A presentation by USDA on developing biofuel indicators for AMIS

The following text is a summary of the concepts on developing biofuel indicators presented to the Fourth Session of the AMIS Global Food Market Information Group on October 1-2, 2013 at FAO Headquarters in Rome Italy.

US biofuel indicators and a changing market dynamic

The rapid growth in US ethanol production after 2004 resulted in a significant new demand component for maize (corn\(^1\)) in the US market. The influence of energy prices has historically been associated with supply impacts where they had their largest impact through crop cost of production. The result is a strengthened linkage between maize, ethanol, gasoline and oil prices (Figure 1). The increase in ethanol production has changed market dynamics in the maize, and related grain markets and thus a new set of relationships could provide indications or warnings of increased grain demand which may impact prices and availability for more traditional usage of grains such as food and feed. In addition to market influences, ethanol production has received policy support, both through use incentives and use requirements, which may inhibit a pure market based interpretation of current price relationships in the ethanol sector. Understanding both the market forces and policy support and presenting appropriate indicators can provide additional information and transparency in grain markets and allow for other grain users to more fully prepare for changes in availability.

Figure 1: Maize price vs. crude oil price

To understand the factor which most directly impacts the near term use of maize to produce ethanol, we start with the primary motivation for the individual ethanol producer, which is economic profit. There are two primary types of ethanol facilities which use maize as an ethanol feedstock in the United States, wet-mills and dry-mills. Wet mill facilities separate the maize into

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\(^1\) Corn and maize are used interchangeably in this text.
components including the starch which then may be transformed into ethanol but may also go into the production of high fructose corn syrup. Germ and corn oil may end up in the food market while gluten enters the livestock feed market. Wet mill facilities are more capital intensive, and while existing facilities have been expanded, no new large-scale wet mill facilities have been constructed in the last decade. Dry mill facilities represent the vast majority of increased ethanol capacity constructed since 2005. A typical dry mill facility grinds and processes the whole kernel, producing ethanol, but also co-products of carbon-dioxide and distillers dried grains with solubles (DDGS), a high value livestock feed. Some facilities may also separate out corn oil from the DDGS, which is not edible by humans but can be used for livestock feed or biodiesel production. Electricity and natural gas are used for power, including the drying of the DDGS at some locations, although it can be fed wet when used in close proximity to the plant. Dry mill ethanol facilities will also incur labor and other variable costs (Figure 2).

**Figure 2: Primary inputs and outputs in dry mill maize ethanol production**

An individual dry mill facility will in theory operate as long as the costs of inputs (maize, natural gas, electricity, labor and other variable costs) can be covered by the sale of outputs (ethanol, DDGS, corn oil and CO₂). While individual plants may utilize capacity over narrow ranges (plants are unlikely to operate at half capacity, but either at [close to] full capacity or they completely stay idle), differences in regional input costs, output prices and efficiency result in an aggregate production response which will appear more continuous. Idled ethanol plants will ‘come on line’ or operating facilities will increase production as output prices rise relative to input costs and thus demand for maize should also rise. As an indicator of this, a representative margin can be established based on local input and output prices in the corn belt of the United States. As margins increase we might generally expect increases in maize used for ethanol as additional facilities become ‘profitable’ and output expands.

The margin is an indicator of profitability for existing ethanol facilities. While margins from existing capacity will be driven by variable costs of production, to induce expansion beyond this, expected margins over the life of the plant must cover the cost of capital and other fixed costs. That is, in the short run, expansion is capped at existing capacity as new facilities will take approximately 18 months to reach operating capacity after a decision has been made to start construction. This ‘cost of capital’ is thought to be approximately $0.25 per gallon of ethanol.
produced over the effective life of a dry mill plant. A representative measure of profitability should therefore be one indicator of the near-term future use of maize in ethanol production.

**Construction of a margin**

While a detailed budget for a typical dry mill ethanol plant representing all the detailed input costs associated with an operating dry mill ethanol facility would be extensive, given the relative size of the various costs we can instead create several simplified margins based on technical efficiencies and prices of a subset of primary input costs and output prices. We can use industry averages for conversion efficiencies determined by a survey of existing facilities. Constructed margins can include additional details by adding adjustments for variable natural gas and electricity prices and then include additional revenue from removing and selling a portion of the corn oil which is found in the co-product distillers dried grains with solubles (DDGS) for those plants which separate out a fraction of the inedible corn oil.

Plant surveys show considerable variation in ethanol and DDGS output per bushel of maize processed in various studies (Perrin et al). Extraction rates of ethanol and DDGS are inversely related. Assuming one bushel of maize (weighting 56lbs) yields 2.7 gallons of ethanol and 17.5 pounds of DDGS at 10% moisture (a common selling specification for dried DDGS) we can construct a basic indicative margin. Plants may also extract corn oil from the DDGS and plant averages for those extracting average near 0.34 lbs per bushel of maize processed. The plants are assumed to use 33 cubic feet (at 1031 btu) of natural gas and 0.75 Kwhr of electricity in the production process. Efficiency improves over time but extraction rates are limited by technical availability of starch and oil in the maize commonly available and in aggregate shift slowly over time, with the latest plants extracting over 2.8 gallons per bushel, the margin is simply meant to reflect industry averages and be indicative.

Using commodity prices as reported by the Agricultural Marketing Service (AMS) at the United States Department of Agriculture (USDA) and energy prices reported by the Department of Energy (DOE) Energy Information Agency (EIA) we can use these technical efficiencies to construct a representative margin for the industry, as illustrated for Aug 2013 (Figure 3). Labor and other variable costs are assumed to average $0.30 per gallon of ethanol produced. Those plants extracting corn oil yield 0.34 lbs of corn oil and are left with 17.14 pounds of DDGS. While CO$_2$ can be captured and sold, representing approximately 1/3 of the output by weight, in most plants it is simply vented and does not add to the revenue stream and is ignored in the construction of the margins. Using the reported industry average efficiencies illustrates that maize represents the primary input cost while ethanol and distillers grains represent the vast majority of receipts.

\[0.0089 \text{ metric tons of inedible corn oil per metric ton of corn processed}\]
We can compare the more complicated margin breaking out energy and natural gas costs and adjusting for the sale of corn oil with a simpler margin which excludes de-oiling. A further simplification wraps natural gas and electricity costs in with labor and other costs at a fixed $0.65 per gallon charge (Figure 4). The separation of corn oil from the DDGS makes a positive contribution to the average ethanol margin but the net-impact (after correcting for the loss of DDGS weight sold) is roughly $0.3 per gallon and does not vary considerably over time. This is not an insignificant contribution to a 100 million gallon ethanol plant, but for purposes of predicting changes in the ethanol grind, it can be ignored. When looking at electricity and natural gas prices one is struck by the improved margins over time when explicitly including electricity and natural gas costs. This is not due to assumed efficiency gains in those inputs: conversions are held fixed, electricity and natural gas volume use is held constant; what this reflects is the decline in US natural gas prices brought on by the rapid increase in production due to hydrofracturing or ‘fracking’. Electricity prices actually increase over the historical period, but the decline in natural gas prices was large enough to offset this. This would indicate that if we assume fixed costs for natural gas and electricity as a simplification, it may be appropriate to consider reducing it from the $0.65 assumed historically to reflect the change in natural gas prices.
A margin using futures market prices

While current cash prices are available for major inputs and outputs, and labor and other variable costs can be assumed fixed as they change more slowly and are a smaller component of the total, most components are less appropriately represented in the futures market where a more forward looking margin could be constructed. Only maize, ethanol and natural gas are well represented in the futures market and given the small share of cost attributed to natural gas, it can be included into a fixed cost of natural gas, electricity labor and other costs of $0.65. Not all operations extract corn oil from the DDGS and the contribution to the margin is small and thus fluctuations in vegetable oil prices is unlikely to impact the margin significantly. There is, at the moment, no futures market for DDGS, as standardization of the product, a requirement for an effective futures contract, has been problematic. Because of the significance of DDGS to the receipts of an ethanol and its use as a livestock feed, we can establish a relationship to maize, ‘crediting’ maize cost in the margin calculation reducing it to a calculation of fixed costs, maize and ethanol (Figure 5)

Figure 5: Margin simplification assuming fixed other costs and a DDGS credit to maize costs

The movement of DDGS prices has largely followed the price of maize but may diverge from maize for periods of time based on changes in supply and outside policy influence. During periods of rapidly expanding ethanol production the supply of the co-product DDGS increased as well. Given the substitutability of maize and DDGS in livestock feeding, prices normally move together. However, during these periods of rapid expansion from demand for the ethanol portion of output, maize has often received a premium over DDGS in the feed market. While DDGS is a high value energy feed, and has been shown to be able to replace both maize and higher priced soybean meal in some rations, it is more difficult to handle and producers must gain experience with its use in livestock feeding and large increases in supply had to be absorbed. More recently, while maize prices fell through the fall of 2013, DDGS declined far less as export demand increased. China increased imports as DDGS are not subject to the quota system which restricts maize imports. The ratio of DDGS to maize prices has since returned closer to 1:1 after the first of the year with issuance of new maize quotas and the rejection of some loads of DDGS derived from an unapproved variety of maize.3 Looking strictly at margins toward the end of 2013 would have suggested stronger ethanol production into 2014 than was likely to occur. A historical

3 http://www.cnbc.com/id/101304022
relationship would put the price ratio of DDGS at just under 1:1. The 17.5 pounds of DDGS in
the simple margin above can then be credited back to maize costs in the simplified margin
calculation. Prices of DDGS which are significantly higher than maize will be supportive of
ethanol margins and encourage increased maize ethanol use. DDGS prices below maize prices
may indicate demand being driven primarily by the demand for ethanol.

Figure 6: INDICATOR: Maize price vs. DDGS price

Incorporating a credit of DDGS output for maize prices, we can use nearby futures prices to try
to establish a relationship between past futures prices and current ethanol production. Regressing
current production using nearby futures prices for the period 3 to 6 months in the past, halving
the importance of the calculated margin in each subsequent month giving the most weight to the
most recent price observation we can predict ethanol production and therefore maize demand. The model results show that while it generally predicts directional movements well (Figure 7),
the performance is moderately successful, missing some turning points, particularly at the end of
calendar years, which is an issue of policy which we will explore.

Figure 7: Ethanol production and change in production, predicted and actual

\[\text{Monthly margin index} = \text{Margin t-3} + 0.5* \text{Margin t-4} +0.25* \text{Margin t-5} + 0.125* \text{Margin t-6}.\]
Purely backward looking cash margins may not reflect the increased importance of mandates or provide an accurate picture of future ethanol production. Figure 8 extends the historical margins using futures market prices for maize and ethanol at the time of the AMIS Information Group Meeting in October of 2013. The margin would seem to suggest a significant future contraction in ethanol production in 2014 despite falling maize prices. What the market may in fact be showing is uncertainty about final mandated levels for 2014 and beyond (as proposed by EPA) and a market unwillingness to engage in large ethanol acquisitions in the face of that uncertainty. Thus far, ethanol production margins in 2014 have remained strong despite continued uncertainty regarding the final mandated levels for the Renewable Fuel Standard for 2014.

**Figure 8: Ethanol margins under alternative calculations**

[Graph showing ethanol margins under alternative calculations]

**Market history and rise of mandates and policy impacts**

While margins, historically, give a general indication of the direction of maize ethanol production, the ability to accurately reflect future production is limited by other factors. Capacity constraints will limit expansion and policy may be the overriding factor in determining ethanol blending. With the passage of the Clean Air Act Amendments of 1990 (CAA) and subsequent Reformulated Gasoline (RFG) program, a market for oxygenated fuels emerged in select urban areas impacted by the regulation. At the time, ‘methyl tertiary butyl ether’ (MTBE), a petroleum based product, was the most economical oxygen fuel additive available. The additive was eventually found to be a groundwater contaminant and California moved to ban the product’s use by 2003 with other States taking similar action. The phase out of MTBE lead to a search for a replacement that was available and not a groundwater pollutant, the most economical alternative was ethanol. During this period, ethanol was acting strictly as a fuel energy replacement, but an oxygenate and octane enhancer. The rapid increase in demand lead to quickly expanding margins, and in the short run, supply of ethanol was limited by existing capacity. The demand surge sustained significant margins, large enough that the number of new plants under
construction was equal to operating plants by early in 2007 (Figure 9). During this period, current ethanol margins were a good indicator of extended future ethanol production and maize feedstock use. As these plants came on line supply expanded and margins moderated significantly.

Figure 9: Ethanol production, existing capacity and capacity under construction

However, it was not the current margins and economics alone which led to capacity expansion. The passage of the Energy Policy Act of 2005 instituted a schedule of mandates, creating a market which was to grow to 7.5 billion gallons by 2012. This provided a base demand for ethanol and reduced the risk to invest in capacity. The base market was further expanded in the Energy Independence and Security Act of 2007 (EISA) which doubled the ‘base’ market for maize ethanol to 15 billion gallons by 2015. In addition, the blenders credit of $0.45 per gallon (after 2010, $0.51 per gallon prior) and an ethanol import tariff of $0.54 per gallon supported domestic ethanol production. But the expiration of this credit too, distorts the simple connection between current mandates and future ethanol production.

Approaching the blend wall

Until recently, expansion of ethanol use in the United States has been used primarily as an oxygenate or octane enhancer in low level blends with gasoline in the United States. Market behavior to date suggests that while the mandate policies provided support, blenders have found the blending of E10, the maximum that regulation allows in the majority the existing automotive fleet, to be profitable. However, as mandated levels have risen beyond volumes that can be easily absorbed, any increase in consumption of ethanol must come in either higher level blends, such as E85 or policy changes to allow for alternative low level blends. At high level blends, ethanol is valued at its energy equivalence to gasoline (2/3 the energy value per gallon). Significant increases in the consumption of ethanol in either E15 or E85 will require a change in availability of appropriate cars and sales infrastructure. As the mandates established in EISA

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6 Some of what was surveyed as ‘under construction’ was eventually cancelled projects leading to a decline in the total the following year.
approach and exceed what can be absorbed readily as E10 (Figure 10), ethanol prices in the retail market must fall to, or below, energy equivalence in the retail market, even then, dispensing and retail fleet constraints limit ethanol absorption. Mandates may force more ethanol into the market, but it may also represent very rigid domestic demand which must be met, but is unlikely to be exceeded. Any additional maize grind would be to service the export market for pure and blended fuels.

Figure 10: EISA mandates and E10 volume limit

Impact of the proposed 2014 reductions in the RFS by the EPA

Subsequent to the AMIS meeting in Rome the United States Environmental Protection Agency (EPA) released the preliminary rules for the 2014 EISA mandates.

While the EPA preliminary rule for 2014 reduces mandated levels, the methodology proposed by the EPA for 2014 and future years would appear to include a continued expansion of E85 and continued binding mandates. Reductions from legislated levels are almost certain to reduce domestic consumption and to lesser extent production of maize-based ethanol. Any increase in mandates in the final rule or successful legal challenges may increase overall ethanol production, but not the significance of this demand determinant. That is to say, despite the reduction in the size of the mandate that maize ethanol may compete for, from this point forward, mandated levels will be a significant determinant of maize use for ethanol under existing policies and thus potential for expansion of maize use for ethanol can be evaluated against this volume.

Indicators and their interpretation

With both market based and policy factors influencing expectations for future maize ethanol production, a handful of indicator variables and graphics are proposed for monitoring maize use in the sector.
The 3-state margin combines average maize prices from Iowa, Nebraska and the Eastern Cornbelt\(^7\) with ethanol prices and DDGS prices at 10% moisture in those same locations (Figure 11). Other costs are assumed to be $0.55 per gallon, a reduction of $0.10 to reflect falling natural gas prices, and de-oiling of DDGS is ignored. Sustained margins above zero should signal short run increases in maize ethanol production. Margins at or below zero may push some higher cost producers out of the market, and positive margins will be required to bring that capacity back on line. Sustained margins above $0.25 per gallon may indicate a long run increase in ethanol production capacity which would develop over 18 months.

**Figure 11: INDICATOR: Ethanol production margin**

Positive margins should suggest expanded production but historically we have seen short run margins increase to exploit aspects of biofuel policy. At the end of 2011, ethanol demand increased rapidly, but not because of an underlying increase in demand for ethanol in the current period, but because the blenders credit of $0.45 per gallon was expiring at year’s end, and additional ethanol could be blended to capture the subsidy and then count this ethanol blending toward mandate compliance in 2012, the following year. At the open of 2012, without a blenders credit but large stocks of ethanol, margins collapsed and ethanol production declined as facilities shuttered their operation (Figure 12). This behavior of shuttering operations will keep margins from falling significantly below ‘zero’ for any extended period of time and production can be falling over a period of sustained zero margins, suggesting that the relationship between ethanol production and margins may be non-linear.

With the uncertainty that surrounds annual EPA regulations, waivers of those mandates, and the fact that the blenders only show compliance once at the end of the calendar year, year-end ‘run-ups’ in ethanol demand may occur for annual compliance purposes. With mandates for the following year uncertain, producers may limit compliance early in the year. Blenders may be shifting blending demand to reduce mandate compliance and cost risks. Understanding what

\(^7\) The Eastern Cornbelt represents several maize and ethanol producing states and is dominated by Illinois. 3 states, Iowa, Illinois and Nebraska represent 45% of the maize production over the 2005-2013 crop years (USDA) and 48% of existing ethanol production capacity (State of Nebraska http://www.neo.ne.gov/statshtml/122.htm).
factors are influencing the change in margins may provide information on the extent and duration of increased maize ethanol production.

**Figure 12: Ethanol margin vs ethanol production on an annualized basis**

Examining the pattern of the last 2 years, it appears that end-of-year compliance activity may have contributed to the increase in margins through the end of 2013 which led to increased ethanol production and maize use (Figure 12). We can further look at margins relative to the primary input prices. While maize prices were already high by historical standards at the opening of 2012, a drought covering a large portion of the maize growing region in the United States caused maize prices to rise rapidly. With maize margins already near zero, production shrank further as feedstock prices rose, there was no ‘run-up’ at the end of 2012.Margins and production began to pick up in the fall of 2013 as maize production reached a record level in the fall of 2013. Maize prices fell by approximately 40% contributing significantly to ethanol margins by reducing input costs. Although ethanol prices softened as production increased (Figure 13), the falling maize prices (Figure 14) were more than enough to offset the decline and margins surged.

**Figure 13: Ethanol production vs ethanol price**
Mandate compliance also played a role in 2013 as we can observe that the pace of production (taking monthly production and annualizing it) in 2012 fell below mandated levels (Figure 15). The shortfall in 2012 was met in part by drawing down the stocks of excess compliance credits, reducing the available credits to carry into 2013. Consumption in 2013 began at a pace well below mandated levels but showed some growth after the EPA preliminary announcement of mandates at levels that were reaffirmed in August, with the consumption pace growing to meet the mandate. Tracking the production pace relative to the mandate for which maize ethanol can qualify can help determine if market demand is determining ethanol production or if mandate compliance is driving demand and thus how maize, ethanol and oil prices might impact production. It would be preferable to use consumption data over production as the US has in some years exported a substantial quantity of maize ethanol, however, consumption data availability has a significant lag and does not distinguish between domestic maize ethanol production and imported sugarcane ethanol which qualifies for the advanced mandate. When the production pace is running above the mandate level, blenders are likely to be more responsive to ethanol prices, when the mandate is determining production, ethanol demand may be very unresponsive, hesitant to both increase or decrease demand for ethanol, despite changes in oil and maize prices that may filter into the cost of ethanol they must purchase to meet their obligation.

It is possible to derive a consumption number from weekly supply, trade and stock holding, however, it is the residual and shows considerable noise from week to week.
Increases in production in the short run are limited by available capacity. As capacity utilization reaches its limit, ever greater changes in ethanol margins will be needed to further expand output. Sustained production at the limit of capacity should be accompanied by strong positive margins and eventually an expansion of existing capacity. Increases in capacity under production will provide a longer run indicator of increased maize use for ethanol.

**Figure 16: Ethanol production and capacity**

As maize ethanol production expanded, concerns grew that energy markets, much larger than biofuel markets, would drive demand and tie agriculture commodity and energy prices together. A manifestation of this relationship should be evident first in the ethanol and gasoline markets. Ethanol properties such as high octane have supported ethanol prices above its energy value when compared to gasoline when used primarily in low level blends. Ethanol and gasoline prices have moved together over time but with some exceptions. Ethanol demand, and thus ethanol prices may be more constrained historically as prices of gasoline fall significantly, due to mandate constraints. (Figure 17). Alternatively, as the E10 market reaches saturation (the blend wall) and mandates bind, ethanol and gasoline prices may become less coupled as ethanol demand is less able to respond. To breach the blend wall, additional ethanol must be absorbed primarily in E85 blends where it has a lower value at energy equivalence. If ethanol prices fall far enough, increased production for export markets is also possible. US produced ethanol saw exports increase as maize prices fell in the fall of 2013. Export destinations have been diverse with a consistent market in Canada, but other countries purchases have been highly variable. Export growth potential is constrained by economics, for many destinations it must be priced favorably at the destination relative to gasoline, as well as the country’s internal policies which may favor domestically produced fuels.

Currently, ethanol consumption in the United States is constrained by the blend wall, and maize prices have fallen significantly, leading ethanol prices lower. Blenders may be hesitant to further

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9 The data for capacity are ‘nameplate capacity’ and thus it is possible for plants to run modestly above stated capacity for short periods of time.

10 We don’t expect that energy equivalence at retail will result in a wholesale ethanol to gasoline price ratio which reflects energy equivalence. When mandates are binding, wholesale and retail ethanol prices need not move together.
expand sales of blended fuels, increasing the stock of compliance credits, due to policy uncertainty. Understanding ethanol prices relative to gasoline combined with other indicators can determine which market and policy dynamics are having the greatest influence.

**Figure 17: INDICATOR: Rack ethanol price vs RBOB gasoline price**

![Figure 17: INDICATOR: Rack ethanol price vs RBOB gasoline price](image)

**Conclusions**

The strength of the market based relationship linking maize to ethanol to gasoline then to oil seen in the years after 2005 seems to have weakened in the last several months as consumption and infrastructure constraints and policy factors play a greater role and interfere with one of the linkages in the chain. The weakness in the relationship of oil prices to maize prices also appears to have spread to other commodities. A simple formulation of a forward looking margin can be instructive but given the changes in market dynamics will not provide insight into the near term consumption of maize to produced ethanol as a combination of several indicators which will give a more complete picture. Policy, which has been generally supportive of ethanol production in the past, will more directly set the level of maize ethanol demand and the market will likely become less responsive to maize prices, but also to oil prices for the foreseeable future. A combination of factors examining productive capacity, mandated levels and changes in individual input and output prices can supplement ethanol margins as an indicator of maize ethanol production.

**References**


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