Biofuels and the Fungibility of Motor Fuels

By F. W. Rusco and W. D. Walls*

Introduction

Interest in biofuels surged in the late 1970s and early 1980s in response to high oil prices but waned by the mid 1980s as oil prices plummeted and remained relatively low for almost 25 years. However, a coincidence of several factors has caused a recent resurgence in interest and growing global production of ethanol and biodiesel. These factors include increasing fossil fuel prices, a growing consensus among policy makers that human carbon emissions should be reduced, and successful lobbying by pro-agricultural interests for biofuel subsidies.

The recent growth in biofuel production has been impressive although biofuels still make up a small percentage of the world's liquid transportation fuels. The United States and Brazil produce the bulk of global ethanol; 6.5 and 5 billion gallons in 2007, a 33 percent and 11 percent increase over the previous year, respectively. European countries have been the leaders in producing biodiesel, in total, producing 4.9 million tonnes in 2007, up by more than 50 percent from the previous year. As of 2007, global ethanol production made up only a small percentage of liquid transportation fuels by volume and less by energy content because of the lower energy density of ethanol compared to gasoline derived from crude oil. Similarly, global biodiesel production is only a small fraction of total global distillate production by volume but has been growing rapidly—global biodiesel production grew at an annual rate of 40 percent from 2002—2006 (Ren21, 2008). Europe has been the largest producer of biodiesel in recent years—85 percent of global production in 2005—but many other countries are expanding their acreage devoted to biodiesel feedstocks and some potentially large consumers—including China and India—are experimenting with biofuels. In addition, many other countries, including the United States, as well as most individual states have either mandated use of biofuels or provided tax or other incentives to encourage production and use of these fuels. To date, there has been little coordination among these governments with respect to setting uniform standards for producing or blending of ethanol and biodiesel with gasoline or diesel produced from crude oil.

Country	2004	2005	2006
Brazil	3,989	4,227	4,491
U.S.	3,535	4,264	4,855
China	964	1,004	1,017
India	462	449	502
France	219	240	251
Russia	198	198	171
South Africa	110	103	102
U.K.	106	92	74
Saudi Arabia	79	32	52
Spain	79	93	122
Thailand	74	79	93
Germany	71	114	202
Ukraine	66	65	71
Canada	61	61	153
Poland	53	58	66
Indonesia	44	45	45
Argentina	42	44	45
Italy	40	40	43
Australia	33	33	39
Japan	31	30	30
Pakistan	26	24	24
Sweden	26	29	30
Philippines	22	22	22
South Korea	22	17	16
Guatemala	17	17	21
Cuba	16	12	12
Ecuador	12	14	12
Mexico	9	12	13
Nicaragua	8	7	8
Mauritius	6	3	2
Zimbabwe	6	5	7
Kenya	3	4	5
Swaziland	3	3	5

Table 1: Ethanol Production in Various Countries Millions of Gallons

Source: Renewable Fuels Association.

As a result of this lack of coordination there is a wide range of ethanol blending standards that have been either mandated or proposed as well as a number of different biodiesel standards. For example, according to the Pew Center on Global Climate Change, 37 U.S. states provide tax exemptions, credits, and/or grants to encourage the production and use of ethanol and or biodiesel. Nine of these states have also imposed renewable fuel standards that mandate varying degrees of use of biofuels. Specifically, the mandated blends of ethanol vary between 2 percent to 85 percent ethanol with different dates associated with state implementation goals. Table 2 shows biofuels standards in some individual U.S. states.

A similar proliferation of biofuel blends and standards is beginning to emerge in Europe and other regions, in which countries with suitable lands and agriculture sectors to produce biodiesel are tending to mandate greater proportions of blending of biodiesel than other countries not so endowed. An additional issue exists with biodiesel in that, unlike ethanol—which is generally fungible regardless of how it is produced or from which bio-feedstock—different biodiesel production processes and feedstocks lead to biodiesels having different performance and other properties. Table 3 shows biofuels standards in various other countries.

Many unintended but significant problems must be addressed if biofuels are to become an increasingly important part of the liquid fuel mix. Among these are the competing uses of land and water, the effects of placing more land under commercial use on biodiversity and traditional or indigenous populations, concerns about the net carbon impacts of some biofuel production processes, and the effects on engine performance and fuel efficiency. Each one of these issues is currently receiving a great deal of interest from researchers and policy makers (*c.f.,* de Gorter and Just, 2007 and 2008). This paper explores the effect of differing biofuel production and blending standards on the liquid fuels supply infrastructure.

* F. W. Rusco is with the U.S. Government Accountability Office and W. D. Walls is with the Department of Economics, University of Calgary, Alberta, Canada.The views expressed in this paper are solely those of the authors and are not to be attributed to the authors' employers.

Petroleum Refining and Biofuels

When ethanol is blended with gasoline, it affects both the energy content, as well as the octane and emissions characteristics of the resulting fuel. Specifically, ethanol is less energy dense than petroleum based gasoline. As a result, cars using gasoline blended with ethanol generally will suffer a reduction in their rated fuel economy. In addition, ethanol is an octane booster. When ethanol is added to gasoline, refiners must remove some lighter-end gasoline components that also boost octane in order to meet vehicle octane specifications. Finally, ethanol has a very high Reid Vapor Pressure, meaning it evaporates at very low temperatures. This means that gasoline blended with ethanol has greater evaporative emissions of volatile organic compounds. This requires further changes to the gasoline blendstocks to mitigate these emissions.

State	Fuel Standard
Hawaii	85% of gasoline to contain 10% ethanol by April 2006
Iowa	25% of motor fuel from renewables (E10, E85, biodiesel by 2020)
Louisiana	All gasoline to contain 2% ethanol; 2% of all diesel to be biodiesel
Minnesota	All gasoline to contain 20% ethanol by 2013; 2% of all diesel to be biodiesel
Missouri	All gasoline except premium grade gasoline to contain 10% ethanol by 2008
Montana	All gasoline except 91 octane to contain 10% ethanol
Washington	All gasoline to contain 2% ethanol by 2008; 2% of all diesel to be biodiesel by 2008

Table 2: Biofuel Standards Mandated by Individual U.S. States
Source: PEW Center on Global Climate Change.
http://www.pewclimate.org/node/5859

Gasoline blendstocks will eventually have to be altered to maintain automobile performance and emissions requirements as biofuels come into increasing use. This will have two main effects on the refining sector and thus on the gasoline market. First, adding ethanol reduces total gasoline refining capacity because some of the lighter components that are produced during refining must be taken out of the gasoline to accommodate the high octane and evaporative qualities of ethanol. These lighter products may be used elsewhere, for example, as feedstocks for petrochemical products or in other refining regions, which do not have high blends of ethanol and can therefore accommodate more of the light-end products; and some can be stored during the summer and reintroduced into the gasoline stream in the winter when colder temperatures reduce evaporative emissions. Regardless, the end result is an increase in the average cost of producing gasoline, either because light-end components are not going to their highest valued use, or because of additional shipping and storage costs.

Country	Fuel Standard
Brazil	5% ethanol in gasoline and 2% biodiesel by 2008; 25% ethanol in gasoline by 2013
Canada	10% ethanol in gasoline by 2010; 5% ethanol in Ontario gasoline by 2007
China	10% ethanol in five provinces
Colombia	10 % ethanol in gasoline in cities with population > 500,000
India	5% ethanol in gasoline
Philippines	5% ethanol in gasoline, 2% biodiesel by 2007
Thailand	10% ethanol in gasoline by 2010

Table 3: Biofuel Standards Mandated by Individual Countries
Source: PEW Center on Global Climate Change.
http://www.pewclimate.org

The second effect is on the wholesale market for liquid fuels. With different states and countries mandating different blending levels of ethanol with petroleum-based gasoline, refineries serving those states and regions will make unique gasoline blendstocks. A similar "Balkanization" of liquid fuels occurred with the proliferation of gasoline blends that followed Clean Air Act requirements. A number of areas that were out of compliance with air quality standards chose to use a cleaner burning gasoline blend to improve air quality. Refiners serving these areas invested billions of dollars in new equipment to make these fuels. The result was a less fungible gasoline market in which relatively fewer refiners regularly serve areas with special gasoline blends compared to areas using conventional gasoline. While it is too early to try to measure the effects of further Balkanization of the refining sector that will occur without coordination on ethanol blending standards, it is likely that, to the extent that differing blending standards lead to smaller numbers of refiners serving specific states or regions, that this could increase the response time to address refinery outages among any group of refiners serving a specific market. This could have the effect of increasing the amplitude and length of price spikes associated with such outages.

Biodiesel is more complicated than ethanol because the properties of biodiesel produced from different feedstocks and processes differ considerably in terms of energy content, impacts on engine performance and wear, usability at low temperatures, and other characteristics (DOE, 2006; National Biodiesel Board, 2008, Knothe and Steidley, 2005). Currently there are at least three biodiesel standards in the United States and Canada and one in Europe (National Biodiesel Board, 2008b; DieselNet, 2008). In addition, the same issues with respect to the wholesale market could also exist with biodiesel.

Biofuels and the Supply Chain

Ethanol produced from agricultural feedstocks will generally be produced in smaller refineries near the sources of the feedstocks because moving the finished ethanol is much cheaper than moving the much larger volumes of feedstocks required for its production. This means that much of the ethanol produced will not be near existing demand or existing suitable pipeline infrastructure. In addition, currently, most petroleum product pipelines cannot ship high concentrations of ethanol because of the corrosive nature of ethanol that destroys certain seals and other parts in the pipelines as well as ethanol's capacity to absorb water. Nonetheless, it is likely that ethanol will eventually be shipped by pipeline because that is by far the cheapest mode of liquid fuel transport for most regions. In order to achieve this, collecting pipelines will likely be built to connect smaller refineries scattered around agricultural areas to larger trunk lines used to serve major fuel demand areas. This, along with adjustments to existing pipelines that will be required to handle ethanol will amount to billions of dollars of investments in supply infrastructure and will require a long time to get permits and negotiate placement of the pipelines. In addition, ethanol will likely be blended with gasoline before it goes into major existing pipelines to reduce the corrosive and water absorption effects on these older and less suitable lines. Finally, if different regions require different blends, this will reduce shipping and storage capacity, similar to what happened with the proliferation of boutique gasoline blends in response to the Clean Air Act. Specifically, just as different gasoline blends must be kept segregated during shipping and storage, so will different ethanol blends. This will require that large tanks that were built to handle a more fungible liquid fuel supply will be handling smaller batches of more types of fuel and this reduces total storage capacity. Similarly, batches going through the pipelines may also be smaller as a result of more different fuel types having to be segregated. This will reduce the capacity of the existing pipeline infrastructure because sending smaller batches through the system requires greater precision in placing and removing these fuels from the pipelines and this is generally achieved at the cost of a slower rate of pipeline flow.

Biodiesel can already be shipped by pipeline, generally without any modifications to the infrastructure. However, biodiesel made from different feedstocks has different properties in terms of the fuels "cloud point," which refers to the temperature at which the biodiesel begins to gel. The variation in cloud point could have impacts on the ability to ship biodiesels in pipelines in different climates. With these exceptions, the other problems associated with incorporating different blends of ethanol apply. Specifically, the biodiesel refineries will generally not be located on or near existing pipeline infrastructure so new feeder pipelines will have to be built or more expensive truck and rail transport will have to be used. Similarly, to the extent that different biofeedstocks are used and that this creates biodiesels with varying qualities, these fuels may have to be segregated during transport and storage, further adding constraints to the existing infrastructure.

Whatever the magnitude of air quality improvements attributable to biofuels, it should be clear that these benefits come at a cost. While there has been no definitive study of the precise price effects of the proliferation of special gasoline blends, there is a consensus among industry experts and government agency analysts that prices are higher and/or more volatile as a result of the increased use of special blends. Studies by the U.S. Environmental Protection Agency (EPA, 2001), the Department of Energy's Energy Information Administration (EIA, 2002), the U.S. Government Accountancy Office (GAO, 2005), and a number of private and academic sector analyses (Muehlegger, 2005; Hirshfeld and Kolb, 1997; NACS, 2003; Walls and Rusco, 2007) have concluded that areas that isolate themselves from a large and fungible gasoline market by adopting a rare or more costly to produce gasoline blend pay for this isolation through higher gasoline prices and greater price volatility. This is especially true in the event of local supply disruptions, because it takes longer to bring in replacement supplies. It is likely that the increased use of biofuels with idiosyncratic standards leading to a further balkanization of the liquid fuel slate will exacerbate the price effects already associated with special fuel use.

Concluding Remarks

There may well be benefits to the expansion of biofuel use in terms of diversifying liquid transportation fuel supplies, adding production capacity to a supply-constrained market with growing demand, and potentially reducing carbon emissions. However, the introduction of these fuels could further divide the motor fuels market into islands of smaller and more local markets for blends of motor fuels that are typically not interchangeable. This transformation of the motor fuels market may further complicate the supply infrastructure, increase production and delivery costs, and reduce the availability of motor fuels in some cases. These and other effects of increasing production and use of biofuels must also be considered, including the effects on land and water use, species diversity, food prices, and other related issues, and policy makers should consider coordinating biofuels standards to avoid unintended effects of further balkanization of the liquid fuels markets.

References

de Gorter, Harry, and David R. Just. The Law of Unintended Consequences: How the U.S. Biofuel Tax Credit with a Mandate Subsidizes Oil Consumption and Has No Impact on Ethanol Consumption. Department of Applied Economics and Management Working Paper # 2007-20, Cornell University, 2007. Available online at URL: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1024525.

de Gorter, Harry, and David R. Just. The Economics of a Blend Mandate for Biofuels. Under review at American Journal of Agricultural Economics, 2008.

DieselNet. *Technical Biodiesel Fuel Standards.* Available online at URL: www.dieselnet.com/tech/fuel_biodiesel_std.html. Accessed June 30th, 2008.

DOE, *Biodiesel Handling and Use Guidelines*, DOE/GO-102006-2358, Third Edition (Washington, D.C.: September 2006).

EIA, *Gasoline Type Proliferation and Price Volatility*, Department of Energy, Energy Information Administration (Washington, D.C.: October 7, 2002).

EPA, *Study of Unique Gasoline Fuel Blends ("Boutique Fuels"), Effects of Fuel Supply and Distribution and Potential Improvements*, EPA420-P-01-004 (Washington, D.C.: October, 2001).

GAO, *Gasoline Markets: Special Gasoline Blends Reduce Emissions and Improve Air Quality, but Complicate Supply and Contribute to Higher Prices,* GAO-05-421 (Washington, D.C.: June 17, 2005).

Hirshfield, David, and Jeffrey Kolb, *The Economics of Gasoline Formulation: Refining Economics, Emissions Standards, and the Complex Model*, MathPro-AM-97-28 (Bethesda, MD: March 16, 1997).

Knothe, Gerhard and Kevin R. Steidley. Lubricity of components of biodiesel and petrodiesel. The origin of biodiesel lubricity. *Energy & fuels,* vol. 19, pp. 1192-1200, 2005.

Muehlegger, E. The role of content regulation on pricing and market power in regional retail and wholesale gasoline. Working paper 008, MIT Centre for Energy Economics and Policy Research, 2005.

NACS, *Motor Fuels Supply Fugibility and Market Volatility Analysis*, Hart Downstream Energy Services (Potomac MD: 2003).

National Biodiesel Board. *Lubricity Benefits.* Available online at the following URL: http://www.biodiesel.org/pdf_files/fuelfactsheets/Lubricity.PDF. Accessed June 30, 2008a.

National Biodiesel Board. *Big Win for Biodiesel: ASTM Approves New Biodiesel Blend Specifications.* Announced June 20th, 2008. Available online at the following URL: http://nbb.grassroots.com/08Releases/ASTM_final/. Accessed June 30, 2008b.

Ren21. *Renewables 2007: Global Status Report.* Renewable Energy Policy Network for the 21st Century, (Paris: REN21 Secretariat and Washington, DC:Worldwatch Institute, 2008).

Stikkers, David. *A Retrospective Study of Reformulated Gasoline Use in Chicago*, Environmental Informatics Archives, vol.1, p. 282-294, 2003

Walls, W. D. and F. W. Rusco. Price effects of boutique motor fuels. *The Energy Journal*, 23(3):145-163, July 2007.