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Bio-Fuels Energy Policy and Grain Transportation Flows: Implications for Inland Waterways and Short Sea Shipping

Final Report

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16. Abstract

This project develops a foundation for analysis of the effects of U.S. biofuel energy policy on domestic and international grain flows and patterns. The primary deliverable of this project is an updated and expanded spatial equilibrium model of world grain economy. The updated model reflects recent changes in the dynamics of grain production, consumption, and transportation particularly in reaction to explosive growth of the biofuel market in the U.S. An improved and modified spatial equilibrium model will be extremely useful in addressing a variety of questions with respect to transportation infrastructure, traffic congestion, and international trade issues. In particular, principal investigators plan to use the improved model as a platform for future research in order to gain insight into potential long-term effects of the current energy policy on grain and biofuel-related transportation flows on inland waterways, outline requirements and justifications for targeted development of transportation infrastructure in order to mitigate projected traffic congestion, and examine potential opportunities for switching rail and truck-transported commerce on North American transport corridors to the inland and intra-coastal waterways.

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Executive Summary

The 2005 Energy Act and 2007 Energy Independence and Security legislation mandated increasing use of biofuels up to 36 billion gallons by 2022. This development has the potential of impacting traffic flows in the U.S. and globally. The primary biofuels are ethanol and biodiesels. Production of ethanol largely relies on Midwest corn, while biodiesel is often made of soybean byproducts, with both corn and soybeans being the principal commodities transported on the upper Mississippi and Illinois Rivers.

The primary objective of the project was to document a spatial equilibrium model of the world grain economy and update model data to 2007–2008 production years. The updated model reflects recent changes in dynamics of grain transportation flows in reaction to explosive growth of the biofuel market in the U.S. The model is intended to be used to evaluate consequences/long-term effects of current energy policy on grain and biofuel-related transportation flows on the inland waterways and short sea shipping routes.

The grain transportation model was originally developed for the Food and Agricultural Policy Research Institute (FAPRI) and simulates flows of corn and soybeans by transport mode between U.S. regions, barge loading/unloading locations, sea ports, and foreign destinations. However the model was calibrated for 2003–2004 production year and thus does not reflect the changes in production and consumption patterns due to increasing use of corn and soybeans for production of biofuels.

A major effort under the project consisted in identifying sources of information, collecting, and transforming data to be used with the grain transportation model for further research. Comprehensive datasets have been constructed reflecting:

- quarterly production, prices, and consumption of corn and soybean (necessary to account for transportation flows between the regions);
- price elasticities of supply and demand for corn and soybeans (necessary to account for changes in supply and demand in response to changes in commodity prices and shipping rates); and
- updated truck, rail, and barge rates (necessary to determine changes in transportation flows and transportation modes in response to or in conjunction with changes in supply and demand of corn and soybeans).

The constructed datasets are available in electronic format for research purposes. The data will be used by the project investigators with the grain transportation model to analyze the implications of U.S. biofuel policies on changes in grain transportation flows by transportation mode.

Problem Overview

Dramatically increasing U.S. freight flows have created congestion in the transportation system, imposing costs on shippers, consumers, and the environment. Roadway congestion affects 60% of roadway mileage in urban areas causing significant delays for truck traffic. Railroads are also experiencing capacity limitations on many corridors. Further, the GAO forecasts an overall increase in freight traffic of 70% by 2020.

In 2007, a document entitled Framework for National Freight Policy issued by the U.S. Department of Transportation (DOT) called, among other objectives, for investment in inland waterways to increase waterborne transportation of freight between domestic ports (short sea shipping) through use of inland and coastal waterways. However, congested portions of the upper Mississippi and Illinois Rivers are an obstacle to this goal of shifting freight to waterways for purposes of relieving congestion on highways and railroad corridors.

The 2005 Energy Act mandated increasing use of biofuels, which was further boosted by EPA's 2007 fuel emissions rules. This development has the potential of impacting traffic flows in the U.S. and globally. The primary biofuels are ethanol and biodiesels. Production of ethanol largely relies on Midwest corn, while biodiesel is often made of soybean byproducts, with both corn and soybeans being the principal commodities transported on the upper Mississippi and Illinois Rivers. Most of the recently constructed and/or planned biofuel facilities are located in the Midwest regions that ship grain for export via the Mississippi/Illinois Rivers. As of January 2009, current and projected ethanol production capacity in proximity to the River was estimated to require about 4.0 billion bushels (bu) of corn or 30% of U.S. production. While the ethanol boom somewhat subsided after escalating corn prices in the spring of 2008, the existing ethanol plants are changing the dynamics of grain transportation flows. In particular, substantial quantities of grain maybe directed away from the Mississippi/Illinois Rivers, which may reduce traffic and congestion at its principal chokepoints, allowing other commodities to enter the River system.

Ethanol

Renewable Fuels Association (RFA) defines ethanol as a "[…] renewable alcohol fuel made from abundant agricultural resources." In the U.S. ethanol is typically produced from grains (e.g., corn or wheat) through a process of fermentation and distillation (RFA, 2010c). Corn is the main feedstock for ethanol production, accounting for nearly 97 percent of the domestic ethanol (Jacobs, 2006).

Ethanol is produced through one of two production processes: wet milling and dry milling, with the latter being the most common in the U.S. The dry milling process yields ethanol byproducts such as condensed distillers' solubles (CDS), dried distillers grains (DDG), and carbon dioxide. Wet milling process also yields byproducts such as corn oil, corn gluten meal, and carbon dioxide. DDGs and corn gluten meal are used as livestock feed, while corn oil and carbon dioxide are used for other industrial purposes (RFA, 2010b).

According to Energy Information Administration (EIA), nearly all ethanol in the U.S. is blended into gasoline at up to 10 percent by volume to produce a fuel called E10 or “gasohol.” All cars that are built after 1970 can run on E10. However, higher-level ethanol blends (from E60 to E85) require “flex-fuel” engines (USDOE/EIA, 2007).

Biodiesel

Biodiesel is defined by EIA as “[…] a fuel typically made from soybean, canola, or other vegetable oils; animal fats; and recycled grease [which] can serve as a substitute for petroleum-derived diesel or distillate fuel” (USDOE/EIA, 2009a). Glycerin is produced as a biodiesel byproduct and is used in soaps and other products. The primary sources of U.S. biodiesel production are soybean oil and yellow grease, with most of the latter coming from recycled cooking oil (Radich, 2004). According to the National Renewable Energy Laboratory, biodiesel blends of B20 (20 percent biodiesel and 80 percent petroleum diesel) or lower can be used in any diesel engine with proper fuel tank maintenance and fuel blending (USDOE/NREL, 2005).

Biofuel Policies and Dynamics of the Biofuel Production in the United States

At the end of the 1990s, states began banning Methyl Tertiary Butyl Ether (MTBE) use as a gasoline oxygenate after discovering its negative effects on health and environment due to gasoline leakage incidents. In 2000, Environmental Protection Agency (EPA) recommended that MTBE be banned. By 2004, 18 states (including California, whose share accounted for 31.7% of total U.S. MTBE consumption in 2002), banned the use of MTBE and began switching to ethanol as a gasoline oxygenate. As a result, demand for fuel ethanol increased in subsequent years.

The biofuels related policies such as The Energy Policy Act of 2005 (EPAct 2005) and The Energy Independence and Security Act of 2007 (EISA 2007) also helped to secure a market for corn-based ethanol through at least 2022 by requiring specified amounts of ethanol to be blended with gasoline.

The Energy Policy Act of 2005 included Renewable Fuel Standard Program (RFS), which mandated a two-fold increase of ethanol and biodiesel use by 2012. More specifically, RFS required that 7.5 billion gallons of the national fuel supply be provided by renewable fuels, including ethanol and biodiesel (USDOE/EIA, 2009b).

The Energy Independence and Security Act of 2007 further expanded the EPAct of 2005 by requiring a total of 36 billion gallons of renewable fuels be blended into gasoline and diesel by 2022, of which 15 billion gallons would originate from conventional biofuels (corn ethanol) and the remainder from the advanced biofuels such as cellulosic ethanol and biodiesel (USDOE/EIA, 2009b).

The biofuel policies also provide various tax incentives for biofuels producers and blenders. In particular, ethanol and biodiesel producers, who produce less than 60 million gallons a year, are given a small producer credit of $0.10 per gallon up to 15 million gallons per year. This subsidy is effective until the end of 2010.

In addition, registered blenders are eligible for the volumetric ethanol excise tax credit (VEETC), which provides blenders with a tax refund of $0.51 per gallon of pure ethanol blended with gasoline. VEETC also provides two types of tax credits—Straight Biodiesel Credit and Biodiesel Mixture Credit—for biodiesel producers. In particular, the producers receive Straight Biodiesel credit equaling $1.00 per gallon of pure agri-biodiesel and Biodiesel Mixtures credit of $0.01 per percentage point of agri-biodiesel blended with petroleum diesel (Cubert, 2006).

Overall, the U.S. ethanol industry has seen tremendous growth during the past two decades, which gained even greater momentum after the Energy Policy Act of 2005 and subsequent biofuels related policies. Between 2000 and 2009, the U.S. fuel ethanol production capacity increased at an average annual rate of 19.7%, reaching 10.57 billion gallons by January 2009 (Figure 1; RFA, 2010a). An estimated 170 biofuel refineries were operating in January 2009.

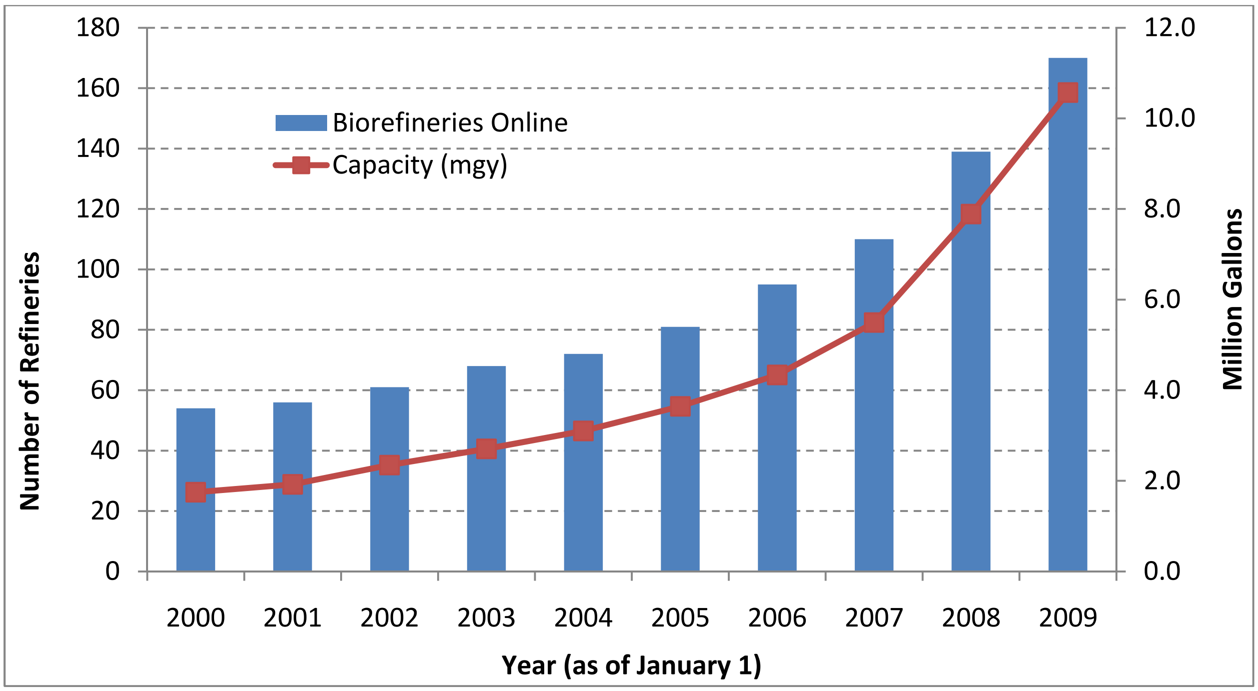

Figure 1: Growth of U.S. Ethanol Industry, 2000–2009. Based on information in (RFA, 2010a)

Annual ethanol production increased at an average annual rate of 25% from 1.63 billion gallons in 2000 to 9.24 billion gallons in 2008. Expressed in terms of corn consumption, the share of total U.S. corn production used for ethanol production rose from 7% in 2000 to 28% in 2008. According to EIA projections, annual production of corn-based ethanol will reach 15.2 billion gallons by 2018 (USDOE/EIA, 2008). This translates into additional annual corn demand equal to 2.1 billion bushels by the end of the next decade. The U.S. biodiesel production industry did not grow significantly until early 2004, but witnessed an explosive growth afterwards with an average annual growth rate of 121% between 2004 and 2009.

Production of ethanol largely relies on Midwest corn, while biodiesel is often made of soybean byproducts. Both corn and soybeans are the principal commodities transported on the upper Mississippi and Illinois Rivers. Eight Midwestern states—Illinois, Indiana, Iowa, Minnesota, Nebraska, Ohio, South Dakota, and Wisconsin—are the major producers of corn and soybean whose combined production accounts for more than 70 percent of the nation's total production of each commodity. In 2009 marketing year, these states produced 9.95 out of 13.11 billion bushels (75.9%) of the nation's corn and 2.19 out of 3.36 billion bushels (65.2%) of the nation's soybeans (USDA/NASS). Historically, these states have shipped important quantities of corn and soybeans via the Upper Mississippi and Illinois Rivers to lower Mississippi River ports for export.

Recently built and planned biofuel facilities are largely located in regions with large corn and soybean production (Figures 2 and 3). As of January 2009, the eight major production states had a combined annual ethanol production capacity of 9.7 billion gallons, or 77.6% of total U.S. capacity (RFA, 2009). This production capacity requires about 3.5 billion bushels of corn (or 26.3% of overall U.S. corn production in 2009.

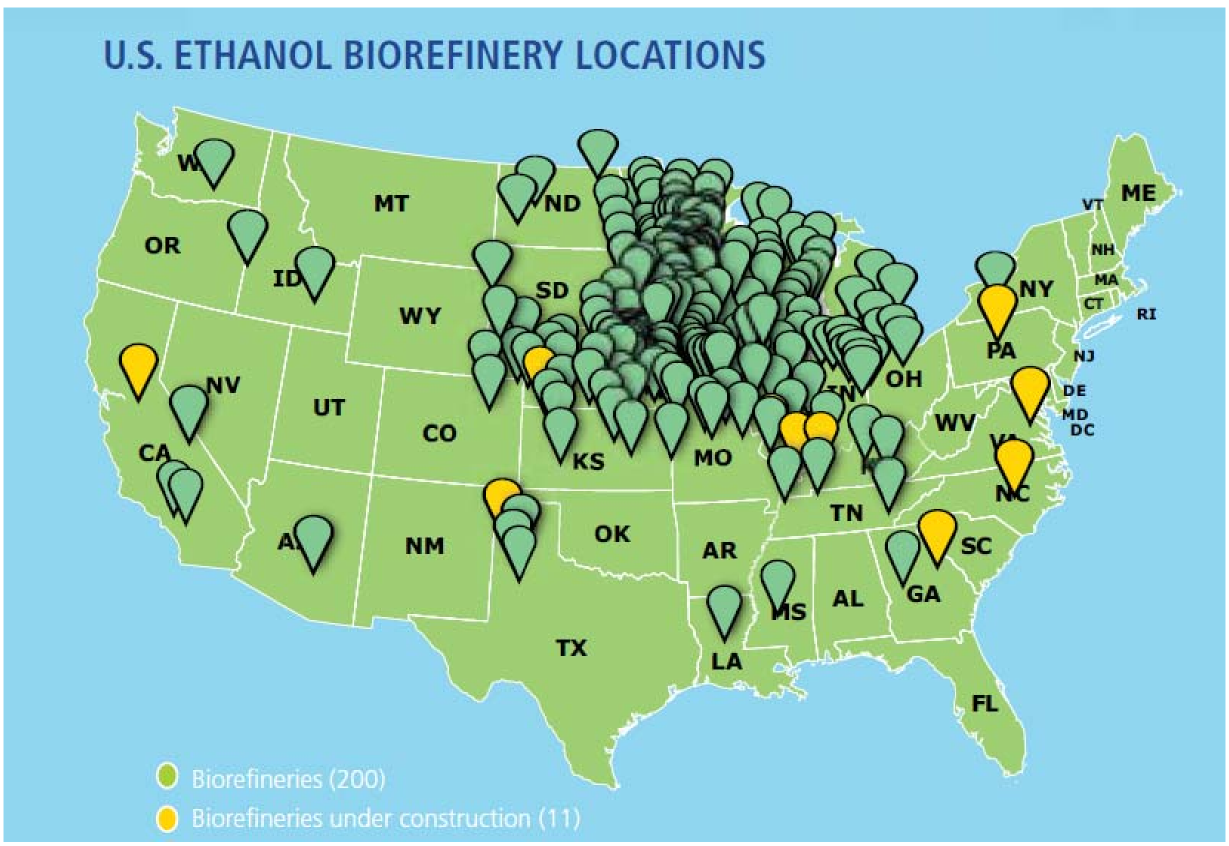

Figure 2: U.S. Biorefinery Locations, January 2010. Source: Renewable Fuels Association (RFA, 2010a).

Overall, current and projected ethanol production capacity in proximity to the river (as of January 2009) is estimated to require about 4.0 billion bushels of corn or 30.5% of U.S. corn production. If locally produced corn is primarily used at the ethanol refineries in the Midwestern states, a substantial amount of grain shipments may be diverted from the Mississippi River basin.

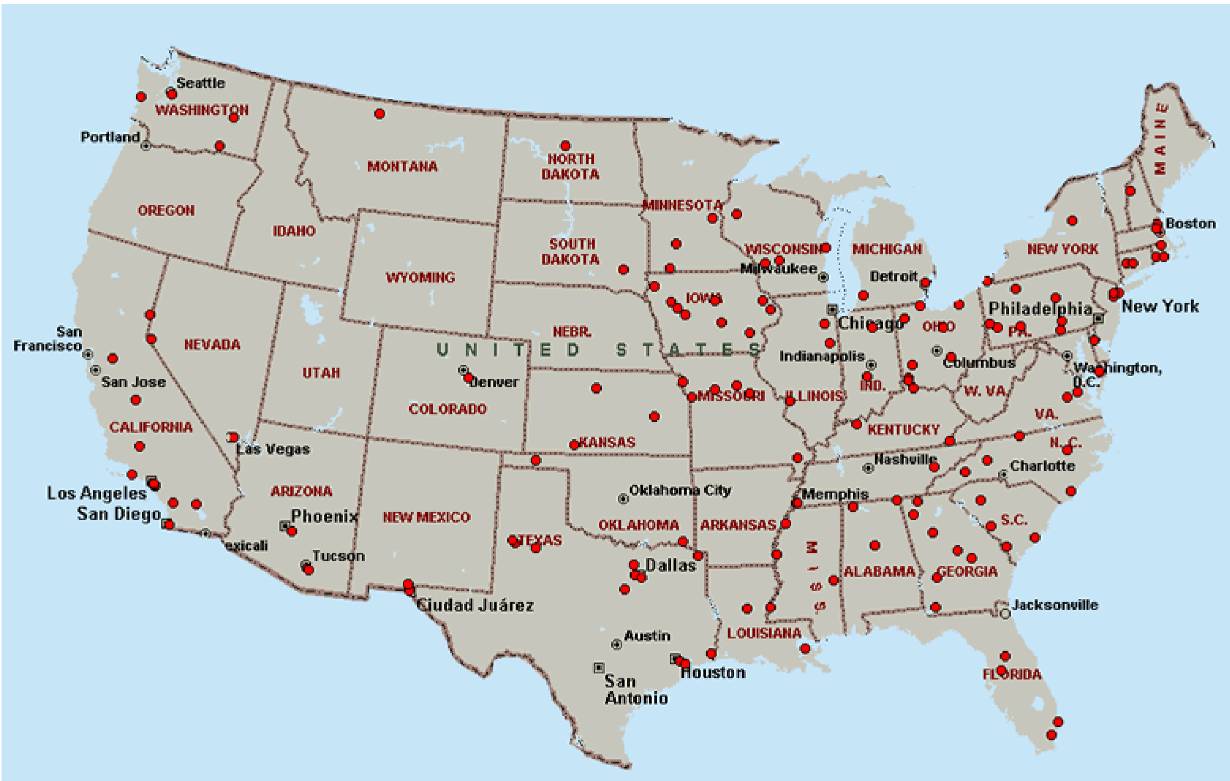

Figure 3: Biodiesel Plant Location. Source: National Biodiesel Board Website (NBB, 2009).

U.S. soybean production during the 2000s varied from 2.45 to 3.1 billion bushels depending on total planted acreage and yield (USDA/ERS, 2008). Despite the production increase from 2003 to 2006, down-bound shipment of corn and soybeans via the Upper Mississippi River declined from 950.5 million bushels to 760 million bushels during this period (USACE, 2009).

This decline can be partly attributed to the expansion of biofuels production in eight Midwestern states during this period. If this trend continues in the near future, it should be expected that substantial quantities of grain may be directed away from the Mississippi River, which could reduce traffic and congestion at its principal chokepoints, allowing other commodities to enter the River.

APPROACH

The primary objective of the project was to document a spatial equilibrium model of world grain economy and update model data to 2007–2008 production years. The updated model reflects recent changes in dynamics of grain transportation flows in reaction to explosive growth of biofuel market in the U.S. The model is intended to be used in order to analyze consequences/long-term effects of current energy policy on grain and biofuel-related transportation flows on inland waterways and short sea shipping routes.

The spatial equilibrium model of the world grain economy was originally developed for the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri. The model estimates flows of corn and soybeans by transport mode between 124 U.S. regions, 37 barge loading/unloading sites, six border locations, 17 U.S ports, and 24 foreign export and import regions. The model has been used by Fuller et al. (2000), to examine the role of the Panama Canal as a grain transport artery and to evaluate the effect of increasing Canal tolls on U.S. agriculture. A more recent edition of the model was calibrated for 2003–2004 production year and thus did not reflect the changes in production and consumption patterns due to increasing use of corn and soybeans for production of biofuels.

The key steps in updating the model were as follows:

- to identify data requirements and data sources for adequate representation of corn and soybeans production, consumption, and transportation patterns for 2007–2008 production year (the last year for which full data were available);
- to update the model structure in order to reflect changes in grain transportation flows and changes in energy policy;
- to re-estimate excess supplies and demands by region in order to reflect current situation in the grain markets;
- to determine current and projected grain/oilseed biofuel processing capacity and corn and soybean use by geographic sub-regions included in the model;
- to estimate produced biofuels that are likely to enter the Mississippi River for barge transportation; and
- to expand multi-modal network aspects, update modal shipping rates, and representation of the international shipping network.

METHODOLOGY

MODEL DESCRIPTION

The spatial, inter-temporal equilibrium model of grain transportation employs quadratic programming to maximize the total net welfare. The latter is determined as producer plus consumer surplus minus grain handling, storage, and transportation costs. The theoretical underpinnings of the model can be found in Samuelson (1952) and Takayama and Judge (1971).

The domestic portion of the spatial model includes 75 excess corn supply regions, 107 excess soybean supply regions, 67 excess corn demand regions, and 35 excess soybean demand regions. Each geographic region in the domestic portion of the model is a crop reporting district or an aggregated crop-reporting district. Crop reporting districts are statistical units used by USDA and generally include from 10 to 20 counties.

Excess corn supply regions tend to be concentrated in the Corn Belt even though this area consumes large quantities of corn for feed, food, alcohol, and industrial uses. Important excess demand regions for corn are in the East-Central U.S. (largely in North Carolina), South-Eastern U.S. (primarily Alabama, Georgia, Mississippi, and Arkansas), Texas, and California. Excess soybean supply regions tend to be located in Arkansas, Corn Belt, and the Dakotas. Excess soybean demand regions are generally located in the Corn Belt, and southeastern states.

The foreign component of the spatial model includes six corn excess supply regions and 29 corn excess demand regions. Foreign corn suppliers include the Black Sea region (Moldova, Ukraine), South Africa, India, Thailand, China, and South America, which includes Argentina, Brazil, Paraguay, and Uruguay. In terms of excess demand, Canada is divided into two, Mexico into five, and European Union into two regions. Japan, Taiwan, and Korea are each represented by one region. The remaining excess demand regions are groups of contiguous countries.

India, Canada, and South America (Argentina, Brazil, and Paraguay) are foreign excess supply regions in the soybean model. Twenty-three regions are identified as foreign soybean excess demand regions. China, Japan, Korea, and Taiwan are each represented by one excess demand region, Mexico is divided into five excess demand regions, Canada is represented by two regions, European Union is also represented by two regions, and other foreign soybeans excess demand regions are groups of contiguous countries.

Grain supply is generated in the fall quarter (northern and southern hemisphere) and carried forward into subsequent quarters. Interregional trade occurs as a result of the quarterly regional excess demands that provide an incentive for trade. Grain storage occurs in the excess supply region until shipped via the transportation/logistic network to applicable locations.

Grain handling costs are incurred at country elevators and inter-modal transfer facilities (barge loading/unloading facilities and ports). Domestic trade is facilitated by a transportation network that links domestic excess supply regions with barge-loading sites, domestic excess demand regions, and ports. In the model, these links are represented via grain handling and storage charges, and quarterly truck, rail, and barge rates.

Grain barge loading sites on the inland waterways are linked to barge unloading elevators at Gulf ports and barge unloading elevators on the lower Mississippi and Tennessee River. These links are modeled through corresponding quarterly barge rates.

Included in the model are 40 barge loading/unloading sites located on the upper Mississippi (11 sites), Illinois (3 sites), Missouri (6 sites), Arkansas (3 sites), Ohio (4 sites), lower Mississippi (7 sites), Cumberland (1 site), White (1 site), and Tennessee (4 sites) Rivers. In the model, the upper Mississippi River elevators are closed above St. Louis during the winter because of freezing. River elevators at most sites are barge-loading facilities with the exception of the four sites on the Tennessee, two sites on lower Mississippi (Memphis and lower Mississippi River port) and a site on Cumberland (Nashville) that may both ship and receive grain. The truck and rail modes connect these river's barge unloading elevators on the lower Mississippi and Tennessee Rivers to nearby excess demand regions. This is modeled through corresponding costs of receiving and loading grain to truck and rail modes.

Domestic excess supply regions are also linked by truck and railroads to the port elevator locations at lower Mississippi River, east Gulf (Mobile), north Texas (Galveston, Houston, Beaumont) south Texas (Corpus Christi), Puget Sound (Seattle), Columbia River (Portland), north Atlantic (Baltimore), south Atlantic (Charleston), Duluth/Superior, Chicago, and Toledo. The truck and rail links are represented by the corresponding quarterly rates.

The ports may ship directly to foreign excess demand regions, which is represented by corresponding quarterly bulk grain carrier rates. The barge unloading elevators at Gulf ports incur charges associated with receiving the grain and loading the grain to ocean vessels. The Great Lakes ports (Duluth/Superior, Chicago, and Toledo) may ship either directly to foreign excess demand regions via ocean-going vessels (salties) or via vessels that shuttle grain between the Great Lake port elevators and the lower St. Lawrence River elevators (Baie Comeau). Grain that moves to Baie Comeau is subsequently loaded to large bulk grain carriers that travel to foreign excess demand regions. In the model, the three Great Lake ports are closed during the winter months due to freezing while Baie Comeau is open year-round.

Domestic excess supply regions are also linked directly to excess demand regions and all U.S. ports by truck and rail modes. Selected domestic excess supply regions are also linked to foreign excess demand regions in Mexico and Canada. Mexico may also import grain via an ocean port (Veracruz), which is then shipped by truck and/or rail to the appropriate excess demand regions. All of these links are modeled via corresponding grain loading (supply region) and unloading charges (excess demand region or port) and quarterly truck and rail rates.

Foreign excess supply regions are represented by upward sloping linear price-quantity relationships, with grain prices represented as free-on-board (FOB) ship. Links between domestic and foreign ports and foreign excess demand regions are modeled by quarterly ship rates that connect representative ports in each region.

Representative foreign ports associated with foreign excess demand regions include Odessa, Ukraine, for Ukraine and Moldova corn exports; Durban, South Africa, for corn exports from South Africa; Madras, India, for corn exports of that country; Bangkok, Thailand, for corn exports from Thailand; Dalian, China, for corn exports from China, and Sao Paulo, Brazil, for exports of Argentina, Brazil, Paraguay, and Uruguay. In the soybean portion of the model, Sao Paulo is also used as the representative port for Argentina, Brazil, Paraguay, and Uruguay exports. Canada is allowed to export soybeans through its west coast ports (Vancouver) and St. Lawrence River ports (Quebec), while India ships soybeans via Madras.

Representative foreign ports for foreign excess corn demand regions (importers) include Rotterdam and Hamburg for European Union North; Genoa for European Union South; Haifa for East Mediterranean; Algiers for North Africa; Damman for Persian Gulf; Singapore for Southeast

Asia; Kaohsiung for Taiwan; Ulsan for Korea; Yokohama for Japan; Veracruz for Mexico; Callao for West South America; Puerto Cortes for Central America; and Maracaibo for Caribbean/North South America.

For soybeans, the primary foreign ports and associated excess demand regions include Rotterdam and Hamburg for European Union North; Genoa for European Union South; Haifa for East Mediterranean; Damman for Persian Gulf; Singapore for Southeast Asia; Kaohsiung for Taiwan; Ulsan for Korea; Yokohama for Japan; Shanghai for China; and Veracruz for Mexico.

The model includes detailed representation of each of the U.S. and foreign regions' excess demands and supplies as well as transportation, storage and grain handling rates/charges. Several constraints are imposed when maximizing the objective function, viz. regional supply and demand balance, transportation mode balance, and storage capacity balance for each region, type of grain, and quarter.

Formally, the model can be written as:

$$\max\left\{-\sum_i\sum_c\sum_q\left(\alpha_{icq}+0.5\beta_{icq}S_{icq}\right)S_{icq}+\sum_j\sum_c\sum_q(\alpha_{jcq}-0.5\beta_{jcq}D_{jcq})D_{jcq}\right.$$
$$\left.-\sum_i\sum_c\sum_q\sum_j\sum_m C_{icqjm}T_{icqjm}+\sum_i\sum_c\sum_q k_{icq}I_{icq}\right\}$$

s.t.

$$D_{icq}-\sum_j\sum_m T_{icqjm}-I_{ic(q-1)}\leq 0\ \ \forall i,c,q \qquad \text{(demand balance)}$$
$$S_{icq}-\sum_j\sum_m T_{icqjm}+I_{ic(q-1)}\leq 0\ \ \forall i,c,q \qquad \text{(supply balance)}$$
$$T_{icqm}^{out}-T_{icqm}^{in}\leq 0\ \ \forall i,c,q \qquad \text{(transport balance)}$$
$$I_{icq}\leq I_{maxcap}^{T}\ \ \forall i,c,q \qquad \text{(storage balance).}$$

Here *S* is excess supply, *D* is excess demand, *C* is transportation and grain handling cost per metric ton for truck, railroad, barge, and ship modes as appropriate, *T* is grain flow in metric tons between nodes, *k* is storage cost per metric ton, *I* is the quantity of grain stored, *α* and *β* are parameters of the price function, and *i*, *c*, *q*, *j*, and *m* index excess supply regions, crops, quarters, excess demand regions, and transportation modes, respectively.

Output of the spatial equilibrium models determines:

- grain production, consumption, and price for each region,
- excess supply and demand by region,
- trade flows between all domestic and foreign regions, and
- the responsible transport mode at each link in the logistics and transportation network that participates in the interregional grain flow.

In order to generate a fully parameterized model, it is necessary to estimate international and domestic excess supply and demand equations; truck, railroad, barge and ship rates; as well as grain storage and handling charges.

Excess Supply and Demand Equations

For each region, the excess supply equation was constructed using an estimate of the excess supply elasticity, quantity exported from the region, and representative price. More specifically, these data were used to estimate the slope and intercept terms of the inverse excess supply equation. In a similar manner, inverse excess demand equations were estimated for each region using excess demand elasticity, quantity imported into region, and a representative price (Shei and Thompson, 1977).

Domestic own-price demand and supply elasticities were obtained from econometric models developed by FAPRI at the University of Missouri–Columbia (2008). Information on domestic corn and soybean production by crop reporting district was obtained from the databases of National Agricultural Statistical Service, U.S. Department of Agriculture (USDA/NASS, 2009). USDA also provided aggregated national estimates of domestic corn use and soybean crush (USDA/ERS, 2009, USDA/NASS, 2009). However, corn consumption and soybean crush by region (crop reporting district) was estimated using data from multiple sources.

Using the estimates of regional production and consumption, regional quantities exported and imported were calculated. The latter were then used to determine regional excess supply and demand elasticities. Finally, the regional elasticities combined with associated exports and imports, and regional prices, allowed for derivation of the regional excess supply and demand relationships. Specific details of the derivation process can be found in Fuller et al. (2000).

The USDA/ERS estimated domestic corn use in 2007–2008 at 10.3 billion bushels. An estimated 4.34 billion bushels was used for food, alcohol, and industrial uses. Another 5.94 billion bushels was used as animal feed and residual. The remaining corn was used as seed (USDA/ERS, 2009).

Domestic corn consumption by livestock, poultry, and dairy was estimated using population data and representative rations for the 2007–2008 crop year. The 2007 Census of Agriculture (USDA/FAS) provided information on county populations, which were subsequently adjusted by state data for 2007–2008. Additional information on livestock and poultry population was obtained from several USDA publications (USDA/NASS, 2008b, USDA/NASS, 2008a, USDA/NASS, 2008e, USDA/AMS, 2009b, USDA/NASS, 2008c, USDA/NASS, 2008d).

Overall domestic soybean crush in 2007–2008 was estimated at 1.83 billion bushels (USDA/ERS, 2008). Soybean crush by region (crop reporting districts) was constructed using monthly crush statistics provided by the National Oilseed Processors Association (NOPA, 2009) and a list of soybean crushers' capacities and locations. Domestic corn and soybean price by crop reporting district was based on a data set of daily prices paid by elevators, terminals, and processors across the United States.

Excess supply and demand elasticities for foreign regions and/or countries were estimated using own-price demand and supply elasticities obtained from the models developed by FAPRI. In addition, data from the Production, Supply and Distribution (PS&D) database compiled by the Foreign Agricultural Service (FAS) of USDA was an important source of information for estimation of excess demand and supply parameters (USDA/FAS, 2009d). In particular, the PS&D database includes information on each country's production, beginning stocks, imports, exports, feed, total disappearance and ending stocks by crop year. The FOB ship grain prices were obtained for many countries from public information sources with the remainder estimated from available price data and ship rates.

The temporal dimension of U.S. international corn and soybean trade was obtained from the FAS Global Agricultural Trade database (USDA/FAS, 2009c) and Global Agricultural Information Network (formerly Attaché Reports) database (USDA/FAS, 2009b), which offer estimates of monthly/quarterly exports and imports for selected corn and soybean exporting and importing countries.

Transportation and Logistics Network

The transportation and logistics network in the U.S. portion of the spatial model links excess supply regions to barge loading facilities, ports, and excess demand regions by applicable modes. Virtually every excess supply region (crop reporting district) within 200 miles of the upper Mississippi and Illinois Rivers is linked to a barge-loading location on the upper Mississippi and Illinois Rivers through a truck route. Many of the excess supply regions are linked to the river elevator sites by railroad routes if the rail configuration lends itself to these routings. Similarly, all excess supply regions are linked by truck, and/or rail, to one, and likely two or three, port areas. The links are expressed in terms of transportation costs for the appropriate modes.

Truck rates in the spatial model are estimated with a regression that is based on data included in the USDA’s *Grain Transportation Report* (USDA/AMS, 2008). Railroad rates are estimated using rates from USDOT’s 2007 and 2008 Public Use Waybill report (USDOT/STB, 2007; 2008). The waybill data were segregated by railroad corridors and then used to estimate rates between excess supply regions and ports, barge loading sites, and excess demand regions.

Grain barge export rates that link the upper Mississippi, mid-Mississippi, lower Mississippi, Illinois, and Ohio Rivers to lower Mississippi River ports are collected by the USDA (USDA/AMS, 2009a). These weekly barge rate data are averaged by quarter to obtain export barge rates and, for barge movements to the Tennessee River, the available rates are adjusted in accordance with mileage and tow size.

International grain ship rate data are obtained from the USDA’s Agricultural Marketing Service and the International Grain Council. These data relate originating world region, originating port, destination world region, destination port, date of shipment, shipment terms, size of cargo, and rate.

In the U.S. portion of the spatial models, grain-handling charges at country elevators are included as are intermodal transfer charges at barge loading and unloading sites, and ports. In addition, storage charges are included in both the domestic and foreign portions of the model. The necessary data were obtained from company websites and conversations with industry personnel.

Findings

The data collection and transformation steps outlined above required:

- searching for, manipulating, and aggregating information from several different databases;
- estimation of economic parameters of grain demand and supply functions for each of the 150+ regions represented in the model; and
- construction of transportation networks for each mode along with modal interchange points and estimation of corresponding transportation charges.

The updated database for the spatial grain transportation model is the primary output of the project. This section presents a description of the individual datasets and steps involved in their construction. The datasets themselves are provided as a supplement to this document in the form of a computer media and can be used by interested parties either directly or as an input to the grain transportation models.

Corn and Soybean Excess Supply and Demand

Domestic corn and soybean excess supply and demand (surplus/deficit) is obtained for each region (crop reporting district or CRD). Since many states have common CRD enumeration system, each CRD is assigned a unique number for identification purposes. Whether the region is identified as a surplus or deficit region is determined by the difference between total supply and total usage plus ending stock (in bushels). The total supply is determined as the stock of corn or soybeans in the beginning of 2007–08 marketing year (September 1, 2007) plus total production within a CRD. The total usage is comprised of:

- seed use,
- consumption for feed purposes, and
- consumption for food, alcohol, and industrial use (use for crushing purposes in case of soybeans).

The ending stock is the corn or soybeans on hand in the end of 2007–08 marketing year (August 31, 2008).

Seed used by each CRD is obtained as the total national seed use times the CRD's share in the total national planted acreage of corn or soybeans. Corn consumption for food, alcohol, and industrial use is obtained as the aggregate corn utilization of wet and dry corn millers (for food, alcohol, and ethanol production) within each CRD. Soybean consumption by soybean crushers in each CRD is obtained as state crush estimates times the CRD's share in total state crushing and capacity utilization. The capacity utilization estimates are obtained from company websites, industry experts, and other publicly available data. The feed estimates for corn are based on per animal consumption of corn for each type of animal and number of animals in each CRD. All necessary data for these calculations are obtained from the USDA website.

Ethanol Refinery Location

The changes in corn and soybean transportation patterns due to increasing production of biofuels as of 2007–2008 crop year is incorporated in the model through the data on consumption of corn and soybeans for industrial use. Furthermore, a list of ethanol refineries currently operating and under construction as well as their production capacities was obtained from the Renewable Fuels Association website (RFA, 2010a). This list was matched with the model regions so as to allow projections/scenario analysis reflecting future changes in the dynamics of biofuel production in the U.S.

Corn and Soybeans Prices

Domestic quarterly per-bushel corn and soybean prices at the CRD level are obtained as the quarterly average of Posted County Prices (PCP) obtained from archived datasets maintained by the Farm Service Agency (USDA/FSA, 2009).

Quarterly FOB prices (in $US/metric ton[1]) for Argentina corn and soybeans were obtained from the official website of Argentinean ministry of agriculture. Quarterly weighted average FOB port soybean prices for Brazil (in $US/MT) were calculated as the weighted average of soybean prices of major export regions times the weighted average transportation charges. These data were obtained from an Agricultural Marketing Service report (USDA/AMS, 2009b). Brazilian quarterly FOB corn prices ($US/MT) are calculated by averaging corresponding monthly prices and converting them into U.S. dollars. The necessary data were obtained from Foreign Agricultural Service reports (USDA/FAS, 2009a).

Elasticities

The long-run excess supply and demand estimates for both domestic and foreign excess supply and demand regions were based on own-price elasticities obtained from FAPRI. Because of the poor representativeness of prices during the 2007–08 period and related reasons elasticities for 2004–05 period were employed.

Domestic corn and soybean elasticity estimates are calculated for each CRD or, in some circumstances, for a group of CRDs. Foreign elasticity estimates are calculated for a specific country if it is a major importing or exporting country and for a group of countries otherwise. For example, major corn importing countries like Japan, Korea, and Mexico have country

[1] 1 metric ton = 39.4 bu of corn or 37.7 bu of soybean

specific elasticity estimates and non-major importing/exporting countries are pooled into broader geographic region.

Distance Data

Distance data includes (1) distance matrices (in miles) that link domestic, Canadian, and Mexican regions to model truck/railroad shipments and (2) an inter-port distance matrix (in nautical miles) linking domestic and international ports to model international grain shipments. Truck/rail distance matrix for domestic movements represented distances between CRD centers and was provided by Texas Transportation Institute. The grain trucking alternative was considered for distances of 400 miles and less, since trucking beyond that mileage is not practical or economically feasible for large shipments. Because Mexico imports U.S. grain via overland sites and primarily East Coast ports, it was necessary to estimate trucking distance between ports (primarily Veracruz) and five major corn and soybeans excess demand regions in Mexico

Separate inter-port distance matrices were constructed for corn and soybeans. Corn port distance matrix reflect links between the U.S. ports and representative foreign ports (see above), which in turn are connected to excess demand and supply regions. The port distance data are obtained from World Ports Distances Calculator at http://www.portworld.com/map.

Handling and Storage Charges

Grain handling and storage charges are included for a representative elevator in each CRD. In addition, grain handling charges are included at domestic intermodal transfer locations (barge loading/unloading sites and ports) Handling charges differ for each transport mode. All charges are in $US per metric ton. These data were obtained from publicly available sources and industry expert estimates. When estimating the excess supply equations for exporting regions, the port FOB price (free on-board vessel price) was used. Hence there was no need to explicitly include handling and transportation charges of these regions.

Rail and Truck Rates

Annual Surface Transportation Board (STB) public waybill data sets for 2007 and 2008 were used for the calculation of rail rates (USDOT/STB, 2007; 2008). Since the rail rates are reported for shipments between Business Economic Areas (BEA), a conversion procedure was implemented to transform data into rail rates for region-to-region (or CRD-to-CRD) shipments as required by the model. For each commodity, the rail transportation corridors that have high volumes were closely studied to obtain representative rail transport charges for that corridor.

Quarterly rates ($US/short ton-mile) were calculated as the arithmetic average of rail rates ($US/short ton-mile) within each corridor for each quarter. Quarterly rates for unit train shipments were calculated as the arithmetic average of rail rates (for shipments equal to or greater than 50 rail cars) within each corridor and for each quarter. These rates are typically lower than non-unit-train shipment rates. The movements that do not belong to any corridor are pooled into "all other" category and the quarterly average rates are calculated for three distinct distance categories—100 to 500 miles, 501 to 1000 miles, and over 1000 miles.

Truck rates were estimated from quarterly data obtained from the USDA's Agricultural Marketing Service. These data generated regression equations that estimated truck rates per ton-mile.

Barge Rates

The barge rate matrices contain barge rates ($US/ ton) from 33 origin barge locations (mostly along the Mississippi River system) to seven major barge destination locations—New Orleans, LA; Florence, AL; Huntsville, AL; Knoxville, TN; Memphis, TN; Nashville, TN; and Chattanooga, TN. These data were from the USDA's Agricultural Marketing Service. Rates are based on weekly per ton spot barge rates and the quarterly barge rates are calculated as the arithmetic mean of the weekly rates. Since the weekly spot barge rates report does not cover low-volume, small river origin and destination points, the rate estimates between those origin-destination pairs are obtained from private consultants and industry expert estimates.

Conclusions and Recommendations

The effort under the present project resulted in an updated and improved data set reflecting dynamics of grain transportation due to increasing production of biofuels in the U.S. A UTCM-funded project is currently underway to capitalize on the developed data set and provide further insight into effect of U.S. biofuel policy on inland waterway traffic and short sea shipping. The updated grain transportation model will be used by project investigators in conjunction with the grain transportation model in order to analyze the consequences of ethanol and biodiesel production on the transportation patterns along the Mississippi River and other modes. The datasets developed as a part of the project are available to interested parties in electronic format.

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