SOYDIESEL: POTENTIAL DOMESTIC AND WORLD SOYBEAN MARKETS

Harold W. Miller and Gary W. Williams

TAMRC Contemporary Issues
Report No. CI-1-95
May 1995
SOYDIESEL: POTENTIAL IMPACTS ON DOMESTIC AND WORLD SOYBEAN MARKETS

Texas Agricultural Market Research Center (TAMRC) Contemporary Issues Report No. CI-1-95, May 1995 by Mr. Harold W. Miller and Dr. Gary W. Williams, Texas Agricultural Market Research Center, Department of Agricultural Economics, Texas A&M University.

ABSTRACT: This study examines the economic impact of soyoil use as a diesel fuel (soydiesel) in the U.S. on the soybean, soymeal, and soyoil domestic and international markets. Also considered are the collateral impacts on other meal and oil markets as well as on the corn market. Two different scenarios of increased soyoil demand in the U.S. for soydiesel use are quantitatively analyzed using a simultaneous equation international trade model. The results indicate that even with the larger of the two scenarios, price increases for soyoil and soybeans are small due primarily to domestic supply increases and the response of foreign producers and consumers to the price increase.
SOYDIESEL: POTENTIAL IMPACTS ON DOMESTIC AND WORLD SOYBEAN MARKETS

EXECUTIVE SUMMARY

The provisions of recent environmental legislation have spurred research and development of alternative fuels and renewable energy sources. This study analyzes soydiesel as an alternative fuel for petroleum-based diesel. Two scenarios of increased soyoil demand for soydiesel use over a five year period are analyzed: 1) 158 mil lbs per year and 2) 886 mil lbs per year. The scenarios were chosen based upon a 30% replacement of the 1992 diesel fuel market in the U.S. by the year 2010 as mandated by the 1992 Energy Policy Act. The purpose of this study is to estimate the effects of each scenario on domestic and international markets for soybeans, soymeal, and soyoil. The quantitative analysis is performed by SOYMOD, a 96-simultaneous equation econometric model.

SOYMOD is an international trade model which incorporates market conditions in major soybean and soybean products trading regions, including the U.S., Argentina, Brazil, the European Union (EU), Japan, and a Rest-of-World (ROW) region. Each soybean product market in the U.S. has an excess supply which makes the U.S. a net exporter. The graphical intersection of the excess supply curve of the U.S. and the excess demand curve facing the U.S. determines the quantity of product traded and the world price. SOYMOD disaggregates the excess demand facing the U.S. into regional models of the domestic demand and supplies of soybeans and soybean products.

In the first year of each scenario, prices for soybeans and soyoil increase slightly above baseline. The price increases in years 2-5 are even more slight. The modest response of price is due primarily to supply adjustments by domestic soybean producers and increased soyoil production by soybean processors in the U.S., Argentina, Brazil, and the European Union (EU). The increased processing of soybeans to produce the higher priced oil results in an increased supply of soymeal leading to a decrease in world soymeal prices and an increase in soymeal use in livestock feeds. Corn is considered a complement to soymeal in livestock feed rations. Therefore, corn use as a feed increases along with increased soymeal consumption. Domestic corn supplies decrease, however, as some corn producers plant soybeans in place of corn in response to higher soybean prices.

The U.S. decreases exports of soyoil to meet the increased domestic demand for soydiesel use. This change in exports opens trade opportunities for other soyoil exporting countries. In response to higher soyoil prices, Argentina, Brazil and the EU crush more soybeans and increase soyoil exports. The simulation results are compared to the changes in prices and exports for soybeans, soymeal, and soyoil detailed in an unpublished study by the Food and Agriculture Policy Research Institute (FAPRI). The FAPRI results illustrate a pattern of low price responsiveness by the international community relative to the results of this study. This pattern may be explained by the use of a single equation to represent the excess demand facing the U.S. which leads to a less elastic (i.e. less price responsive) excess demand curve. Previous studies show that a single excess demand equation
cannot effectively represent the many factors involved in determining each region's excess supply or excess demand. A disaggregated excess demand function, such as the one used in this study, is proven to be a more accurate method in determining international price responsiveness.

In conclusion, the results of this study indicate that although there is a short positive impact on soyoil and soybean prices, the long-run effects are small. The primary forces which dampen the price increase in the long-run include domestic soybean supply increases and the response of foreign producers and consumers to the price changes. Increased supplies of soyoil internationally put downward pressure on soybean and soyoil prices. The FAPRI analysis appears to have underestimated the response of the international regions to price increases which allows for the U.S. soybean producers to enjoy higher price changes according to the FAPRI results. This study suggests that soybean producer groups continue development efforts for new markets for soymeal simultaneously with soyoil in order to experience larger price increases for soybeans in the future.
SOYDIESEL: POTENTIAL IMPACTS ON DOMESTIC AND WORLD SOYBEAN MARKETS

TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>ii</td>
</tr>
<tr>
<td>Executive Summary</td>
<td>iii</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Objectives</td>
<td>2</td>
</tr>
<tr>
<td>Literature Review</td>
<td></td>
</tr>
<tr>
<td>FAPRI</td>
<td>3</td>
</tr>
<tr>
<td>Anderson</td>
<td>4</td>
</tr>
<tr>
<td>Kane, Et Al.</td>
<td>5</td>
</tr>
<tr>
<td>Summary</td>
<td>6</td>
</tr>
<tr>
<td>Legislative Background</td>
<td></td>
</tr>
<tr>
<td>1990 Clean Air Act</td>
<td>7</td>
</tr>
<tr>
<td>1992 Energy Policy Act</td>
<td>8</td>
</tr>
<tr>
<td>Biodiesel</td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>10</td>
</tr>
<tr>
<td>Soydiesel</td>
<td>12</td>
</tr>
<tr>
<td>Structure of the Soybean industry</td>
<td></td>
</tr>
<tr>
<td>Background</td>
<td>13</td>
</tr>
<tr>
<td>Soydiesel</td>
<td>15</td>
</tr>
<tr>
<td>Methodologies</td>
<td></td>
</tr>
<tr>
<td>Conceptual Analysis</td>
<td>18</td>
</tr>
<tr>
<td>The Econometric Model</td>
<td>24</td>
</tr>
<tr>
<td>Simulation and Results</td>
<td></td>
</tr>
<tr>
<td>Results</td>
<td>29</td>
</tr>
<tr>
<td>FAPRI Comparison</td>
<td>38</td>
</tr>
<tr>
<td>Summary and Conclusion</td>
<td>42</td>
</tr>
<tr>
<td>References</td>
<td>46</td>
</tr>
<tr>
<td>Appendix Tables</td>
<td>48</td>
</tr>
</tbody>
</table>
SOYDIESEL: POTENTIAL IMPACTS ON DOMESTIC AND WORLD SOYBEAN MARKETS

The 1991 Persian Gulf War brought the issue of U.S. energy security to the political surface. National security concerns coupled with trends of increasing environmental awareness has spawned Congressional legislation mandating the research, development and use of alternative fuels and renewable energy sources. In Title III of the 1992 Energy Policy Act (EPACT), alternative fuels are defined as any fuel that the Secretary of Energy determines is "substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits." Examples of alternative fuels include compressed natural gas, alcohols, electricity, vegetable oils and animal fats (EPA). Renewable energy is any energy-producing natural resource that is inexhaustible. Examples include solar energy, hydropower, geothermal energy, wind and biomass.¹

In much the same way that ethanol markets developed in response to government mandated emission reductions in gasoline engines, markets are developing for biodiesels to aid in the reduction of diesel engine emissions. Soybean oil is a vegetable oil which has undergone extensive testing in diesel engines and proven to be a legitimate alternative fuel option. Soyoil also has the added benefit of being a renewable energy since it is a processed by-product derived from soybeans, a biomass energy source.

The use of soydiesel as a replacement fuel has the dual effect of decreasing U.S. reliance on foreign oil while increasing the quality of the air we breathe, which are the main goals of the EPACT and the Clean Air Act (CAA), respectively. Due to the presently higher costs per gallon for most alternative fuels compared to petroleum fuels, the use of fuels such as soydiesel will likely continue to be federally mandated and subsidized. Such mandates, consequently, will likely create a demand

¹Biomass is a biological resource (examples: crops, forests, animal populations) that is considered renewable given the flow of solar energy, reproduction, human restraint, and sound husbandry (RANDALL, P. 16).
for soydiesel which will in turn spur soydiesel fuel production. An increase in soydiesel production means an increase in the demand for the inputs of production, including soybean oil. This study focuses on the economic impact of an increase in the demand for soybean oil for use as a fuel in diesel engines. While the results of engineering studies are cited, the study is not an effort to determine which of the available alternative fuels is best. Instead, the engineering studies, along with the provisions of the EPACT and CAA, provide general support for research on the subject of soydiesel use.

OBJECTIVES:

The overall objective of this paper is to analyze the effects on the U.S. and world soybean and products markets of an expansion in the demand for soybean oil. Of particular interest is the effects of increased soyoil use in diesel fuels. Specific objectives include the following:

1. To justify soydiesel research using the results of engineering studies and the provisions of the EPACT and the CAA.

2. To qualitatively assess the soybean industry and predict the impact of an increase in soyoil demand on the soybean complex using a conceptual analysis.

3. To quantitatively analyze the impact of two simulation scenarios of soyoil demand increase for diesel fuel (158 mil lbs and 886 mil lbs) which are selected based upon a 30% replacement of the U.S. diesel market by the year 2010.

LITERATURE REVIEW:

A number of studies have been done on the use of ethanol as a fuel and the economic effects of such on the corn industry. There has been little research, however, on the impacts of soydiesel use on the
soybean industry. A 1994 study conducted by the Food and Agriculture Policy Research Institute (FAPRI) is the only one which specifically addresses soydiesel as a substitute for petrodiesel (petroleum-based diesel). Two other studies (Anderson and Kane, et. al.) analyze demand expansion programs for corn producers based on the usage of a corn byproduct as a replacement fuel. These analyses of the corn industry contain direct parallels to the objectives of this paper on the soybean industry.

FAPRI

The Food and Agriculture Policy Research Institute (FAPRI) of the University of Missouri analyzed the effects of a soydiesel market on the soybean industry in an unpublished report for the Department of Defense. FAPRI ran an econometric analysis under two different scenarios for a sustained annual soyoil demand increase. Scenario 1 assumes an increase in soyoil demand of 250 million pounds above baseline. Scenario 2 assumes an increase of 500 million pounds above baseline. Selected results of these scenarios are provided in Table 1.

The soybean price changes represent the changes in the first production year of the introduction of the demand increase. FAPRI notes that in the following years there is a supply response which "dampens" the price increase to a 5 cent per bushel increase and a 10 to 12 cent per bushel increase for scenario 1 and scenario 2, respectively. Over the long run, production adjusts to the increase in demand so that farmers receive a 2 cent per bushel price increase for every 100 million pounds of additional oil demand.

Table 1. Selected FAPRI Results: Changes from Baseline

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>250 MIL LBS</th>
<th>500 MIL LBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean prices</td>
<td>+ $.09/bu</td>
<td>+ $.18/bu</td>
</tr>
<tr>
<td>Soymeal prices</td>
<td>- $4.50/ton</td>
<td>- $9.00/ton</td>
</tr>
<tr>
<td>Soybean acres planted</td>
<td>+ 300,000</td>
<td>+ 500,000</td>
</tr>
</tbody>
</table>
The FAPRI study also analyzes the effects on the corn industry. In the years following the demand increase for soyoil, the study estimates a 100,000-200,000 acre decrease in area planted to corn. This is in response to higher soybean prices (corn producers decide to plant soybeans) and lower soymeal prices. Because corn and soymeal are close substitutes in the feed market, according to the FAPRI model, a soymeal price drop results in a decrease in corn feed demand.

The soybean price increases in the FAPRI study appear unreasonably large given the small increases in quantity of soyoil demanded. For example, soybean price increase of 9 cents per bushel represents a 1.5% price increase from only a 0.4% increase in soyoil production. In addition, even though there are several large soybean exporting countries (Ex: Brazil and Argentina), the results of the FAPRI study do not include any soybean supply responses by the international community.

In a 1993 study, Margot Anderson of the Economic Research Service analyzed the corn gluten feed (CGF) market. Ethanol and CGF are coproducts of the wet-milling process of corn. Therefore, much like soyoil and soymeal, any policy affecting one coproduct also has some effect on the other. Anderson used a partial equilibrium, static European Union econometric model which included 23 feed ingredients and four livestock categories. With this model, she analyzed two different policy changes: (1) the effect of proposed changes in EU farm and trade policies and (2) the effect of increased ethanol production due to proposed U.S. environmental policies, such as the reauthorization of the Clean Air Act.

The policy change of significance to this study is that of increased ethanol production from proposed U.S. environmental legislation. The U.S. is the world's major supplier of CGF, the production of which is determined by the demand for its higher-valued coproducts: ethanol and high-fructose corn syrup (HFCS). The demand for HFCS, according to Anderson, is not
expected to grow much due to market saturation. Growth in ethanol production depends on the Clean Air Act and the availability of alternative fuels.

Anderson's model projected that without reauthorization of the Clean Air Act, the 1995 baseline for CGP production would have been about 7.9 million tons. On the other hand, with reauthorization of the Act, ethanol production would increase to 2 billion gallons in 1995 (from 900 million gallons in 1989). This increase in ethanol production would increase CGF production to 9.1 million tons in 1995, an increase of 1.2 million tons above baseline. This increase in the U.S. CGF supply resulted in a decrease in EU CGF price, a decrease in U.S. CGF price, and, therefore, an increase in both U.S. exports and domestic demand for CGF in the Anderson study.

KANE, ET AL.

Kane, et al. analyze the economic role of ethanol in the U.S., its environmental impact, and the effects on agricultural industries from the use of ethanol as a fuel. The stated objective was to provide a factual basis for assessing the contribution of ethanol production to "national objectives" which include improved air quality, energy security, and alterations in agriculture policies. The study notes that due to approaching deadlines under the amended Clean Air Act, many metropolitan areas see ethanol blends in motor vehicles as a "painless" means of meeting required emission reductions. This potential for expansion of consumption of ethanol is viewed as a means to increase demand for grains and thereby support farm incomes, as opposed to traditional agricultural policy.

Kane uses a statistical model developed at the University of Illinois to assist in determining the effects of ethanol production on agriculture production, prices, and farm income. In order to simplify the projections of ethanol production, Kane constructs three ethanol production scenarios from 1988 to 1995: (1) low growth (5% annual growth), (2) moderate growth (13% annual growth), and (3) high growth (20% annual growth). These three scenarios are based on
different prices for oil, different production cost levels, and different government mandate levels. Each scenario naturally gives different results for the corn and oilseeds markets and farm income.

Kane finds that the primary effect of any increase in ethanol production is an increase in corn prices, the level of which depends upon how much corn is demanded and the willingness of farmers to shift acreage to corn production. Increased processing of corn means increased supply of ethanol's byproducts which includes corn gluten feed and corn oil, which are oilseed product substitutes. An increase in the supply of these byproducts without an equal increase in demand means a price decrease and a decrease in demand for oilseeds. For example, with large increases in ethanol production (high growth scenario), soybean market prices may initially fall by 20 percent. However, this negative impact on soybean price may be offset by a reduction in soybean supply during the following season as farmers switch to more profitable corn production.

The total effect of ethanol production on net farm income is determined by combining the gains to crop producers with the losses of livestock producers. Kane concludes that increased ethanol production increases net farm income. Therefore, an ethanol program may be effective in replacing some government income support programs. These effects are relatively small for moderate growth, and are more significant for the high growth scenario.

SUMMARY

In summary, the previous literature related to the topic and objectives of this paper contains some of the same general characteristics, but differs in the specifics. Anderson and Kane, et al. analyzed the demand expansion effects from ethanol use as a fuel on the corn and other markets. Because soyoil has been proven to be an effective diesel fuel, a similar study of soyoil and the soybean industry is needed. The FAPRI study analyzed the soybean market effects of soydiesel use. However, the price responsiveness of the model used seems too low. Also, the lack of results detailing the changes made in soybean production by countries other than the U.S. is
circumspect since soybeans and soybean products are traded internationally in large quantities.

**LEGISLATIVE BACKGROUND:**

Over the last few years, the U.S. Congress has passed some of the most comprehensive and specific environmental legislation in U.S. history. Examples include the 1990 Clean Air Act Amendments and the 1992 Energy Policy Act. One thing these new laws have in common is their impact on the research and development of soydiesel as an alternative fuel and renewable energy. The provisions of the CAA which relate to alternative fuel research will be briefly reviewed and followed by a discussion of the 1992 Energy Policy Act with an emphasis on their relationship to soydiesel.

**1990 CLEAN AIR ACT AMENDMENTS**

The Clean Air Act was originally signed in 1963 by the Johnson Administration. The latest amendment in 1990 is the most far reaching air quality regulatory document to date. The 1990 Clean Air Act Amendment provides federal assistance to the states through the Environmental Protection Agency (EPA) for scientific research, expert studies, engineering research and development and federal money to support clean air programs (EPA). The Act encourages the development of alternative fuels by mandating that harmful engine emissions such as carbon monoxide (CM), nitrogen oxides (NOx), particulate matter (PM) and sulfur be reduced to specified levels by a specified year. Initially, some emission reductions may be achieved with minor engine modifications and/or changes in the petroleum refining process. However, many of the emission reduction requirements will be difficult for manufacturers to meet without either major engine modifications or using a different source of fuel which burns cleaner than petroleum-based fuels.

Under the CAA, diesel manufacturers are required to reduce emissions in stages. Typically, diesel fuel contains 0.15-0.3 wt% (percent weight) sulfur. In the engine, 98% of the sulfur is combusted to sulfur dioxide and the remainder exits as particulate matter. By order of the 1990
CAA, diesel fuel sulfur content was limited to .05 wt% beginning in October 1993. In 1994, PM must decrease by more than 50%. In 1998, NOx must decrease by 20% (Farranto). Diesel engine engineers anticipate problems in meeting all stages of the reduction requirements due to what is termed the "NOx/particulate tradeoff." This means that when PM is decreased, NOx tends to increase, and vice versa. Since NOx will be the primary target of the CAA in 1998, alternative fuels will grow in importance through the 1990s as a means of controlling diesel emissions (Farranto). A later section on biodiesels will show that soydiesel is capable of overcoming the NOx/particulate tradeoff by decreasing PMs and NOx emissions simultaneously. First, however, we will review the relevant provisions of the 1992 Energy Policy Act.

1992 ENERGY POLICY ACT

While the Clean Air Act was in place to improve environmental air quality, on October 24, 1992 President Bush signed EPACT in "the first legislative attempt to curb U.S. oil dependence in more than a decade" (Cong. Quarterly). Key provisions of this document include promoting renewable energy and the use of vehicles that run on alternative fuels. The EPACT sets the course for a national energy strategy by requiring the Energy Secretary to develop a least-cost plan which promotes energy efficiency and seeks to limit harmful emissions. The plan will take into account the economic, energy, environmental, and social costs of various energy technologies.

One goal is to attain a 75% increase in the use of renewable energy by 2005, based on 1988 levels (Cong. Quarterly). The legislation proves its strong commitment to this goal by authorizing $275 million in appropriations for renewable energy research and development in FY1994. For biofuels, the appropriation represents a 19% increase in funding from 1992 (in 1992 constant dollars) (Congressional Research Service). In discussing the need for renewable energy, the EPACT states:

"Increased use of solar, wind, biomass, and geothermal energy will provide
environmentally benign energy, create economic benefits, and increase the security of energy supply" (USCAN, p. 1968).

The federal government pushes for renewable energy commercialization by means of joint ventures, production incentives and the subsidizing of low interest loans. As an example, Section 1204 of EPACT Title XII authorizes a payment of up to 2.5 cents per kilowatt hour generated to owners of power plants, built in the first ten years after enactment, that operate on renewable energy (USCAN).

The alternative fuel provisions of EPACT promote alternative fuels and replacement fuels (motor fuels that can be mixed with gasoline or diesel) with the specific goal of "replacing 30 percent of projected petroleum-based motor fuel by the year 2010" (USCAN). The 1992 Energy Policy Act addresses the demand side of alternative fuels through both federal and non-federal programs. The federal program requires that the federal government buy at least 5,000 alternative-fuel vehicles (AFVs) in 1993, 7,500 in 1994, and 10,000 in 1995. This mandate applies to any federal fleet of 20 or more vehicles located in an urban area (Cong. Quarterly).

Title IV of EPACT deals with the non-federal programs. Included in the non-federal programs area is a section amending the Alternative Motor Fuels Act (AMFA) of 1988, an alternative fuel bus program, and a nonroad vehicle program. The AMFA provided fuel economy credits to manufacturers of alcohol and natural gas AFVs. Section 403 of EPACT amends this to include all forms of alternative fuels. Section 411 authorizes a $30 million per year alternative fuel urban bus program in an apparent attempt to reduce diesel emissions which are notorious for generating a great deal of smoke and particulate matter. Section 413 also addresses diesel engines by requiring that a study be conducted on the benefits of nonroad AFVs which would include locomotives, boats, and agricultural equipment (USCAN).

In summary, the 1992 Energy Policy Act and the 1990 Clean Air Act have significant impacts on the research, development and deployment of alternative fuels and renewable energy sources. As
for diesel engines, the CAA identifies the need for reductions in sulfur and NOx emissions while the EPACT encourages the use of replacement fuels in diesel engines for economic, environmental, and national security reasons. Among the many tests done to find cleaner burning fuels, a large number of engineering studies have been conducted to test the feasibility of an alternative fuel commonly referred to as biodiesel which is produced from renewable resources (biomass).

**BIODIESEL:**

This section defines biodiesel and provides an explanation of its importance as an alternative fuel. Also, the manner in which biodiesels in general are able to meet the emission requirements set forth by the Environmental Protection Agency is discussed. Included is a discussion of test results providing evidence of biodiesel's compatibility with petrodiesel (or No. 2 diesel). Finally, soydiesel as a specific type of biodiesel is discussed.

**GENERAL**

Technically defined, biodiesel refers to an ester-based fuel oxygenate derived from biological sources for use in compression-ignition (diesel) engines (Holmberg). There are several reasons for biodiesel research and development. First, supplies of oil and natural gas in the U.S. are approaching economic limit. Second, traditional diesel fuel sources have been under threat from rising costs, quality deterioration, and supply disruption (Mazed et al.). Third, increased environmental awareness has led to laws calling for a reduction in harmful engine emissions. In pure form, biodiesel is biodegradable, non-toxic, and essentially free from sulfur and carcinogenic aromatic compounds. The question which agricultural engineers have attempted to answer in several studies is whether biodiesel meets the "substantially similar" requirements of the EPA.

In order to ensure that diesel engines meet the standards set forth by the CAA, the Environmental
Protection Agency requires that fuels sold for diesel engine use be "substantially similar" to certified diesel fuel. In determining whether a fuel is substantially similar, the EPA requires their emissions to be lower than or equal to the certifying fuel in the following emission categories: particulate matter (PM), total hydrocarbons (THC), carbon monoxide (CO), nitrogen oxides (NOx), and smoke capacity (Holmberg).

Although 100% biodiesel does function effectively in a standard diesel engine, the biodiesel industry has focused on the commercial development of blends of 20/80 biodiesel to petrodiesel (commonly called BD-20). This blend burns significantly cleaner than pure petrodiesel while being more cost-effective than pure biodiesel. Table 2 illustrates the emission reduction capabilities of BD-20 blend which qualify it as a "substantially similar" candidate. The best emission results have been obtained using the combination of BD-20, an injector timing change, and a catalytic converter (Holmberg). With just 20% biodiesel, both PM and NOx are reduced, thereby overcoming the problem of the "NOx/PM tradeoff" (discussed in the CAA section). The results of this and many other studies and demonstrations have shown that the "performance of biodiesel to be substantially similar to if not better than petrodiesel" (Holmberg).

As an illustration of its practical use and the reason for the biodiesel industry's pursuit of the urban bus and nonroad vehicle provisions of the CAA and EPACT, biodiesel has been successfully used as a motor fuel in a variety of equipment from watercraft to locomotives. In fact, biodiesel has accumulated over 8 million miles in demonstrations across the country mainly in urban buses (Holmberg).

**TABLE 2:** Biodiesel Emissions as Compared to No. 2 Diesel.

<table>
<thead>
<tr>
<th></th>
<th>PM</th>
<th>CO</th>
<th>THC</th>
<th>NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD-20 with engine timing change and catalytic converter</td>
<td>-26.8%</td>
<td>-72.8%</td>
<td>-73.2%</td>
<td>-3.1%</td>
</tr>
</tbody>
</table>

Source: Holmberg and Peeples: Biodiesel
The biodiesel which has been studied the most in the U.S. and is the most likely candidate as a government mandated alternative fuel because of its widespread availability is soydiesel. While rapeseed oil has experienced widespread use in Europe as a biodiesel, soyoil is preferred in the U.S. due to availability, relatively low cost, ease of use, and quality as a fuel (Banse). In one engineering study using soydiesel, the engineers concluded that "in terms of combustion behavior and exhaust emissions characteristics, soydiesel can basically be regarded as interchangeable with diesel fuel" (Holmberg).

The most likely areas for initial soydiesel market penetration are the farm, railroad, and off-highway (includes boating) markets. In 1992, these three markets consumed a total of 8,431 million gallons of petrodiesel (Weber). If soydiesel were to replace 30% of this market by the year 2010 (EPACT mandate), then 158 million gallons of soydiesel fuel would be required each year beginning in 1994. More optimistically, if soydiesel replaced 30% of the entire U.S. diesel market by the year 2010, then 886 million gallons of soydiesel would be required annually beginning in 1994.²

In summary, much engineering research has been performed and practical tests conducted to show that soydiesel is as good as and even perhaps better than petrodiesel. Soydiesel has the added benefits of being a renewable energy source, non-toxic, and biodegradable. These characteristics combined with the fact that the United States is the world's largest producer of soybeans make soydiesel fuel an excellent candidate to replace or supplement petrodiesel in order to meet the requirements set forth by the 1990 Clean Air Act and the 1992 Energy Policy Act. The production of soydiesel adds an extra component to the structure of the soybean industry which could have potential important impacts on soybean producers and world markets.

²Assumes that the 158 mil gal and 886 mil gal annual increases (approx. 2%/year) are co-incident with a 30% replacement of the respective diesel markets by the year 2010.
STRUCTURE OF THE SOYBEAN INDUSTRY:

This section provides some discussion of the structure of the soybean industry as background to the analysis of soydiesel impacts on that industry. First, a brief history of soybean industry is provided. This is followed by a qualitative analysis of soybean production procedures, processing methods, byproduct uses, and a basic description of the processing required to turn soyoil into soydiesel. The section ends with a cost comparison of soydiesel to No. 2 diesel.

BACKGROUND

History. Soybeans were introduced into the United States in the early 1800's from Asia. They were mainly cultivated for hay and were not processed in the U.S. until 1914. Soybeans have become a major cash crop in the U.S. over the last 50 years. In fact, since 1950 U.S. production has increased over seven-fold (Figure 1), making the U.S. one of the world's leading producers and the leading exporter of soybeans and its derivative products, oil and meal (Schaub et al.). Soymeal is used primarily as a protein source in livestock feeds. Soyoil has been used primarily in edible oil products, such as salad dressings and cooking fats and oils.

Production. The soybean is a legume and considered a short-day plant which means it can only be grown effectively between 20 and 50 degrees latitude. For this reason, and other climatic condition requirements, approximately 95% of the world's soybeans are produced in three areas: United States, east central South America, and China (Williams). In the U.S., planting occurs in May-June and harvesting from September to mid-November. Soybean production has experienced tremendous growth in the last 50 years, with U.S. production increasing over 600% from 1950-1993 (Schaub et al.). The popularity of soybeans with respect to other oilseeds is due to the quality of its protein meal and vegetable oil byproducts.

Soybean Processing. In the first stage of processing, soybeans are crushed to extract the oil from the bean, leaving meal and hulls (Figure 2). The hulls may be added to the meal to increase the meal
Figure 1: U.S. Soybean Production

(000) bushels


years
protein content. The most popular crushing method used today is solvent extraction which involves cracking the beans and then soaking them in a hexane solution to separate the oil (Schaub et al.).

The demand for crush is determined by the demand for and prices of the resulting byproducts. A bushel of soybeans when crushed will yield approximately 11 pounds of oil and 47 pounds of meal. On average, the meal accounts for about 62% of the value of the soybeans while the oil accounts for 38% (Schaub et al.). Recently, however, oil prices have been up so that soybean oil in 1994/95 accounted for over 49% of the product value (USDA).

Soybean meal is considered a high-quality livestock feed because the protein content is 42-50% which is much higher than most other oilseed meals (Williams). Therefore, soymeal is a valuable input in livestock production.

Soybean oil demand is considered the driving force behind the demand for crush (USDA). The oil is traditionally more ubiquitous than its meal counterpart since it can be found in some form in most households. Soyoil is the dominant vegetable oil on the U.S. market with a majority going into edible oil products, including cooking oils, salad dressings, baking and frying fats, and margarine. Over 47% of the soybean oil produced in the U.S. goes into salad and cooking oils (Schaub, et al.). One reason for a preference for soybean oil is the lower content of saturated fats relative to other oils on the market (Williams). An additional processing step is necessary to transform soyoil into soydiesel.

**SOYDIESEL**

**Soydiesel Processing.** To make soydiesel, pure soyoil with a viscosity higher than that of No. 2
FIGURE 2: Structure of the Soybean Industry

SOYBEANS

CRUSH

SOYOIL

COOKING OIL
SALAD DRESSING
ETC.

SOYMEAL

LIVESTOCK FEED

SOYDIESEL
diesel is combined with methanol and sodium hydroxide in a chemical process called trans-esterification (Banse). This chemical reaction causes the heavier carbon chains to settle out of the solution thereby leaving a less viscous methyl ester and glycerine by-product. The methyl ester can be used directly as a diesel fuel with a viscosity similar to that of No. 2 diesel. In 1992, Bryan Peterson travelled around the Pacific Ocean on a boat named Sunrider powered by 100% soydiesel. However, soydiesel is likely to be blended (20-40%) with petroleum-based diesel to optimize emissions reductions and reduce the cost less per gallon of the fuel (Banse).

**Soydiesel costs.** The one inescapable drawback keeping soydiesel from being used commercially now is its high cost per gallon compared to No. 2 diesel (Table 3). Although biodiesel is currently more expensive than some other alternative fuels, its use does not require major engine, vehicle, or infrastructure changes. Overall, therefore, biodiesel is competitive with other alternative fuels when the full "life-cycle" costs of alternative fuels are considered (Holmberg).

Eventually, the price of petroleum products may increase reflecting their increased scarcity. Also, technological advances and economies of scale from increased soydiesel production may lower soydiesel prices. It is, therefore, foreseeable that soydiesel may someday be more cost advantageous relative to No. 2 diesel. In the meantime, however, soydiesel use will likely be mandated and regulated by the federal government.
Table 3: Wholesale Fuel Cost Comparison

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>$/Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 2 diesel</td>
<td>0.70</td>
</tr>
<tr>
<td>Pure soydiesel</td>
<td>2.50</td>
</tr>
<tr>
<td>BD-20</td>
<td>1.06</td>
</tr>
<tr>
<td>BD-20 w/tax credit</td>
<td>.89</td>
</tr>
</tbody>
</table>

**METHODOLOGIES:**

This section begins with a conceptual analysis of the expected general impacts on soybean, soymeal, and soyoil supplies and prices from a federally mandated increase in soyoil demand for processing into soydiesel. This analysis will also involve the effects on substitute markets such as corn and other oilseeds. Then, the econometric model being used will be described.

**CONCEPTUAL ANALYSIS**

Soybean oil and meal supplies are determined directly by the quantity of soybeans demanded for crush. The supply and demand relationship between soybeans and its byproducts is known as the soybean complex. In this section, the soybean complex is graphically illustrated and described.

---

3 S.465 and S.1736, legislation introduced by U.S. Sen. Tom Daschle (D-SD), would extend a federal tax credit to manufacturers of biodiesel in a "manner similar to" the credits already available to alcohol fuels. Basing the value of the credit on the energy providing capabilities of the fuel, biodiesel would be eligible for a blenders tax credit equivalent to $0.85 per gallon (Holmberg, p.3 footnote).
Then the effects of increasing the demand of soybean oil on all three markets (soybeans, soyoil, and soymeal) in the short run and the long run will be analyzed graphically. Finally, the impact on corn and other oilseeds resulting from the price changes in the soybean complex will be discussed.

**General Description.** To facilitate the graphical analysis, definitions of the symbols used are first provided:

- BS, MS, OS = Supply of beans, meal, and oil, respectively.
- BD, MD, OD = Demand of beans, meal, and oil, respectively.
- PB, PM, PO = Price of beans, meal, and oil, respectively.
- EBS, EMS, EOS = Excess supply of beans, meal, and oil, respectively.
- EBD, EMD, EOD = Excess demand facing the U.S. of beans, meal, and oil, respectively\(^4\).
- XB, XM, XO = Export level of beans, meal, and oil, respectively.

The BS curve is vertical (perfectly inelastic) reflecting the fact that short run supply is available at the beginning of the year and cannot be changed during the year. The BD curve represents the domestic crush demand which results in the production of meal and oil. The trade panel for soybeans contains the EBS and EBD curves. Assuming away transportation costs and trade

\(^4\)The econometric model used in this analysis disaggregates the excess demand function into its component parts representing the major soybean and products exporting and importing countries. Importing countries (the EU, Japan, Rest-of-World) add to ED and exporting countries (Brazil and Argentina) subtract from ED. This could be written mathematically as follows: ED facing U.S. = EDEC+EDJ+EDROW-ESB-ESA.
barriers only for graphical simplicity, the intersection of these curves determines the world price for soybeans (PB) and the quantity traded (XB). The EBS is derived from the difference between supply and demand in the U.S., while the EBD curve is the aggregation of the excess supply curves of U.S. export competitors and import demand curves of importing countries.

Ceteris paribus, the price of soybeans determines the quantity of soybeans demanded by domestic processors (OAs in Figure 3). This quantity represents a fixed supply of meal and oil as illustrated by the MS and OS curves. These supply curves are also vertical because a given quantity of soybeans will yield a fixed supply of meal and oil when crushed. The meal and oil markets both face a domestic demand curve, MD and OD. The supply and demand differences in these markets determine the intercept and slope of the EMS and EOS curves since the U.S. is a net exporter of meal and oil. Each market also has a world price level (PM and PB) which are determined by the intersection of the respective excess supply and excess demand curves. Next, the effects on these markets due to soydiesel production will be analyzed.

**Increased soyoil demand.** The effects of soyoil demand increase on the entire soybean complex can be analyzed in four stages. The first three stages represent the short-run effects (i.e., no supply response) and the fourth stage represents the long-run effects. Stage 1 is the immediate impact on the soyoil market. Stage 2 is the impact on the soybean market, and stage 3 is the effects of supply adjustments in the meal and oil market resulting from stage two. Stage 4 is the dynamic effects due to supply adjustments over time.
Stage 1: As previously discussed, production of soydiesel results in an increased demand for soyoil. This is illustrated as a rightward shift of the oil demand curve (OD to OD'). Since the EOS curve is derived from a difference between domestic supply and demand, the immediate effect is a parallel shift left of EOS to EOS'. This results in less exports (XO') and an increase in the world price of soyoil to PO'. An increase in the price of soyoil has a positive effect on the profit margin of soybean processors. Therefore, increased oil demand translates into increased crush (i.e., increased demand for beans).

Stage 2: The increased bean demand (BD to BD') has a similar effect on the bean market as oil demand had on the oil market. Namely, a shift left of the EBS to EBS' along the EBD curve resulting in a higher price for beans to PB' and a decrease in exports to XB' which determines the level of crush at As'. This new crush level defines a new supply of meal and oil (MS' and OS', respectively) which introduces stage three.

Stage 3: In the meal market, the rightward shift of the meal supply translates into a rightward shift of EMS to EMS'. This results in a decrease in the meal price to PM' and an increase in meal exports to XM'. In the oil market, there is a similar effect where the excess oil supply curve adjusts back to the right from EOS' to EOS", thereby decreasing price to PO" and increasing exports to XO". This effect partially moderates the initial price increase for soyoil due to the stage 1 shift of the oil demand curve.

Stage 4: Over the long-run, soybean producers make planting decisions based on expected
soybean price. The supply adjustments give a dynamic effect to the soybean complex that includes changes in meal and oil supplies and world prices. This year's soybean price is the producers' best guess of next year's soybean price. Therefore, when prices are high this year, the soybean supply increases next year. Imagine the BS curve (Figure 3) experiencing a rightward shift each year in response to higher soybean prices the previous year. A rightward shift of BS causes a rightward shift of EBS and results in a decrease in the world price for soybeans. Processors respond to the lower soybean price by increasing consumption (crush) which increases the supplies of soymeal and soyoil. The increased supply in the meal and oil markets in turn cause a decline in meal and oil prices. Thus, supply adjustments put downward pressure on the prices of the soybean, soymeal, and soyoil markets over time.

In summary, the initial increase in the demand for oil causes price of oil to rise to PO' and then decrease to PO'' after additional beans are crushed. In the short run, soybeans experience an increase in price and quantity demanded. Since there is not a supply response in the first year, the domestic demand increase is met by exporting less beans. Although soymeal experiences no demand shifts, there is a shift in the MS curve which results in lower meal prices and an increase in domestic soymeal consumption and exports. Over the long-run, soybean supply adjustments cause prices in the bean, meal, and oil markets to decrease.

Other Oilseeds and Corn. Several other oilseeds, such as cottonseed, peanuts, and sunflower seed, as well as corn are processed into meal and oil. These products are substitutes for soymeal and soyoil. With the increase in price of soyoil, manufacturers of cooking oils and salad
dressings would likely substitute these other oils in production to replace the more expensive
soyoil to some extent. This change in demand will put downward pressure on the price of soyoil
and upward pressure on the price of the substitute oils. For soymeal, however, the decrease in
the price of soymeal will increase the quantity of soymeal demanded for livestock feed. This
will put upward pressure on the price of soybean meal and downward pressure on the price of
substitute meals or other sources of protein in feed rations which will be in less demand. Corn,
on the other hand, is largely a complement to soymeal in livestock feed rations and should,
therefore, experience an increase in consumption along with soymeal. The result would be
upward pressure on the price of feed corn.

THE ECONOMETRIC MODEL

The analysis of the market effects from soydiesel production is performed by SOYMOD, a
model of U.S. and world soybean and corn markets developed by the Texas Agricultural Market
Research Center (TAMRC) at the Texas A&M University and co-owned by the American
Soybean Association. SOYMOD has its roots in the work of Houck, Ryan, and Subotnik on the
formulation of the U.S. soybean industry and follows from earlier work by Dr. Gary W. Williams
(Williams and Myers). It is a 96-equation econometric model which allows for simultaneous
determination of the supplies, demands, prices, and trade of soybeans and soybean products in
the U.S. and other major trading regions, including Japan, the European Union, Argentina, Brazil

---

5The figures and description of the World Soybean Model are taken from Williams and Myers.
and a Rest-of-the-World net importing region.

The market in each region is divided into 4 blocks: (1) a soybean block, (2) a meal block, (3) an oil block, and (4) an excess supply or excess demand block (Figure 4). The endogenous variables in each block respond to changes in exogenous variables such as prices of substitutes, technology, and income (see circles in figure 4). Each region of the model interacts with other regions of the model through price and trade linkages.

The markets of each region are linked in SOYMOD through international prices and trade flows (Figure 5). Equations (1) to (10) represent the soybean, meal and oil blocks of any exporting country in SOYMOD. Equations (14) to (23) represent the corresponding blocks of any importing country in the model.

The excess supplies of the exporting countries and the excess demands of the importing countries are represented by equations (11) to (13) and (24) to (26), respectively. Note that the ES and ED relationships are not behavioral. Rather, excess supply and demand are calculated as the simple differences between the domestic supply and demand schedules in the respective countries. The U.S. is an exporter of soybeans, meal and oil. Therefore, the domestic consumption is less than what is domestically produced of these products. The remainder is excess supply available for export.

The remaining equations represent the international price and trade linkages between exporting
and importing countries. Equations (27) to (29) represent the international price linkage. The prices for seed, meal, and oil in the exporting and importing country differ by transportation costs, exchange rates, tariffs, and subsidies which are represented by $Z_1$ and $Z_2$.

Equations (30) to (32) represent the flow of goods between countries. To clear the world market, the equations specify that the sum over all exporting countries of the quantity exported of soybeans, meal, and oil must equal the sum over all importing countries of the quantity imported of each.

SOYMOD is used in this study to simulate an increase in oil demand which means an alteration of equation (5) in Figure 5 for the U.S. market. Oil demand is separated in the model into two components for the U.S. market: soydiesel use and other domestic use. This paper analyzes the effects of increasing the amount of oil demanded for soydiesel use.

**SIMULATION AND RESULTS:**

SOYMOD is used to simulate two scenarios of increases in domestic soyoil demand for soydiesel production discussed earlier in the paper: 158 million lbs and 886 million lbs. The results of each of the two scenarios will be compared to baseline levels for five years of sustained increase in soyoil demand. Price changes are first quantified and discussed for each market. Then various markets will be individually analyzed in the following order: soyoil, soybeans, soymeal, other oils and meals, corn, and the international market. Lastly, comparisons are made
RESULTS

The discussion of results concentrates on the 158 mil lb scenario. The directional changes are the same for the 886 mil lb scenario but are of a greater proportional magnitude. The full simulation results are provided in appendix tables 1.1-1.10 and 2.1-2.10 for both the 158 mil lb scenario and the 886 mil lb scenario, respectively.

**Price Changes.** In general, prices for soyoil and soybeans increase while soymeal prices decrease in both scenarios as expected (Figure 6). In the first year, soyoil prices increase 1.1% for the 158 mil lb scenario and 6.4% for the 886 mil lb scenario. By the fifth year, the oil price increase dampens to .8% and 4.3% for the 158 mil lb and 886 mil lb scenarios, respectively. The dampening of the price increase between years 1 and 5 reflects the supply adjustment made by soybean farmers in response to higher prices for soybeans.

Similarly, soybean prices increase the most in the first year since soybean supply is fixed, making soybeans more scarce. Once supply adjustments are made in the subsequent years, however, the price increase virtually disappears. By the fifth year, soybean prices for the 158 mil lb scenario are only .05% above baseline projections, and only .29% above baseline for the very optimistic 886 mil lb scenario. Another factor which keeps soybean prices down is lower soymeal prices. The lower price for soymeal has a negative effect on the crush margin and thus
FIGURE 6: PERCENT CHANGES IN WHOLESALE PRICE

158 Mil Lb Scenario

<table>
<thead>
<tr>
<th>years</th>
<th>1st year</th>
<th>2nd year</th>
<th>3rd year</th>
<th>4th year</th>
<th>5th year</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>soybeans</td>
<td>0.35</td>
<td>0.05</td>
<td>0.08</td>
<td>0.06</td>
<td>0.05</td>
<td>0.12</td>
</tr>
<tr>
<td>soyoil</td>
<td>1.10</td>
<td>0.81</td>
<td>0.92</td>
<td>0.83</td>
<td>0.75</td>
<td>0.88</td>
</tr>
<tr>
<td>soymeal</td>
<td>(0.13)</td>
<td>(0.30)</td>
<td>(0.27)</td>
<td>(0.29)</td>
<td>(0.28)</td>
<td>(0.31)</td>
</tr>
</tbody>
</table>

886 Mil Lb Scenario

<table>
<thead>
<tr>
<th>years</th>
<th>1st year</th>
<th>2nd year</th>
<th>3rd year</th>
<th>4th year</th>
<th>5th year</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>soybeans</td>
<td>2.02</td>
<td>0.25</td>
<td>0.48</td>
<td>0.34</td>
<td>0.29</td>
<td>0.68</td>
</tr>
<tr>
<td>soyoil</td>
<td>6.41</td>
<td>4.65</td>
<td>5.32</td>
<td>4.72</td>
<td>4.31</td>
<td>5.08</td>
</tr>
<tr>
<td>soymeal</td>
<td>(0.73)</td>
<td>(1.74)</td>
<td>(1.53)</td>
<td>(1.63)</td>
<td>(1.58)</td>
<td>(1.44)</td>
</tr>
</tbody>
</table>
the demand for soybeans and, therefore, keeps the price of soybeans from rising very much. The average soybean price increase over the 5 year period is .04 $/bu for the 158 mil lb scenario.

The graphics for soymeal show the opposite price effects from those experienced by soyoil and soybeans. Price for soymeal decreases in the first year by .13% and .73% for the 158 and 886 mil lb scenarios respectively. In each of the subsequent years, this price decrease is greater than in the first year. The price decrease for soymeal exists because the supply of soymeal has increased due to increased crush to produce soyoil. This price decrease is smallest in the first year because increased crush comes mainly from ending stocks. Once soybean supplies adjust in years 2-5, more beans are crushed and more meal byproduct is produced, thereby putting greater downward pressure on soymeal price.

**Soyoil.** Total soyoil demand and supply increase in the simulation (Figure 8). Total soyoil demand consists of soydiesel use, other domestic use, and soyoil exports. For the 158 mil lb scenario, in the first year, exports decrease by 128 million lbs and other domestic uses decrease by 14 million lbs because consumers domestically and internationally buy less of the higher price product. As a result, the total demand for soyoil only increases by approximately 16 million lbs in the first year, a .11% increase. Note that the increased domestic demand for soyoil is almost entirely taken from soyoil exports. In years 2-5, the decrease in exports is about the same, however, other domestic disappearance decreases are slightly greater resulting in an average increase in total soyoil demand of 12.23 million pounds.
Figure 7: Soybean Changes From Baseline
158 million lb scenario

<table>
<thead>
<tr>
<th>year</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>total supply</td>
<td>0.00</td>
<td>1.82</td>
<td>2.29</td>
<td>2.83</td>
<td>3.11</td>
</tr>
<tr>
<td>total demand</td>
<td>1.09</td>
<td>1.80</td>
<td>1.99</td>
<td>2.33</td>
<td>2.51</td>
</tr>
<tr>
<td>exports</td>
<td>0.68</td>
<td>0.60</td>
<td>0.93</td>
<td>1.17</td>
<td>1.32</td>
</tr>
</tbody>
</table>

Figure 8: Soyoil Changes from Baseline
158 million lb scenario

<table>
<thead>
<tr>
<th>year</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>total supply</td>
<td>4.48</td>
<td>1.88</td>
<td>(1.23)</td>
<td>1.36</td>
<td>3.14</td>
</tr>
<tr>
<td>total demand</td>
<td>15.87</td>
<td>14.89</td>
<td>10.26</td>
<td>11.46</td>
<td>12.32</td>
</tr>
<tr>
<td>exports</td>
<td>(126.13)</td>
<td>(125.77)</td>
<td>(128.76)</td>
<td>(126.81)</td>
<td>(126.07)</td>
</tr>
</tbody>
</table>

Figure 9: Soymeal Changes from Baseline
158 million lb scenario

<table>
<thead>
<tr>
<th>year</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>total supply</td>
<td>9.79</td>
<td>28.65</td>
<td>25.77</td>
<td>27.97</td>
<td>28.81</td>
</tr>
<tr>
<td>total demand</td>
<td>9.72</td>
<td>28.11</td>
<td>25.34</td>
<td>27.52</td>
<td>28.38</td>
</tr>
<tr>
<td>exports</td>
<td>0.46</td>
<td>9.69</td>
<td>7.70</td>
<td>7.58</td>
<td>8.48</td>
</tr>
</tbody>
</table>

Figure 10: Corn Changes from Baseline
158 million lb scenario

<table>
<thead>
<tr>
<th>year</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>total supply</td>
<td>0.00</td>
<td>(0.81)</td>
<td>(0.80)</td>
<td>(0.59)</td>
<td>(0.33)</td>
</tr>
<tr>
<td>total demand</td>
<td>0.09</td>
<td>(0.28)</td>
<td>(0.39)</td>
<td>(0.26)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>exports</td>
<td>(0.06)</td>
<td>(0.28)</td>
<td>(0.41)</td>
<td>(0.47)</td>
<td>(0.49)</td>
</tr>
</tbody>
</table>
Total soyoil supply is a function of beginning stocks, imports and production. To meet the soyoil demand increase in the first year, ending stocks of soyoil are consumed and crush is increased using existing soybean stocks to give an increase in production of 4.48 mil lbs. In subsequent years, production levels are higher than the first year since more soybeans are available for crush due to increased soybean production. Due to decreases in beginning stocks, however, total supplies of soyoil are less than the first year.

**Soybeans.** The total demand and supply for soybeans increase for each scenario (Figure 7). The total demand for soybeans includes crush, exports, and other use. Increased crush demand to produce more soyoil increases soybean price. In the simulation, both domestic crush and exports increase. Exports increase because the EU region increases import demand for soybeans to crush and take advantage of higher world oil prices. The combined change in domestic crush and exports sums to an increase in total demand for soybeans of 1.09 mil bushels (.06%) for the first year of the 158 mil lb scenario and 6.35 (.32%) mil bushels for the 886 mil lb scenario. In subsequent years, the demand for beans is higher, driven by the demand for crush domestically and internationally. In years 2-5, U.S. soybean farmers respond to higher market prices for soybeans by increasing production.

Total U.S. soybean supply in the model is the sum of beginning stocks, imports, and production. In the first year of the simulation, soybean stocks are used to meet increased crush demand. Thus, in the second year of the 158 mil lb scenario, beginning stocks are down by 1.09 mil bushels which is subtracted from the 2.91 mil production increase to give a total supply increase
the second year of 1.82 mil bushels. Soybean beginning stocks are replenished in subsequent years due to soybean supply increases above the level of soybean demand increase. As a result, the total supply increases to a greater degree for years 3-5 because beginning stocks are above baseline in those years.

**Soymeal.** Unlike soyoil and soybeans, there is not a shift in the demand schedule for soymeal (see Figure 3). However, there is a shift of the supply schedule because more soybeans are crushed to produce oil for soydiesel, additional soymeal is also produced. The total supply of soymeal in the U.S. increases in the first year of the 158 mil lb scenario by 9.79 thousand tons (.03%) (Figure 9). In years 2-5, there is a greater supply of soybeans and a greater amount of crush so that soymeal supplies increase by an even greater amount. This increasing supply puts downward pressure on soymeal price which increases the level of consumption.

Increased consumption is represented by increases in domestic disappearance and exports. For the 158 mil lb scenario, total demand for soymeal increases 9.7 thousand tons (.03%) the first year and an average of 27.3 thousand tons per year (.09%) for years 2-5.

**Other oils and meals.** The model used here contains equations for peanut oil, peanut meal, cottonseed oil and cottonseed meal which are examples of substitutes for soybean oil and meal. With the increase in the price of soybean oil due to soydiesel production, the demand increases for other vegetable oils which are substitutes in the production of salad dressings and cooking oils. Peanut and cottonseed oils experience domestic disappearance increases of 1.2% in each
year of the 158 mil lb scenario and approximately 6.7% for each year of the 886 mil lb scenario.

In response to lower soymeal prices, the consumption of other livestock feeds decreases due to increased consumption of soymeal. Peanut meal and cottonseed meal exhibit this behavior in the model through decreases in domestic disappearance of approximately .12% and .68% annually (years 2-5) for the 158 and 886 mil lb scenarios respectively.

**Corn**. Corn production in the U.S. decreases in the second year of the simulation (Figure 10) as farmers shift acreage from corn to the more profitable soybean production. The decrease in corn supply is too small in the 158 mil lb scenario to indicate any associated price change. However, for years 2-5 of the 886 mil lb scenario, the price of corn increases by one cent per bushel (see Appendix: Table 2.5). This higher price decreases total corn consumption. The only good news for corn producers is that the consumption of corn as feed increases slightly since feed corn is a complement to soybean meal.

**International Markets**. Generally, fewer soybeans and soyoil are traded on the international market due to higher prices for these commodities (Table 4). The exceptions are the U.S. which increases exports and the EU which increases imports. Trade of soymeal, on the other hand increases due to its lower world price.

Argentina and Brazil are net exporters of all three commodities. Since the world price of soyoil increased in the simulation, these countries crush more beans to extract the higher priced oil for
Table 4: Summary of International Trade Effects

<table>
<thead>
<tr>
<th></th>
<th>SOYBEANS</th>
<th></th>
<th>SOYOIL</th>
<th></th>
<th>SOYMEAL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imports</td>
<td>Exports</td>
<td>Imports</td>
<td>Exports</td>
<td>Imports</td>
<td>Exports</td>
</tr>
<tr>
<td>ARGENTINA</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>BRAZIL</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>U.S.</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>EC-12</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>JAPAN</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>ROW</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
</tr>
</tbody>
</table>
export. Therefore, soybean exports decrease while the exports of oil and meal increase from both countries. The excess supply of meal predictably increased due to the increase in crush. Note that even though the world price of soybeans also increased, fewer beans are exported because the demand for domestic crush in the exporting countries is greater. The higher costs of soybeans as an input for processors is compensated for by the increased revenue from soyoil, i.e. the crush margin is greater.

Japan and the ROW are net importers of soybeans, meal and oil. Since the import price of soybeans and soyoil increased, imports of these commodities decrease for both regions (Table 4). Because the import price of soymeal has decreased, Japan and the ROW respond with increased soymeal imports.

In the U.S., the amount of crush increases, but the increase in soybean production is greater than the crush demand so that excess supply of soybeans actually increases. The level of U.S. soybean exports increases in each year of both simulation scenarios. The international demand for soybeans exported by the U.S. comes from the European Union. The EU imports soybeans and soymeal and exports soyoil. Although the price of soybeans on the world market increased, the EU increases imports of beans for crush in order to produce more of the higher priced soyoil for export. The EU increases exports of soyoil and decreases imports of soymeal because the domestic meal supply increased as a byproduct of increased crush.
FAPRI COMPARISON

The magnitude of the changes from baseline in the results of SOYMOD and the FAPRI model suggests linearity of the models. This linearity allows for the construction of an estimation table (Table 5) which can be used to determine the approximate market effects from any level of soydiesel use. Table 5 lists the results of a 100 mil lb increase in soyoil demand for soydiesel use. By multiplying any of the figures in Table 5 by five, the effects of a 500 mil lb increase can be estimated. Selected results of this calculation are compared to the results of the FAPRI model (Table 6).

The magnitude of the changes in prices and export quantities are significantly different between the two models. For example, the FAPRI results imply that soyoil price increases in the first year by 3.65 cents per pound while the SOYMOD analysis determined only a 1.00 cent per pound increase. Soyoil exports decrease by 141 mil lbs in the FAPRI analysis and by 402 mil lbs in the SOYMOD model. Note that while FAPRI estimates larger price effects than those from SOYMOD, the FAPRI estimation of export effects are less than those from the SOYMOD simulation. Soymeal exports do not appear to follow the same pattern of larger price effects and smaller export effects for FAPRI as compared to the SOYMOD results. However, as a percent of the increase in total demand, soymeal exports in the SOYMOD analysis do represent a larger change than the FAPRI model (35% v. 22%).
Table 6: 500 mil lb Scenario Comparison with FAPRI (1st year effects)

<table>
<thead>
<tr>
<th></th>
<th>FAPRI</th>
<th>SOYMOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean Prices ($/bu)</td>
<td>+.18</td>
<td>+.07</td>
</tr>
<tr>
<td>Soybean Exports (mil bu)</td>
<td>+1.00</td>
<td>+2.25</td>
</tr>
<tr>
<td>Soyoil Prices (cents/lb)</td>
<td>+3.65</td>
<td>+1.00</td>
</tr>
<tr>
<td>Soyoil Exports (mil lbs)</td>
<td>-141.00</td>
<td>-402.25</td>
</tr>
<tr>
<td>Soymeal Prices ($/ton)</td>
<td>-9.00</td>
<td>-.80</td>
</tr>
<tr>
<td>Soymeal Exports* (000 tons)</td>
<td>+74.00</td>
<td>+32.05</td>
</tr>
</tbody>
</table>

* 2nd year effects

These differences in the magnitude of change in prices and export levels between the two models for the soybean, soymeal, and soyoil markets are most likely due to the way in which each model depicts the excess demand curves facing the United States. Figure 11 illustrates that a less elastic excess demand curve (ED') allows for larger changes in price and smaller changes in exports when the ES curve shifts (ES to ES') than changes associated with shifts along a more elastic excess demand curve (ED). As previously described in the conceptual analysis section of this paper, the ED curve facing the U.S. in the SOYMOD model is the summation of the respective excess demand and excess supply curves for each importing and exporting region in the model. In other words, the total ED curve facing the U.S. is disaggregated so that each region's ED or ES curve is based upon the domestic market conditions and trade policies particular to that region. It may be the case that the FAPRI model aggregates excess demand functions facing the U.S. into a single equation for each of the three products (soybeans, soymeal, and soyoil) which would
Figure 11: Comparison of ED Elasticities
explain the low levels of international price responsiveness in the FAPRI analysis. Previous research shows that when excess demand and supply curves are disaggregated (as in the SOYMOD model), the importing and exporting countries are more price responsive. This price responsiveness is an accurate depiction of real world behavior. All of the factors necessary to properly specify the excess demand facing the U.S. (transportation costs, exchange rates, trade policies, etc. for each country) are "simply too much to ask of a single equation" (Gardiner and Dixit, p.36).

CONCLUSION:

The Clean Air Act and the Energy policy Act have led to an increase in the amount of money being spent domestically on alternative fuels research and development. Engineering tests funded by the soybean check-off programs have proven that soydiesel is a viable replacement fuel for diesel engines. Given that soydiesel is a viable alternative, this study assesses the impact of the production and use of soydiesel on the U.S. and world soybean and products markets. The impacts were analyzed using econometric results of simulated increases in soyoil demand for use as a diesel fuel. Two scenarios of soyoil demand increase (158 mil lb and 886 mil lb) were used based upon a 30% replacement of diesel markets by the year 2010 as mandated by the EPACT.

The results of this study indicate that although there is a short positive impact on soyoil and soybean prices, the long-run effects are small. For example, in the 158 mil lb scenario, the long-run price increase averages less than 1.0% for soyoil, and only approximately 0.1% for soybeans.
There are a combination of forces in action to prevent increases in prices from being as high as U.S. soybean producers might prefer. These forces include the demand for "other domestic uses" for soyoil, supply responses, the price of soymeal, and the international market.

When the demand for soydiesel use increases, this increases the price of soyoil and causes less soyoil to be consumed by the "other domestic uses" category of soyoil demand. In addition, a large portion of the domestic demand increase is taken directly out of exports. The result is that total demand for soybean oil in the U.S. increases by only a fraction of the amount demanded for soydiesel production because soyoil simply shifts out of one use and into another.

The slight increases in total demand for soybean oil (a less than 0.1% average for the 158 mil lb scenario) increase the demand for crush. Thus, the demand for soybeans boosts the price of soybeans initially. Over the long-run, however, supply adjustments are made domestically and internationally which dampen the price increase to zero for the 158 mil lb scenario and a slight .34% for the 886 mil lb scenario.

The more soybeans crushed means the greater the supply of soymeal on the market. With no demand shift for soymeal, the price goes down and partially undermines the increase in the crush margin created by higher oil prices. If soymeal prices were instead to increase, or at least remain at baseline levels, then the crush margin would increase more, thereby creating a higher demand and price for soybeans. This would provide more revenue increasing opportunities for soybean producers, as well as processors. Soybean producer groups may want to continue development

43
efforts for new markets for soymeal simultaneously with soyoil to avoid this problem.

Another force which interferes with soybean price increases for U.S. soybean producers is the market reaction of the international community. When world prices increase, the U.S. is not the only country ready to respond. Argentina and Brazil increase soybean production and both countries along with the EU increase crush. These increased supplies internationally put downward pressure on soybean and soyoil prices. The FAPRI analysis appears to have underestimated the response of the international regions to price increases which allows for U.S. soybean producers to enjoy higher price changes according to the FAPRI results. The low level of price responsiveness in the FAPRI model may be due to the estimation of the price elasticities of excess demand facing the U.S. in the soybean, soyoil, and soymeal markets. The model used in this study (SOYMOD) disaggregates the excess demand function into the individual excess demand and excess supply functions for the representative international regions included in SOYMOD and, therefore, gives a more accurate estimate of price responsiveness.

As a suggestion for further research, the results of this and other studies should be used to determine the increases in revenue to soybean producers that the soydiesel market is estimated to provide. A comparison of these revenues with the soybean check-off dollars invested into soydiesel research and development would give the members of professional soybean associations an idea of return on investment. In addition, the Kane, et. al. and Anderson studies reviewed in this study illustrate that ethanol production impacts prices of soybeans, soymeal, and soyoil. Since ethanol is currently being sold as a gasoline replacement fuel, it is suggested that
further studies combine the economic impacts of soydiesel use with analyses of the economic impacts of the growth in ethanol use as a fuel.
REFERENCES


Williams, Gary W. and Myers, Lester H. "The Economic Effectiveness of Foreign Market Development Programs: The Case of Soybeans and Soybean Products." International Agriculture Service. Chase Econometrics, Inc.