

Impacts of U.S. biofuel policies on international trade in meat and dairy products

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Abstract

The rapid increase in oil prices has spurred intense interest in alternative energy sources, with biofuels being one of the more debated and controversial alternatives. In the United States, existing and proposed biofuel policies and the increased price of oil have led to a rapid expansion of ethanol supply. With U.S. federal government policies like the Renewable Fuel Standard (RFS) in the Energy Policy Act of 2005, there was a certainty around a demand for biofuels into the future.

Currently, the major feedstock for ethanol is corn, and as a consequence of policies like the RFS, corn prices and corn production are increasing. This is leading to a change in U.S. cropping patterns and impacts on industries like livestock, which rely on corn as an input. Furthermore, it is argued that this increase is affecting the intensive livestock production systems more than the extensive systems, changing the relative production costs.

In this research, a partial equilibrium model, the LTEM, was used to quantify the price, supply, demand and net trade effects of shocks induced by biofuels policies. The LTEM is a multi-country, multi-commodity trade model focused on the agricultural sector; links to other industries, factor markets and the macroeconomy are exogenously specified. This partial equilibrium framework allows a high degree of commodity disaggregation and uses readily available OECD and FAO data on production, consumption and trade.

There are 18 countries and 22 agricultural commodities included in the model. Major grain producers, including the Australia, Brazil, and the United States, are included as specific countries in the LTEM. Major sources of intermediate demand for corn are also included: intensive beef, intensive dairy, poultry meat and eggs. The model simulates the commodity-based world market-clearing price on the domestic quantities and prices in each country, accounting for the impacts of agricultural and trade policies. Excess domestic supply or demand in each country spills over onto the world market to determine world prices. The world market-clearing price is determined at the level that equilibrates the total excess demand and supply of each commodity in the world market by using a non-linear optimisation algorithm.

The LTEM is used to simulate the impacts of alternative policy scenarios into the near future. The impacts on Australia, Brazil, Europe, New Zealand, and U.S. are compared, with a specific focus on revenues to the agricultural sector and differential impacts on livestock producers depending on intensity of production. The implication for U.S. biofuel policies on domestic production and international production and trade are discussed.

Introduction

In the last thirty years, several factors have reinvigorated interest in biofuels especially ethanol: the Arab oil embargo, concern over greenhouse gas emissions from fossil fuel combustion, demand for gasoline oxygenates and improved cost-effectiveness of corn-based ethanol production. However, the prospect of diverting large amounts of corn into the ethanol market has also generated a debate about 'food versus fuel' in the use of agricultural resources. The United States currently provides around 60 per cent of the world's corn exports. Diverting U.S. corn from food and feed uses to ethanol is likely to cause food prices to increase in the crop and livestock sectors.

One U.S. policy that helps support the market for ethanol is the Renewable Fuels Standard (RFS) that mandates increased blending of renewable fuels into the fuel supply. The aim of the policy is that by providing a minimum size of the biofuels market, the RFS will promote investment and technological development in biofuels. A side-effect of the policy, however, is the diversion of corn from food and feed uses. Given the concern over competition between food and biofuel production, this research was undertaken to determine the impact on the agricultural sector of increased demand for corn (maize) for ethanol. A partial equilibrium model of international trade in agricultural commodities was used to analyse the impact of the RFS mandate on prices, production, and trade in the U.S. and a number of other countries involved in world trade in livestock products.

This paper presents the research in several parts. The next section of the paper discusses recent developments in bioethanol and the RFS, with indications of potential impacts on the agricultural sector. Following that, the paper presents the Lincoln Trade and Environment Model (LTEM), a partial equilibrium model of world agricultural trade. The paper then discusses the specific scenarios modelled and the results obtained. The final sections of the paper discuss the modelling results and provide a conclusion.

Background on U.S. ethanol

Recent market and policy changes have increased attention in the ethanol industry, and as gasoline prices have recently risen to \$3.00 per gallon in many parts of the U.S., interest is being expressed about the feasibility of ethanol as a motor fuel. Since 1980, ethanol has been used extensively as a gasoline additive to boost gasoline's octane level and improve engine performance. All vehicles can accommodate low-level blends, up to 10% ethanol (E10), without modification to engine systems. Cars called 'flex-fuel' vehicles, however, are designed to accommodate fuel blends up to 85% ethanol (E85). Despite higher octane ratings, ethanol has lower heat content than gasoline, and its use may therefore result in a drop in fuel efficiency. In

low blends the effect is quite small (1.5-2%), but the use of E85 blends may result in a 10-25% drop in mileage. Flex-fuel vehicles, however, are not optimised to E85 blends. If dedicated ethanol vehicles emerge that are optimised specifically to ethanol's high octane levels the differences in fuel efficiency may disappear or even reverse.

The ethanol industry has received substantial federal support in the form of tax relief and research and development expenditures. Since the 1970s, the federal government has relied primarily upon tax incentives to stimulate the ethanol industry. The Volumetric Ethanol Excise Tax Credit (VEETC) provides blenders with a tax refund of \$0.51 per gallon of ethanol blended with gasoline. The Small Ethanol Producer Tax Credit provides an income tax credit of \$0.10 per gallon (on up to 15 million gallons annually) for ethanol produced in plants smaller than 60 million gallons/year. A variety of other federal policies have also encouraged domestic ethanol production, including air quality legislation such as the winter oxygenated fuel requirements and the now-retired reformulated gasoline requirement, the Commodity Credit Corporation Bioenergy Program. More recently, research and development funding has been given to develop technologies enabling the production of ethanol from cellulosic biomass. To catalyse expansion of renewable fuels markets in the United States, Congress included in the Energy Policy Act of 2005 (EPACT) a federal Renewable Fuels Standard (RFS) that mandates increased blending of renewable fuels into fuel supply. The current RFS of the Energy Savings Act of 2007 establishes a 15 billion gallons mandate of ethanol in 2015 (FAPRI, 2007).

Much of the early justification for government ethanol support was expressed in terms of energy security and rural revitalization objectives. The original version of the blenders credit (VEETC) was established as part of the Energy Security Act of 1979 and was intended to subsidize the domestic ethanol industry to promote energy independence. That blending subsidy, however, is not restricted to domestic ethanol and provides an equally strong incentive for import of ethanol. To offset this, in 1980, the United States therefore also established an import tariff of \$0.54 per gallon on ethanol, which, while distorting the global ethanol market and raising prices to consumers, also provides protection for domestic producers from foreign competitors with lower ethanol production costs.¹

Several states have developed additional incentives for ethanol production. State-based measures include incentives to support ethanol production, such as producer payments, income tax credits, grant and loan programs, property or business tax exemptions, and siting and permitting process facilitation, as well as incentives to increase ethanol demand, including fuel tax exemptions, market mandates, public fleet requirements, and incentive programs for investment in alternative fuel vehicles and fuelling facilities (California Energy Commission, 2004). As of June, 2006, six states have enacted state level renewable fuels standards to supplement the federal RFS—Hawaii, Iowa, Louisiana, Minnesota, Montana, and Washington.

Prior to the RFS, most policy incentives established for ethanol supported the production side of the market. On the demand side, the industry faced uncertain government commitments and no energy price signals demonstrating to consumers the need for a gasoline substitute. As a result,

¹ Exemptions to the tariff have been negotiated; member countries of the Caribbean Basin Initiative are exempt, for instance.

the use of ethanol as a fuel remained largely restricted to a niche market in the mid-western states. In April, 2004, there were only 180 gas stations in the nation that sold E85, and 80 of them were in Minnesota (USDOE, 2004).

However, recent events have demonstrated to both consumers and policymakers that U.S. vulnerability to environmental, economic, and political disruptions in oil supply makes it prudent to develop gasoline alternatives. In 2005, record-high gasoline prices, the phase-out of MTBE as a gasoline oxygenate, and the establishment of the RFS stimulated rapid expansion of the ethanol industry. In mid-2006, there were 676 E85 pumps nationwide, being supplied by 101 ethanol plants from 21 states with a capacity of approximately 4.8 billion gallons/year. And investments are flowing into ethanol; the Renewable Fuels Association projects that within the next 18 months, ethanol production capacity will increase by roughly 40 per cent, with newly constructed plants providing an additional capacity of 2.0 billion gallons/year. Such an expansion will put the industry's production capacity well ahead of the use increases mandated by the RFS, and the 2006 Annual Energy Outlook projects that the 2012 production of ethanol will significantly exceed the mandated levels. Even with these new supplies, however, ethanol will only displace a moderate portion of our gasoline-equivalent energy demand in the near term.²

Ethanol in the United States is largely produced from corn. The majority of ethanol investment continues to be for proven technologies—generating ethanol from corn by converting starch, a simple sugar, to alcohol. However, the much-discussed state of the art in ethanol production refers to the conversion of cellulose, a complex sugar, to alcohol. Cellulosic technologies allow the conversion of biomass feedstocks such as stalks, leaves, grasses, and even trees into ethanol. This technology offers significant benefits over grain-based production, including a higher ethanol yield per acre from a diverse array of feedstocks, the use of perennial feedstocks that require less intensive management than annual grains, and a significant reduction in the demand for fossil fuels during processing.³ Due to the variety of potential feedstocks, it could also be possible to locate cellulosic ethanol processing plants closer to the point of actual use, eliminating the need to transport ethanol from the Midwest corn-growing regions to the more populated coasts. The combined result is projected to be substantial reductions in greenhouse gas emissions, significant gains in cost-effectiveness, and greater flexibility in finding biomass feedstock production pathways with a smaller environmental footprint.

Prior analyses

The impact of increased ethanol production is expected to be complex. The increased production will require new plant and equipment, which will need to be constructed. Ongoing production

² Assuming that full production capacity were realized and consumed in 2006, it would only provide around 2.4 per cent of the Energy Information Administration's projected gasoline-equivalent energy demand for the transportation sector in that year.

³ Most ethanol processing plants today combust coal or natural gas. Cellulosic biorefineries generate their own power by burning non-fermentable lignin by-products from their biomass feedstock, considerably reducing their dependence on fossil fuels.

will, in the short term, pull corn and potentially other biofuel feedstocks out of food and feed uses. In the longer term, other biofuel technologies will compete with ethanol from corn, requiring biofuel feedstocks produced with agricultural land, labour, and capital. Each of these impacts has feedback effects on the economy, as increased incomes to one party are higher costs for another, and competition for inputs and outputs shifts production costs and input mixes. This complexity suggests that modelling potential impacts is useful in considering the issues surrounding biofuels.

One issue is the potential for bioethanol to lead to regional development in areas where ethanol plants locate. These plants increase the amount of physical capital and the annual production in a region. A useful tool for examining the impacts is an input-output analysis, which indicates the net impact on a regional economy of increased corn prices or increased investment in local production as it works its way through as higher incomes and higher costs. Swenson (2006) provided a critical review of input-output analyses, which were sourced from a combination of private consultant reports, regional government departments, and academic conference and discussion papers. Swenson cited instances in the popular press in which biofuel-based development was credited with enormous potential for jobs creation and regional development. By contrast, the modelling in Swenson (2006) suggested much more modest benefits from bioethanol production. The difference resulted from lower price premia for corn produced in the vicinity of ethanol plants, smaller benefits from construction projects, and explicit modelling of the diversion of feed corn to ethanol production. In the model of a simulated tri-county region in Iowa, a bioethanol plant increased household incomes by 0.14 per cent. Nevertheless, Swenson did suggest (p. 19) that there could be increases in food prices as a result of ethanol production.

Another perceived benefit of bioethanol is reduction of greenhouse gases. Because bioethanol is produced from carbon sources that have grown only recently, as opposed to long-buried deposits of carbon, it is cycling carbon through the environment rather than increasing the level of carbon dioxide equivalents. As carbon emissions become priced and enter into the cost of production, the cost differences between renewable and non-renewable sources of energy narrow. Policies that increase the cost of carbon thus can be used to support agricultural prices by increasing the price of bioethanol feedstocks and offset the production of greenhouse gases (Schneider and McCarl, 2003). However, the economic notion of opportunity cost arises here, also, because offsetting greenhouse gases can be achieved in a number of ways, of which biofuels is only one. Schneider and McCarl (2003) thus modelled the reaction of different methods of offsetting to changes in the price of carbon emissions. They found that bioethanol – whether from corn or newer cellulosic technologies – offered limited scope for reduction of greenhouse gases when considered in a portfolio of reduction options. Furthermore, welfare impacts on producers and consumers were under ten per cent at carbon prices of 50 dollars per tonne, roughly double current carbon prices. This modelling suggested that policies to promote bioethanol through carbon pricing would reach maximum impact at relatively low prices, and that at those prices the impact on agricultural producers and food consumers would be small.

Other research has examined the impact of bioethanol policies on agricultural producers more closely. Because the U.S. is a major supplier of corn the world market and also an important participant in trade in livestock products, the impacts of these policies should be considered not only within the U.S. but also by taking account of world trade. An important tool for applied analysis of trade impacts of agricultural policies is partial equilibrium (PE) modelling (Francois & Hall, 1997). PE model focuses on specific sectors of the economy, while linking those sectors

to the macroeconomy through exogenously specified variables. PE models are not able to capture fully the feedback effects on the modelled sector from its impacts on the macroeconomy. On the other hand, they provide flexible and transparent specifications of the chosen sectors, and permit a fine level of disaggregation (Francois & Hall, 1997).

An example of the use of PE modelling in this area is a paper by Elobeid and Tokgoz (2006). They presented and used a model of the ethanol market that comprised the U.S., Brazil, and the Rest of the World. Production of ethanol was a function not only of market prices but also specific policies, such as the RFS and the blenders tax credit. One benefit of this model was that it endogenised the price of ethanol feedstock, allowing the impact of U.S. ethanol policies on corn to be analysed directly. Overall, they found that ethanol policies were leading to higher U.S. domestic ethanol prices, raising ethanol production and therefore the price of the corn feedstock. Removal of the policies and subsidies led to a fall in corn prices of 2.78 per cent in 2007, the year with the highest impact, and a fall of 1.75 per cent by 2015.

These few examples of estimating the complex impacts of bioethanol do suggest the importance of modelling the system in which biofuels are to be produced. This is true whether the focus of the study is the agricultural sector, the potential for greenhouse gas reduction, or the regional economy. These examples further suggest that the net impacts of biofuels policies are likely to be relatively small, as world markets adjust to new sources of demand for corn, alternative mitigation measures come into use, and local economies adjust their resource markets to account for new opportunities.

An interesting issue that arises with the increased demand for corn and the competition between feed and fuel uses is that the use of corn in livestock production varies by country. In some countries, such as the U.S., much of the livestock is raised intensively and corn is a major input to production. The increase in the cost of corn directly affects the cost of raising livestock, and acts as a negative supply shock. On the other hand, other countries, such as Australia, New Zealand, and Brazil, have more extensive, pasture-based livestock sectors. Their supply costs are much less affected by the price of corn. Nevertheless, they are selling livestock products into the same commodity markets as U.S. producers, so receive the benefit of higher output prices. As a result, the livestock sectors in countries with pasture-based production are likely to benefit from the U.S. biofuels policies.

To analyse the potential impact of U.S. RFS on livestock sectors in these countries, a partial equilibrium model was used. The following section describes the model itself, and this is followed by a discussion of the method used for modelling the RFS.

The Empirical Model

A model of international trade in agricultural commodities was used to analyse the impact of changes in agricultural markets due to increasing interest in biofuels. The model is built on the platform of the Lincoln Trade and Environment Model (LTEM) (Cagatay and Saunders, 2003; Saunders et al., 2000), with a country and commodity mix specific to the issue of biofuels. It is a non-spatial, partial equilibrium model of international agricultural trade developed originally from SWOPSIM (Roningen, 1986), later VORSIM (Roningen, 2007), and its model structure.

Furthermore, it is a synthetic model, based on parameters taken from the literature. The biofuels modelling comprises 17 specific countries or regions plus the Rest of the World (ROW), and contains 22 commodities, including three for the oilseed complex and five for the dairy industry. These commodities are considered homogenous with respect to country of origin.

The LTEM can explicitly consider various domestic and border policies, including production quotas, set-aside policies, input and/or output related producer subsidies/taxes, consumer subsidies/taxes, minimum prices, import tariffs and quotas, and export subsidies and taxes. The parameters associated with these policies can be modified to simulate policy changes in order to estimate their economic impacts.

The dynamic framework of the LTEM allows the paths of endogenous variables to be assessed through the modelled time period, and a comparative statics analysis can be conducted by comparing different years or the final results of different policies. The model seeks a price equilibrium of a series of production, consumption, and trade equations for each year, solving each year in succession until the final period. The structure of the model is based on a set of supply and demand equations and one economic identity for each commodity in each country. These are presented below with an explanation following each equation.

$$pp_{ij} = f(WDppi, Zs_{ij}, forex) \quad (1)$$

The producer price (pp) for a commodity (i) in a specific country (j) is a function of the world producer price for the commodity ($WDppi$); the country's policies, especially producer policies, affecting the commodity (Zs); and the exchange rate ($forex$).

$$pc_{ij} = g(pp_{iw}, Zd_{ij}, forex) \quad (2)$$

The consumer price (pc) for a commodity is also related to the world producer price for the commodity, but is additionally affected by the country's policies affecting demand (Zd) and the exchange rate ($forex$).

$$qp_{ij} = h(fp_{ij}, Z_j, pp_{ij}, pp_{kj}, qp_{ij, t-1}) \quad (3)$$

The level of production of a commodity is influenced by the country's policies (Z_j), the producer price for the commodity, the producer price for other complementary and substitute commodities (pp_{kj} , $k \neq i$), and a one-year production lag term ($qp_{ij, t-1}$). In addition, the production equation includes a parameter, fp_{ij} , that can be used to shift productivity from its base levels. This represents changes in production that are exogenous to the model and affect the relationship between prices and quantities, such as introduction of a new cultivar or a new production technology. Because the production equation uses a constant elasticity of substitution functional form, the generated shift is pivotal.

$$qc_{ij} = m_{food}(fc_{ij}, Z_j, pc_{ij}, pc_{kj}, GDP_j, pop_j) \quad (4)$$

The disappearance of a commodity is divided into food, feed, and processing components, with the residual disappearance included in the trade identity (see below). Food demand (qc) is modelled as a function of policy variables (Z), the consumption price of the commodity, the

consumption price of other commodities (pc_{kj} , $k \neq i$), an index of gross domestic product (GDP), and the country's population (pop). This equation also includes a shift variable, fc , which allows exogenous changes to consumption to be modelled.

$$qf_{ij} = m_{feed}(fc_{ij}, Z_j, pc_{ij}, pc_{kj}, qp_{kj}) \quad (5)$$

Some commodities have a feed component of their disappearance. The feed demand of a commodity (qf) is based on policy variables, the commodity's own price, and the prices of other commodities (pc_{kj} , $k \neq i$). The feed demand is also affected by the production of livestock commodities, such as beef and dairy products, and these enter directly into the equation. Finally, the feed equation contains a shift variable for exogenous changes to feed consumption.

$$qr_{ij} = m_{proc}(pp_{ij}, pp_{kj}, qr_{ij, t-1}) \quad (6)$$

For the oilseed complex, the model contains equations for processing demand. This demand is a function of the commodity's own price, the prices of co-produced products (pp_{kj} , $k \neq i$), and the processing in the prior period ($qr_{ij, t-1}$).

$$qe_{ij} = n(qp_{ij}, qc_{ij}, pc_{ij}, qe_{ij, t-1}) \quad (7)$$

Commodities have a stock equation to account for changes in inventory. The ending stock of a commodity (qe) is based on the quantity produced, the quantity consumed, the consumer price of the commodity, and a lag variable for the prior year's ending stock.

$$qt_{ij} = qp_{ij} - qc_{ij} - qf_{ij} - qr_{ij} - \Delta qe_{ij} \quad (8)$$

The final in each country equation is an identity that sets the amount of trade (qt) equal to the quantity produced less consumption, feed uses, processing uses, and the change in ending stocks. This quantity traded, positive in the case of exporting countries and negative in the case of importers, then becomes part of the world trade equation.

$$\sum_j qt_i = WDqt \quad (9)$$

The world trade equation sums the quantity traded over all countries and region for each commodity. The model is solved by finding the world producer price ($WDpp_i$, see above) that allows the net world trade to sum to zero, or for total imports to equal total exports. This solution is found using a non-linear algorithm. The model is calibrated for the base year of 2004, and then solved for each successive year. In the biofuels modelling, the final year for simulations was 2015.

Trade experiments

In order to measure the impact of U.S. biofuels policies domestically and also in selected other countries, different scenarios were analysed. In this model, ethanol is not one of the commodities considered. The impact of increased production of ethanol is therefore modelled as an exogenous

increase in the demand for corn. The increased demand leads to a price increase in the corn market, increasing the cost of corn to livestock producers. The producer price of corn is an input into the equation for the supply of livestock products (eq. 3), with the sensitivity of production to the price of corn controlled by an elasticity parameter. Countries with higher usage of corn in livestock production are thus modelled as being more sensitive to the price of corn, while pasture-based production is less sensitive. To simulate this increased production of ethanol, the shift parameter (fc) in the quantity consumed equation (eq. 4) is used. Changing the value of fc produces a pivotal shift of the consumption curve, leading to a new market equilibrium. The amount of the shift is calculated based on the amount of ethanol to be produced and the number of bushels of corn required to produce it. According to Baker & Zahniser (2006), the conversion rate of corn-to-ethanol is 2.7 gallons per bushel.

A second possibility in the bioethanol market is that new technologies may be commercialised that make more efficient use of corn plants. An example would be corn cultivars bred to be better for ethanol production. Improvement in agricultural biotechnology may increase the productivity of corn for food, feed, and/or biofuel uses. These types of changes increase the amount of corn that would be supplied at given prices, amounting to an outward shift of the supply function. For modelling purposes, such a shift is represented as an increase in the fp shift variable in the supply equation for corn (eq. 3).

Three scenarios for the U.S. corn market were considered. In the base scenario, ethanol production was modelled as reaching 5 billion gallons in 2012, which appears to be a relatively modest level of production given current activity in the biofuels sector (Marshall and Greenhalgh, 2006). In addition, no allowance for technological change was included in the base scenario.

Scenario 1 modelled the impact of the increased demand for corn as a result of the RFS. To determine the extent of the shift in demand and the value for the fc parameter, it was assumed that the higher ethanol demand was the sole factor affecting demand for corn (NCGA, 2007). In the 2003/2004 year, about 12 per cent of the U.S. corn crop was used to produce ethanol (Baker and Zahniser, 2006). Producing 15 billion gallons of ethanol in 2015 would require about an extra 4.07 billion bushels of corn going into ethanol production. Given 2004 U.S. corn production levels in the OECD database of 11.8 billion bushels, a 37 per cent increase in U.S. demand for corn was calculated. In the modelling, the fc parameter was therefore set to 1.37.

Scenario 2 considered the impact of the same demand shift as scenario 1, but with the addition of a shift in productivity in the corn sector. Productivity was modelled as increasing by ten per cent to simulate an improvement in ethanol production from corn, either by better use of the grain or more extensive use of cellulose from corn. The fp for U.S. corn production was thus changed to 1.10.

Results

The results of the modelling can be shown by comparing price and producer returns (farmgate revenues) for the baseline and the two alternative scenarios. The modelling found that higher corn demand in the U.S. resulted in an increased producer price for corn and, as a response, in a higher production level (Table 1). In the scenario 2, however, the producer price increase was less than

the scenario 1 because the ten per cent shift in the U.S. corn productivity (*fp*) provided the country with a greater supply at any given price level. A significant impact was observed for the U.S. corn trade. In both scenarios, U.S. corn exports decreased considerably; for example, exports fell by nearly one-half in scenario 1. This result indicated that, to meet the estimated demand in 2015, corn for ethanol production will be shifted from the international into the domestic market.

Table 1 - Impacts on corn producer prices, production and trade in the United States (per cent change)

	Baseline – Scenario 1	Baseline – Scenario 2
Producer price	15.1	8.3
Production	8.9	16.5
Trade	-46.4	-26.1

As the U.S. is a major corn exporter, a reduction in U.S. exports affects world prices for corn, which were predicted to increase by 15 per cent and 8 per cent for scenarios 1 and 2, respectively, compared to the baseline (Table 2). The higher world prices for corn did cause an increase in world prices for livestock and milk. However, this price rise was quite small (Table 2). Furthermore, in scenario 2, when more corn supply was available, the overall impacts were similar but lower (scenario 2 in Table 2).

Table 2 - Impacts on corn, meat and milk world prices (per cent change)

	Baseline – Scenario 1	Baseline – Scenario 2
Corn	15.15	8.28
Beef and veal	0.93	0.52
Pork	0.95	0.53
Sheep	1.06	0.60
Poultry	1.11	0.63
Whole milk powder	0.59	0.33
Skim milk powder	0.53	0.30
Butter	0.78	0.44
Cheese	0.72	0.41

A disaggregated analysis by country for both scenarios 1 and 2 revealed two major effects in terms of agricultural revenue (Tables 3 and 4): (1) the level of intensification had an impact on the extent to which the country was affected; and (2) within a country, different livestock sectors showed different levels of impact. Regarding the intensification level, the scenario 1 analysis showed that in the U.S., with intensive, corn-based livestock systems together with higher corn demand for ethanol production, the livestock and milk producer returns decreased compared to

the baseline. Countries such as Australia and New Zealand that rely on pasture-based systems, however, benefited from higher livestock prices resulting in higher producer returns (Table 3). The European Union, whose livestock and milk production is relatively more intensive, also benefited but by a smaller amount as the costs of production were negatively affected by higher corn prices. The results for Brazil also demonstrated that the more intensive an industry was, the larger effects it had. An illustrative example was the Brazilian beef industry, which relies mainly on pasture-based systems and, therefore, exhibited higher producer returns, taking advantage of the higher world prices.

Table 3 – Producer returns changes: comparison between the baseline and the scenario 1 for selected countries (per cent change)

	USA	AUS	BRA	EUR	NZL
Corn	25.41	32.21	29.34	27.14	32.43
Beef and veal	-0.32	1.49	1.25	0.75	1.42
Pork	-0.34	1.49	0.01	0.82	1.50
Sheep	-0.12	1.54	-	0.77	1.96
Poultry	0.00	1.94	0.04	1.19	2.08
Raw milk	-0.04	0.24	-0.07	0.31	1.22

The analysis of the U.S. policies' effects on the agricultural sectors showed that corn producers were the major beneficiaries in all countries. The greatest impact was in New Zealand and Australia (around 32.3 per cent) while the smallest was in the U.S. The change in producer returns for livestock and milk showed a small but probably insignificant increase. Of interest is the relatively low impact on the more intensive livestock industries such as pork and poultry.

The producer returns were also analysed within the scenario 2, where the U.S. corn supply increased due to productivity increases. The results followed the same pattern as the scenario 1 for each country and commodity. The major difference though was the amount of change in the results (Table 4). With a greater supply meeting the higher demand for corn in the U.S., the magnitude of impacts was reduced.

Table 4 – Producer returns changes (%): comparison between the baseline and the scenario 2 for selected countries

	USA	AUS	BRA	EUR	NZL
Corn	26.17	17.06	15.62	14.50	17.17
Beef and veal	-0.18	0.84	0.70	0.42	0.80
Pork	-0.19	0.84	0.01	0.46	0.84
Sheep	-0.07	0.87	-	0.43	1.10
Poultry	0.00	1.09	0.02	0.67	1.17
Raw milk	-0.02	0.14	-0.04	0.17	0.69

Discussion

A higher demand for corn in the U.S. is being stimulated by the U.S. policy regarding the ethanol production (NCGA, 2007). The higher demand for corn is predicted to result in higher corn prices in the U.S., which was estimated by the LTEM at 15 per cent and 8 per cent for scenarios 1 and 2, respectively. Similar results were found by Marshall & Greenhalgh (2006) when they assessed the environmental and economic impacts of increased corn-based ethanol in the U.S. In that analysis, the price of corn was predicted to increase by 17.5 per cent in 2015 under a 15 billion gallons of ethanol mandate when compared to a baseline of 5 billion gallons.

As a response to higher producer prices, the production of corn in the U.S. was found to increase, but exports fell. In fact, the simulation of both scenarios revealed that using corn for ethanol production was likely to result in 40 per cent less corn going to the international trade. Thus, the major impact of the RFS would appear to be reduced exports, rather than curtailing of domestic uses of corn.

The gap created by the shortage in U.S. exports may present opportunities in the short term for other countries to increase their production of corn. In Brazil, for instance, production in the 2006/2007 season is to be increased by more than 4 million metric tonnes as a response to favourable international corn prices; this will allow Brazil to increase its exports (Garcia, 2007).

While the reduction in exports is predicted to cause a significant increase in world prices, the impact on meat and dairy prices appears much smaller. Although the price of corn increased by up to 15 per cent, the impacts on meat and dairy products were nearly always under two per cent, and often less than one per cent. The countries that benefited the most from the high price of corn were those selling livestock products at the new, higher world prices, but not paying increased costs of production. These were the pasture-based sectors, such as meat and dairy products from Australia and New Zealand.

These results suggest that concerns over a competition between food and fuel uses of agricultural production or resources are not likely to be borne out at the levels of ethanol production mandated under the RFS. This is particularly the case if the world agricultural trading system is considered, rather than the U.S. agricultural sector in isolation. Decreases in U.S. corn exports

may be compensated by increased production in other countries and shifts to less intensive livestock production systems, at least at the margin. These results also suggest that impacts in the U.S. agricultural sector are likely to be confined largely to corn producers, rather than spilling out into large increases in total producer costs or consumer prices for food.

Higher productivity could dampen further any price changes, as shown in the scenario 2 modelling results. The scenario considered a modest increase in productivity of ten per cent, roughly one per cent per year until 2015. With such a productivity increase, the demand for corn for ethanol production could be met with nearly no impact on prices for livestock products.

Conclusion

In the short term, a growing ethanol market will increase corn prices, stimulating the corn production worldwide until a new equilibrium between corn supply and demand is established. This will affect world prices of livestock and milk products, but modelling results presented in this paper suggest that price impacts will be fairly small. Livestock producers who use pasture-based systems are likely to see the most benefits from these changes. The biggest impact is likely to be on U.S. exports, which fall dramatically in the scenarios modelled here. Nevertheless, ethanol production at the RFS levels are not likely to cause significant increase in consumer food prices.

Other issues have not been examined in this paper, however. These include the potential for cellulosic ethanol technologies to compete extensively for agricultural resources; the impact of larger shifts into corn-based ethanol; and the potential environmental impacts of changes to production systems. These impacts all have the potential to be complex, however, and more extensive modelling should be attempted to analyse them.

There are two further areas of research that the authors are exploring. The first is a closer analysis of the impact on Brazil of the U.S. regulations. Because Brazil is a major livestock producer and is becoming an important corn exporter, the impacts of ethanol demand are likely to be significant. In the modelling presented here, Brazilian livestock sectors were either positively or negatively affected, a result that will be further analysed. A second area of research is the environmental impact of the economic changes described here. New Zealand, for example, produces a large share of its greenhouse gas emissions from livestock. Increasing ethanol production in the U.S. may reduce greenhouse gases there but increase their production elsewhere as livestock production shifts overseas.

The modelling results presented here are a first look at the impact of the RFS on agricultural commodity trade. Future research will focus on refining the model for biofuels scenarios and investigating the model results further.

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