CHOICES
The magazine of food, farm, and resource issues

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Agriculture and Biofuels Issues: Cellulose, Greenhouse Gases, and EU and U.S. Policies

Wallace E. Tyner

A number of issues have arisen around the production of biofuels from agricultural products. These include evaluation of alternative policies, price impacts, environmental considerations, and land use. This agriculture and biofuels theme covers some very important topics ranging from local to global in scope.

The first paper by Farzad Taheripour and Wally Tyner provides an assessment of what these authors have learned in economics and policy research related to biofuels over the past four years. It covers the linkage between energy and agriculture, and the linkage between biofuels and commodity prices. It summarizes some of the important conclusions with respect to the impacts of various U.S. ethanol policy alternatives. In addition it covers the importance of the blending wall, surveys some important cellulose ethanol issues, and describes a bit of the work on global land use change impacts of U.S. and European Union (EU) biofuels policies.

The second paper by Tom Elam argues that biofuels policies in the United States need to be re–examined in light of the unintended consequences that have arisen over the past couple of years. In particular, he argues that the food cost increases may be a heavy price to pay for the relatively small energy gains.

The third paper by Madhu Khanna covers the economic prospects for and carbon mitigation potential of cellulosic biofuels. She concludes that cellulosic based fuels are likely to be more expensive than grain based ethanol. However, if environmental externalities are taken into consideration, the cellulosic based fuels become more competitive because of their advantages in reducing greenhouse gases and otherwise enhancing ecosystem services.

Finally, the fourth paper by Martin Banse, Hans van Meijl, and Geert Woltjer examines the consequences of EU biofuels policies on agricultural production and land use. They make use of a general equilibrium model to estimate the impacts of EU biofuels policies and programs and conclude that targeted EU biofuels consumption levels would have a strong impact on agriculture both in the EU and globally. Furthermore, they conclude that without mandatory blending, the EU targets cannot be achieved as the increased demand for feedstocks would pull up agricultural prices to the point that biofuels would be very expensive and blended fuel prices would not be competitive. So, clearly, these papers cover some of the most important issues in the biofuels arena today.

Articles in this Theme:

It is interesting to note that there are sometimes important differences among the papers both in terms of value estimates and conclusions. For example, Khanna has a cost estimate range for corn stover of \$82–\$101 per metric ton, whereas Taheripour and Tyner (from Brechbill and Tyner, cited in that paper) use an estimate of \$40 per short ton (about \$44 per metric ton). Most of that difference comes from the fact that Khanna included a land opportunity cost of \$34–\$36. per metric ton, but Taheripour and Tyner assumed the land rent would be attributed to the corn. Elam attributes much of the food/feed price impact to the ethanol subsidy and mandate, whereas Taheripour and Tyner argue that a large share of the corn price increase is linked to the oil price increase. Banse, van Meijl, and Woltjer find somewhat different impacts of EU policies than Taheripour and Tyner, although the approaches used were somewhat different.

These kinds of differences are to be expected. Readers will find others. The differences arise because of differences in data, assumptions, methods, etc. A better sense of the basis for these differences will help improve our understanding of these complex issues. We hope that this *Choices* theme helps advance that understanding.

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Ethanol Policy Analysis—What Have We Learned So Far?

Farzad Taheripour and Wallace E. Tyner

JEL Classifications: Q48, Q42

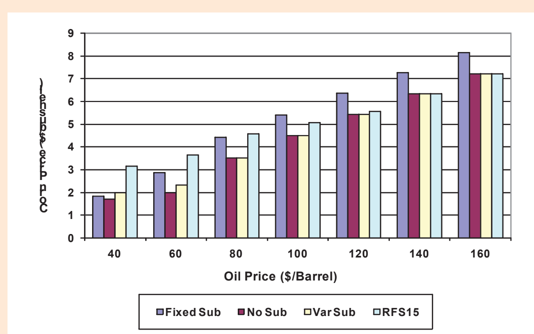
Having done research on various aspects of ethanol production and policy for several years, we decided to take stock of what we have learned so far for this paper. Of course, our research has benefitted from the work of many others, and we will try to capture some of that work as well. An assessment of where we are now is particularly important because so many changes have occurred in agriculture that are affected by ethanol growth and policy. Furthermore, the U.S. ethanol subsidy is set to expire in 2010, so Congressional action will be taken in 2009 to determine what form future U.S. ethanol policy will take. We will group the items under the following general categories: linkages between energy and agriculture, biofuels and commodity prices, policy analysis, the blending wall, cellulosic ethanol issues, and global biofuels impacts. We have done our research using firm level models, as well as partial and general equilibrium analysis.

Energy and Agriculture Linkages

Historically, the correlation between energy product and agricultural product prices has been quite low (Tyner and Taheripour, 2008a and 2008b). The forces determining crude oil and other energy product prices have largely been different from those determining agricultural commodity prices. However, today, with agriculture being called upon to produce not only food, feed, and fiber, but also fuel, that is all changing. We have shown that in the future, corn and crude oil prices can be expected to move together. Previously, we demonstrated that with break–even analysis at the firm level (Tyner and Taheripour, 2008c), and more recently with partial equilibrium analysis (Tyner and Taheripour, 2008a and 2008b). The Iowa State group among others reach similar conclusions (Elobeid et al., 2007; Tolgoz et al., 2007; McPhail and Babcock, 2008a and 2008b). Figure 1 illustrates the combination of corn and crude oil prices which maintain the U.S. ethanol industry at the break–even condition under alternative policy options. Policy options in this figure are: 45 cent fixed subsidy effective January 2009 (Fixed Sub); no ethanol subsidy (No Sub), a subsidy which varies with the price of curde oil (Var Sub), and the 15 billion gallon ethanol Renewable Fuel Standard (RFS) (U.S. Congress, 2007). The fixed blender's credit was changed in the 2008 Farm Bill (U.S. Congress, 2008) from 51 to 45 cents for corn ethanol. In addition, for cellulosic ethanol, there is now an additional production tax credit of 46 cents, a small producer credit of 10 cents and the standard blender's credit of 45 cents bringing the total cellulose credit to $1.01.

Figure 1 shows that the crude and corn prices move up together under all alternative policy options. We have called this a revolution in American and global agriculture. Since ethanol is a near perfect substitute for gasoline, higher gasoline price means more demand for ethanol and induces investment in ethanol plants. More ethanol plants and production means more demand for corn, which, in turn, means higher corn prices. The same is true going in the downward direction. If oil price were to fall, less ethanol would be demanded, corn would be freed up for other uses, and corn price would fall.

Figure 1. Break–even corn and crude oil prices at the market level



Biofuels and Commodity Prices

There is no doubt that ethanol production in the United States has contributed to higher corn prices. A large portion of the growth in corn demand is associated with growth in ethanol production. In the European Union (EU), the same is true for biodiesel and vegetable oils. Between 2004 and earlier in 2008, crude oil went from $40 to $120. Over that same time period, corn went from about $2 to about $6. With the results from our prior work (Tyner and Taheripour, 2008a, 2008b, and 2008c) one can partition the $4 corn price increase into two parts: price increase due to the U.S. ethanol subsidy and price increase due to the demand pull of higher crude oil price. The result is that about $1 of the increase is due to the US subsidy and $3 to the crude oil price increase. The crude oil price increased due to many factors such as higher demand for crude oil, devaluation of the U.S. dollar, political instability in the Middle East, and many other factors. So the crude oil price is the major driver in corn price increases, and the U.S. ethanol subsidy less so. Of course that was not the case before the surge in crude oil prices. Prior to 2005, the ethanol industry would not have existed without the subsidy. In our earlier work (Tyner and Taheripour, 2007), we estimated that with corn around $2 and no subsidy, $60 oil would be required for profitable ethanol production. Oil did not reach $60 until 2006, so the whole development of the ethanol industry was enabled by the subsidy. Today, the oil price is the larger driver.

Policy Analysis

In addition to the subsidy, the United States has other policies in effect as well—a renewable fuel standard (RFS) and a tariff on imported ethanol. The RFS (U.S. Congress, 2007) has to date not been binding; that is, the market plus the subsidy have always produced a higher amount than the level of the RFS. Our analysis indicates that if oil stays above $120, the mandate will not become binding under normal circumstances. The market would produce more than the amount dictated by the mandate. Of course, if weather events such as the 2008 flood occurred, the mandate could become binding in any given year. However, the EPA administrator has authority to waive or reduce the RFS under that type of circumstance. The major qualification to this conclusion would be a continuation of very high corn production input prices such that the market would be unwilling to produce enough corn to meet the ethanol, food, feed, and export demands without substantially higher corn prices. Under that condition, especially if oil prices were relatively lower, ethanol plants would bring production down to the mandate level, and the mandate would become binding.

Another U.S. policy is the import tariff. The import tariff originally was established to offset the U.S. ethanol subsidy, which applies to both domestic and imported ethanol. Clearly, Congress wanted to subsidize domestic but not imported ethanol, so the tariff accomplished that objective. Early on, the specific tariff was equal to the domestic subsidy of 54 cents per gallon. However, since then the subsidy was reduced to 51 cents and will be reduced again in January 2009 to 45 cents per gallon. In addition to the specific tariff of 54 cents per gallon, there is also an ad valorem tariff of 2.5%. The total tariff today for an import price of $2/gal. is 59 cents/gal., quite a bit more than the 45 cent U.S. subsidy. Brazilian sugarcane based ethanol is much cheaper to produce than U.S. corn ethanol, especially at today's corn prices. Three years ago, Brazilian ethanol was in the range of $1.10–$1.20, but with depreciation of the U.S. dollar, it is now about $1.70 even though the Brazilian domestic cost has changed little. Adding transport cost and the tariff to that cost figure makes Brazilian ethanol not generally competitive in the U.S. market today. Imports in 2008 to date are far below the 2006 level. However, if the tariff were reduced significantly or eliminated, there could be substantial imports of Brazilian and Central American ethanol. If that were to happen, it would likely reduce pressure on corn prices. Thus, the import tariff is an important policy instrument.

The Blending Wall

The blending wall refers to the maximum amount of ethanol that could be blended at the current national blending level of 10%. Since we consume about 140 billion gallons of gasoline annually, the theoretical maximum amount of ethanol that could be blended as E10 is 14 billion gallons. The practical limit, at least in the near term, is more like 12 billion gallons (Tyner, Dooley, Hurt, and Quear, 2008). We already have in place or under construction 13 billion gallons of ethanol capacity. At present E85 is tiny, and it would take quite a while to build that market. There are only about 1,700 E85 pumps in the nation and few of the flex–fuel vehicles that are required to consume the fuel. We would need a massive investment to make E85 pumps readily available for all consumers, and a huge switch to flex–fuel vehicle manufacture and sale to grow this market. Without strong government intervention, it will not happen.

What options exist? The most popular among the ethanol industry is switching to E15 or E20 instead of E10. The major problem is that automobile manufacturers believe the existing fleet is not suitable for anything over E10. Switching to a higher blend would void warranties on the existing fleet and potentially pose problems for older vehicles not under warranty. In the United States, the automobile fleet turns over in about 14 years, so it is a long term process. We could not add yet another pump for E15 or

E20. The costs would be huge. So the blending wall in the near term is an effective barrier to growth of the ethanol industry. Without a breakthrough (such as cost effective butanol production), the EPA administrator will be forced to cap the RFS far below the planned levels—to the levels that can be blended at E10 plus whatever can be sold as E85.

Cellulosic Ethanol Issues

Cellulosic ethanol development is fraught with risks. There are at least four categories of risks: oil price uncertainty, technological uncertainty, RFS implementation uncertainty, and raw material supply and contracting uncertainty. A 100 million gallon cellulosic ethanol plant is expected to have a capital cost of at least \$400 million at current prices. It is unlikely investment will occur without policies aimed at addressing these uncertainties. We will discuss each in turn.

Cellulosic ethanol is likely to be economic at oil prices of \$140 and higher. However, there is absolutely no assurance oil price will remain that high. Indeed, at this writing it is substantially below that level. A policy, such as a variable subsidy, could help alleviate the oil price uncertainty risk. Investment is unlikely without some change in policy. There are no commercial ethanol plants today. The increase in the cellulose subsidy described above is set to expire in 2012, before cellulosic production will occur, so it will not provide an incentive to invest unless promptly extended. Many companies and universities are doing path–breaking work to develop viable technologies. However, moving from laboratory or even demonstration scale to commercial scale is quite a leap. It is difficult for government policy options to provide protection against technical risk. Over time, the market will accomplish that with firms which are able to produce economically being the survivors.

The third risk is RFS implementation. Each year, EPA in consultation with DOE and USDA must decide the level of the RFS for the next year for cellulosic ethanol (and the other categories included in the RFS). It is unclear how this will be done. Given the rules of the RFS, it appears if the level is set high enough to absorb all cellulosic ethanol produced, the firms would be able to market the ethanol at a price a bit higher than energy equivalent gasoline, but not substantially higher. There is an option for blenders to pay 25 cents per gallon for a Renewable Fuel Identification Number (RIN) in lieu of actually blending the fuel. Again, it is not clear how this will be implemented. The bottom line is that there is considerable policy uncertainty, and that uncertainty also will impede investment.

Finally, there will be difficulties securing raw material supply. It is likely that potential cellulosic investors will want to be assured raw material supply before sinking steel and laying concrete. Cellulosic ethanol plants will have to source locally, unlike corn ethanol plants. Two potential sources are corn stover and switchgrass. They are quite different in many ways. First, according to our analysis (Brechbill and Tyner, 2008) corn stover is substantially cheaper that switchgrass. It costs about \$40 per dry ton compared with \$60 for switchgrass. This cost includes fertilizer replacement but does not place a value on soil carbon reduction. The literature on this topic is not consistent, but our reading is that most scientists who have worked on the issue conclude that one–third to one–half of the residue could be removed without subsequent adverse yield effects (Barber, 1979; Benoit and Lindstrom, 1987; Karlen, Hurt, and Campbell, 1984; Linden, Clapp and Dowby, 2000; and Lindstrom, 1986). Second, corn stover and other residues or waste products clearly and unequivocally reduce GHG emissions (because there is little or no direct or indirect land use change). It might be argued that the additional revenue stream from corn stover would induce more corn planting. There might be a very small effect, but we argue that the incremental net revenue would not be sufficient to cause a significant area shift.

Third, corn (and thus corn stover) is an annual crop, whereas switchgrass and similar crops are perennials, meaning in this case that they are planted and harvested over a period of about 10 years. Ethanol plants will want to contract with farmers for supply of raw materials. It should be easier to come up with contracting and risk sharing mechanisms for corn stover than for a crop like switchgrass that will require long–term contracts. This will be new territory for farmers and ethanol producers alike. And unlike corn ethanol, all the raw material must be sourced locally—normally within 50 miles of the plant. Therefore, we must develop new contracting and risk sharing mechanisms to protect both farmers and ethanol producers.

The 2008 Farm Bill contains a provision providing incentives for farmers to plant and grow cellulosic feedstock. It is sort of a plant it, and they will come provision. In our view, it is ill–conceived in that it will not ensure the supply for a plant. The only way dedicated cellulose crops will get off the ground is if adequate private contracting mechanisms are developed. The University of Tennessee is doing good work on this issue.

We will need to deal with all these issues to successfully launch a cellulose ethanol industry. In terms of policy, perhaps a variable subsidy would be first choice since that is the main mechanism for reducing oil price risk at low cost. Extension services might be used to help bring farmers and ethanol producers together to hammer out acceptable contract terms for raw material supply. Consideration might be given to providing better information on RFS implementation for cellulosic ethanol to help reduce the government policy uncertainty.

Global Biofuels Impacts

Many countries have announced and implemented plans and programs to increase production and use of biofuels renewable energy. In both the United States and the EU programs are already in effect that either require or provide incentives for significant production of bioenergy. China, India, Indonesia, and Malaysia, among others, also have announced and implemented biofuels initiatives. More than 13 billion gallons of bio–ethanol and about 2 billion gallons of biodiesel were produced globally in 2007. The ethanol production is driven by a combination of high oil prices and government support. Biodiesel production is driven mainly by government support, as it is further from being economic without policy support (OECD, 2008).

This large–scale global implementation of bioenergy production causes global economic, environmental, and social consequences. It can affect the global economy in several ways. In addition, it induces major land use changes across the whole globe which may lead to significant environmental impacts. To assess the global impacts of biofuel production, a computational general equilibrium (CGE) framework has been developed. This framework builds upon the standard Global Trade Analysis Project (GTAP) database and modeling framework and modifies it in several ways. Three types of biofuels (ethanol from sugarcane, ethanol from crops, and biodiesel from oilseed) and their byproducts - distillers dried grains with soluble (DDGS) and biodiesel byproducts (BDBP) - are explicitly introduced into the standard GTAP model. The new framework has been used in several research activities to examine global impacts of biofuel production. In this short paper we address some key findings of these research activities. In particular, we report some results from Hertel, Tyner, and Birur (2008), and Taheripour et al. (2008).

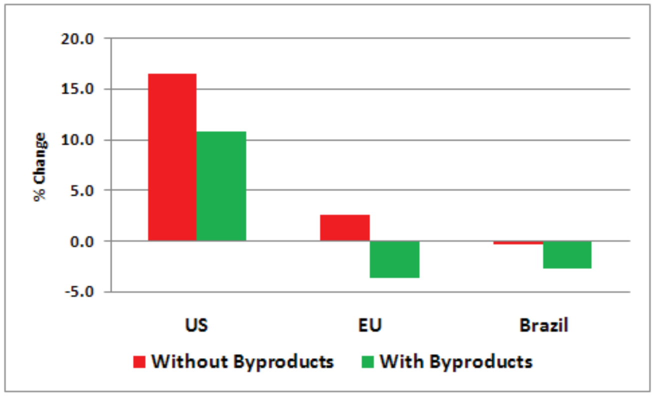
Hertel, Tyner, and Birur (2008) have examined the implications of U.S. and EU biofuel mandate policies for the world economy during the time period of 2006–2015. According to this paper, biofuel mandates sharply increase the production of coarse grains (mainly corn) in the United States and production of oilseeds in the United States, EU and Brazil. The United States and EU would use a large portion of their corn and oilseed outputs to meet their biofuel mandates for 2015. In the United States, the share of corn used in ethanol production could increase from 12.7% in 2006 to 29.9% in 2015, while the share of oilseeds going to biodiesel in the EU could increase from 23.3% in 2006 to 69.2% in 2015. The United States and EU mandates policies interact, and the most dramatic interaction between these policies is for the U.S. oilseed production. While, the U.S. mandates alone would reduce U.S. oilseed production, the combination of both the U.S. and EU mandates would increase oilseed production in the United States. In general, about one–third of the growth in the U.S. crop cover is attributed to the EU mandates. The U.S.–EU mandates affect the rest of the world as well. The combined policies have a much greater impact than just the United States or just the EU policies alone, with crop cover rising sharply in Latin America, Africa and Oceania as a result of the combined U.S.– EU biofuel mandates. These increases in crop cover come at the expense of pasture (first and foremost) as well as commercial forest.

Taheripour et al. (2008) have revealed the importance of incorporating biofuel byproducts into the economic analysis of biofuels policies. The model with byproducts reveals that production of DDGS and BDBP would grow sharply in the United States and EU. For example, the U.S. production of DDGS would grow from 12.5 million metric tons in 2006 to 34 million metric tons in 2015. A major portion of this byproduct would be used within the United States, and the rest would be exported to other regions such as Canada, the EU, Mexico, China, Africa and Asia.. On the other hand, the EU production of BDBP would grow from about 6.1 million metric tons in 2006 to 32.5 million metric tons in 2015. The EU production of BDBP would be mainly used within the region.

The CGE models with and without byproducts tell quite different stories regarding the economic impacts of the United States and EU biofuel mandates for the world economy in 2015. While both models demonstrate significant changes in the agricultural production pattern across the world, the model with byproducts shows smaller changes in the production of cereal grains and larger changes for oilseeds products in the United States and EU, and the reverse for Brazil. For example, as shown in Figure 2, the U.S. production of cereal grains increases by 10.8% and 16.4% with and without byproducts, respectively. The difference between these two numbers corresponds to 646 million bushels of corn which could be used to produce about 1.7 billion gallons of ethanol. This is really a big number to ignore and disregard in the economic analyses of biofuel production.

With byproducts included in the model, prices change less due to the mandate policies. For example, the model with no byproducts predicts that the price of cereal grains grows 22.7% in the United States during the time period of 2006 to 2015. The corresponding number for the model with byproducts is 14%. Introducing byproducts into the model alters the trade effects of the U.S.–EU man-

Figure 2. Percentage change in coarse grain production due to the U.S. and EU biofuel mandate policies 2006–2015



date policies as well. For example, the model with no byproducts estimates that the U.S. exports of coarse grains to the EU, Brazil, and the Latin American region would drop sharply by –4.8%, –25.5%, and –12.7%, respectively. The corresponding figures for the model with byproducts are –2.1%, –15.7%, and –7.9%.

Next Steps

We have learned a lot in the economic analysis done to date, but there is much more work needed. Our next step is to improve the data and models such that we will be able to estimate global land use changes induced by national biofuels programs. Land use changes are important in estimating greenhouse gas emissions changes associated with biofuels.

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Food or Fuel? Choices and Conflicts

Thomas E. Elam

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The quiet world of farming and food production is undergoing a "sea change" of unprecedented proportions. Since 2005 we have seen a rise in energy prices coupled with policy decisions that have expanded biofuels markets for crops that were traditionally used almost exclusively to feed people and farm animals. In addition, a weak U.S. dollar and increasing global food demand have added to the upward price pressure and increased volatility in major crop markets.

Governments of the United States and the Economic Union (EU) have reinforced changing market conditions with policy choices that tilt the balance towards channeling crop production into biofuel production. The mandates and subsidies in these policies are not transparently linked to market forces. Debate over the wisdom of market–insensitive biofuels policy that adds to crop demand and price uncertainty in a time of record–high prices has become heated.

The basics of what is happening to market supply and demand forces are not difficult to understand. The wrinkles added by biofuels policy are, on the other hand, both significant and add complexity.

Energy Markets Alone Are Causing Major Changes in Agricultural Markets

For economists, the increase in oil prices and the resulting link to the energy value of crops has turned out to be a test of just how well our theories can predict the outcome. I am happy to report that the theories have passed the exam with flying colors. This is cold comfort for those paying historically high prices for gasoline, corn, soybean oil and soybean meal, but at least we know "how" and "why".

Market–based demand for crops used in food production is somewhat different from market–based demand for biofuel in one important sense. In the food market, as production increases price is expected to decline along a short–run demand curve. Price–inelastic demand for food generally leads to large changes in price for relatively small changes in production. Food demand for crops is also not strongly linked to other commodity sectors. This is not true for demand for food crops used as biofuels.

The global market for petroleum–based energy alone, in terms of energy production, is substantially larger that all the potential fuel energy that can be produced from the world's food crops. Unless we are willing to sharply reduce food consumption we can use only a fraction, and a small one at that, of the current world's food supply to produce fuel. In the world of energy, potential food–based biofuel production simply cannot come close to replacing a meaningful amount of petroleum, much less total fossil fuel consumption. (Including natural gas and coal)The 15 billion gallon U.S. ethanol RFS for 2012 would use about 6.2% of the 2008 global grain crop to replace about 6.8% of the 2008 U.S. gasoline supply and only 0.8% of global oil production. This creates an asymmetric situation where the biofuel supply is too small relative to the global energy market to have much effect on energy prices, but energy prices can have a major effect on food prices.

To put it simply, the limiting factor on expanding food–based biofuel production is the world's desire for food, not fuel demand. Even more simply, we like to eat. Open up the possibility of producing biofuels from other sources that do not compete for farmland (algae, wood waste, manure, solid waste, and others) and the limits on production can be expanded. That technology is still, after many years of work, "not quite" ready. It may be a factor in the long term biofuels market, but not today's.

If biofuels are priced competitively, they are a near–perfect substitute for petroleum fuels. A gallon of ethanol has about 66% of the BTU content of a gallon of gasoline.

Gallon–for–gallon methyl ester (the chemical name for the purified product extracted from fats and blended with diesel fuel to make bio–diesel) has very close to 100% of the BTU content of diesel.

For current engine technology that means that, at 66% of the price of gasoline, ethanol is a near–perfect substitute for gasoline. If E85 (85% ethanol, 15% gasoline) is priced at 71% of the price of gasoline, motorists will not care whether they buy regular gasoline or E85 as their fuel cost per mile will be about the same. Modified engines can take advantage of ethanol's higher octane rating and reduce the energy penalty through higher efficiency than is possible with today's gasoline–based technology. There are none of these engines on the market today. Diesel buyers can pay the same price for methyl ester as diesel and get the same fuel cost per mile.

Until oil prices passed about $70 per barrel the market economics of converting crops to fuel were not very favorable. Grains and fats were priced too high compared to their energy value to make it profitable to convert them into motor fuels. We did produce some ethanol and methyl ester, but only with the help of government subsidies. With oil at over $100 a barrel in 2008 the value of crops converted into fuels has been significantly higher than food–market values of just a few years ago. Subsidies are no longer required for biofuels to be a viable use of crops. That is a huge change in market fundamentals.

So, what happens if crop–based production of biofuels is limited to only a small fraction of the petroleum market and petroleum prices suddenly increase, setting values for crops that are higher than prevailing food–market prices? According to economics textbooks the classic market–based process should unfold something like this:

1. Biofuel prices will increase with energy prices, but crop prices will not immediately follow.
2. Biofuel producer profits will increase from higher biofuel prices.
3. Biofuel producers will expand production, but with a time lag.
4. Biofuel production increases are too small to have a material affect on overall fuel prices.
5. However, as biofuel production grows so does demand for the crops used.
6. Production of the biofuel crops is limited by available land and yields, less of those crops are available for food use.
7. The biofuel crops will take acres from other crops, and their prices will also increase.
8. With time lags, higher crop prices will be reflected in higher food prices and lower food production.
9. Higher demand for limited crop supplies will cause crop prices to increase until biofuel profits disappear and fuel value of crops equals food value.
10. Biofuel expansion will stop, and some marginal producers may exit.
11. If crop production increases enough to cause a crop price declines, loop back to Step 3.

Although it seldom happens in real life, the economics textbooks in this case predict what has happened up through Step 9. A marked slowing of new ethanol plant construction indicates that Step 10 is also in the process of occurring. Longer term implications of higher energy prices for agricultural markets include, but are not limited to:

1. Energy markets and food markets become tightly coupled. That is, increases (decreases) in energy prices will cause crop prices and food production costs to increase (decrease).
2. Prices for crops and feedstuffs other than those used for biofuels will also be affected due to competition for land and substitution in use.
3. Land prices and rents will move in tandem with changing energy prices; landowners are potentially the major beneficiaries in the form of higher land prices.
4. High (relative to pre–2007) energy prices will cause increased demand for farm inputs and will cause crop production costs to increase.
5. Food production volume will be affected by the demand and price for energy via the biofuels market.

Bruce Babcock of Iowa State University and Wallace Tyner of Purdue University have come to essentially these same conclusions (Babcock) (Tyner).

Energy Policy Reinforcing the Energy Market Linkage to Agriculture and Food

Energy policy affects food and agriculture through biofuels and their links to both energy production and crop demand and use. The biofuel policy tools commonly used are subsidies for biofuel producers, mandated production and/or use, and tariffs designed to protect the domestic market. Current U.S. policy makes use of all three of the tools. EU policy is focused in mandates.

Mandated use of ethanol in the United States was first proposed in 2003, but not enacted until 2005. The Energy Policy Act of 2005 had an ethanol mandate (the Renewable Fuel Standard, or RFS) that was relatively modest and did not have a significant effect on agricultural markets. However, enacted on December 19, 2007, the Energy Independence and Security Act of 2007 (EISA) set forth a much higher RFS.

To put the higher EISA RFS in perspective, the crop year 2008/2009 EISA RFS is about 10 billion gallons of ethanol. It would require at least 91 million tons of corn be used from the 2008 U.S. crop. USDA is currently (as of August 12, 2008) forecasting 104 million metric tons of corn use, about 4% of total global grain production, for ethanol production from the 2008 corn crop. While the 2008/2009 ethanol mandate may be slightly smaller than forecast production, the presence of a market guarantee of this magnitude could be underpinning current corn prices.

In addition to the RFS mandate, U.S. policy also grants the biofuels industry tax credits, paid to the company that blends ethanol or biodiesel with petroleum fuels. The tax credits do not adjust with market conditions. Fixed cash infusions into biofuel use raise the value of biofuels to the blending company and raise the market price of biofuels without regard to energy or crop prices. With higher biofuels prices the biofuel producer has an advantage over other crop buyers. However, there can be only one market price for any crop, so the biofuels industry eventually bids much of the value they receive from the tax credits into crop prices. The tax credits are adding to the upward pressure on crop prices on top of the market pressures from higher energy prices.

The end result with both the tax credits and mandates is that much of their value will always eventually be bid into biofuel prices, and then crop prices. Crop farmers, not the ethanol industry, become the major beneficiaries of the tax credits. Eventually, higher crop prices will be capitalized into land prices, and the ultimate benefit will accrue to landowners.

Finally, the ethanol tariff of $0.54 per gallon is a barrier which helps protects U.S. ethanol producers from more efficient producers outside of the United States. However, in a sense the tariff and tax ethanol credit cancel each other, and the net effect is to deny foreign ethanol producers the value of the U.S. tax credit paid for all ethanol in the prices they receive.

There has also been political fallout over biofuels policy. The voice of agriculture is fracturing along lines of crop producers versus crop users. As the public sees crop farmer income grow while their food prices increase (MSNBC) support for farm programs and biofuels policy may erode.

What Happens When Policy Meets Cold Reality?

History teaches us that in most cases reality eventually wins. We also often see "unintended consequences." Energy policy can set any mandated level of ethanol production, but even the U.S. Congress or the President cannot change the weather or double crop yields overnight. Actually, to replace just 50% of U.S. gasoline consumption with E85 would take 100 billion gallons of ethanol. Including 9 billion for food, feed and exports, corn production would need to be over 40 billion bushels to make that happen. From 80 million acres of U.S. corn it would take a yield of over 500 bushels per acre. We are currently at about 160 bushels in a good year. We also would still be importing significant amounts of crude oil. When it appeared that the 2008 corn and soybean crops were at risk from flooding, corn prices soared to unprecedented highs. On June 18, 2008, several corn futures contracts closed at over $8 for the first time ever. Cash corn was selling for close to $9 per bushel in California. Prices of soybeans and wheat were also on the rise. Within a few weeks it became apparent that the crops were improving, and prices declined, but remained at historically high levels.

Why did this happen when even a damaged 2008 corn crop could still have been the 4th largest on record? A major factor was likely that for the first time in history we had $140+ crude oil prices coupled with an expanded biofuels industry with a RFS mandate large enough to use sufficient grain relative to production to make a substantial difference in crop prices.

While improved weather at least temporarily alleviated the 2008 supply crunch, it is not clear at this point just how such a scenario of tight crop supplies and EISA policy will interact. Corn prices at the levels of June, 2008 were not profitable for ethanol producers, food or animal feed users. We were, for a few weeks, in an unprecedented bidding process to determine who was to have access to a corn crop that was predicted to be much smaller than that of 2007. At some point we would have reached prices that would have rationed use, or the RFS would have been reduced. Had the RFS been reduced, prices may have dropped sharply overnight.

Finally, along with higher crop prices we have also seen a marked increase in price volatility. The coefficient of variation of monthly 2007–crop cash corn prices has been about three times the level of the 2000–2006 crops. The increased demand for biofuels, partly market driven and partly as a result of policies promoting their production, has reduced crop stocks levels, driving price volatility higher. Less stable crop prices raises another set of issues regarding how crop users will manage higher risks.

Why We May Need to Re–examine Current Energy Policy

Arguably, the biofuels features of the Energy Independence and Security Act of 2007 (EISA) will achieve few of the goals implied by the law's name. A recent Iowa State study of EISA policies concludes that they are in fact not designed to promote cleaner energy production, energy independence or energy security, but rather are intended to increase farm incomes and land prices (Rubin, Carriquiry, and

Hayes). The study examined a wide range of policy options, and concluded that the policy set contained in EISA had the largest benefit for agriculture of the options examined. In their conclusions the authors state "There is strong evidence to suggest that the primary purpose of these (EISA biofuel) polices was to remove land from food and feed production and in so doing to increase farmers' and landowners' incomes."

By establishing price–insensitive subsidies and mandates EISA also partially isolates a large portion of key crops from market forces, pushing adjustments in production and prices onto the food production sector. The result is higher, more volatile, food prices and reduced security of our world's food supply. Increased biofuel production, subject to the whims of weather, also arguably reduces even our overall fuel security.

The payoff for ESIA biofuels policy is small relative to the energy market. Even if the 36 billion gallon EISA mandate for 2022 could be met it would not make a material change in the country's dependence on foreign oil. The petroleum equivalent of the mandate is about 570 million barrels of oil per year, or only about 15% of 2008 U.S. oil imports. That still leaves the U.S. highly vulnerable to world oil market interruptions.

On equity grounds biofuels policy has helped promote a transfer of income and wealth from food consumers and crop users to crop producers and land owners (Taheripour and Tyner). In effect, biofuels policy can be seen as a regressive food tax, the proceeds of which largely go to farm owners.

Current U.S. biofuels policy deserves to be revisited by Congress and the Administration. Together with oil price instability, EISA's inflexible biofuel mandates, subsidies and tariffs have increased both costs of food production and price volatility. Both higher costs and higher risks have been imposed on the food production sector.

At a minimum, a more flexible biofuels policy that is responsive to agricultural and energy market realities should be preferable to the fixed tax credits, RFS and tariffs contained in EISA. An energy policy that more strongly emphasizes energy conservation and fuel production from non-food sources, including incentives to increase U.S. oil and natural gas production, could also be part of that debate.

To solve the potential dilemma of "food vs. fuel" demands that we effectively address long– term energy consumption, production and prices. Failure to do so could lead to a future of significant increases in global food and energy costs, a marked decline in global living standards, and an increase in global poverty rates. If this happens the world will be neither a more independent nor secure place to live.

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Cellulosic Biofuels: Are They Economically Viable and Environmentally Sustainable?

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JEL Classification: Q01, Q54, Q55

Biofuels are being extensively promoted for their potential to contribute to energy security, stable energy prices, and climate change mitigation in the United States. A key constraint to our ability to expand biofuel production to significantly reduce dependence on fossil fuels is likely to be the limited amount of agricultural land available to produce food, feed and energy crops. The use of crop residues like corn stover, wood chips and high yielding herbaceous energy crops such as perennial grasses is being explored to mitigate this competition for land and achieve higher quantities of biofuel per acre of land than being achieved by corn–grain based ethanol. Among herbaceous energy crops, miscanthus and switchgrass have been identified as promising crops because they have higher yields than other perennial grasses, provide high nutrient use efficiency and require growing conditions and equipment similar to those for corn, which makes them compatible with conventional crop cultivation (Heaton et. al., 2004). They also have several positive environmental attributes.

To be economically viable, energy crops must compete successfully both as crops and as fuels. Biofuels produced from these energy crops (referred to as cellulosic biofuels) need to compete with fossil fuels and corn–based ethanol. Owners of cropland will produce cellulosic feedstocks only if they can receive an economic return that is equivalent to or preferably higher than the returns from the most profitable conventional crops, particularly if energy crop production is exposed to more price risks. The foregone returns from these conventional crops are the opportunity cost of using cropland for producing energy crops. Geographical variations in the costs of producing these crops and in the opportunity costs of land are likely to make the economic viability of cellulosic biofuels differ across locations.

Energy crops and the cellulosic biofuels produced from them offer the potential for various environmental benefits compared to the row crops they may displace and compared to grain–based ethanol. These include reduced soil erosion and chemical run-off, extended habitat for wildlife, stabilization of soil along streams and wetlands, sequestration of more carbon in the soil than row crops grown using conservation tillage, and lower input requirements for energy, water and agrochemicals per unit of biofuel produced (McLaughlin and Walsh, 1998; Semere and Slater, 2007). These environmental benefits tend to differ across different energy crops, due to differences in their energy input requirements, ability to sequester carbon in the soil, canopy cover and palatability of leaves for insects. There have been some concerns that miscanthus, as an introduced species, might be an invasive plant. However, most varieties used for biofuel production (like *Miscanthus x Giganteus*) are sterile hybrids and do not produce seed. Environmental groups are also concerned that demand for biofuels might lead to the dominance of single species of perennial grasses within a landscape rather than polycultures with mixed prairie grasses, like Indian Grass and Big Bluestem, which would enhance biodiversity.

The potential to mitigate greenhouse gas emissions by using biofuels for transportation is a key benefit, since there are few substitutes for transportation fuel given current vehicle technology. We will examine the costs of producing biofuels from alternative feedstocks (corn stover, switchgrass and miscanthus) using data for Illinois. Life–cycle analysis allows us to estimate the CO_2 mitigation potential of these feedstocks relative to gasoline. We will then discuss the implications of valuing these CO_2 mitigation benefits for the competitiveness of these feedstocks relative to each other and to gasoline.

Costs of Cellulosic Feedstocks

The economic potential of cellulosic feedstocks depends on their yields, input requirements and costs of production and is expected to vary spatially with differences in climatic and soil conditions. Corn (and thus corn stover) require good soil quality while perennial grasses require long growing periods and higher temperatures and can be grown on less fertile lands. Corn stover yields are expected to be in the ratio of 1:1 with corn yields and to range from a low of 2.25 t dm per acre (metric tons of dry matter per acre, with 1kg=0.001 metric ton) in southern Illinois to a high of 4 t dm per acre in northern and central Illinois; of this, the amounts that can be sustainably harvestable vary between 40% and 70% depending on tillage practice (Sheehan et al., 2004). In contrast to this historically observed pattern of corn yields, peak yields of miscanthus (simulated using a crop productivity model), are estimated to be lower in northern Illinois (12 t dm per acre) than in southern Illinois (18 t dm per acre) (Khanna, Dhungana and Clifton-Brown, 2008). The spatial pattern of switchgrass yields is expected to be similar to that of miscanthus, however, switchgrass yields are about a quarter of those of miscanthus based on field experiments conducted in Illinois and Iowa. Yields per acre of these crops influence not only their costs of production per ton but also the volume of biofuels that can be obtained per acre of land and thus the amount of land that would need to be diverted from row crops to meet a given level of biofuel production.

Table 1 presents an estimate of annualized costs of producing switchgrass and miscanthus and the annual costs of collection of corn stover in 2007 prices. These cost estimates are developed for average delivered yield levels for Illinois (for details about agronomic assumptions see Khanna, Dhungana and Clifton-Brown, 2008; Khanna and Dhungana, 2007). Switchgrass is assumed to have a life of 10 years, while miscanthus is assumed to have a life of 20 years.

Fertilizer and chemical input requirements for corn stover and energy crops relative to conventional crops are fairly low. In the case of corn stover, fertilizer applications are needed to replace the nutrients removed with the stover to sustain soil fertility (Sheehan et al., 2004). The largest component of the costs of producing cellulosic feedstocks is the cost of harvesting, baling and storing them, particularly if they are stored in an enclosed building for several months after harvest. Since there is considerable uncertainty about the methods of harvesting and storage of biomass, we consider two alternative scenarios for estimating baling and storage costs. In the high cost scenario, we consider baling costs per acre as linearly related to the yield per acre, while in the low cost scenario, we treat a portion of the baling costs (those related to the equipment, tractor and implements) as fixed and a portion as variable (fuel and labor) that depend on the biomass yield to be baled. The high cost scenario also considers storage of bales in an enclosed building, while the low cost scenarios assumes it is on the field on crushed rock and covered by tarp.

Another large component in the case of energy crops is the opportunity cost of the land, which is tied to the price of row crops such as corn and soybeans. In the case of corn stover, we assume that the use of stover

Table 1. Farmgate Costs of Production of Cellulosic Feedstocks in Illinois

Cost Items ($/Acre)	Switchgrass		Miscanthus		Corn Stover	
Scenario	High	Low	High	Low	High	Low
Fertilizer	66.7	66.7	29.8	29.8	15.3	15.3
Chemicals	7.7	7.7	0.5	0.5	-	-
Seed	7.0	7.0	70.8	70.8	-	-
Interest on operating inputs	5.7	5.7	7.1	7.1	1.1	1.1
Preharvest Machinery	14.1	14.1	11.0	11.0	-	-
Harvesting	86.8	64.0	277.5	151.6	69.5	60.2
Storage	54.2	10.2	199.3	37.6	41.7	7.9
Annualized Total Operating Cost	**242.2**	**175.4**	**595.9**	**308.4**	**127.3**	**84.1**
Annualized deliverable yield (t dm/acre)[a]	2.5	2.3	8.5	8.1	1.9	1.8
Opportunity cost of land ($/ t dm)[b]	179.4	189.0	51.9	54.7	43.9	46.3
Break–even total cost ($/t dm)	**277.8**	**264.2**	**122.0**	**92.9**	**111.3**	**93.1**

[a] Deliverable yield at the farm gate estimated after including losses during harvest and storage. Losses during storage are assumed to be 7% of harvested yield in the low cost scenarios and 2% in the high cost scenario.

[b] Opportunity cost of land is estimated assuming a price of $5 per bushel for corn and $12 per bushel for soybeans and a yield of 145 bushels/acre for corn and 50 bushels/acre for soybeans with a corn–soybean rotation.

for biofuels leads farmers to switch from a more profitable corn–soybean rotation to a corn–corn rotation with a 12% lower yield of corn, imposing an opportunity cost of land. As can be seen in Table 1, the per ton costs of producing switchgrass are more than two times higher than those of miscanthus and corn stover, in large part because of the high opportunity cost of using land given switchgrass yields. The per ton costs of producing miscanthus are similar to those of corn stover in the low cost scenario.

The costs of producing these feedstocks vary considerably spatially due to differences in their yields as well as differences in the costs of land as shown in the case of Illinois in Figure 1. Costs of producing corn stover are relatively lower in parts of northern and central Illinois where corn yields are high while those of miscanthus are relatively low in the southwestern and southern regions of Illinois where its yields are high. Costs of producing switchgrass in Illinois are much higher than those of corn stover and miscanthus (given its present yields). Thus, unlike the present generation of ethanol which is dominated by a single feedstock, corn, the next generation of (cellulosic) biofuels in the United States might be produced from a mix of feedstocks with more corn stover being used in central and northern Illinois and more miscanthus in southern and southwestern Illinois.

Table 2 shows the quantity of ethanol per hectare of land with different feedstocks with current yield of 2.8 gallons of corn ethanol per bushel of corn and projected yield of 87.3 gallons per delivered metric ton dm of cellulosic feedstocks (Wallace, Ibsen, McAloon and Yee, 2005). Costs and yield estimates in Table 2 are under the high cost scenario described above. Miscanthus can produce more than twice as much ethanol as corn can per unit of land and more than three times as much as corn stover or switchgrass. Miscanthus can produce at least 30% more ethanol per acre of land than combined ethanol production from corn grain and corn stover.

Figure 1. Farmgate Costs of Producing Cellulosic Feedstocks in Illinois

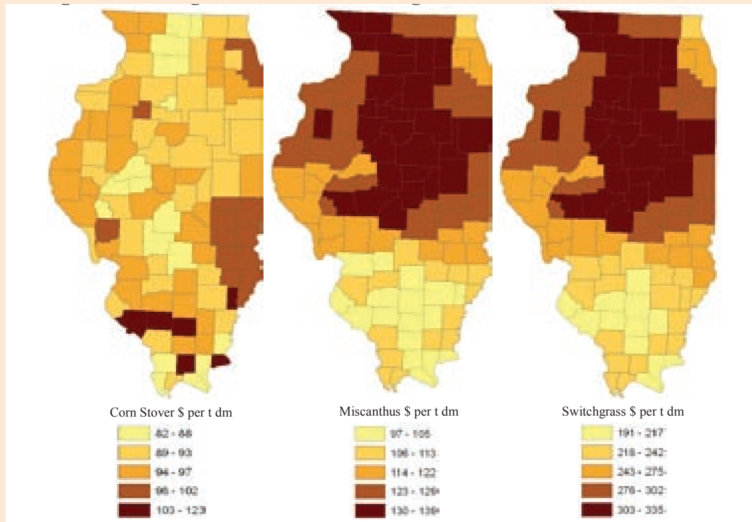

Table 2. Quantity and Costs of Production of Biofuels

	Gallons per Acre	Feedstock Cost	Cost of Conversion	Coproduct Credit	Total[a]
		Dollars per Gallon of Ethanol			
Corn Ethanol	398.75[b]	1.82	0.78[c]	0.48	2.12
Corn Stover	165.04[d]	1.27	1.46	0.12	2.62
Miscanthus	742.45	1.40	1.46	0.12	2.74
Switchgrass	214.74	3.18	1.46	0.12	4.53

[a] Wholesale costs at the refinery including zero return to equity. Feedstock cost for corn ethanol assumes $5/bu corn.

[b] Assuming an average yield of 145 bushels/acre under a corn-soybean rotation; [c] http://farmdoc.uiuc.edu;

[d] Assuming average yield under a corn-corn rotation.

Costs of Producing Cellulosic Biofuels

The per gallon cost of producing biofuel in Table 2 includes farmgate cost of the feedstock (including cost of land), cost of converting the feedstock into fuel, and credit for the value of coproducts produced during the conversion process (for example, dried distillers grains in the case of corn ethanol and electricity in the case of cellulosic biofuels). The technology for producing cellulosic biofuels is not yet commercially available. Projected estimates of these costs for cellulosic biofuels produced in a biorefinery with a 25 million gallon a year capacity are obtained from Wallace, Ibsen, McAloon and Yee (2005) and updated to 2007 prices using the GDP deflator. As can be seen from Table 2, delivered feedstock costs per gallon for corn stover and miscanthus are lower than those for corn. However, even optimistic projections of costs of conversion for cellulosic fuels ($1.46/gallon) are about twice as high as those of corn ethanol ($0.78/gallon) making cellulosic biofuels from corn stover and miscanthus 24% and 29% more expensive than corn ethanol, respectively. Biofuel from switchgrass is more than twice as expensive as corn ethanol making it very unlikely that current varieties of switchgrass will be competitive on cropland in Illinois unless their yields improve dramatically.

The market demand for cellulosic biofuels will depend on their competitiveness relative to corn ethanol and gasoline. The market price of denatured corn–ethanol is increasingly being determined by its energy content (which is about two–thirds of that of gasoline) and the blender's tax credit (Tyner and Taheripour, 2008). The recently enacted Energy Bill and Farm Bill provide several new incentives to encourage production of cellulosic biofuels while lowering the blenders' tax credit for corn ethanol from \$0.51 per gallon to \$ 0.45 per gallon.

Current Policy Incentives for Cellulosic Biofuels

To induce a market demand for cellulosic biofuels, the Energy Independence and Security Act of 2007 has imposed a renewable fuels standard of 36 billion gallons of ethanol by 2022. It mandates 21 billion gallons of advanced biofuels that can reduce life–cycle greenhouse gases by 50% relative to baseline levels. The recent Food, Conservation and Energy Act of 2008 includes more than \$1 billion to provide incentives to farmers to grow cellulosic feedstocks and to biofuel producers to use cellulosic feedstocks. This includes a \$1.01 per gallon tax credit for producers of cellulosic biofuels and cost share payments (up to 75% of establishment costs, plus annual payments to cover the cost of the land during establishment and \$45 per ton to cover costs of harvest, storage and transport). It also provides assistance for cellulosic biorefineries and for research and development, and incentives for using biomass (instead of fossil fuels) to power existing ethanol plants, thus creating a market for biomass feedstocks. Whether these incentive payments will stimulate production of cellulosic biofuels will depend on the price of gasoline, the costs at which it will be commercially viable to convert cellulosic feedstock into fuel and the costs of producing corn–based ethanol.

Policy Incentives to Encourage a Sustainable Mix of Biofuels

From a social efficiency perspective, the case for government intervention in biofuel markets is arguably justified, if biofuels reduce market failures caused by environmental externalities. If market prices of biofuels do not reflect environmental benefits then they are likely to lead to under–production of biofuels. Market based policies that reward environmental services are preferable to arbitrarily set mandates or subsidies. Biofuels not only provide a renewable source of energy but also a range of other environmental benefits. These benefits differ across biofuels from different feedstocks. While some feedstocks such as switchgrass may provide better habitats for wildlife, others such as miscanthus may have greater greenhouse gas mitigation potential. Feedstock derived from native mixed prairie grasses such as Indian grass and Big Bluestem contribute to enhanced biodiversity in the agricultural landscape and other ecological benefits but have much lower yields than even switchgrass. We estimated the average greenhouse gas mitigation potential of alternative biofuels in Illinois relative to gasoline using the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model (http://www.transportation.anl.gov/software/GREET/) (Table 3). The estimates below are illustrative based on current knowledge and reasonable assumptions about input application rates, energy requirements and emissions coefficients.

While corn and corn stover reduce greenhouse gas emissions (including soil sequestration) by 37% and 94%, respectively, relative to energy equivalent gasoline, miscanthus and switchgrass can serve as net carbon sinks. These estimates show that corn ethanol produced with the current production technology would not qualify as being an advanced biofuel.

Table 3: Life Cycle Carbon Emissions Kg CO_2 per Gallon of Ethanol

	Feedstock Production	Biorefinery Phase	Coproduct Credit	Displacement due to change of land use[a]	Total Above Ground CO_2 Emissions	Soil Carbon Sequestration[b]	Total CO_2 Emissions Net of Soil Sequestration	Emissions Reduction Compared to Gasoline [c]
Corn	2.42	4.93	-1.99	0.00	5.36	-0.62	4.75	2.79
Corn Stover	1.22	0.28	-0.40	0.45	1.54	-1.09	0.46	7.08
Miscanthus	0.97	0.28	-0.40	-0.88	-0.04	-2.25	-2.29	9.83
Switchgrass	3.78	0.28	-0.40	-2.89	0.76	-6.40	-5.63	13.17

[a]These emissions include those due to direct land use changes from conversion of cropland to energy crops (column 5) but do not include those due to indirect land use changes in other countries due to diversion of U.S. cropland to energy crops.

[b]Of the estimated soil carbon sequestration by corn under conservation till, 50% is allocated to corn ethanol and 50% to stover ethanol.

[c]Emissions from gasoline are 7.54 Kg CO_2e per energy equivalent gallon of ethanol.

While volumetric subsidies and cost–share payments are market–based policies, they do not distinguish among biofuels based on their environmental sustainability and are likely to encourage production of feedstocks that have high yields per acre and low costs of production. They also tend to make fuel cheaper and lower cost of vehicle miles for consumers which tends to increase vehicle miles travelled and can reduce or even negate any greenhouse gas mitigation benefits due to substitution of renewable fuels for gasoline (Khanna, Ando and Taheripour 2008). Subsidies for corn–ethanol have also tended to expand production of corn grain ethanol and contributed to the rise in corn prices (Abbott, Hurt and Tyner, 2008). An alternative approach would be to provide carbon mitigation subsidies, the magnitude of which would depend on the market price of CO_2. Most analysts expect the price of CO_2 to be around $34 per metric ton over the 2008–2012 period in Europe (http://www.euractiv.com/en/climate-change/european-co2-emissions-2007/article-171327). At this price, the carbon mitigation (including sequestration) provided by biofuels relative to gasoline (indicated in Table 3) would imply a subsidy of $0.09, $0.24, $0.33 and $0.45 per gallon ethanol from corn, corn stover, miscanthus and switchgrass, respectively. Other environmental services provided by cellulosic feedstocks could be similarly monetized using appropriate values to correct the market prices of biofuels.

A Final Note

Crop residues can be used for cellulosic biofuel production without creating a food–fuel competition for land. A USDA/USDOE (2005) report estimates that 68 million metric tons of corn stover could be sustainably harvested from existing corn acres in the United States with a potential to produce 7 billion gallons of cellulosic biofuels. This would meet only about a third of the ethanol mandate for advanced biofuels in 2022 in the United States necessitating the development of other feedstocks such as switchgrass and miscanthus that are promising due to their relatively high yields per acre and low input requirements. This article explores the economic viability of these feedstocks using data for Illinois and finds that it is likely to differ across geographic locations. A mix of cellulosic feedstocks is, therefore, likely to be more economically viable than a single feedstock. Current estimates suggest that cellulosic biofuels are likely to be more expensive to produce than grain–based biofuels. However, the advent of new technologies for harvesting, storing, and converting cellulosic sources into biofuels could make them more competitive. Rewarding biofuels based on their environmental services would help to internalize environmental externalities and promote a sustainable mix of feedstocks. Aligning energy policy and climate policy through tax credits that are inversely related to their carbon footprint can provide incentives to produce low carbon cellulosic feedstocks. Policy incentives could also be created to encourage feedstocks that increase biodiversity and enhance ecosystem services.

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Consequences of EU Biofuel Policies on Agricultural Production and Land Use

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JEL Classifications: D58, Q13, Q24, Q27,Q28

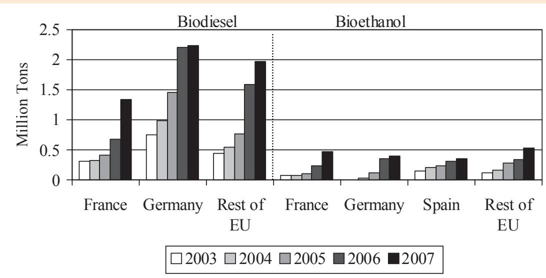
World–wide expansion in the production of biofuels is currently one of the hot topics on the agenda of agricultural and food research. On the one hand the development is welcomed as an additional source of income for farmers on otherwise saturated markets for agri–food products. One the other hand, however, there are growing concerns that with biofuels the level and volatility of agricultural world prices which are now linked to the development of the crude oil price will increase further. A few papers study the causes of the current increase in prices and contribution of biofuels (see, e.g. Von Braun, 2008; Banse, Nowicki, 2008; OECD–FAO, 2008; Trostle, 2008).

For the European Union (EU) the driver in biofuel production is mainly political, including tax exemptions, investment subsidies and obligatory blending of biofuels with fuels derived from mineral oil. Increasing biofuel production either due to 'pure' market forces and/or 'policy' has significant impacts on agricultural markets, including the trade in agricultural raw materials. Linkages between food and energy production include the competition for land, but also for other production inputs. For instance, the effect of an increasing supply of by–products of biofuel production such as oil cake and gluten feed also affects animal production.

EU Biofuel Markets and Policies

European biofuel production is based more on biodiesel production compared to ethanol production. At the current level biodiesel accounts for more than 6.0 million t while ethanol production in Europe is about 3.0 million t. Almost half of the EU biodiesel is produced in Germany where it was stimulated by tax exemptions, Figure 1. In the European Union in 2004, about 0.4% of the EU cereal and 0.8% of the EU sugar beet production was used for bioethanol, and more than 20% of oilseed production was processed into biodiesel. The annual growth rate between 2005 and 2007 was 53% and 44% for bioethanol and biodiesel, respectively, see F.O. Licht (2007).

Figure 1. Biodiesel and bioethanol production in selected regions of the EU, in million tons, 2003 to 2007



Source: Data derived from F.O. Licht (2007).

Biofuels are just one element in the complex EU strategy to meet the future energy demand. The EU Biofuels Directive presented by the EU Commission in 2003, set out indicative targets for Member States. To help meet the 2010 target—a 5.75% market share for biofuels in the overall transport fuel supply—the EU Commission has adopted an EU Strategy for Biofuels. The 'European Union Biofuel Strategy' (European Commission, 2003) and the 'Renewable Energy Road Map' (European Commission, 2008) propose an overall binding target of 20% renewable energy by 2020 and a 10% biofuels target by 2020.

These goals are not yet mandatory, but this might be changed and a discussion about higher shares in the future is ongoing. These measures were accompanied by measures giving additional leeway to member states for tax exemptions in favor of biofuel. Germany, for example, subsequently made use of the full tax exemption which has been a key determinant for the remarkable growth of its biofuel use. The German tax exemption stopped at the beginning of 2007. We did not take this elimination of the tax exemption into account in our baseline. However, the impact of that elimination was a clear decline in the use of biofuels in Germany. This example underpins the importance of policy measures to enhance biofuel consumption in the EU. Most of the EU member states are far from reaching the target of 5.75% in 2010 with a current average use of biofuels in transport of around 1.5%.

However, in many EU member states the biofuel shares for transportation purposes increased during recent years. This development can be explained by the above mentioned introduction of tax exemptions for renewable energies but also by an increase in oil prices which changes the relative prices in favor of biofuels. This endogenous growth can be expected to continue under a continuously increasing price for fossil fuels. However, the question to be considered is whether the objective can be reached in 2010.

Table 1. Progress in the Use of Biofuels in the EU Member States, 2003–2005

	2003	2004	2005
	Member State Biofuel share		National Indicative Target
Austria	0.06	0.06	2.50
Belgium	0.00	0.00	2.00
Cyprus	0.00	0.00	1.00
Czech Republic	1.09	1.00	3.70[1]
Denmark	0.00	0.00	0.10
Estonia	0.00	0.00	2.00
Finland	0.11	0.11	0.10
France	0.67	0.67	2.00
Germany	1.21	1.72	2.00
Greece	0.00	0.00	0.70
Hungary	0.00	0.00	0.60
Ireland	0.00	0.00	0.06
Italy	0.50	0.50	1.00
Latvia	0.22	0.07	2.00
Lithuania	0.00	0.02	2.00
Luxembourg	0.00	0.02	0.00
Malta	0.02	0.10	0.30
The Netherlands	0.03	0.01	2.00 [2]
Poland	0.49	0.30	0.50
Portugal	0.00	0.00	2.00
Slovakia	0.14	0.15	2.00
Slovenia	0.00	0.06	0.65
Spain	0.35	0.38	2.00
Sweden	1.32	2.28	3.00
UK	0.03	0.04	0.19
EU25	0.50	0.70	1.40

[1] 2006; [2] Estimate.

Source: European Commission (2007). Biofuels Progress Report

Consequences of EU Biofuels Policies

To analyze the impact of enhanced use of biofuels as the consequence of the EU Biofuels Directive requires an analytical tool which considers not only the agricultural but also the energy markets. Within the last two years many existing models focusing on agriculture and food processing have been extended to represent the production and consumption of biofuels. All results show that a shift in demand for agricultural products as a consequence of increasing biofuel demand leads to substantially increased agricultural market prices and increased land use. However, whether this increase in production takes place within or outside the EU depends on the underlying assumptions on the degree of openness of the EU. Therefore, two different baseline scenarios have been calculated up to 2020 which describe different visions of the future. This analysis is part of the EUruralis project (Wageningen UR and Netherlands Environmental Assessment Agency, 2007). A detailed description about the background, definition and set-up of the Eururalis scenarios can be found in (Westhoek, van den Berg et al. 2006) and the quantification of the scenarios are described in (Eickhout and Prins 2008). The scenarios have been calculated with the LEITAP model which is an extended GTAP model. The 'Global Economy' scenario depicts a world with fewer borders and regulation compared with today. Trade barriers are removed and there is an open flow of capital, people and goods, leading to a rapid economic growth, from which many (but not all) individuals and countries benefit.

The other vision, called 'Regional Communities' depicts a world of regions with people having a strong focus on their local and regional community and prefer locally produced food. Economic growth is lower compared to the 'Global Economy' scenario. Furthermore under the 'Regional Communities' scenario it is assumed that agricultural subsidy increases of some 10%, linked to environmental and social targets and export subsidies, are eliminated. Import barriers remain in place to protect local markets against cheap imports while imported goods have to comply with high EU standards regarding health, environment, and animal welfare.

For both scenarios two simulations with and without mandatory blending for biofuel use have been calculated. Even without mandatory blending, the use of biofuel crops changes due to shifts in relative prices (biofuel crops vs. fossil fuel).

Ambitious goals have been set by the EU Biofuel Directive (BFD) for the transport sector: the minimum share of biomass or other renewable transport fuels must be 2% in 2005 and 5.75% in 2010. For 2020 the EU target has been put at 10% under the condition that the so–called second generation biofuel technology will be available then. Currently bio–energy is coming from both waste material and growing first generation biofuel crops. To meet the ambitious future targets large scale production of crops used specifically for biofuel production in Europe will be necessary. In the 'Global Economy with BFD' scenario the demand for such biofuel crops used in the petrol sector will be $7.3 billion U.S. dollars (USD) (in 2001 values). Around 42% of these inputs will be produced domestically and 58% of biofuel crops used in the petrol sector will come from imports.

If mandatory blending is not enforced, the use of biofuel crops is much lower in all scenarios; only $2.5 billion USD under the 'Global Economy' scenario and only $1.7 billion USD under the 'Regional Communities' scenario. The lower demand under 'Regional Communities' is due to a smaller increase in income compared to the 'Global Economy' scenario. The degree of openness under both scenarios is also reflected in this figure. Under the 'Global Economy' scenario without mandatory blending, the share in imported biofuel crops used for biofuel production is 53.5% while under the higher protection under the 'Regional community' scenario imported biofuel crops contribute only by 28.5% to total biofuel production.

With these strong changes in import demand world prices for biofuel crops are affected by EU policies. The impact of the EU biofuel policies on world prices is illustrated in the following figure. With an enhanced biofuel consumption as a consequence of the EU biofuel directive prices of agricultural products tends to increase. Banse, van Meijl and Woltjer (2008) show that under a scenario 'Biofuel, global' which includes biofuel policies in the United States, Canada, South Africa, Japan, Korea and Brazil the real price of oilseeds shows an increase of 26% in contrast to the long–term trend projected in the reference scenario, see Figure 3. The mandatory targets in the scenario 'Biofuel, global' are set in the EU and in other countries. Based on IEA (2008), we assume a 10% blending target for the United States, Canada, Japan and South Africa. In IEA (2008), a 25% blending target for Brazil is also indicated. Compared to the United States and Brazil, where ethanol consumption dominates the biofuel sector, EU biofuel is based on bio–diesel, which is reflected by the increase in prices of the bio–based inputs in the production of biofuels. The increase in world prices for cereals is more than

Figure 2. Biofuel crops used in the EU (in mill. USD, 2001), 2020

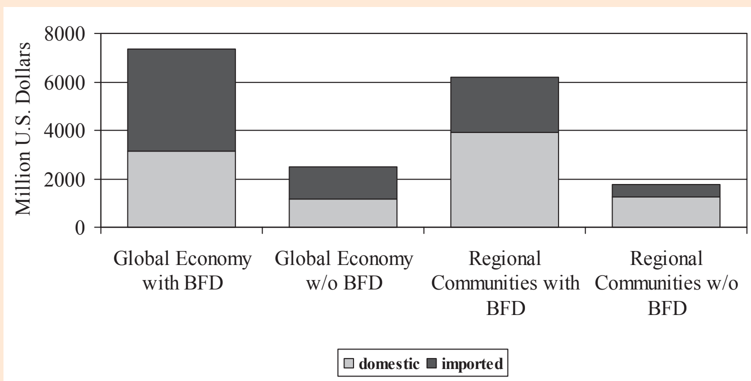
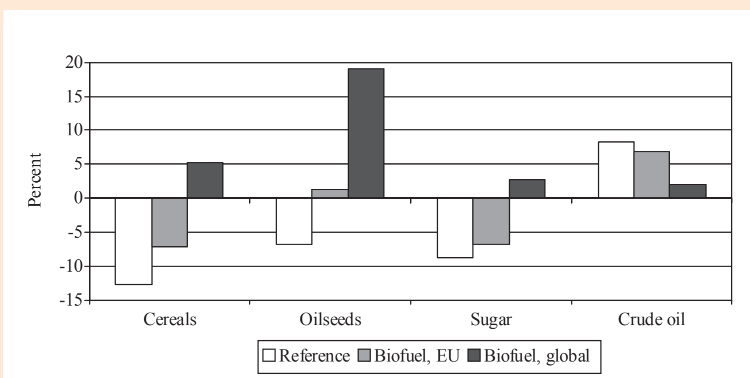


Figure 3. Changes in real world prices, in %, 2020 relative to 2001



18% under the 'Biofuel, global' scenario. The increase in crude oil price is smaller under the 'Biofuel, global' scenario as demand for crude oil diminishes due to the introduction of the BFD.

Without mandatory blending, real world prices for agricultural products decline and confirm their long–term trend, see Figure 3. This is caused by an inelastic demand for food in combination with a high level of productivity growth. Under an EU mandatory blending target the oilseed sector has the highest price difference, because biofuels in EU transport are dominated by biodiesel from oilseeds.

Even without enforced use of biofuel crops through mandatory blending, the share of biofuels in fuel consumption for transportation purposes increase, see Figure 4. This endogenous increase in biofuel production is due to the fact that the ratio between crude oil price and prices for biofuel crops changes in favor of biofuel crops (see Figure 3). The highest increase is in the already integrated market of Brazil where the initial 2005 share of more than 29% expands to more than 42% in 2010. In Germany and France the endogenous growth of biofuel share leads to biofuel consumption for transportation in 2010 of 4.0% in Germany and 3.4% in France. These results reveal that without mandatory blending the 5.75% biofuel share will not be reached in the EU member states.

With mandatory blending the EU member states fulfill the required targets of 5.75% at the expense of non–European countries, Figure 4. Under the BFD scenario the share of biofuel use declines in Brazil by around 6%. Under the 'EU Biofuels Directive' scenario the biofuel share in petrol used for transportation decreases by more than 20% in the North American Free Trade Agreement (NAFTA) countries. This decline in biofuel production in non–European countries is due to the increase in relative prices between biofuel crops and crude oil.

The enhanced demand for biofuel crops in the EU under the BFD scenarios leads to an increase in world prices for these products and hence to a decline in the profitability in fuel production compared to crude oil. However, the increase in biofuel crop demand in the EU over–compensates the decline in non–EU countries and at a global level the use of biofuel crops for fuel production increases under the BFD scenario. A good indicator for this development is the decline in crude oil price under the BFD scenario compared with reference scenario, see Figure 3.

Figure 5 shows that the EU will increase its trade deficit in agricultural commodities used for the production of biofuels under the biofuel scenarios. South and Central America as well as other high income countries expand their net–exports in agricultural products for biofuel production.

Compared to world income growth, the annual growth rates of agricultural production are quite moderate in the reference scenario. In the EU and in the region of high income countries, production of biofuel crops is also negatively affected by the liberalization which is also implemented in both scenarios. At the aggregated level, total agricultural production increases in both the reference and policy scenario. In all regions, mandatory blending also leads to an increase in total agricultural output. EU biofuel policies have a strong impact on agricultural production inside the EU but also on agricultural output in

Figure 4. Development of share of biofuels in fuel consumption for transportation for selected regions, in %, 2005 and 2010

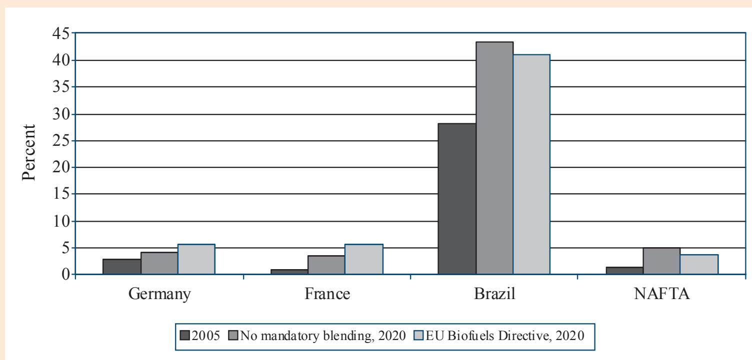
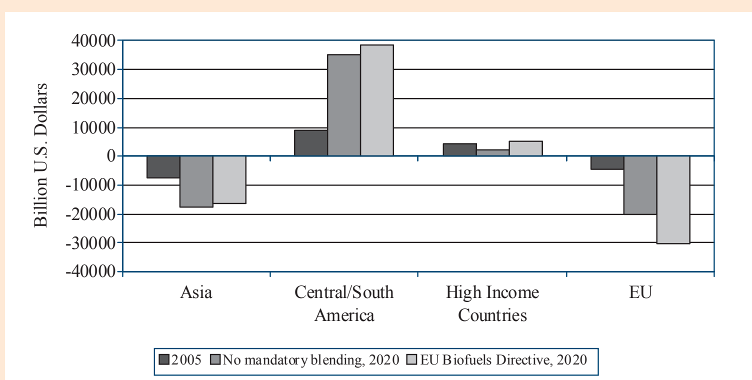


Figure 5. Balance in biofuel crop trade, in bill. US$, base situation and 2020 under different scenarios



South and Central America. Without mandatory blending, EU oilseed production increases by 7.6% compared to 26% under a mandatory blending scenario.

These production developments lead to a similar pattern of land use developments (Figure 6). Land use increases in all regions when comparing the impact of the EU Biofuels Directive and biofuel policies outside Europe. This expansion of agricultural land use on a global scale and especially in Southern America might lead to a decline in biodiversity in these countries as land use is an important driver for biodiversity.

The mandatory blending requirement for the petrol sector implies an increase in petrol price because biofuels are more expensive than crude oil. To meet the 5.75% obligations in 2010, the petrol price will rise by 2%, and a 6% petrol price increase accompanies the 10% BFD target in 2020. The subsidies on biofuel crops in the petroleum sector, which are required to meet the targets by making feedstock competitive with crude oil, are high and range from 30% in Sweden to almost 60% in the UK in 2020. These additional subsidies indicate the difficulties that most EU member states will have in trying to meet the BFD targets.

Concluding Comments

The analysis shows that enhanced demand for biofuel crops has a strong impact on agriculture at the global and European level. Biofuel policies contribute to the current rise in world food prices, especially for those products which are in direct competition in final consumption for food and fuel, e.g. corn, sugar and oilseeds. With increased biofuel consumption, the long term trend of declining real world prices of agricultural products slows down or might even be reversed for the feedstocks used for biofuels. This positive effect on world agricultural prices has consequences especially for poor urban populations in low–income countries with food and energy deficits. Those consumers will suffer most in any sudden or rapid price shift for basic commodities, of which foremost is food.

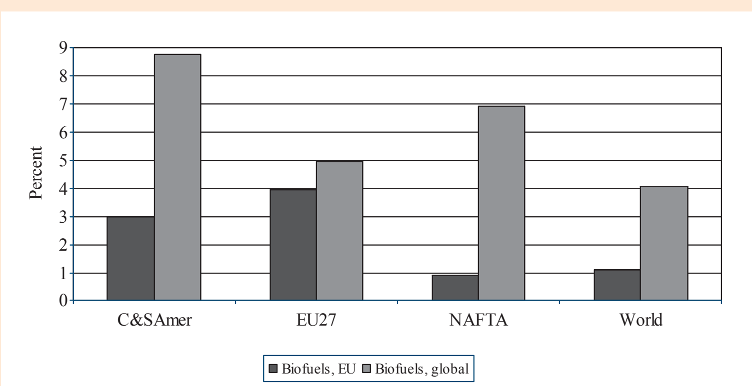
In principle, higher agricultural prices provide additional income opportunities for farmers. As shown in this article, the incentive to increase production in the EU will tend to increase land prices and farm income in the EU and other regions. The EU will not be able to produce the feed stocks needed to produce the biofuels according to the BFD domestically and will run into a higher agricultural trade deficit. Biofuel crop production expands in other highly industrialized countries and especially in South and Central America (Brazil). Whether farmers in developing countries will benefit from higher prices of crops used for biofuel production remains questionable and depends on the degree of integration of regions in global food markets.

Apart from income effects, the environmental effects of higher biofuel production are also not clear, (see, e.g. Searchinger et al. 2008). These biofuel crops need scarce resources such as land, water and agricultural inputs like fertilizers. This will impact the environment—CO_2 balance, soil erosion, and biodiversity. The GHG balance of biofuels varies dramatically depending on such factors as feedstock choice (lowest for corn and wheat and highest for switchgrass and poplar), associated land use changes, feedstock production system, and the type of processing energy used.

The results presented here depend heavily on the level of crude oil price. The higher the crude oil price the more competitive biofuel crops become versus petroleum production. Therefore, biofuels create a more direct link between food and fuel prices. High feedstock prices make biofuels less profitable, as does a low oil price. Even at the current level of crude oil prices of $120 USD per barrel, almost no biofuels are economically viable without support policies. A low oil price implies that biofuels will be produced only under mandates or that they are heavily subsidized.

Without mandatory blending to stimulate the use of biofuel crops in the petroleum sector the targets of the EU Biofuel directive will not the reached. Mandatory blending leads to higher petrol prices as feedstocks are not profitable to use in fuel production given the current technologies. The increased demand for feedstock raises their price relative to the oil price and adds to the challenge of making biofuels competitive. Therefore, if biofuels have to be competitive in the long run, investments in

Figure 6. Changes in agricultural land use, in %, 2020 relative to 'No mandatory blending'



R&D are needed to obtain higher yields or better conversion technologies. Decisions on R&D investments should take into account the second generation biofuels as these promise to be more cost–effective and more effective in reducing greenhouse gas emissions. However, the current high food prices in combination with the disputed environmental benefits fuel the debate inside the EU whether the Biofuels Directive is desired at all or whether the target of the Biofuels Directive should be made dependent on the degree of technical progress (first and second generation), environmental benefits and impact on world prices.

For More Information

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