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Long-term Biofuel Projections under Different Oil Price Scenarios

John Miranowski
Iowa State University

Alicia Rosburg
University of Northern Iowa

With rapid expansion of biofuel production, major concerns have arisen over higher food costs and competition between food, feed, and biofuel for energy-rich commodities. Most projections are based on short- and intermediate-term commodity price shocks. We estimate long-term biofuel demand and cost-minimizing supply functions for feedstock and biofuel in developed and developing countries. We assume input and output coefficients and substitution elasticities adjust over time in response to changing prices in a dynamic market environment with productivity growth. Three alternative oil price scenarios are considered for biofuel feedstock production and conversion. The price of oil puts both a floor and ceiling on feedstock price. We conclude that global biofuel expansion will be limited in the absence of government incentives and mandates, unless high real oil prices prevail. Countries and regions need large, excess feedstock supplies (price-elastic response) if biofuel expansion is to be competitive with oil or other liquid fuels.

Key words: biofuel, biomass, feedstock price ceiling, feedstock price floor, land use change, long-term biofuel projections, productivity growth.

Introduction

The foremost questions debated in biofuel research reports and the press include 1) what impact will expansion of biofuel have on short- and intermediate-term food prices and security? 2) How will agriculture expand short- and intermediate-term output in response to increased short- and intermediate-term demand for food and feedstock, and 3) What will expanded biofuel production cost? Yet, there has been little effort to consider what will happen to biofuel expansion and production in the long term. As a natural resource issue, the long-term sustainability of biofuel as a significant source of liquid fuel and substitute for fossil fuel in transportation is an important issue.

When considering short- and intermediate-term agricultural projections, it may be appropriate to extend current country and regional agricultural trends, market relationships, and resource use patterns into the future. However, current market relationships and resource use patterns are not indicative of long-term agricultural commodity production, resource use, and production technologies. It is more difficult to support long-term projections beyond 10 to 20 years (Fischer, Byerlee, & Edmeades, 2009) even when adjusted by expert opinion. Long-term agricultural and biofuel projections require a modern global economic environment characterized by dynamic agricultural growth, trade, and development.[1]

This article highlights some key preliminary findings from a long-term breakeven model for biofuel feedstock production and biofuel conversion with long-term biofuel expansion projections. Complete model specifications and results are provided in Miranowski and Rosburg (2012) and Miranowski (2012). The article is divided into four sections designed to address the long-term expansion and sustainability of biofuel production. The first section discusses the rationale underlying long-term projections and the breakeven or parity pricing framework based on producers' willingness to supply feedstock (or long-run supply cost) and biofuel processors' willingness to pay for feedstock (or long-term derived demand) given alternative long-term oil-price scenarios. Then, the article provides a summary of the model and data used in Miranowski and Rosburg (2012) and Miranowski (2012) to consider long-term breakeven or parity price relationships for alternative biofuel feedstock. Next is a summary of some of the key results from the model discussed in the previous section, including alternative biofuel feedstock and production locations and the long-term expansion potential of biofuel production given alternative oil-price scenarios. This is followed by a summary of the projections of future expansion and production in the absence of government biofuel policies.

1. *To paraphrase D. Gale Johnson in his address to the 1998 American Economic Association meetings, modern agriculture has seen more changes in the last 50 years than in the preceding 500 years.*

Framework for Long-term Biofuel Projections

Several studies have developed agricultural—and sometimes biofuel—projections to at least 2050 (Alexandratos, 2009; Bruinsma, 2009; Bruinsma & Alexandratos, 2012; Fischer et al., 2009; Msangi & Rosegrant, 2009). These studies all rely on models, frameworks, and expert opinions based on historical trends, resource use patterns, and known technologies to project the future. Such projections are useful in informing short- and intermediate-term food security, agricultural development, land use, and energy policy decisions. Other studies (e.g., International Energy Agency [IEA] Bioenergy, 2009; Food and Agricultural Organization of the United Nations [FAO], 2008) consider future potential for and consequences of global biofuel expansion but do not attempt to make projections. We assume that longer-term biofuel projections are driven by the long-term price that prevails in the transportation fuel market. In addition to the long-term price of transportation fuel, global biofuel market development will be constrained by the long-term supply cost of feedstock and conversion cost to biofuel. Further, we assume that long-term biofuel projections are not driven by short- or intermediate-term government policy provisions or by "engineering" or "techno-economic estimates" of short- or intermediate-term estimates of land-use change, conversion efficiency, or biomass availability. We propose a less complex, market fundamentals approach to long-term biofuel projections.

Long-term biofuel projections do not require specifying numerous linkages, coefficients, and assumptions that are typically used in detailed short- and intermediate-term projections models, including partial equilibrium programming or computable general equilibrium models. More detailed programming models consider short- and intermediate-term impacts of existing government policies on agriculture or the impacts of policy changes on a given sector. In specifying representative linkages, relationships, and coefficients for short- and intermediate-term projections, current trends, linkages, and underlying relationships are assumed to prevail. Relying on such trends, linkages, and relationships in long-term models—when all outputs, inputs, and technologies are variable and sometimes unknown—is highly questionable. Countries are at different stages of development; have different and multiple feedstock sources; have limited knowledge and commercialization of biofuel conversion platforms; and face competing food, feed, and fuel feedstock demands. Further, unlike most feedstock for other manufacturing processes, agricultural food, feed, and feedstock supplies are dependent on weather and climate change, leading to higher risk and uncertainty.

The question is not whether an integrated biofuel and agricultural projections model can be developed; rather, the question is how useful such a model is in developing long-term biofuel projections. We propose a more direct approach that assumes the price the biofuel processor can pay for feedstock (including commodities) is driven by the price of oil, which biofuel substitutes for as a liquid transportation fuel. Then we compare biofuel feedstock production and conversion cost data for representative countries and feedstock. We illustrate how these future biofuel feedstock costs and biofuel prices may impact long-term agricultural and biofuel projections. Finally, we suggest an approach to identifying the countries and regions where competitive biofuel investment and expansion could be sustainable given three oil price scenarios. Working backward from alternative oil price scenarios, we provide indications of which feedstock and locations may sustain long-term feedstock production and conversion to biofuel.

Economic Rationale and Framework

The economic rationale underlying our long-term biofuel projections is the traditional market paradigm of declining long-term real prices for food and other commodities, including agricultural commodities. Figure 1 illustrates these price phenomena for select commodities.

If technological change and productivity growth lower per-unit costs of production, competitive markets will lead to lower profit margins. In the intermediate-run, farmers intensify cropping to expand output; in the long-run, some farmers expand their land base (while others leave farming) to maintain net returns per operator. At the same time, population growth and accompanying food demand is slowing in developed and many developing countries (Schmidhuber, 2007). Thus, growing food supply coupled with slowing demand growth leads to decreasing real food and agricultural commodity prices over time.[2] Developed nations intervene with policies to maintain incomes, slow farmer exodus from

2. *With the exception of periodic price shocks generally caused by short-run factors, this pattern of real resource price behavior is common to all competitively produced commodities including most forms of energy. In part, this is due to technological change and substitution on the consumption side.*

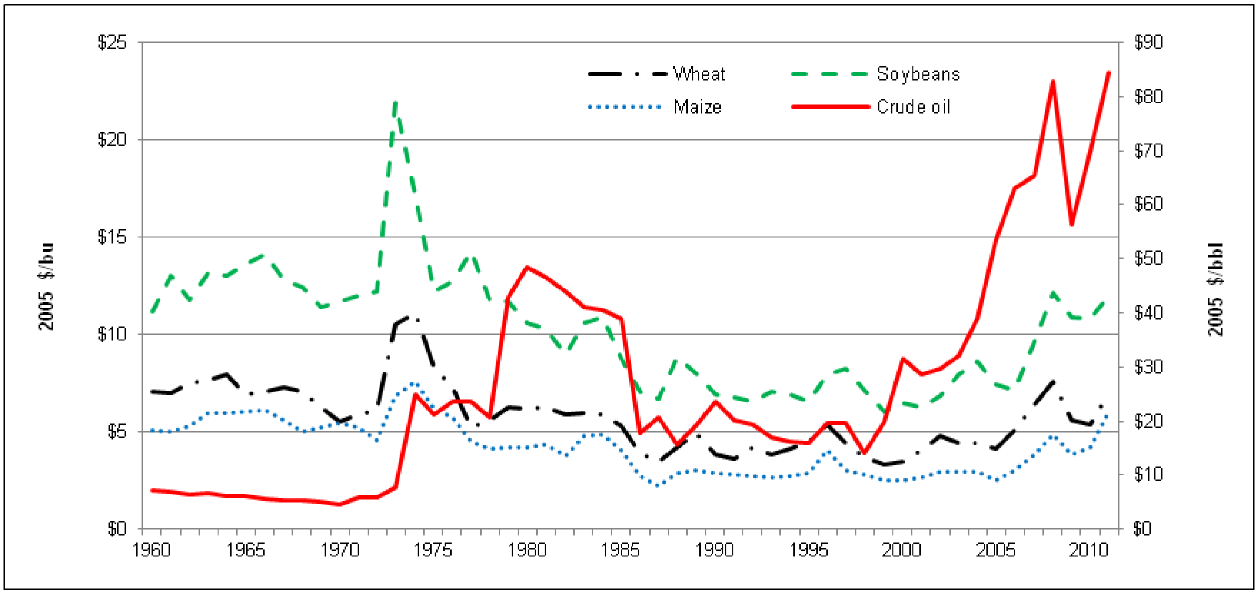

Figure 1. Select world commodity prices, 1960-2011.
Source: World Bank (2012)

agriculture, control agricultural supply, or to "create demand" for agricultural commodities. These public policies have met with limited success given the competitive market environment of globalized commodity agriculture and only stalled the traditional market paradigm.

Most low-value/high-volume agricultural commodities are produced for their energy and protein value (somewhat less so for fruits, vegetables, and other specialty crops). The energy content of the commodity is demanded by a biofuel processor to convert to liquid fuel—typically ethanol or biodiesel. Co-products (e.g., protein) are sold into other commodity markets. Thus, assuming no government policy intervention, the demand (price) for feedstock is determined by its energy value and driven principally by the price of oil.[3,4] Assuming biofuel remains a small share of the total liquid fuel market (Schmidhuber, 2007), the demand for biofuel is perfectly elastic for a given oil price. Biofuel supply will also depend on oil price and the cost of producing and converting feedstock to biofuel. Land competition will drive up the opportunity cost of cropland and reduce the competitiveness of cellulosic feedstock at high oil prices. Additionally, biofuel will have to compete with other fossil fuel substitutes if oil prices are high (America's Energy Future Panel on Alternative Liquid Transportation Fuel [ALTF], 2009; Committee on Economic and Environmental Impacts of Increasing Biofuel Production [RFS], 2011; IEA, 2011).

In the long-term, the price of oil puts both a floor and ceiling on commodity and biomass feedstock prices (Schmidhuber, 2005, 2006). To illustrate, consider the long-run breakeven feedstock price for a biomass supplier (i.e., farmer) and biofuel processor at a given price of oil. The long-run minimum price at which the farmer is willing to deliver feedstock to the biofuel conversion plant reflects the cost of production, harvest, storage, and transportation to the biorefinery, plus the opportunity cost of cropland (i.e., supply cost). The maximum price the biofuel processor can pay (i.e., derived demand) for feedstock in the long-run is equal to the unit energy value of the final product (relative to oil), plus co-product value, less costs of feedstock conversion. When the long-run derived demand for feedstock equals the long-run supply cost of feedstock, a competitive market equilibrium price is established. This is the feedstock price that will sustain a long-term feedstock market and biofuel production.

The long-run price that sustains the market is both the floor and ceiling price for feedstock commodities. If oil prices increase, the biofuel processor is able to pay more for feedstock in the intermediate-term and biofuel production will expand along with derived demand for

3. *Even though initial or intermediate-term biofuel demand is driven, at least in part, by government incentive schemes and mandates, we assume such transitory schemes will not persist in the long-term.*
4. *IEA (2011) considers different degrees of price transmission from oil to biofuel feedstock.*

feedstock until a new, higher long-term equilibrium price (floor price) is established. The additional feedstock supplied for biofuel production will compete with other feedstock uses (i.e., food and feed) as well with other commodities for cropland. The consequence will be an increase in the supply cost of feedstock (i.e., higher opportunity cost). On the other hand, if oil price is lower and some biofuel processors cannot cover intermediate operating costs, processors will shut down less efficient bioconversion plants until a new long-run biofuel equilibrium price and feedstock quantity are established. At the new feedstock market equilibrium, a lower ceiling on feedstock price is established.

It is important to note that the breakeven prices do not represent a long-run supply curve for biofuel feedstock. If the oil price scenario is representative of the long-run equilibrium price, that price would represent the perfectly elastic derived demand curve for biofuel feedstock. What the long-run breakeven feedstock price represents is a point estimate of the minimum long-run average total cost curve, which is also equal to the long-run marginal cost at that point. The feedstock breakeven cost estimate also tells us which feedstock is competitive at what oil price. To determine the actual long-run supply curve would require working backwards from major producing-country feedstock supplies, feedstock yields, and long-run supply elasticities. Instead, we map the relationships between the price of oil, price of biofuel, and feedstock prices to provide an indication of which feedstock will enter biofuel production across a range of oil prices.

Schmidhuber (2007, 2011) argues that current demand for biofuel feedstock is not driven by an infinitely large market demand for biofuel. Only Brazilian sugarcane ethanol in the petrol market gives strong statistical evidence of market integration with biofuel feedstock price. In other feedstock markets, various constraints—including government intervention in pricing and mandates, transportation and marketing bottlenecks, blending limits and systems, and environmental concerns—limit market co-integration. We assume such constraints will be resolved in the long-term, permitting market integration in major biofuel feedstock markets. Thus, we do not consider such constraints in deriving long-term biofuel projections.

Also, co-movements of oil and feedstock prices do not impact all agricultural markets equally or directly. Only commodities that supply competitively-priced feedstock will enter the biofuel market in the absence of policy distortions. The commodities that enter most readily are energy-rich crops, which have low breakeven or parity prices like sugar-rich, starch-rich, and oil-rich crops (e.g., sugarcane, maize, palm oil), and their long-term prices should benefit most. Crops that produce both energy and protein value will constitute the next group depending on their energy content and price of oil. Finally, woody and biomass residues and dedicated energy crops, requiring advanced conversion technologies, constitute the third group. As energy-rich crop production expands in response to high oil prices, competition for cropland increases as do supply costs for all commodities (including food). The second group of feedstock crops (e.g., maize, wheat, oilseeds) entering the biofuel market may increase protein co-product supply and lower protein-rich commodity prices. Lastly, woody crops and biomass residues[5] will have little or no impact on other commodity prices or competition for cropland (except possibly in the pulping and wood residue markets). Dedicated energy crops (e.g., switchgrass, jatropha, miscanthus) could ultimately compete for cropland under high oil prices or biofuel mandates such as the EU Renewable Energy Directive (RED) or the US Renewable Fuel Standard ([RFS] revised).[6]

Long-term Biofuel Projections Framework

Most existing agricultural price impact and biofuel projections rely on short- to intermediate-term modelling frameworks (e.g., partial equilibrium or computable general equilibrium) with detailed linkages, using historical trends and known technologies to project future agricultural food, feed, and feedstock production and the impacts of biofuel expansion (Alexandratos, 2009; Bruinsma, 2009; Bruinsma & Alexandratos, 2012; Msangi & Rosegrant, 2009). Further, they frequently assume future biofuel production is going to be driven by government incentives and mandates. As we argue above, it is inappropriate to use such frameworks for long-term biofuel projections. Rather, all inputs, technologies, and outputs should be free to vary.

A local biofuel market will only exist if the processor can acquire sufficient feedstock in the local market

5. *Conceivably, sufficiently high oil prices could increase net returns to crops (e.g., maize) with high residue content, but even if we assume no yield penalty with continuous maize cropping, maize stover would not increase net returns until crude oil sold for well over USD $100/bbl.*
6. *Given the current costs of supplying feedstock from dedicated energy crops, unless mandated, they are not likely to compete for cropland (ALTF, 2009; Committee on Economic and Environmental Impacts of Increasing Biofuel Production, 2011; Rosburg & Miranowski, 2011).*

at a price that allows both parties to break even in the long-term. Therefore, without biofuel subsidies and mandates, economic sustainability of biofuel markets depends on the long-term price the producers will accept for feedstock and the biofuel processor is willing to pay for feedstock.

Commodity and biomass market prices will reflect what biofuel processors can pay for energy-rich feedstock determined through oil price transmission, establishing both a floor and ceiling on feedstock prices in biofuel production. We estimate the feedstock producers' long-run breakeven cost for feedstock and the biofuel processors' long-run breakeven price or derived demand for feedstock at given oil prices. Oil price scenarios of US $60, $100, and $140 per barrel (bbl)[7] are used to estimate derive demand for biofuel and determine the long-run breakeven or parity prices (i.e., willingness to pay for biofuel feedstock by processors).

Miranowski and Rosburg (2012) and Miranowski (2012) consider three categories of feedstock: crops with established feedstock prices tied to global market-clearing prices, crop residues and waste, and dedicated bioenergy crops. Crop residues and waste and dedicated bioenergy crops are not widely produced on a commercial scale so established market prices do not exist. Conversion costs are available for conventional ethanol and biodiesel plants. Comparable conversion cost data for biomass platforms are obtained from engineering cost estimates obtained from Kazi et al. (2010), FAO Bioenergy and Food Security Projects ([BEFS] 2010a, 2010b, 2010c), IEA (2011), Rosburg and Miranowski (2011), ALTF (2009), and Committee on Economic and Environmental Impacts of Increasing Biofuel Production (2011).

Long-term Biofuel Projections Model

In this section, we provide a brief overview of the long-term breakeven models used for local feedstock supply systems and the feedstock conversion processes. Complete model specifications are provided elsewhere, specifically Miranowski and Rosburg (2012) and Miranowski (2012). The processor's long-run breakeven price or derived demand per ton of feedstock equals total expected revenues per ton of feedstock converted to biofuel less non-feedstock conversion costs. The expected market price of biofuel is calculated as the energy-equivalent price of oil or liquid fuel that the market is willing to pay in a competitive market.

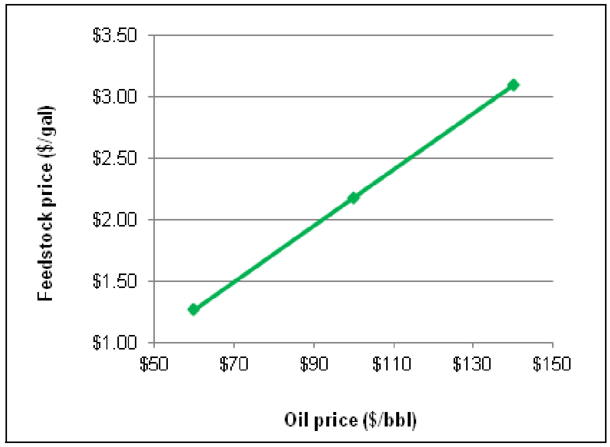

Figure 2. Breakeven sugarcane parity price.

The model of biomass supply evaluates the long-run per-ton feedstock cost faced by the biorefinery in a competitive local feedstock market.[8] With a competitive market, the biorefinery cannot price discriminate and the price paid to all suppliers will be the price paid for the marginal unit. The minimum payment a supplier of the marginal unit would accept is the value at which the supplier breaks even in the long-run.

The long-run breakeven price for the marginal unit of feedstock delivered to the plant will depend on all long-run costs incurred—including land and biomass opportunity costs—to produce, store, and transport feedstock to the biorefinery.

A local biofuel feedstock market will only exist when the processor can acquire sufficient feedstock at a market price that allows both parties to break even in the long-term. Therefore, without subsidies and mandates, economic sustainability of biofuel feedstock markets depends on the long-run price the producers will accept for biomass and the price the biofuel processor is willing to pay for biomass. If the difference between the feedstock supply price and derived demand price is zero or negative, the long-term biofuel feedstock market is sustainable, and if positive, the price gap indicates the market cannot be sustained.

The model does not estimate actual feedstock supply curves, but rather, derives point estimates for a fixed plant capacity in the feedstock market. The model estimates the difference between the perfectly elastic

7. *Given the cost estimates for alternative liquid fuels (ALTF, 2009; IEA, 2011), several fossil fuel alternatives will likely compete at prices below $140/bbl.*

8. *We assume the biorefinery will outsource feedstock production and acquire feedstock from several local suppliers.*

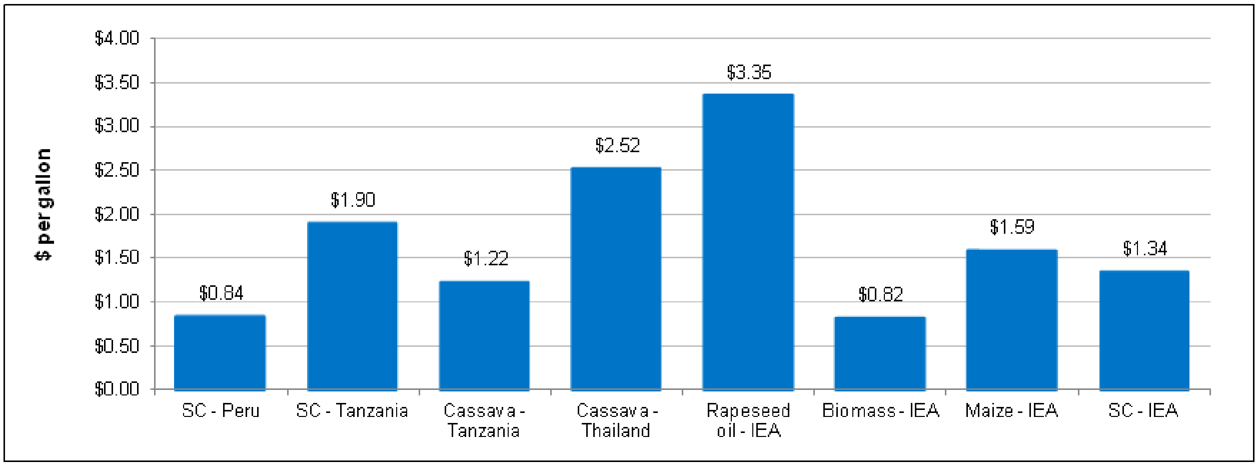

Figure 3. Feedstock cost per gallon.

derived demand curve based on the oil equivalent price of biofuel and the long-run minimum point on the average total cost curve for a fixed capacity plant.

Making long-term biofuel projections requires clarification of assumptions and steps. First, biofuel development is assumed to be driven by the price of oil, and alternative oil prices are used to determine the derived demand for biofuel and the long-run breakeven or parity price for feedstock. Short- and intermediate-term government subsidies and mandates are not a factor in the long-term. Second, energy-rich commodity price floors and ceilings will be driven by oil price as well. Non-feedstock commodity crop prices will be integrated with feedstock commodity prices through competition for cropland. Third, commodity prices are assumed to be transmitted through world markets and long-term trade distortions are ignored. Fourth, oil price scenarios are used to project future growth in feedstock productivity and conversion efficiency. Productivity growth will impact future demand and supply prices for energy-rich feedstock in major biofuel-producing countries and may impact future biofuel expansion.

Model Estimates and Results

To illustrate future biofuel expansion potential, we use the long-term biofuel projections model to evaluate alternative feedstock production and conversion processes for select, representative countries under alternative oil price scenarios. Long-term parity or breakeven price curves were developed that relate the oil price scenarios to the derived demand prices that biofuel conversion plants are willing to pay for feedstock, assuming technologies and other prices are held constant. For example, Figure 2 provides the processor's parity price (derived demand) curve for sugarcane feedstock. This figure simply illustrates what an ethanol processor could afford to pay for sugarcane feedstock per gallon of ethanol produced under alternative oil prices.

The supply cost or price for select, representative feedstock alternatives are summarized in Figure 3 based on data formatted and standardized across countries, time, currencies, and feedstock sources to maximize comparability.[9] The results indicate the importance of regional and feedstock source differences due to production environment, management systems, and climate as well as implications for per gallon biofuel feedstock costs.

Impact of Productivity Growth on Long-term Biofuel Production

Many proposed biofuel feedstock crops are not traditional commodity crops with established production practices, or they do not have established, commercial-scale conversion platforms. Agronomists and engineers argue that following significant research investments, new feedstock crops and conversion platforms will develop, feedstock production and conversion productivity will increase, and biofuel production and conversion costs will decrease.

To determine the impacts of improved productivity growth on the breakeven results, Miranowski and Rosburg (2012) tied biofuel productivity growth to oil price. High oil prices provide incentives for productivity increasing research, and the higher the price of oil, the greater the payoff to R&D in feedstock production and conversion. A caveat is in order at this point. Since pro-

9. *Sugarcane feedstock is denoted by "SC" in Figure 3.*

ductivity growth is anticipated for other liquid fuel substitutes, both fossil and renewable with high oil prices, the relative competitiveness or productivity gains from biofuel relative to all other liquid fuel are likely unchanged.

Although lacking an argument for why biofuel would witness higher rates of productivity growth than other substitute fuels, we assume higher rates of productivity growth in biofuel production for expository purposes. Crops that are not in the sustainable range, such as biomass, are only competitive with a higher rate of productivity growth over an extended period time. Yet, given the length of time to reach payback, the net present value of achieving the improved productivity is unlikely to be positive. Even though the productivity growth concern is usually with respect to biomass and dedicated energy crops, it is also important to note that well-established and heavily-researched feedstock crops like maize and rapeseed oil are only sustainable at high oil prices or higher rates of productivity growth.

Oil Price as a Floor and Ceiling on Energy Feedstock Crop Prices

In discussing the analytical framework, it was indicated that oil price functions both as a floor and ceiling on high-energy crop use for feedstock. A recent example from the ethanol market clearly makes this point. Brazil was a major source of ethanol for meeting the EU-RED requirements as well as its own. In 2011, the world price of sugar had risen to a level where it was more profitable to export sugar than to use the feedstock to produce ethanol. Sugar had priced itself out of the ethanol feedstock market because consumers outbid the derived demand for sugar feedstock in ethanol production. At the higher price of sugar relative to US maize prices, US maize ethanol was exported to the European Union and Brazil to meet their biofuel requirements. By 2012, some US ethanol plants are idle due to the high world-market price for maize; growing world demand for maize accompanied by supply shortfalls is allowing feed consumption to outbid ethanol production for maize.

Long-term Sustainability of Region and Country Biofuel Industry

Is a regional biofuel feedstock and conversion industry sustainable in the long-term? Sustainability will depend on a price-elastic, long-term feedstock supply and the potential to expand that supply. Additionally, access to an efficient biofuel conversion process, especially in the case of non-traditional feedstock, is critical. Only countries and regions that have excess feedstock supplies and potential to expand feedstock production under different oil price scenarios have an opportunity to develop a sustainable biofuel industry. Efficient biofuel conversion plants require continuous throughput, large-scale plants, and high-density and dependable feedstock supplies. Feedstock supply interruptions, small-sized plants, or transportation constraints may render biofuel plant investment unsustainable.

Ignoring public policy intervention in stimulating biofuel production, where and what crops have the greatest potential in terms of production location and feedstock and conversion potential? Based on the results presented here and the studies cited in Miranowski and Rosburg (2012) and Miranowski (2012), feedstock crops demonstrating the greatest potential at $100/bbl oil are sugarcane produced in more tropical regions of South America and possibly Sub-Saharan Africa. The IEA study (2011) found sugarcane to be the most competitive feedstock for biofuel expansion. Likewise, palm oil production has potential for expansion in South Asia and possibly in tropical South America.

In the absence of policy intervention, maize and rapeseed biofuel will only expand if world oil price is sustained at $140/bbl over the long-term. Biofuel production from temperate feedstock sources is only sustainable under the high oil price scenario and sensitive to feedstock ceiling prices, so we do not project market-driven biofuel expansion except to meet EU-RED, US-RFS, and other renewable energy mandates.

Summary Implications and Conclusions

This article presents and discusses some of the key, preliminary findings from Miranowski and Rosburg (2012) and Miranowski (2012). The results presented here indicate that global, market-based expansion of biofuel production will be limited in the absence of high oil prices or government incentives and mandates. Only sugarcane ethanol and palm oil biodiesel in more tropical areas (especially in South America) and potentially in Sub-Saharan Africa and South Asia are projected to expand significantly, unless the high oil price scenario prevails.

First-generation biofuel is based on well-established technology, conversion costs, and commodity feedstock sources. Even for most first-generation biofuel feedstock (with the exception of sugarcane), the ability to compete in the current liquid-fuel market is driven by government intervention (i.e., biofuel subsidies and mandates).

The biofuel industry is capital-intensive with large-scale economies and requires dependable year-round feedstock supply for efficient (continuous) operation. This is not a typical problem in major feedstock-producing countries. Biofuel production will develop in local regions that have relatively price-elastic domestic feedstock supplies that can supply large quantities of consistent feedstock competitively and sustainably from the regional market and competitively sell biofuel into the region/national fuel market. With the exception of sugarcane ethanol and palm oil, the net margin on biofuel produced from other commodity feedstock may provide limited incentive to invest in new capacity in the absence of government biofuel policy intervention. If a high oil price ($140/bbl) is sustained over the long-term, more countries and feedstock will come into the solution and biofuel supply will expand.

Significant uncertainty surrounds advanced cellulosic biofuel technology, feedstock fuel yield and conversion efficiency, operating and capital costs, and sustainable and economic feedstock supplies. The lack of initial capital investment in advanced biofuel refining is not likely to be resolved by intermediate-term mandates, output subsidies, or investment incentives. Conversion platform, biofuel yield, plant scale, operating costs including input costs, and n^{th} commercial plant performance are largely unknown. A high oil price that significantly exceeds feedstock cost ($140/bbl) will have to prevail to incentivize commercial industry development and deployment.

Role of feedstock and biofuel production in developing countries depends on a large number of factors, including food security, potential feedstock supply and supply elasticity, farm structure, and rural infrastructural investment. Given the technology challenges in both cellulosic feedstock and biofuel production, pursuing cellulosic biofuel is a high-risk investment for developing countries in the near term. Developing countries already are the largest users of biomass for energy without going through the costly conversion process to biofuel. Commodity feedstock may be more appropriate if sufficient excess feedstock supplies exist or can be developed without pricing feedstock out of the biofuel market (i.e., oil price puts both a floor and ceiling on feedstock price). From the perspective of the feedstock producer, market flexibility, arbitraged prices, and diversified market opportunities reduce risk.

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Author Notes

John Miranowski is a Professor in the Department of Economics at Iowa State University, Ames, Iowa. Alicia Rosburg is an Assistant Professor in the Department of Economics at the University of Northern Iowa, Cedar Falls, Iowa. Contact information: jmirski@iastate.edu (515-294-6132) and alicia.rosburg@uni.edu (319-273-3263).

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