substitutes). If, however, supply expanded to keep up with this demand then price impacts would be limited.

US grew its contribution to maize markets till 2007 but then a steep decline occurred in 2008

We now examine whether this biofuel expansion impacted on US maize exports. US exports play a significant role in the global maize market. Over the last 3 years the US has supplied on average 60% of world maize exports. However exports can fluctuate substantially from year to year – often depending on production domestically in the US – for reasons other than biofuel policy.

Before 2007 the steep growth in maize production going into biofuels was matched by production increases and exports actually increased. However, after a bumper crop in 2007, exports fell sharply, lending support to the suggestion of a contraction in the supply for food and feed. From 2007 to 2008 production declined by 936 million bushels whilst exports fell less markedly by 686 million bushels.

Figure 15: US maize production and exports 2001 to 2009
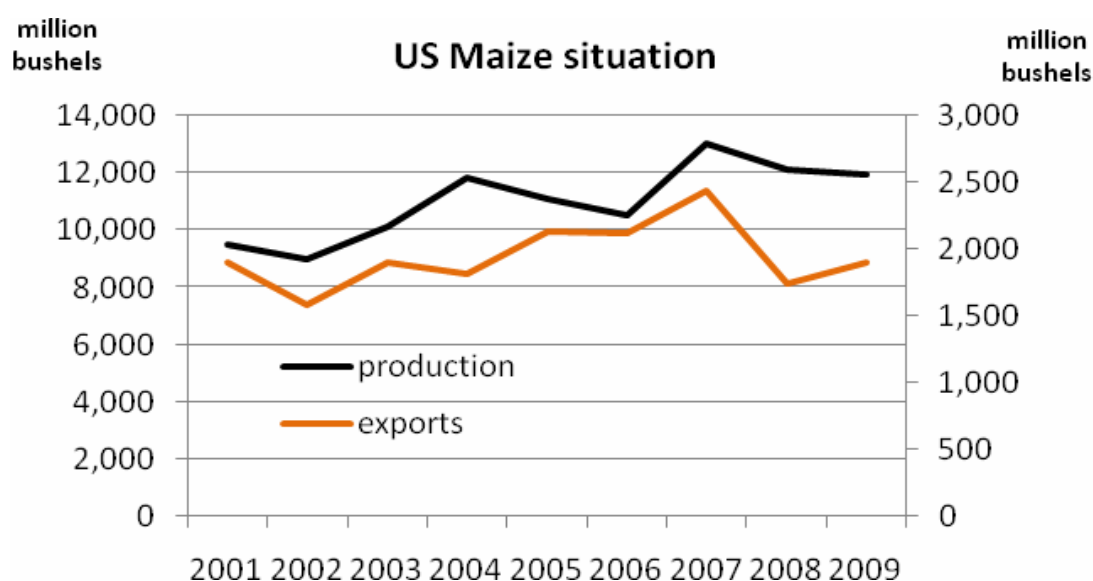
Source: USDA website

In summary then, although the evidence is not conclusive, it suggests that a dramatic increase in demand for biofuels, particularly between 2006 and 2008 contributed to the reduction in the quantity of US maize available for export in 2008 and appeared to have a notable effect on world maize prices – but a more important factor in explaining lower exports in 2008 is simply the lower level of maize production in that year, reflecting the fact that there was a bumper harvest in 2007 driven by above-average yields and very favourable weather. Maize represents around 13% of the three main staples for food consumption (rice, wheat and maize). However, it is a significant staple in central America and in many African countries. This paper now considers whether there is any evidence that substitution effects contributed to rises in other commodities, specifically, soybeans and wheat.

b) Substitution effects on wheat and soybean markets

A key argument in whether biofuels significantly contributed to the 2008 price spike in a range of agricultural commodities is around whether any direct effect on maize prices resulted in price increases in substitute foodstuffs and, in particular, in wheat. This section examines the evidence of supply effects in wheat and then the closer substitute, soybeans.

The table below summarises the main incentives to substitute between maize and wheat/soybean. Relative prices and the substitution effects are, however, not the only factors influencing production and consumption decisions for maize, soybeans and wheat; rotational considerations, input costs as well as climatic conditions also play an important role in the allocation of land. On the demand side, complexity is added as soybeans and cereals can be complements as well as substitutes in feed rations. In the following, first supply and then demand side substitution is considered.

Table 12: Summary of supply and demand-side substitution effects

	Supply-side	Demand-side
Change in price ratio of wheat/ soybean to maize	Planting decisions (delayed) at the margin	Feed decision at the margin
Increase	Substitute wheat/soybean for maize in plantings	Substitute maize for wheat/soybean as livestock feed
Decrease	Substitute maize for wheat/soybean in plantings	Substitute wheat/soybean for maize as livestock feed

Observers suggest increases in maize plantings created strong displacement effects in wheat and soybeans

FAO (2009) and Mitchell (2008) both contend that one of the major factors behind the rise in wheat prices is biofuel-led maize demand in the US. They claim that increased maize plantings for use in biofuel production displaced both soybean and wheat area in the US. From 2006 to 2007, soybean plantings fell signficantly, by around 15% whilst maize plantings rose by almost 20% over the same period.

No evidence that wheat plantings were reduced in advance of 2008

Some studies, such as FAO (2009) and Mitchell (2008), have suggested that the price rises seen in wheat during 2007 and early 2008 were due to expansion of production of maize and oilseeds for biofuel production at the expense of wheat production. However, US plantings for wheat have been on a downward trend for some time but actually increased in the 2007/08 and 2008/09 marketing years as shown in Figure 16.

Figure 16: US wheat planted area 1975/76 to 2009/2010 (mln acres)
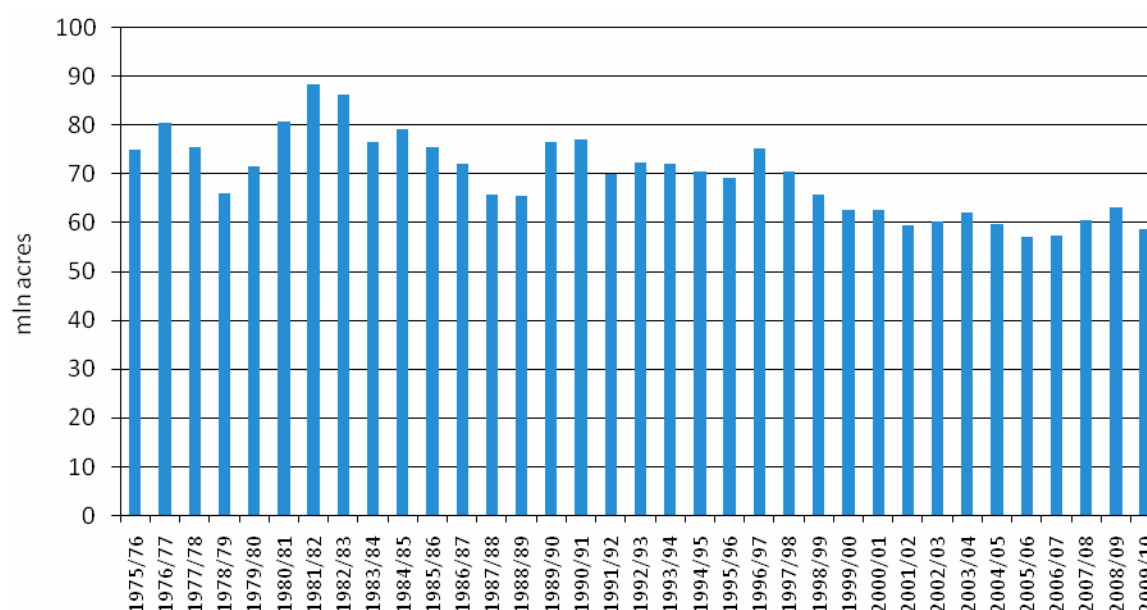
Source: USDA website

And the medium-term decline in US wheat area has not accelerated since the large increases in biofuel production

In the period between 1990 and 2005, the area planted to wheat decreased in 11 years and only increased in 4 years. If anything, the downward trend in wheat area has slowed down since the turn of the millennium and thus in the period of time where maize use for biofuels expanded rapidly.

Price movements over the last couple of years can help explain the increase in area between 2006/07 and 2008/09. Higher relative prices for maize compared to wheat due to an increase in demand for maize, all other things equal, would incentivise farmers to substitute maize plantings for wheat. However, as is evident, the wheat-maize price ratio rose substantially throughout 2007 and 2008 improving the economic incentives for wheat over maize plantings (for most of the period since 2000 the ratio oscillated between 1.25 and 1.75) and maize over wheat in feed use. This was driven by a surge in wheat prices throughout the first six months of 2007.

Falls in wheat production outside of the US were primarily driven by other factors

In the EU15 the wheat area has been between 16 and 18 million ha since 1991. Variations in wheat area since 2000 have been unremarkable by the standards of the previous ten years. They cannot be solely attributed to the increase in oilseed production as suggested by Mitchell (2008). Other relevant factors include changes in the Common Agricultural Policy such as the decoupling of payments and changes to the intervention arrangements.

Figure 17: EU15 wheat area 1991 to 2008 (million ha)
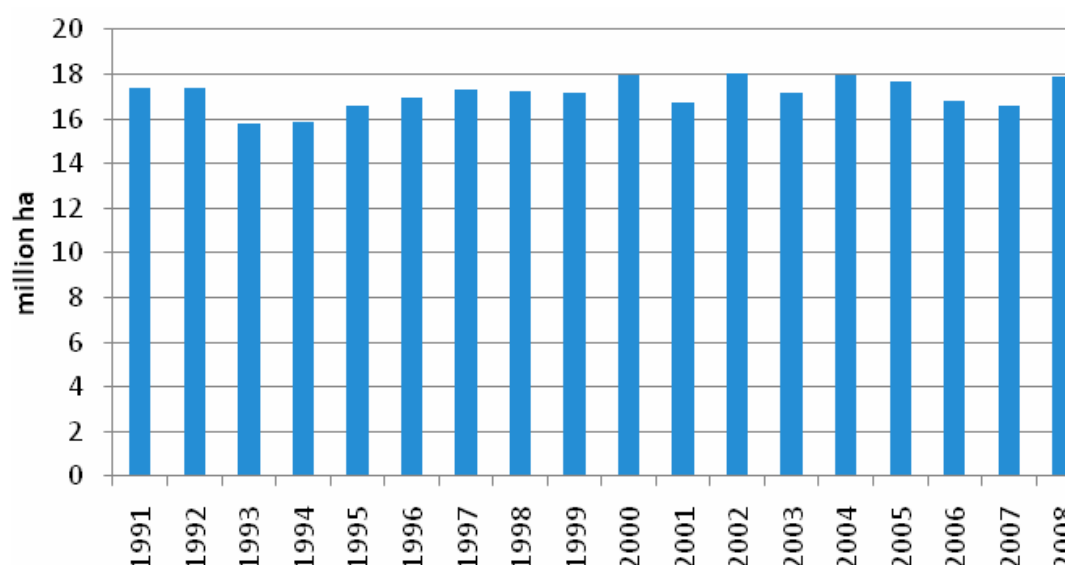
Source: Eurostat website

In Russia, Ukraine and Kazakhstan, important wheat producing countries, the decline in wheat area pre-dates the increase in biofuel production and has been due to other drivers. Arable area had decreased by about 40 million ha between 1990 and 2002 following the collapse of the Soviet Union and the farming structure in these countries. There was no shortage of suitable arable land and little evidence that increase in other crops led to a decrease in wheat area.

It also needs to be borne in mind that wheat and maize only compete for land in some areas of the world. In more northern wheat growing areas such as northern US states and northern part of the Europe, little maize is grown as the climatic conditions are not suitable for growing maize.

We now consider the soybean supply-side substitution effect.

Soybean area was influenced by other factors as well

The main supply substitution effect for maize in the US is with soybeans as they compete for the same land to a greater extent than maize and wheat. However, due to rotational considerations, the substitution is not unlimited. The following chart gives the relative prices of maize and soybeans.

Figure 18: US soybean and maize prices from 2000 to 2008
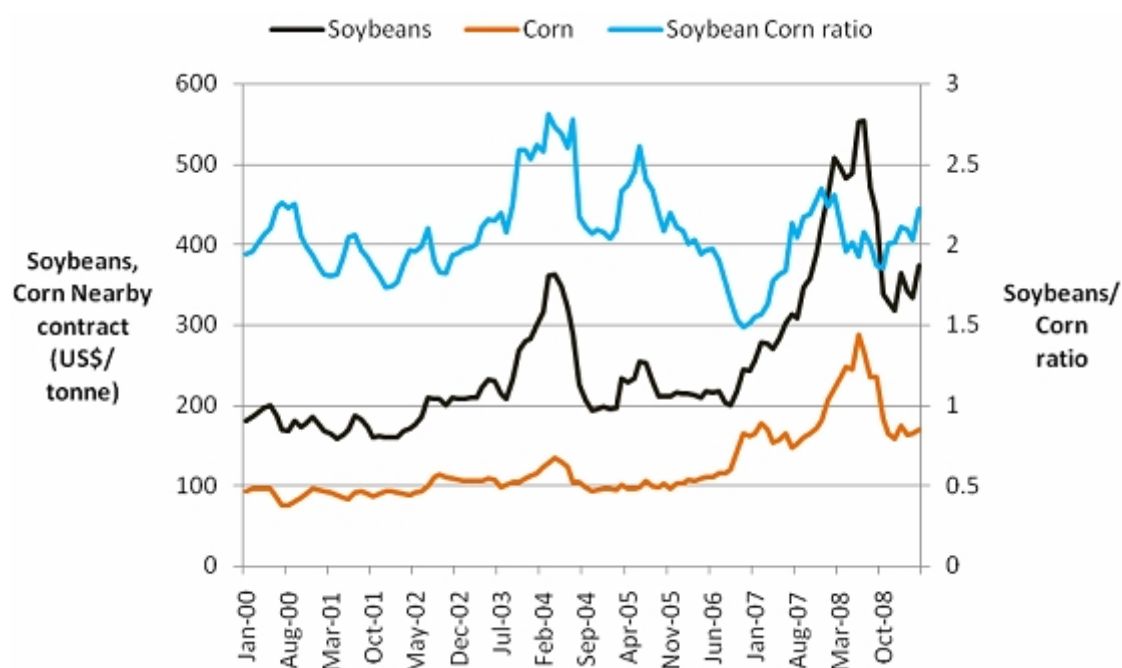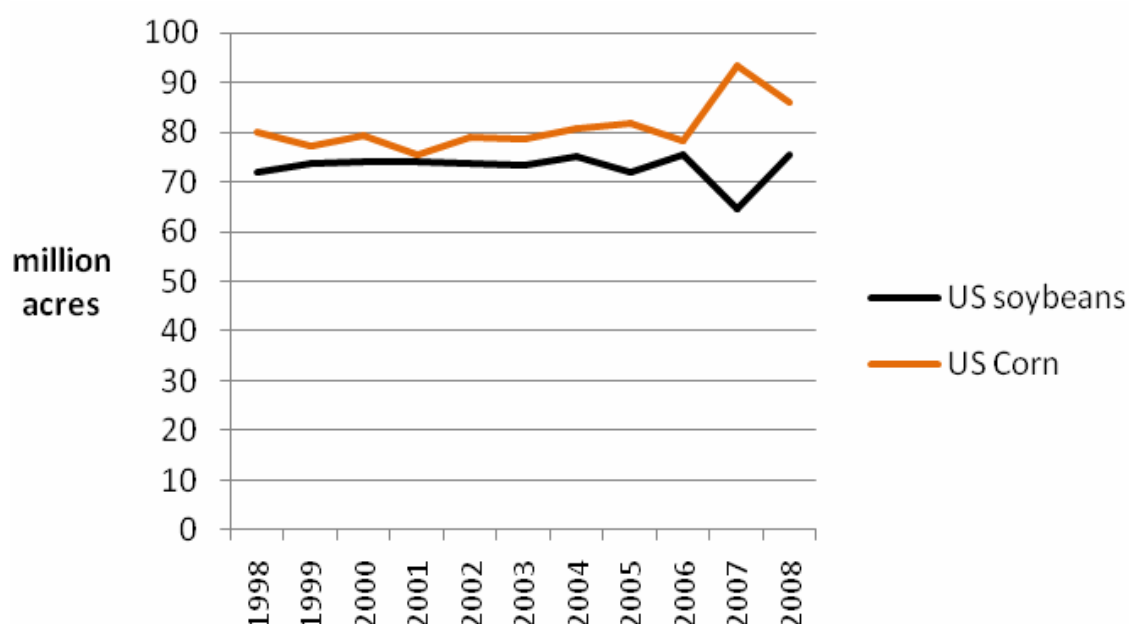

Source: USDA website

Relative prices created incentives for the substitution from soybeans to maize

It can be seen in figure 18, that in late 2006 soybeans were less attractive to plant compared to maize than they had been for some time (significant decline in soybean maize price ratio). The soybean to maize price ratio declined by around 40% over the 18 months from June 2005 to December 2006. All other things equal this would tend to provide an economic incentive for farmers to substitute maize for soybean in plantings. Part of this fall was driven by rising maize prices, although it should also be noted that soybean prices were much lower than they had been in 2003/2004.

And this drove a fall in soybean plantings

Figure 19 gives US plantings of maize and soybeans from 1998 to 2008. Plantings of soybean and maize remained relatively stable for most of this decade. Given the price movements, it is not surprising that from 2006 to 2007, soybean plantings fell signficantly, by around 15%, whilst maize plantings rose by almost 20% over the same period. It has been suggested that the fall in soybean plantings and the rise in maize plantings could be explained by increased demand for maize as a biofuel feedstock – hence biofuel demand being responsible for the rise in soybean prices.

Figure 19: US plantings of maize and soybeans from 1998 to 2008

Source: USDA website

Whilst it is likely that increased maize plantings are an important factor in explaining the decrease in soybean plantings, it was not the only driver behind the reduction in soybean plantings in the US. Figure 20 shows soybean production, stocks and area in the US since 2000. Planting decisions are made on expected price movements over the following months. Increases in stocks are used as indicators for likely price movements as they indicate ample supply.

Figure 20: US soybean production, stocks and area 2000 to 2008

Source: USDA website

50
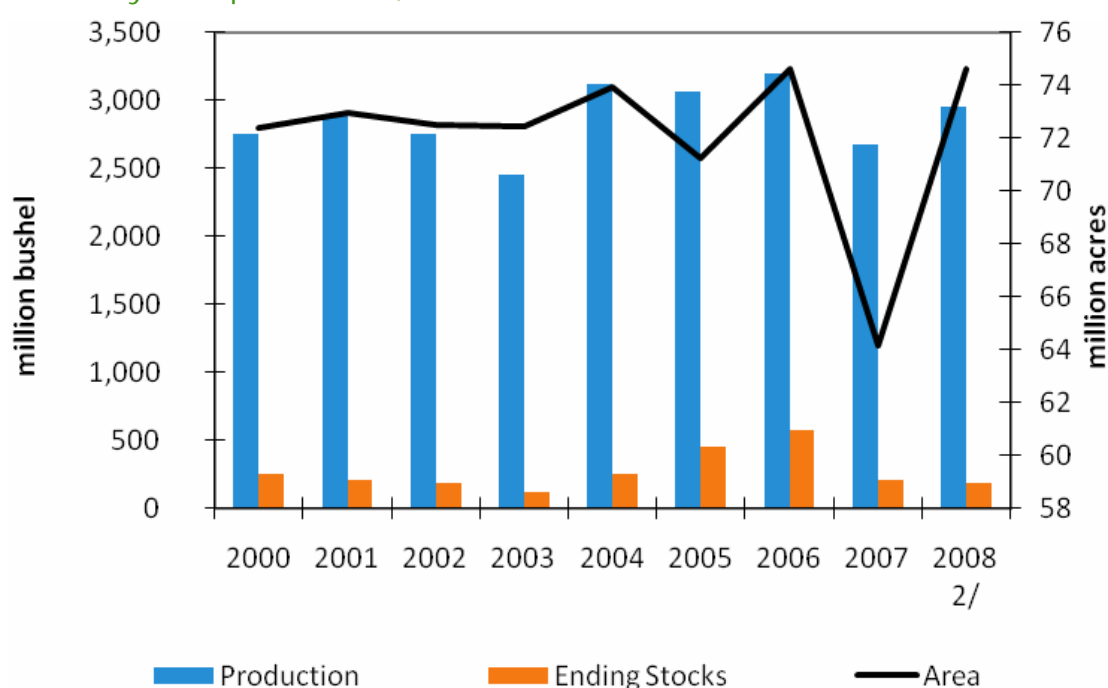
As to be expected, there is some link between the level of ending stocks in the previous marketing year and plantings in the following year. In 2003, for example, stocks had fallen to a fairly low level and prices increased as we have seen before. As a consequence plantings in 2004 increased. Stocks increased into 2004 and the area in 2005 decreased again. Stocks nevertheless increased further. In 2005, however, despite higher stocks, the area increased. This shows that there is no perfect correlation between stocks and plantings and that other factors also play a role. However, considering the very high ending stocks in 2006 and that stocks had increased for 4 consecutive years, it is not surprising that the area planted dropped. The magnitude of the drop was certainly also influenced by the developments in the maize market. Thus, it can be seen that high stocks in 2006 also played a part in the fall in plantings.

Suggesting that soybean saw more important supply-side substitution effects than wheat

In terms of soybeans, there's much clearer evidence that an increase in the relative price of maize contributed to a fall in the quantity of soybean planted and produced, leading to upward pressure on its price.

We now turn to demand-side substitution effects.

Wheat is a close substitute for maize in terms of animal feed, at least in the EU – but less so in the food market

No agricultural commodities are *infinitely substitutable* – the degree of substitution within the band where substitution is possible depends on relative prices. Wheat and maize are substitutes in the animal feed market but substitution in the food market is limited. In the US domestic sector, the role of wheat as animal feed is fairly limited. Wheat's role as an animal feed ingredient in other regions such as the EU means that for US export opportunities they can be considered to be close substitutes.

But the timing and degree of the price rise in wheat casts doubt on maize prices as a cause

If US ethanol production had led to the increase in maize price and indirectly through substitution to an increase in the wheat price, one would expect the maize price to move first and to a higher peak than the wheat price. The chart shows that in 2007 the wheat price continued to increase but the maize price seems to have levelled off. In mid 2007, the wheat price started to increase at a much faster rate and it reached its peak in early spring 2008. In other words, the wheat price rose first, rose further and the ratio of the wheat to the maize price remained above historic levels into 2009.

## Figure 21: US maize and wheat prices from 2000 to 2009
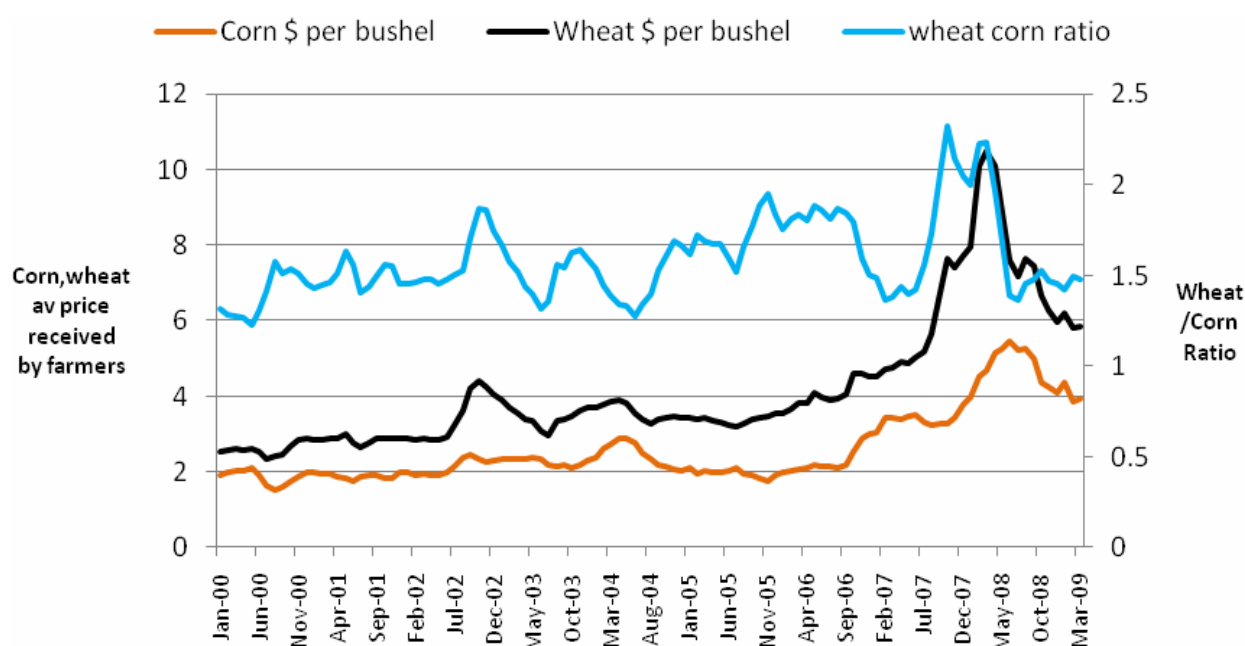
Source: USDA website

The high ratio of wheat to maize prices, and a fall in EU wheat imports suggests the substitution effect was away from wheat

The maize price seems to have followed the wheat price and not the other way round. If there was a substitution effect at the start of the 2008, then it would appear to have been from wheat to maize. The use of wheat as feed is fairly limited in the US so we now consider trends in the EU where wheat and maize are closer substitutes.

EU trade figures also support the suggestions that there was substitution of maize for wheat. In 2007/08, the EU imported more grain than usual due to a bad harvest. In the second half of 2007, both wheat and maize imports increased but the increase was more pronounced for maize. In early 2008 though, following the steep increases in the wheat price, wheat imports declined sharply and maize imports increased. This pattern would suggest that due to shortages in the feed grain market, especially in the wheat market, demand for and imports of maize into the EU increased. The pattern of imports does not support the suggestion that there was substitution of wheat for maize due to higher usage of maize for biofuels.

Figure 22: EU imports of key feed commodities from 2005 to 2008 (tonnes)
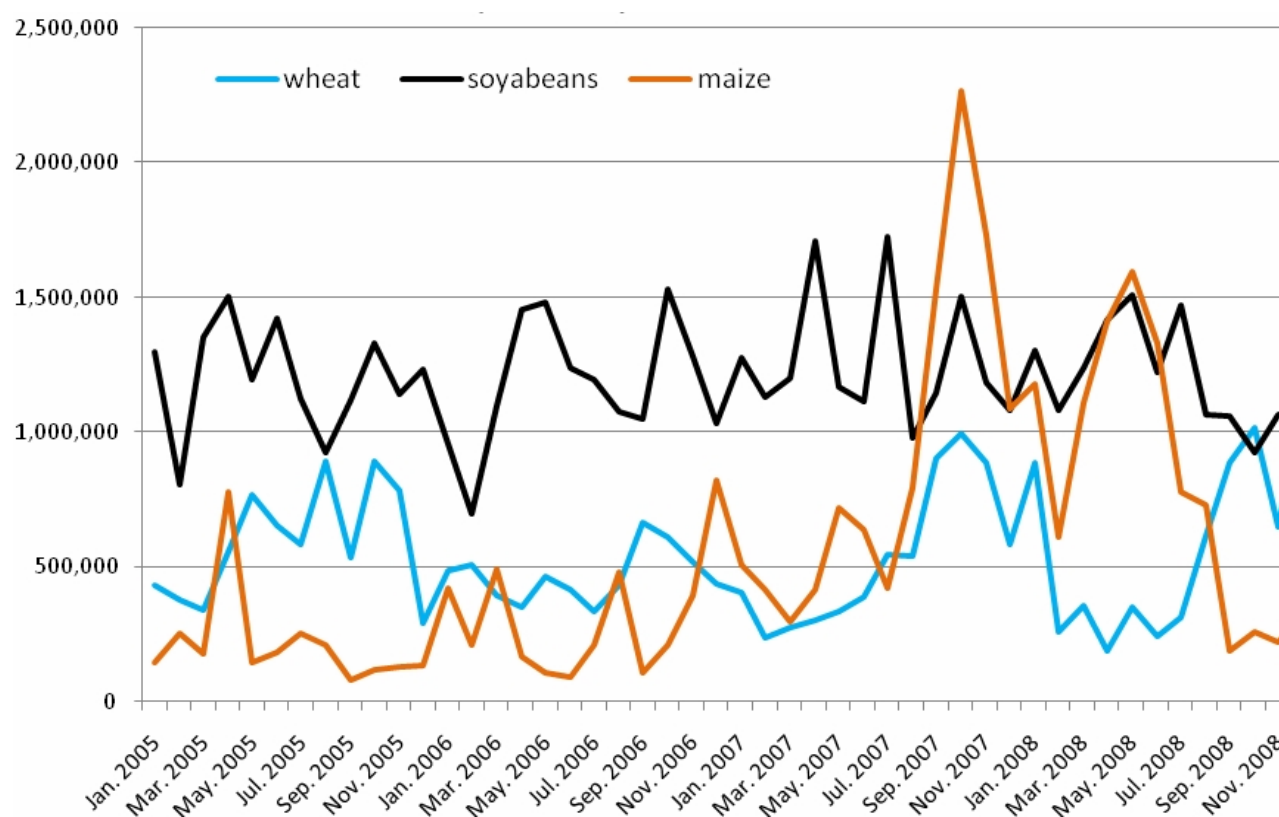
Source: USDA website

The above discussion suggests that in the run up to the spike in prices in 2008, the increase in the price of maize did have some knock-on to soybean planting decisions and therefore the price of soybeans. US soybean exports are a significant part of international supply, oscillating between 40% and 50% over the last few years. On the more important question of whether biofuel demand led to increases in maize prices which then impacted indirectly on the wheat price, we find no evidence that maize was substituted for wheat and, indeed, find that the steep price increase was led by wheat and the relative prices suggest demand substitution was into maize rather than away from it. In addition, there appears no evidence that biofuel production accelerated declines in US and European wheat area as some have claimed. As a consequence, there does not seem to be any evidence that wheat stocks declined as a consequence of biofuels production. By contrast, some of the fall in maize stocks can be attributed to the increased use of maize for feed. Taken together then, there is little evidence that the biofuels induced price increases in US maize contributed to the increase in wheat prices. Indeed, it is more likely that there was some substitution away from wheat to maize.

c) Build-up of biofuels demand and the impact on grain stocks

This section examines whether the increase in production of maize for biofuel use contributed to the price spike by lowering stock levels over the period leading up to 2008.

We have already seen in previous sections that biofuel demand has and will exert upward pressure on the prices of agricultural commodities over the medium term – but this section examines whether this has prompted an increase in production to cover the demand, or whether demand has significantly depleted stock levels.

Biofuel demand linked to low grain stocks

Biofuel demand has been put forward as a driver of the apparent fall in global grain stocks prior to 2008 (Mitchell, 2008; World Bank). Tyner at al. (2009) identified biofuels as a significant contributor to the decline in stocks – "*low world crop production in 2006 and 2007, growing demand for food and strong markets for biofuels drove global stocks to extremely low levels and sent commodity prices skyrocketing*". Timmer (2008) sees stocks as the major transmission mechanism through which biofuels have an impact on agricultural markets; "*Declining stock-to-use ratios for corn since the late 1990s are the main rationale offered by analysts who see corn-based ethanol as the main driver of higher food prices for staple food grains*".

Stock levels are driven by a range of factors

Commentators have identified ethanol production as a contributing factor to a general tightness in the market in the years leading up to 2008 and thus to lower stocks. However, there were also other drivers that led to reduced global stocks. Timmer (2008) suggests that "*the recent gradual increase in the prices of food commodities – from 2002 to 2007 – is a direct result of sharply declining prices a decade ago. We are paying a high price, literally, for the destocking of grains since the mid-1990s, a process that pushed down prices*". Another driver for a reduction in global stocks since 2000 was the reduction in stocks in China which was driven by policy considerations rather than market fundamentals. In addition, the US and EU have introduced policies aimed at reducing overproduction and thus stocks. A separate paper looks into the role of stocks and thus, the role of stocks will not be dealt with in detail here.

Anticipated increases in demand are much less likely to be the cause of abrupt market responses

An important consideration is that the increases in biofuel demand were expected. Expected changes in supply and demand have much smaller impacts on prices than unexpected events such as bad harvests because supply is fairly responsive in the medium term. An expected increase in demand will see a supply response and thus a more limited price effect. As Baier et al. (2009) argue "*Presumably, farmers have been aware of the subsidies and the mandated increases in ethanol production for*

several years and have likely taken this into account when making their production decisions." There was an unanticipated element as the additional increase in demand through the unexpected scale of increase in oil price – but as argued above, this made a limited contribution to the increased demand.

Thus, it seems likely that harvest shortfalls in the wheat market were more important than biofuel production in the maize market. This is supported by the timing of the wheat and maize price increases in 2008.

Unanticipated changes to production of wheat are more likely to have contributed

The chart below shows monthly global wheat and maize production estimates for the 2006, 2007 and 2008 harvests and the wheat and maize price over that period. Figure 23 suggests downward revisions of the 2006 wheat harvest in major exporting countries (the EU, Russia, the Ukraine, the USA and Australia) coincided with an increase in the wheat price. This pattern was repeated and accentuated in 2007 with lower harvests in the EU, Canada and Australia, as well as in important importing countries such as Morocco and Egypt. Upward revisions of wheat production from April 2008 onwards coincided with a fall in world wheat prices implying a role for expectations in price formation, although this is not to suggest that the wheat price movement during this period was solely due to harvest shortfalls. The movement in the maize price was not as closely linked to revisions in production estimates, which suggest a smaller role for harvest shortfalls and that the maize price partly followed the wheat price, with increased utilisation in animal feed.

Figure 23: Wheat and maize production estimates and prices from 2006 to 2009
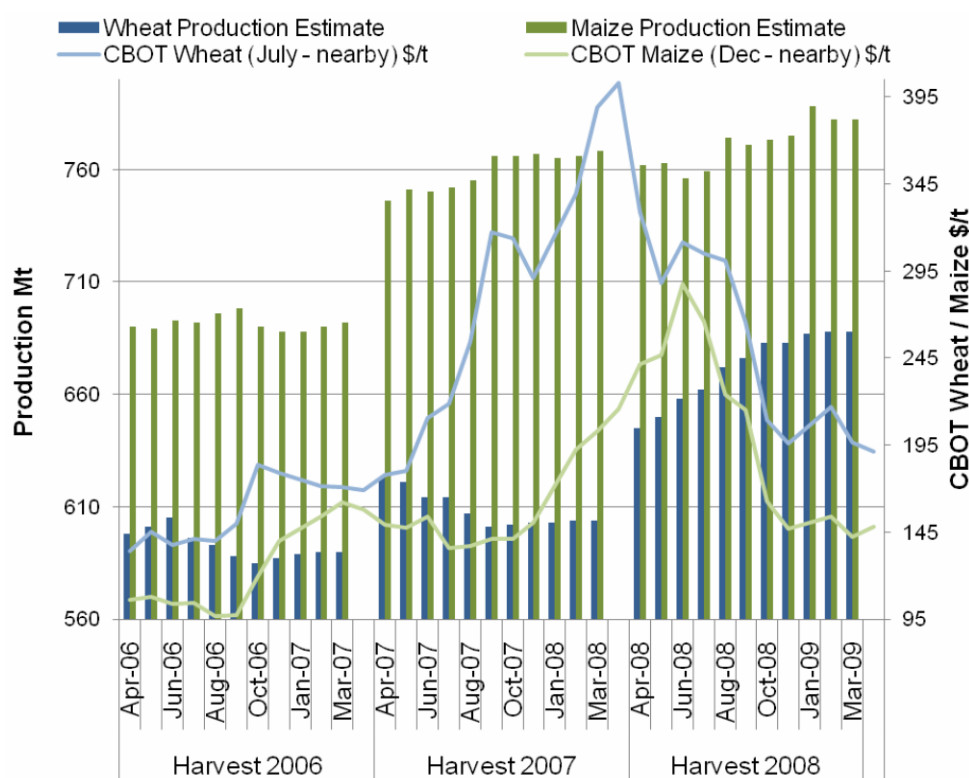

Source: IGC and HGCA websites

The shortfalls in grain supply during 2006 amounted to around 60 million tonnes

Leading up to 2008, in two consecutive years, weather-related losses in production occurred in a number of countries and regions. The regions that have been worst affected include the US, the EU, Canada, Russia, Ukraine and Australia. For example, wheat production in Australia more than halved as it declined from 25.4 million tonnes in 2005/06 to 10.8 million tonnes in 06/07 and remained far below expectation in 07/08 with an estimated production of 13.0 million tonnes (International Grains Council, 2009). OECD and FAO (2008a) estimated that the combined cereal supply shortfall of North America, Europe and Australia was over 60 million tonnes in 2006 which was followed by a lower than expected wheat harvest in 2007 where wheat production estimates were reduced by 20 million tonnes between April and September 2007.

Market responses to increased biofuel demand

Any analysis of the contribution of ethanol production to a general tightness in the market also needs to consider the impact that the anticipated increase in maize demand had on supply. It seems highly unlikely that production of maize in the US would have increased by as much as it has without ethanol production. It is misleading, therefore, to assume that all maize used for ethanol production in 2008 would have been available for feed or food. So the question is: what would supply have been without ethanol production? This is a complex question and cannot be answered robustly in this paper. A look at US maize production and use since 2000 is nevertheless informative.

Figure 24: Trends in US maize production and use from 1998/99 to 2009/10
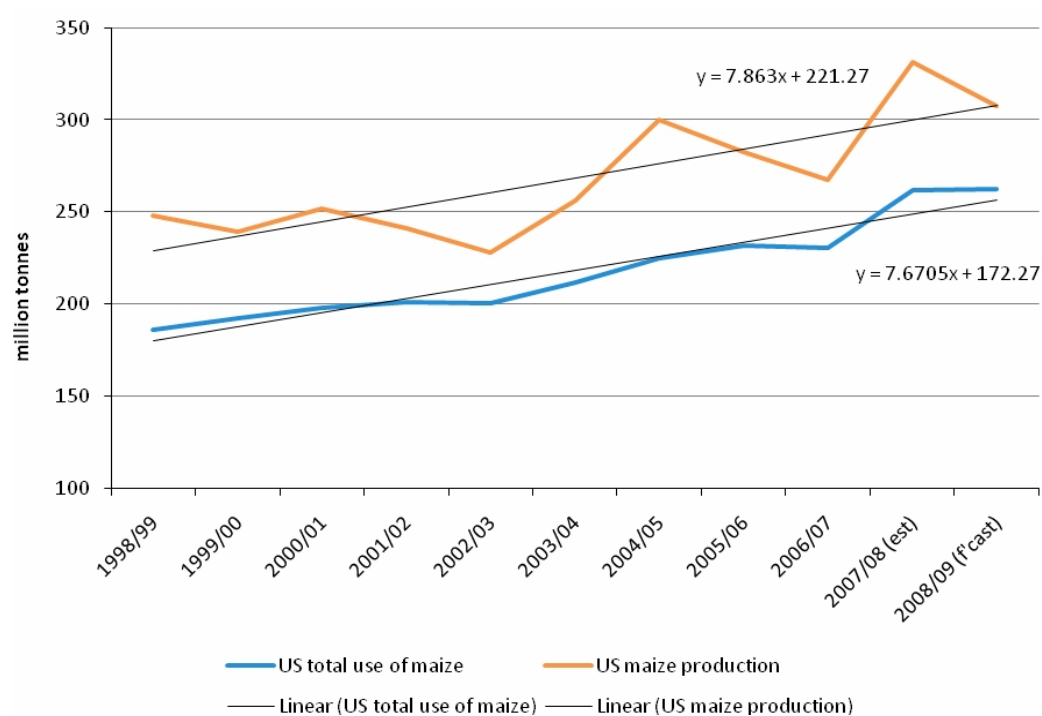
Source: IGC website

Maize production kept pace with domestic use over the past decade

Two things are worth noting in Figure 24. Firstly, a simple trend line suggests that production and use increased more or less in parallel. Secondly, production is more volatile than use. Without careful modelling, one can only speculate about what would have happened without ethanol production: the increase in use would not have been as steep; the same is probably true for the increase in production. Of course, it is possible that, in the absence of biofuels, production would have increased more quickly than use.

A full analysis would need to consider the impact of policy changes on the production of maize. One explicit purpose of biofuel production in the US was to reduce stocks and, in the absence of biofuels, an alternative destocking policy might have been developed. In addition, there doesn't seem to be any reason to assume that, without ethanol demand, maize production would not have been more volatile than use. Thus, short-term shocks to production would still have led to some short-term tightness in some of the years.

It is too simplistic to argue that biofuel production could have been switched for wheat

In terms of biofuel production outside the US, Mitchell (2008) makes an argument that rapeseed and sunflower area in Argentina, Canada, EU, Kazakhstan, Russia and Ukraine increased by 8.4 million tonnes between 2002 and 2007. He then calculates that the wheat production potential amounted to 80 million tonnes if rapeseed and sunflower production had not increased. He then assumes that this would have prevented wheat stocks from falling and thus would not have led to an increase in the wheat price. It is not reasonable to assume that these areas would have all been planted with wheat that would then have gone into stocks. Wheat prices would have fallen, stimulating demand and dis-incentivising further supply – with stocks being reduced in due course. The CIS countries demonstrate this – they have seen a large drop in arable area after the collapse of the Soviet Union. In 2002, the arable area in Ukraine, Russia and Kazakhstan was about 40 million hectares below the 1990 area (Rylko, 2008). Hence, there was not much competition for land and the current arable area is still below the 1990 level.

Consistent data on oilseed production for Kazakhstan, Russia and Ukraine are not available pre-1992 but information is available for Eastern Europe. Figure 25 shows that increased oilseed production in those countries was not at the expense of wheat area – rather, between 1991 and 1992 the wheat area is estimated to have dropped by 15 million hectares and has been below the average in the 1980s since then. The drop in wheat area in 2003 was mainly due to difficult planting and growing conditions. The trend is otherwise stable.

Figure 25: Wheat area harvested in Eastern Europe from 1980 to 2007
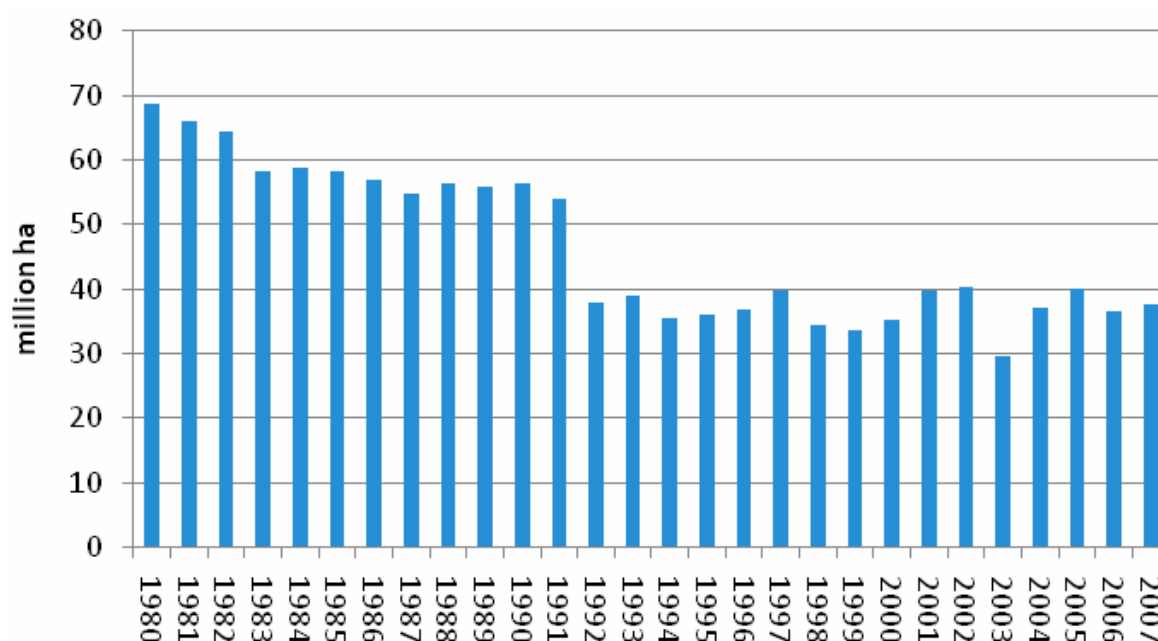
Source: FAOSTAT

The same argument can be made for EU production - it is highly unlikely that all of the area used for biofuels production would have been planted with wheat or even at all. The calculation is at best, illustrative of the relative magnitudes of production and at worst, misleading. Had the wheat market been supplied to the degree suggested (an increase in stocks of 80m tonnes) there would have been downward pressure on wheat prices leading to reduced plantings.

As discussed previously, unanticipated and anticipated changes in supply and demand have different effects on the market, especially because supply is much more elastic in the medium term than in the short term. Expectation of increased future demand might lead to investment in infrastructure or converting land. It is therefore difficult to establish an appropriate counter-factual for comparison.

In conclusion, on the impact of biofuels on maize stock levels in the lead-up to 2008, it is clear that in the absence of biofuel production, there would be less pressure on the maize market.

d)   What has happened since 2008

This section examines what has happened since the peak in food commodity prices in mid-2008. Some of the factors that may have contributed to the price spike, for example export restrictions, have receded while others have persisted. Very few of the studies in the literature review were able to take account of these recent movements in prices.

Agricultural commodity prices have fallen from their peaks and oil has decreased much more quickly

World agricultural commodity prices have fallen significantly since their peaks in 2008. US Wheat prices declined from $450/tonne in March 2008 to $240/tonne in February 2009, whilst Thai rice prices fell from over $1000/tonne in May 2008 to $600/tonne in January 2009. The fall in energy prices was even more spectacular – from July 2008 to Dec 2008 oil prices fell from around $150/bl to $40/bl.

But biofuel demand is expected to remain on an upward trend

If biofuel demand is increasing in response to in the oil price, or even the relative price of oil to the relevant feedstock as we argue above, we would expect to see a fall in biofuel demand reflecting the reduced competitiveness relative to oil. Table 13 gives projections of maize used in ethanol production from the USDA.

Table 13: Projections for US maize use for ethanol, maize production and percentage of maize used for ethanol
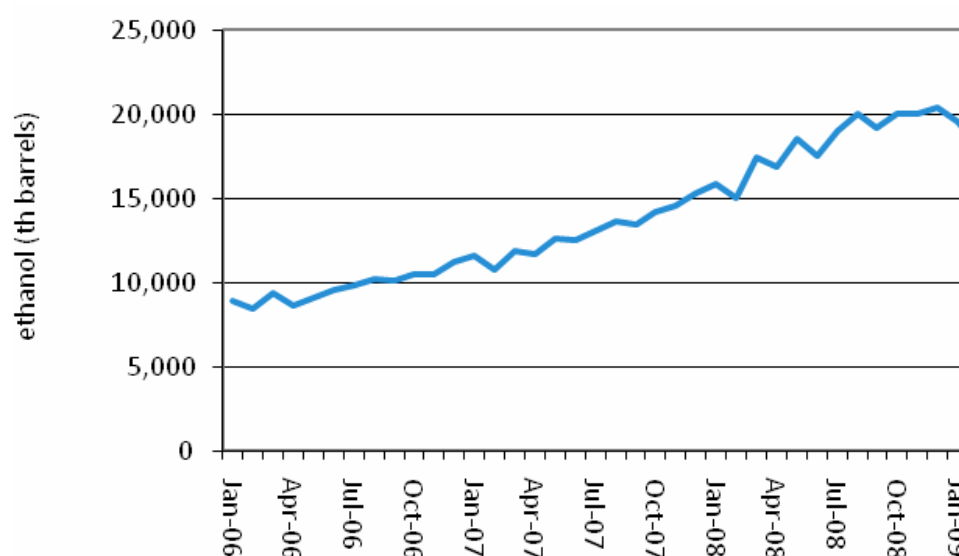
Commodity	Year Projected	Year	US maize ethanol for fuel (million bushels)	Total US maize production (million bushels)	% of US maize production for fuel ethanol
Maize	actual	2007/2008	3,026	13,074	23
Maize	2009	2008/2009	4,000	12,020	33
Maize	2009	2009/2010	4,200	12,685	33
Maize	2009	2010/2011	4,300	13,005	33

Source: USDA Agricultural baseline data, ERS, 2009

And with maize prices nearly halving, this casts doubt on biofuels as a significant contributor to the spike

As we can see from Table 13 there has been no decline in maize use for ethanol – indeed it is projected to rise by 32% from 2007/08 to 2008/09; by 5% from 2008/09 to 2009/10 and by 2% from 2009/10 to 2010/11. Despite this trend, world maize prices fell from $300/tonne in June 2008 to around $170/tonne in March 2009 – this fall is in spite of an estimated decrease in world maize production from 787 million tons in 2007/08 to a forecasted 782 million tons in 2008/09 (IGC, 2009).

Figure 26: US fuel ethanol production 2006 to 2009 (thousand barrels)

Source: EIA (2009), Monthly Energy Review available at http://www.eia.doe.gov/emeu/mer/renew.html

Growth in ethanol production slowed slightly in late 2008

Figure 26 shows monthly biofuel production figures for the US. The monthly maize price peaked in June 2008. Ethanol production continued to increase until August and then stayed at that level until the end of the year. Monthly US maize prices reached their peak in June 2008 and had fallen by 20% by August 2008. In December 2008, the price was 45% below its peak level (based on UNCTAD monthly prices).

It seems that if biofuel policies were the main explanatory factor behind the 2008 price rise, then agricultural commodity prices should not have receded as they have. This is primarily because biofuel demand has been an anticipated change in demand which has not receded.

e)   Conclusion on the contribution of biofuels to the 2007/08 price spikes

There has been a significant and sustained increase in biofuel production in the last ten years. Evidence suggests that this rise in biofuel production was driven primarily by government policies rather than by increasing energy prices.

In terms of maize, even though this increase in demand was largely anticipated and has led to a proportionate increase in the production of maize, it seems clear that maize prices are higher than they would otherwise have been. As biofuel production accelerated in 2006, it also seems fair to conclude that part of the increase in maize prices in 2008 was due to biofuels.

The above discussion also suggests that, in the run up to the spike in prices in 2007/08, the increase in the price of maize did have *some* knock-on effects to soybean planting decisions and therefore the price of soybeans. On the more important question of whether biofuel demand led to increases in maize prices which then impacted indirectly on the wheat price, we find no evidence that maize was substituted for wheat and indeed, find that the steep price increase was led by wheat and the relative prices suggest demand substitution was into maize rather than away from it. The increased demand for biofuels has had some effect on soybean prices but probably a very small effect on wheat prices.

Finally, the fact that production of biofuels has remained steady since mid-2008, whilst prices of the food commodities used directly for biofuels have fallen dramatically (between June 2008 and December 2008, maize prices fell by 45%) suggests that biofuels were not the key driver, even in those feedstocks used directly in biofuel production.

Taken together then, this suggests that biofuel demand played a role in the increased price of maize during 2008 but the case for its contribution to the general rise in food commodity prices through is much weaker.

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# Appendix 1: Theory of biofuel demand and its dependence on policy design

In the charts in the main text, demand for cereals for biofuels was represented as a straight line. This is a gross simplification. In reality the shape of the demand curve is more complex. The shape of the demand curve depends on the policy measures that drive the biofuels market.

In the most simple case, a mandate has to be met 'no matter what'. This means that one part of the demand for cereals for biofuels is completely inelastic to the price of the feedstock (other things being equal, like the price of alternative feedstocks for biofuel and the oil price). However, when the price of the feedstock falls enough to make biofuel production profitable without any policy support, then demand becomes much more elastic. How elastic depends, among other things, on the timeframe considered. In the long term, if ethanol becomes price competitive compared to petrol, at least in theory, ethanol could replace most of the petrol. The potential energy demand is very large compared to the current cereals market. Therefore, in such a simplified scenario, demand becomes almost perfectly elastic below that threshold level. It would more or less put a floor in the cereal market at this level. However, in the medium term this is unlikely to happen. Production capacity is limited and new investment takes time to come on line. It would not be enough if the current price ratio of oil and cereals prices made ethanol profitable without subsidies. It would require that investors expect the ratio to stay at a level that would make ethanol profitable over the medium term. This is further discussed in the section that covers the link between the energy and crops markets. Here, an intermediate scenario is considered, where demand for biofuels is fairly elastic but not perfectly elastic when the threshold level is reached that makes biofuels competitive without support.
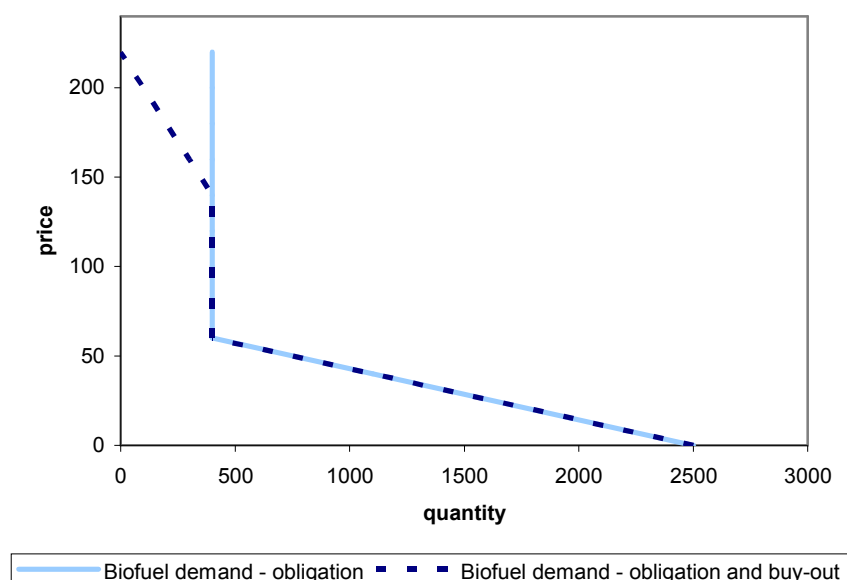
The chart above shows the general shape of the demand for cereals for biofuel production (shortened here and elsewhere in the text to – biofuel demand). The light blue line has an inelastic section at high cereal prices, and an elastic section when the price of cereals is very low. In some countries, such as in the UK, there is an obligation accompanied by a buy-out price. This introduces another kink in the demand curve. Above a certain price, the buy-out becomes preferable to some obligated parties and eventually it will be preferable for all obligated parties. As mentioned above, the US has a consumption mandate to be achieved by 2022 with safeguards that make it unlikely that demand for maize for bioethanol is completely inelastic at high prices. In addition, the policy measures used to achieve the mandated consumption include tariffs and a tax credits. These make the short-term demand for maize for ethanol price dependent. The fact that some mandates are consumption mandates and not production mandates complicates the picture further since the consumption can be met by maize-based ethanol or imported sugar-based ethanol. Thus, the demand also depends on the relative price movement in maize and sugar.

In the following charts the shape of the biofuel demand curve does not include a buy-out option or any other complicating factor. It has a completely inelastic section of biofuel demand. This is a gross simplification but it helps to keep the charts simpler. Due to these complex issues and the difficulty in modelling them, it is important to understand how demand and supply are modelled when interpreting modelling results.
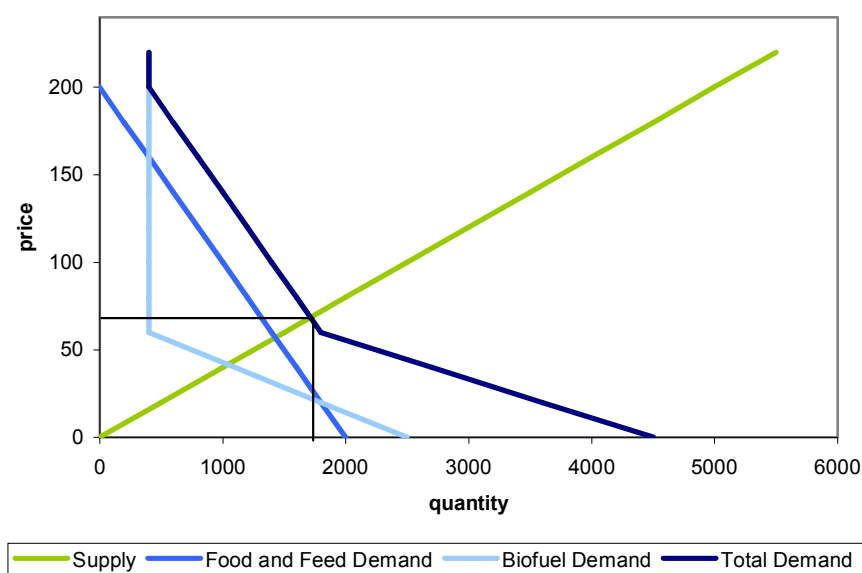

In the situation described above, the demand curve for cereals for biofuel production has a section where demand is completely inelastic as demand stems from a mandate. The bottom section of the demand curve is very elastic due to the large potential market of biofuels when biofuels are competitive with fossil fuels without support.

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This leads to three distinct sections of the total demand curve with two kinks and means that the impact of a supply shock depends on the equilibrium position before the shock and as well as the size of the shock.

The two sets of charts below show that the impact of the change in demand due to biofuel policy can have small or large impacts on the equilibrium price following a supply shock.

In the first example, a positive supply shock (i.e. a bumper harvest) leads to a large price drop in a market where demand is solely for food and feed. By contrast where demand also includes biofuels, the same supply shock leads to a much smaller price drop and a larger change in the equilibrium quantity. In such circumstances, the addition of demand for biofuels to total demand would make the market price subject to less variability.
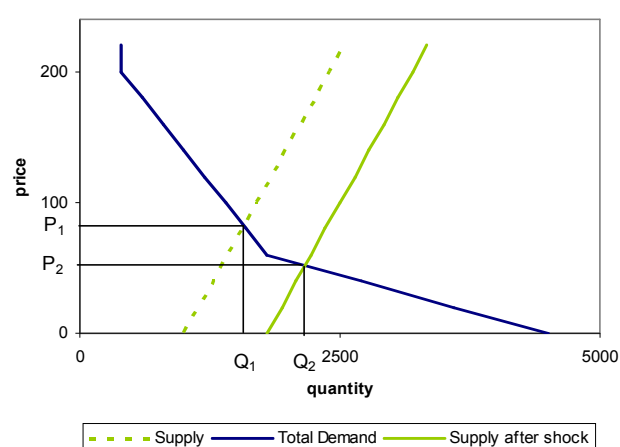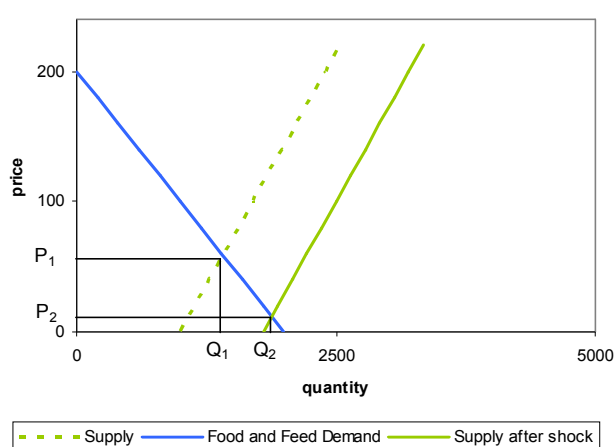
If, however, a supply shock does not lead to a large enough fall in the equilibrium price to make biofuel production competitive without support, the absolute changes in the equilibrium price and quantity are the same in a situation with or without biofuel demand as the slope of the two demand curves in this section are the same.
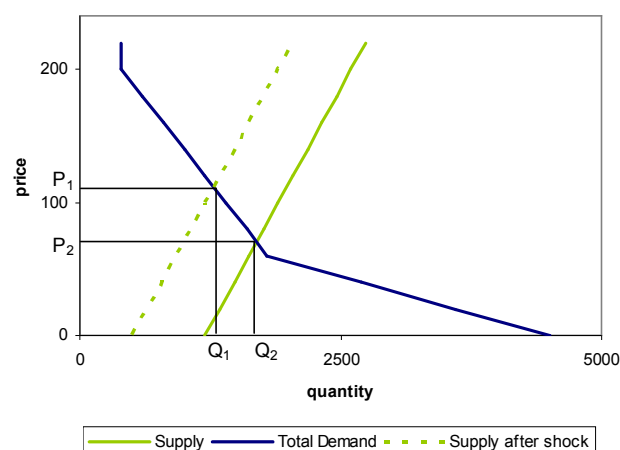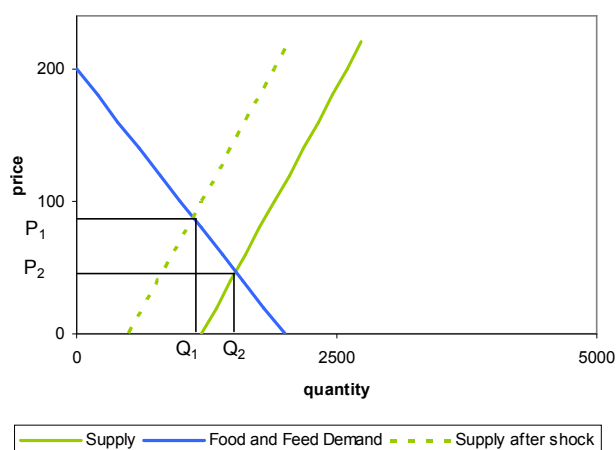
The situation is further complicated by the fact that biofuel production results in **co-products**, for example wet and Dried Distiller's Grains (DDGs). DDGs and other co-products can be fed to livestock as a substitute for other feed grains such as maize[10]. Everything else being equal, biofuel production therefore reduces the demand for cereals for food and feed. The magnitude of the effect depends on what proportion of the co-products is used for feed (energy is an alternative use) and which animal feed stuffs are replaced (cereals or oilmeals). If biofuel production is significant, the impact on the demand for feed can be large as well. The role of co-products is highlighted by the OECD in their modelling approach to biofuels.

[10] For a detailed explanation of the role of ethanol co-products in cattle feeding and their relative nutrient content see
http://www.ers.usda.gov/Publications/FDS/2009/04Apr/FDS09D01/FDS09D01.pdf

Appendix 2: Links between energy and crop markets in theory

As a start to exploring the interaction between the energy and cereal markets, the simple supply and demand framework can be used to illustrate some of the complexities. Energy price changes are external shocks to the cereal market and lead to shifts in the supply and demand curves.

The first chart shows the impact of a higher oil price on the demand for cereals under the assumption of a biofuel policy that leads to a price insensitive part of demand and a part that is very price sensitive. Other things held equal, in the elastic section of the demand curve, a higher oil price leads to greater demand for cereals at the same price level. That is, it shifts the demand curve up/to the right. In addition, the threshold cereal price at which biofuel production becomes competitive is higher for a higher oil price than for a lower oil price; but there is no change in the demand curve above this threshold price level. Demand for cereals for biofuels above this level is determined by mandates which are independent of the oil price (as noted above this is a significant simplification of the real world). If there is a buy-out price, the buy-out threshold would also shift up. It should be mentioned that if mandates are defined in terms of a percentage of total fuel use, such as in the UK policy, then there will be an indirect impact on the inelastic section. A higher oil price will reduce the quantity demanded of petrol and thus the quantity of biofuels needed to meet the obligation. We ignore this indirect impact of the higher oil price here, together with the fact that mandates are consumption and not production mandates, the effects of safeguard clauses, buy-out options etc.
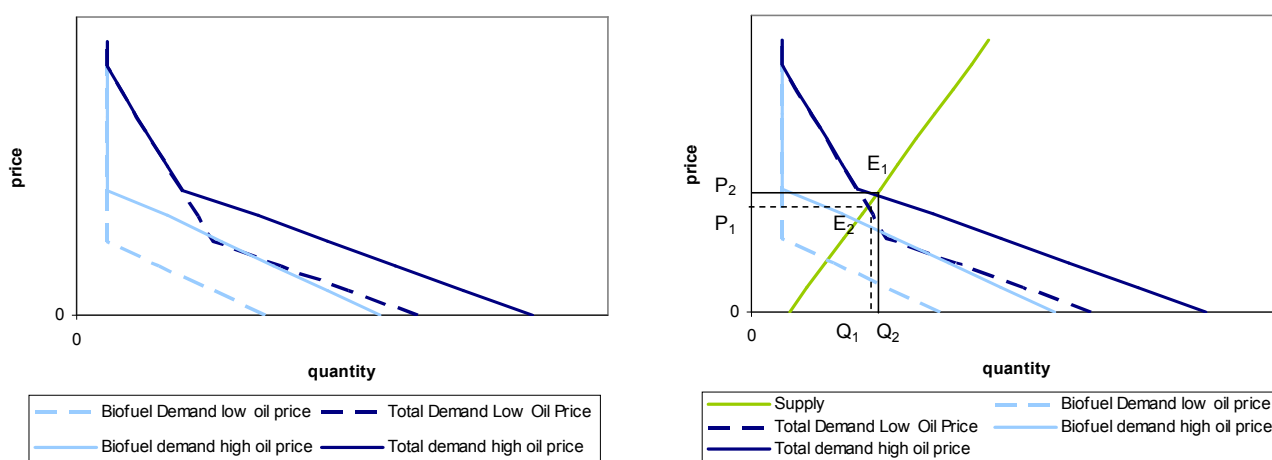

In the case above, the move from the low oil price equilibrium E_1 to the high oil price equilibrium E_2 leads to a small increase in the quantity (from Q_1 to Q_2) and a small increase in the price of cereals (from P_1 to P_2). The magnitude of the change depends on the slope and intercept of the demand and supply curves. That is, it depends on how much demand (including food and feed demand) and

supply there is in the market and how sensitive the supply and demand are to price changes. At one extreme, the equilibrium before and after the oil price shock remains in the area where production is entirely determined by policy, there is no impact on the equilibrium quantity or price in the cereals market.

In reality, a higher oil price not only impacts on the demand for cereals but also on the supply. The price of energy has a significant impact on the costs of production. A higher oil price therefore shifts the supply curve to the left. Again, the overall impact will depend on the shape of the supply and demand curves. The charts below illustrate the supply curve shift in isolation.

The overall impact is complex and depends on the supply curve and the demand curve which in turn is influenced by the implementation of biofuel policy but also by a lot of other factors.
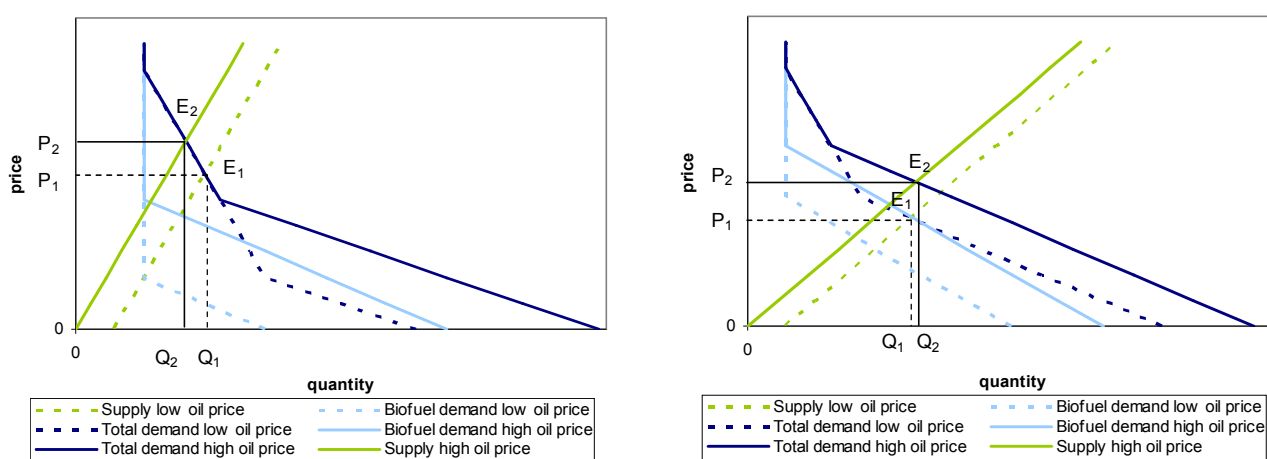
In the chart on the left, the change in the equilibrium quantity (from Q_1 to Q_2) and price (from P_1 to P_2) is entirely due to the oil price induced shift in the supply curve. In the chart on the right it is a combination of the oil price induced supply and demand effects. It should be noted that indirect effects, such as the impact of a higher oil price on food and feed demand are ignored here. For example, higher energy costs increase non-feed costs in livestock and dairy sectors, reducing supply as result and hence reducing the demand for feed grain in these sectors. This could offset some of the increased demand pressures from the biofuel sector. Given other influences on agricultural markets it is not straightforward to robustly estimate the magnitude of all links between energy and agricultural commodity markets. Prices of agricultural commodities are subject to other influences which makes estimation of the energy effects more difficult.

Whether or not, in reality, the link between the energy and cereals market is changing significantly with increased biofuel production and policies depends on the relative importance of the supply and demand side effects. These in turn are likely to be different in the short and longer terms.