A Competitive Market in the Short and Long Run Exemplified: U.S. Biodiesel from 2004-2009

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Abstract

This paper discusses the U.S. biodiesel industry from 2004 to 2009 as an example of the competitive model. We illustrate several key concepts including firm and industry cost curves, short and long-run elasticity of supply and demand, firm entry and exit, and deadweight loss of subsidies. We provide some policy questions that may be addressed using the competitive model.

Introduction

When teaching Intermediate Microeconomics, one of most important topics is analysis of competitive markets in the short and long-run. If our models are not useful in explaining changes in competitive markets, then the course ends up as a theoretical exercise of limited use to students. We are therefore always interested in discovering new real-world examples that are best explained by appealing to the competitive model, including the ideas of firm and industry cost curves, short and long-run elasticity of demand and supply, and external economies and diseconomies.

Over the 2004-2009 period the market for biodiesel experienced dramatic changes, including large scale entry and variation in profitability. These changes are best explained by a straightforward application of the competitive model, and substantiate the model in a manner that seems intuitively correct to our students. We present this application, with some real world data, for other instructors to use when teaching the competitive model.

We first provide background information on biodiesel, including characteristics that motivated large scale Federal mandates and subsidies for its use. We then analyze short and long run equilibrium for both biodiesel and it major input, soybean oil. We are able to provide price and quantity information over time, as well as anecdotal information on profitability. The fate of one biodiesel startup provides a concrete example. One practical question motivating this case study is: “How can businesses that are the recipients of massive subsidization fail to thrive?” We end with policy questions that may be addressed by the competitive model.

A Description of the Product

Biodiesel is a renewable fuel that may be used as a substitute or supplement for petroleum diesel. It is primarily composed of vegetable oil that has been chemically modified to work in modern diesel engines, usually blended with petroleum at the one to twenty percent level (B_{20} is composed of twenty percent biodiesel and eighty percent petroleum diesel). One gallon of vegetable oil produces one gallon of biodiesel. Proponents of the fuel cite three advantages of biodiesel: environmental benefits including reduced air pollution and biodegradability, reduced petroleum imports, and greater economic returns for US agricultural producers.

The first two alleged benefits are subject to serious challenge (Dittmer & Wassell, 2008[1]), but were sufficient to result in substantial Federal subsidies and mandates. The American Jobs Creation Act 2004, signed in October of 2004, gave a $1 per gallon subsidy for each gallon of biodiesel blended into petroleum diesel. Mandated quantities were also scheduled to be phased in over time. Additionally, a number of

[1] Because of the inelastic supply of agricultural output in developed economics and growing world population, expanding demand for biofuels has resulted in widespread deforestation in the tropics.

states, particularly in soybean growing sections of the country, mandated blending biodiesel into locally sold petroleum diesel.

Analysis of Cost Functions for Biodiesel Production and Marketing

At the time the 2004 subsidies were passed, very few firms were capable of responding to the increase in demand for biodiesel. Other industrial processes could be switched to biodiesel production at low cost, but this required forgoing production of other goods, and networks for biodiesel distribution were not in place. A substantial increase in production required construction of new plants and equipment, as well as expenditures for distribution and marketing. This left the short term supply curve entirely dependent on existing producers or producers of related products.

The demand curve for biodiesel revolves around the price of petroleum diesel. Biodiesel has reduced energy per gallon, and may harm older engines if used in high concentration. These factors make it a less desirable product as compared to petroleum diesel. However, it is marketed as a "green" product because of its renewable nature, leading some consumers to have a higher willingness to pay than for petroleum diesel. Given sufficiently high prices, even these consumers will substitute away.

Another demand factor reducing biodiesel price elasticity is government mandates. Governmental agencies and some commercial blenders will make fleet purchases at a substantial price premium over petroleum diesel in order to satisfy Federal, state and local quantity mandates. This makes the demand more price inelastic at the mandated quantity.

A final limitation on the elasticity of demand relates to the distribution networks of biodiesel. In 2004 few retailers with infrastructure to market biodiesel existed. A substantial drop in biodiesel prices would still have resulted in limited additional sales because of limitations in these networks.

Figure One illustrates hypothetical demand and supply curves for 2004, with an equilibrium at the pre-subsidy/mandate average price and annual quantity. The price we provide is an average of several spot prices published by the Department of Energy taken over the course of the year (Clean Cities Alternative Fuel Price Report, 2004).

Figure Two A includes the type of demand and supply shifters we teach in microeconomics. In the 2005 diagram we shift the demand curve to reflect the 74 cent increase in the price of diesel and the expanding state and local mandates. We shift the supply curve to reflect the $1 per gallon subsidy, the decrease in the price of soybean oil, and the entry of additional biodiesel production facilities in response to the federal subsidy. The net result is a large increase in the quantity produced and consumed, with an inconsequential change in the market price.

Figure Two A allows the instructor to analyze the welfare effects of the $1 per gallon subsidy. Assuming any reduced pollution is offset by the effects of deforestation, the 2005 demand curve represents the social benefit of another gallon of biodiesel. The subsidy is captured in the increased supply curve – with $0.53 of the downward shift representing lower resource costs (lower soybean oil prices) and $1 representing the subsidy. Given our representation of the 2005 demand curve, shifting the supply curve down by $0.53 instead of $1.53 results in an equilibrium quantity of approximately 71 million gallons instead of the subsidized quantity of 91 million gallons. This difference in quantity – 20 million gallons – times the $1 per gallon subsidy results in a deadweight loss triangle of $10 million dollars.

In Figure Two B we represent somewhat hypothetical cost curves of a Washington State 2005 startup, Seattle Biodiesel. While we do not have complete production or cost information for this facility, we do know that it was designed for production of between 2 and 5 million gallons per year (Biodiesel Magazine, 2005). We assume $6 million in fixed costs, a constant marginal cost of soybean oil at the market price of $2.29 per gallon, and a rising marginal cost curve for all other variable costs. We justify these rising marginal costs by appealing to diminishing marginal product. Given existing equipment including various tanks, pipes and pumps, more biodiesel can be produced by adding inputs such as soybean oil, water, and labor, but the fixed nature of the capital equipment results in decreasing marginal product and increasing marginal costs.

Note that the blender, not the biodiesel producer, receives the $1 per gallon subsidy. We have reflected this by shifting market price received by the producer up by $1 per gallon. We have also subtracted off the average markup of retail petroleum diesel over its wholesale cost in order to reflect the difference between what the consumer pays and the biodiesel refiner receives. As we have constructed Figure Two B, Seattle Biodiesel experiences losses, but does cover all variable costs (Timmerman, 2007).

Its production level is very near that which minimizes average total cost. Note that we draw the marginal revenue function as the market price, since Seattle Biodiesel is small enough to act as a price taker.

Seattle Biodiesel promoted its product as beneficial to the local community (State of Washington). For example its web site claimed:

> "**Made from Local Feedstocks"**
> Seattle Biodiesel works directly with regional farmers to develop the finest virgin feedstock oils for use in our processors. Our "farmers to fuel pump" approach and commitment to local production benefits our regional economy by keeping energy dollars within our communities.

During 2004 and 2005 the quantity of soybean oil turned into biodiesel was a relatively small share of the total soybean oil market. Consequently, the demand for biodiesel did not substantially increase the demand and price of soybean oil. Figure Three shows the 2006 increase in supply and demand for biodiesel. Small increases in the average price of diesel, combined with expanded marketing of biodiesel, increased the demand. As production increased, the price of soybean oil began to rise, but this decrease in firm-level biodiesel supply was offset by the many new biodiesel firms that had entered the market. Continuing anticipated profits created further incentive for entry.

Seattle Biodiesel reacted to this continuing growth in demand by planning dramatic expansions in production. The company's president, John Plaza, announced plans for a 100 million gallon annual capacity plant in Grays Harbor County, a site with access to a deep-water port and rail lines. The development of this facility was encouraged by local and state government officials. Local officials desired increases in employment, for the Grays Harbor region had experienced significant loss in employment related to declines in the timber industry. State lawmakers passed legislation mandating 2 percent of the state's diesel be composed of biodiesel by 2008 (Roesler, May 10, 2006).

The connection to local and regional farmers was eliminated with the planned Grays Harbor facility. The deep-water harbor provided access to Malaysian Palm oil, and Plaza indicated that the plant would use whatever feedstock was least costly. "You have to be competitive on a cost basis, not just for the environmental or social play," said Plaza. "Otherwise, this would never grow the way we want it to grow." (Timmerman, 2007)

Seattle Biodiesel, now named Imperium Renewables, was able to acquire $214 million in private financing for both the expected $40 million (later revised to $65 million, then $78 million) Grays Harbor plant as well as newly planned facilities in the Northeast US and Hawaii (Environmental Leader, February 22, 2007). It opened its new 100 million gallon Grays Harbor plant in August 2007, and sold its 5 million gallon Seattle plant in 2009. Imperium's largest customer was the Royal Caribbean Cruise line, which planned purchases of 18 million gallons per year, and owned 7% of Imperium.

Imperium's owners planned an initial public offering, estimating the company was worth $345 million. These proceeds would be used to build additional plants, including one in Hawaii to supply an electric utility with between 5 and 12 million gallons of biodiesel per year (Hawaiian Electric Company, 2007).

Imperium's expansion plans were not unique. 2007 saw massive entry throughout the industry, with production capacity doubling. In Figure Four A we illustrate this by making the supply curve much more elastic. Increases in the price of petroleum, combined with expanding distribution networks, increased demand for biodiesel, but not of a magnitude to consume this massive increase in supply. Decreases in price were avoided by the development of a very large export market.

The European Union is the world's largest consumer of biodiesel. By 2007, US producers began taking advantage of the one dollar per gallon subsidy by exporting biodiesel blends to Europe. The subsidy was granted for blending biodiesel with petroleum diesel, and they did not depend on the location of the consumer (in Europe) or producer (potentially in Malaysia). As long as the blending process occurred in the US, the one dollar per gallon of biodiesel subsidy was granted. This subsidy made the US supply curve much more elastic, for if sellers received a relatively low price in the US market they had the option to export subsidized biodiesel to European markets. Net exports increased from 10 million imported gallons in 2006 to 132 million exported gallons in 2007.

Because exports were now a major component of the demand faced by US producers, we now move from a closed economy market – ignoring the international sector – to an open economy. Following standard treatment in introductory and intermediary texts, the market price becomes the international price, allowing net exports to become the difference between domestic supply and domestic demand. This model is correct in circumstances where the domestic economy is sufficiently small to have a negligible effect on international price. This is a reasonable approximation given the disparity between US and European biodiesel production and consumption.

Figure Four B represents for 2007 Domestic Demand, Domestic Supply, and the Domestic Social Marginal Cost curve. This is calculated by adding the $1 per gallon subsidy back into the private marginal cost or supply curve. Q_s represents domestic production (490 million gallons), Q_e represents the efficient quantity produced at the international price (290 million gallons). The deadweight loss is the difference times one half the per gallon subsidy, or $100 million dollars. This deadweight loss represents the additional cost of production beyond the revenue received by producers.

The structure of the subsidy also created the process of "splash and dash" (EIA, April 2009). Foreign biodiesel producers could divert bulk transport ships to US ports, add small quantities of petroleum diesel (satisfying the blending requirement), and then continue shipment to European markets. This diversion earned a dollar per gallon subsidy from the US Government. Legislation in 2008 ended this practice, but did not eliminate the subsidy for US-produced biodiesel. Any resource misallocation resulting in "splash and dash" is not included in the $100 million dollar estimate of deadweight loss, and a more complete calculation would include resources diverted into European biodiesel consumption.

Continuing domestic and export market profits resulted in further massive entry in 2008. Production capacity increased from 672 million gallons to 1,925.8 million gallons. While biodiesel producers had only been a small portion of the demand for soybean oil in 2004, with the doubling and redoubling of production biodiesel increased the demand for soybean oil and drove up its price. The soybean supply is very inelastic, for the simple reason that most fertile agricultural land is already in agricultural production. More soybeans are produced only by planting more acres in soy, which requires planting fewer acres in substitute crops, such as corn. However, the corn market was also subject to subsidy-driven increases in demand, in this case for ethanol.

Figure Five A displays this increase in demand and change in supply, with the supply curve becoming more elastic as US production capacity and exports to the EU increased. The flattening of the supply curve represents the combination of US capacity with a rise in soybean oil prices. The combination of these two changes makes it possible to sell much more on the US market if the price increased (because there was more capacity), but also creates a shut-down point at a higher price (because of the higher input price).

Figure Five B shows how the large increase in production capacity, and exports, increases deadweight loss. The deadweight loss of $100 million per year represents the additional cost of domestic production when biodiesel was available from international producers at a resource cost equal to the international price.

Figure Five C provides time series data on the output and price of soybean oil, as well as US production and industry capacity of biodiesel. The graph demonstrates the doubling of the price of soybean oil and the inelastic supply response on the part of soy farmers. This figure also suggests the reason for the run up in soybean oil prices – biodiesel production begins to use a substantial portion of the soybean oil crop.

This same Figure Five C gives industry capacity. New entry drives the price of biodiesel down and the cost of its major input, soybean oil, up. This is the long-run process that eventually limits entry and production. In the case of biodiesel, the addition of a substantial subsidy created short term profits for those firms able to produce, and stimulated construction plans for many additional plans.

Figure Five D shows hypothetical cost curves for Imperium's new 100 million gallon plant. We use soybean oil prices, although Imperium was designed to have access to less expensive Malaysian palm oil. We assume annual fixed costs of $10 million, and marginal costs (excluding the oil input) that are minimized at 20 million gallons after which they rise. Even with a high price of biodiesel ($4.38) and the $1 per gallon subsidy, the high price of vegetable oil makes Imperium unprofitable.

While these costs curves are at best approximations, we do know Imperium's fate. In 2008 the Royal Caribbean Cruise line canceled its contract and sold its equity stake in Imperium. The planned IPO was cancelled, and Imperium's CEO resigned. The planned construction of the Hawaii plant was canceled, with Imperium proposing a revised contract to supply the Hawaiian utility from its Grays Harbor plant.

Imperium's fate is an illustration of two very general economic principles: (1) expected profits attract entry into competitive markets, and (2) entry drives input prices up and output prices down, reducing expected profits.

2009 was a disastrous year for biodiesel producers. Total US production declined in spite of the completion of additional plants (Murphy, 2010). Several supply and demand changes drove this. First, the demand for biodiesel was reduced because of a significant decline in the price of petroleum diesel. 2008 petroleum diesel prices were on the order of $4 per gallon, while 2009 average prices were approximately $2.50. This drop in demand for both types of fuel was driven by economic recession in the US.

The drop in the price of soybean oil was of a similar magnitude to the drop in petroleum diesel – $4 to $2.50. Reduced demand for biodiesel reduced the price of soybean oil. Equally important for the US supply of biodiesel was the addition of tariffs on US production exported to Europe. European biodiesel producers successfully convinced the EU to add tariffs of between $1.40 and $2.50 per gallon (Biofuels Digest, 2009) because of the US $1 per gallon subsidy that applied to biodiesel produced in the US and exported to Europe. These tariffs created a gap between the international and domestic price, reducing net exports from 362 million gallons in 2008 to 91 million gallons in 2009.

Federal mandates, which would have guaranteed two billion gallons of biodiesel would be blended into petroleum diesel supplies, were delayed during 2009. In performing a life-cycle analysis, the EPA concluded biodiesel caused increased carbon dioxide emissions as compared to petroleum diesel. Soybeans used for biodiesel would have otherwise been used for human consumption. The reduced supply of soy based food products drove up vegetable oil prices, and increased production of food crops in tropical forests. This conversion of tropical forest to agricultural land released more carbon dioxide than the carbon dioxide saved by using biodiesel instead of petroleum diesel.

This ruling was modified by the Obama administration in 2010, qualifying soybean based biodiesel for Federal mandates. However environmental groups had by this point changed their view of biodiesel, and now opposed its production or use (Bradbury, 2010). Therefore, the political support for biodiesel was concentrated in producer organizations alone.

The final blow was the expiration of the $1 per gallon tax credit. The aggregation of these considerations resulted in a decline in demand for biodiesel, and in 2009 less biodiesel was produced than in 2008. At the end of 2009 the industry operated at only 15% of its capacity.

Imperium was one of the many idled refiners. After opening with much fanfare in late 2007, it had ceased production by the summer of 2008, and was using its facility for storage of South American biodiesel (Bernton, 2009). Its proposal to supply the Hawaiian utility from its Grays Harbor plant was denied because of projected costs. Washington State mandates were effectively repealed. The plant did begin production again at the end of 2009 in order to satisfy mandates for biodiesel use in Oregon and British Columbia, only to experience an explosion which forced it to close.

Classroom Discussion Questions

The example of biodiesel's development in the U.S. can be used to illustrated changes in short and long run equilibrium in a competitive market. It should provide a concrete example for students that is more interesting than widgets or compact disks. The Microsoft Excel graphs may be downloaded off of our website for in class use.[2]

[2] Graphs are available at: http://www.cwu.edu/~dittmert

The example also may be used to address policy questions. We suggest the following list for classroom discussion:

1. How does the elasticity of the long run industry supply curve for soybeans relate to the elasticity of long-run supply for biodiesel?
2. How would knowledge of the elasticity of the supply curve for soybeans help an economist predict declining margins for biodiesel producers?
3. Under what conditions will the subsidization of biodiesel result in deforestation in the tropics? Will the following facts be important in answering this question:
    a. The supply curve for US produced soybeans is very inelastic, and the US is the world's largest producer of soybeans.
    b. The cross price elasticity of demand for palm oil relative to the price of soybean oil is very large.
    c. The long run elasticity of supply for palm oil is very high, but additional supply comes about through clearing tropical forest.
4. Do subsidies guarantee long-run profits if there are not any barriers to entry?
5. Did the environmental community achieve their aims by promoting then discouraging the use of biodiesel? What does the history of biodiesel suggest for future green/business cooperation?
6. Biodiesel producers began their industry with considerable support from politicians. Did this support pay off?
7. What does the experience of biodiesel subsidies suggest for the potential for successful industrial policy?
8. With a $1 per gallon subsidy and no externalities, the deadweight loss from overproduction is ½ times the change in quantity. How would we estimate the deadweight loss that resulted from the plants idled by the elimination of the subsidy? What is the nature of this loss?

Conclusion

In this pedagogical article we use the U.S. biodiesel industry from 2004-2009 to illustrate how long-run entry in a competitive industry eliminates profitability. Furthermore, subsidization of the end product amplifies firm entry into the market. In addition, we illustrate the deadweight loss that arises from subsidization. Elimination of the subsidy creates excess capacity and deadweight loss.

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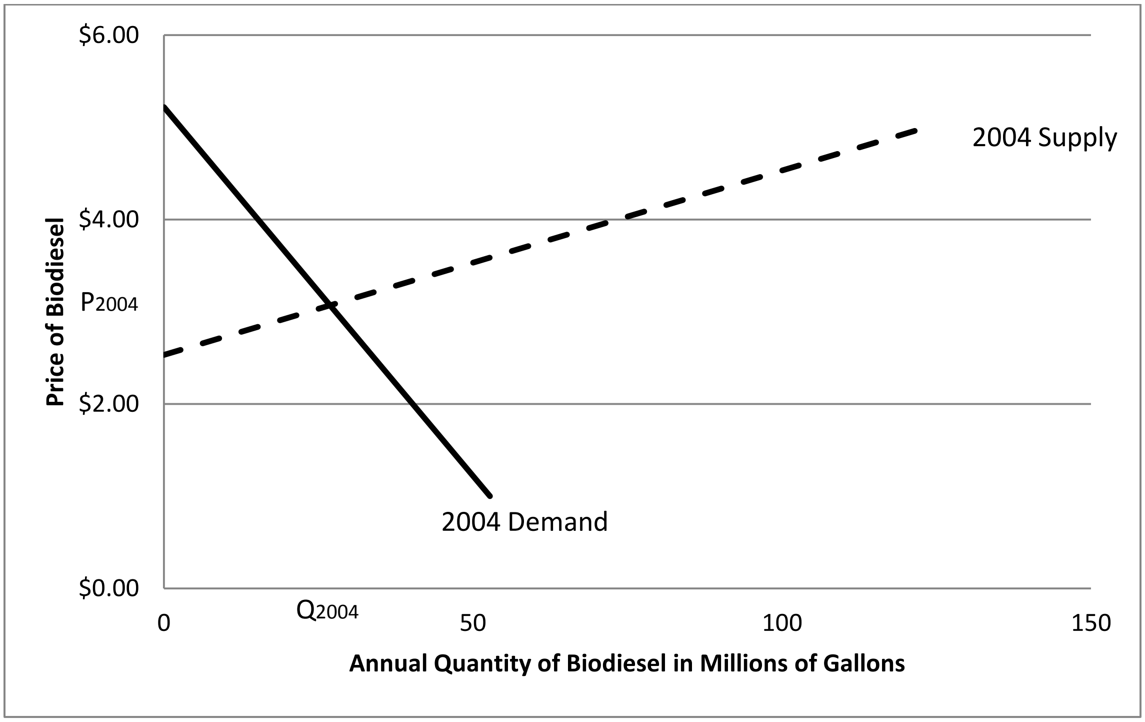

Figure One: 2004 Supply and Demand. Demand is based on a petroleum average retail price of $1.92 per gallon. Supply is based on an industry production capacity of 162 million gallons and soybean oil price of $2.29 per gallon.

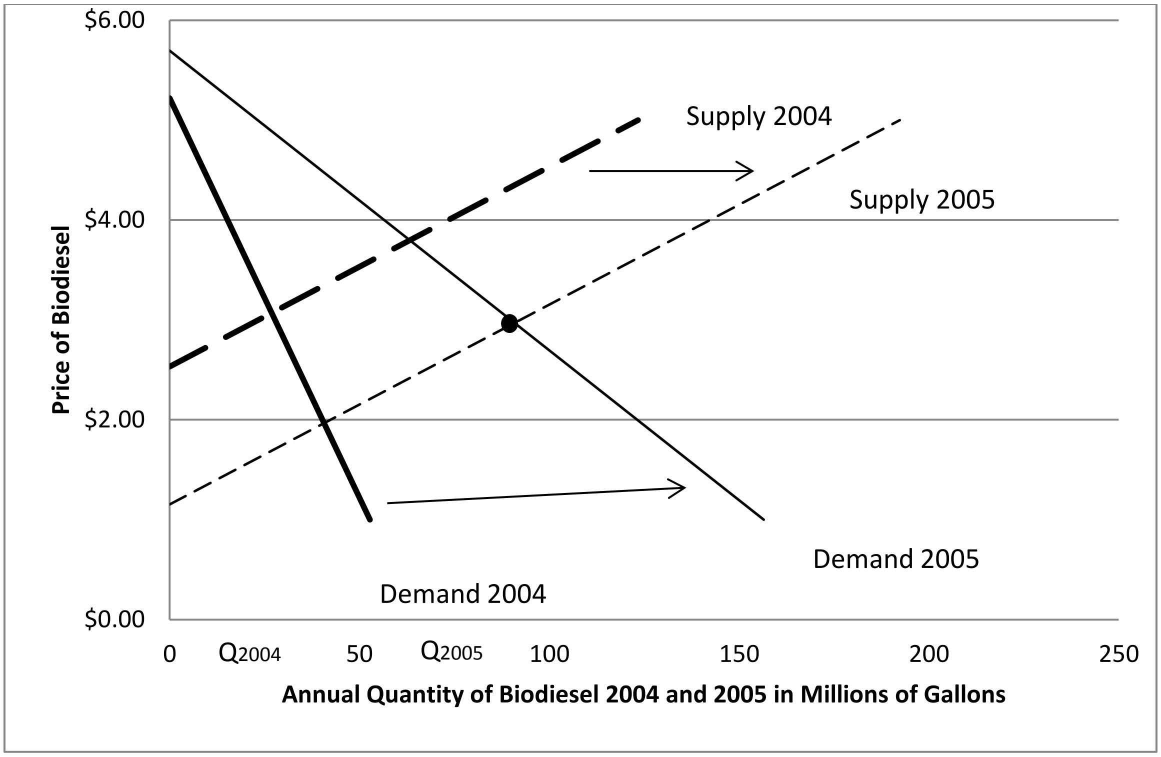

Figure Two A: 2005 Demand and Supply. Demand shifters include an increase in petroleum average price to $2.66 per gallon. Supply increases because of a $1.00 per gallon subsidy, a decrease in the price to soybean oil to $1.76 per gallon, and an increase in industry production capacity to 240.3 million gallons.

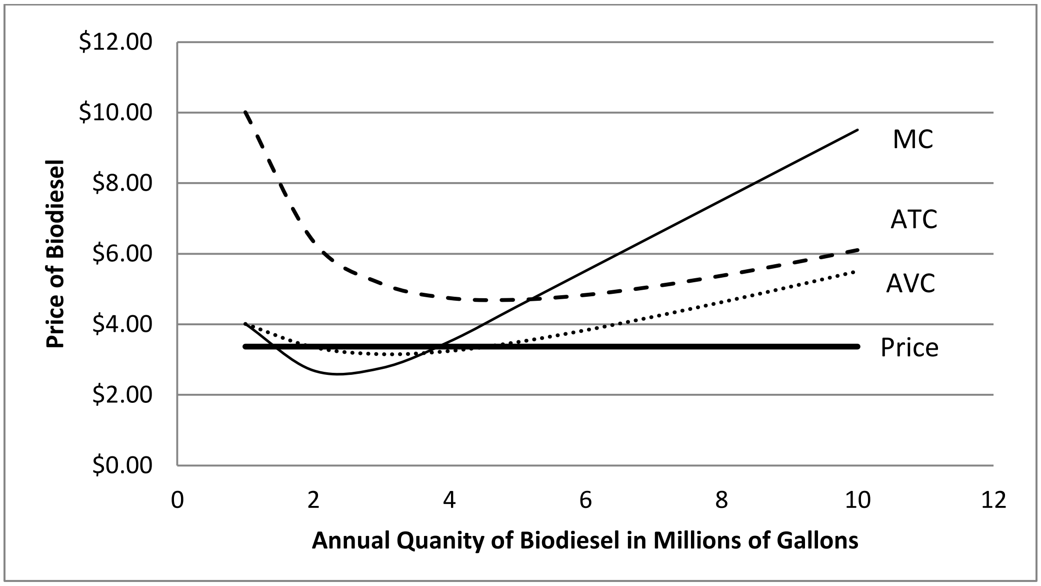

Figure Two B: Hypothetical 2005 Seattle Biodiesel Cost curves. Price is greater than minimum average variable cost, but less than minimum average total cost. Seattle Biodiesel incurs losses, but finds it worthwhile to produce output.

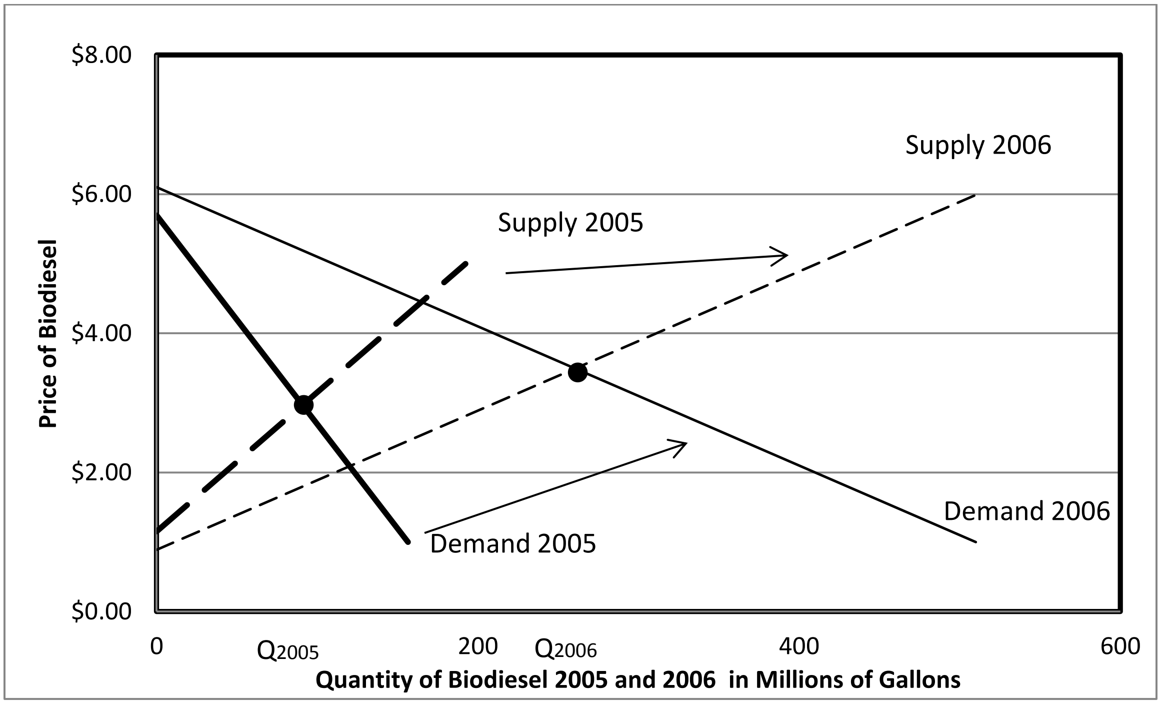

Figure Three: 2006 Demand and Supply. Demand shifters include a small increase in the price of petroleum diesel to $2.77 and an expansion of retail outlets carrying biodiesel. The small increase in the price of soybean oil to $1.79 is offset by the increase in industry capacity to 332.9 million gallons.

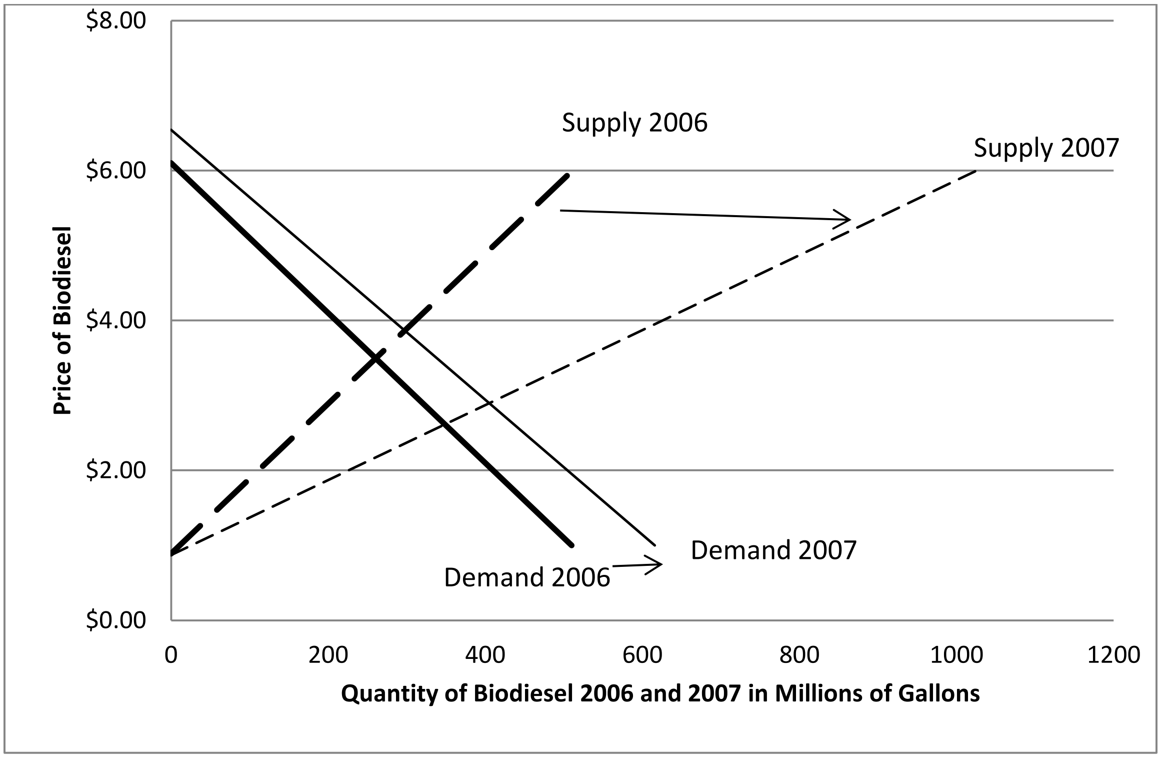

Figure Four A: 2007 Supply and Demand. Demand increases as the price of petroleum increases to $2.90 per gallon. Supply increases with new entry, more than doubling industry capacity to 672 million gallons. Net imports change from 10 million gallons imported to 132 million gallons exported. Increased production becomes significant enough to increase soybean oil price from $1.79 per gallon to $2.37 per gallon. With the expansion of the export market, the domestic price becomes the international price, allowing domestic supply to exceed domestic demand.

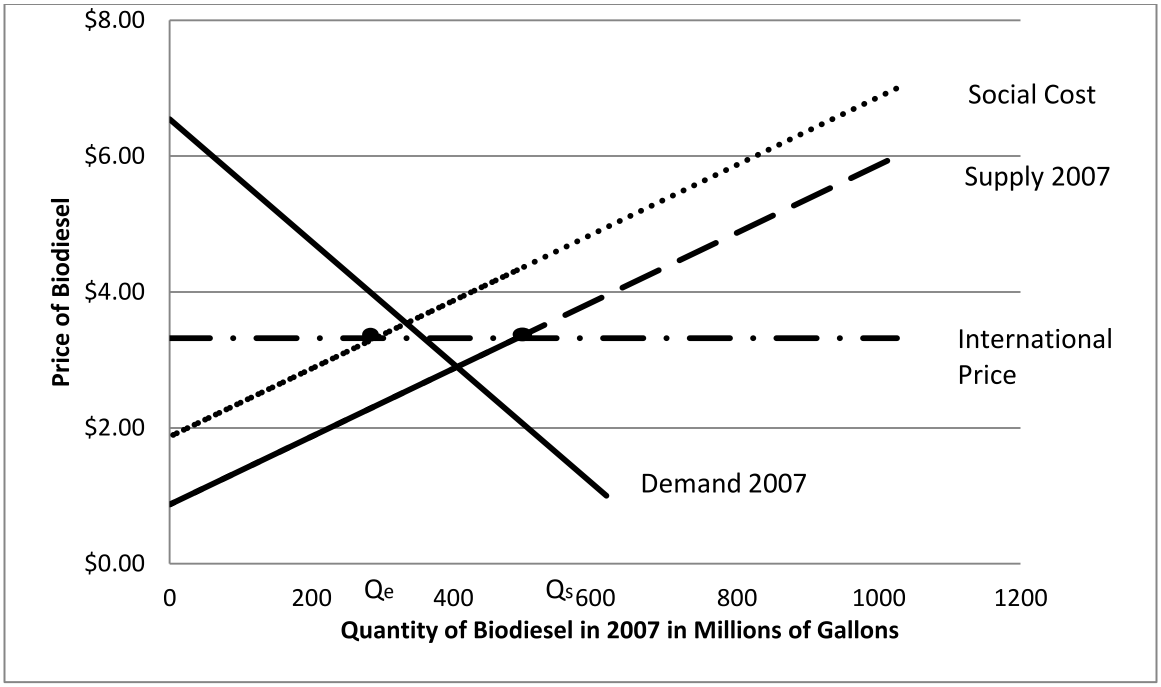

Figure 4 B: 2007 Domestic Demand, International Price, Domestic Supply, and the Social Cost of production.

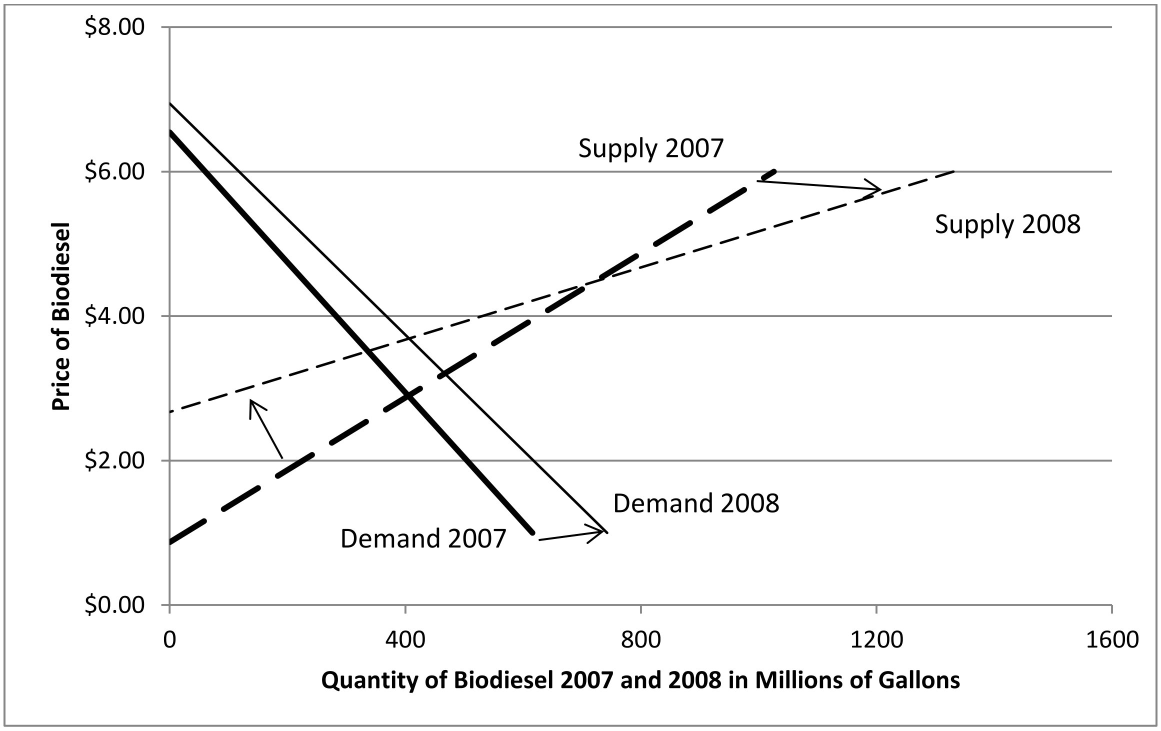

Figure Five A. Demand increases with an increase in petroleum diesel price to $3.98. New entry almost triples industry capacity to 1,925.8 million gallons, and drives soybean oil prices to $3.98. Net Exports increase to 362 million gallons. The combination of much higher input prices, with increased capacity and exports, makes the domestic supply curve much more elastic.

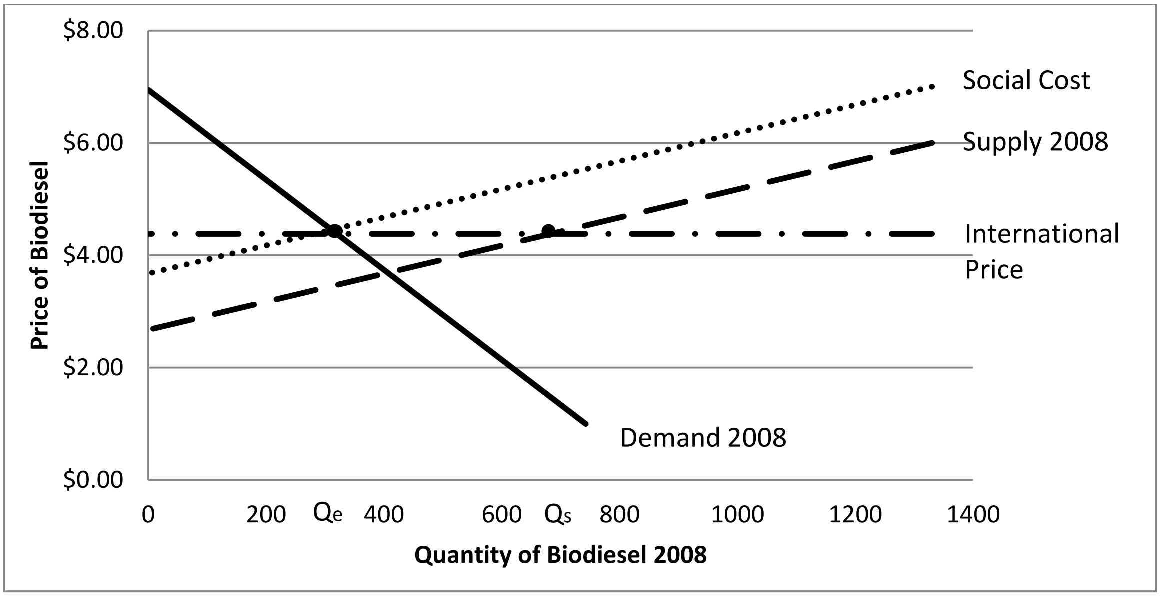

Figure 5 B. With the large increase in production capacity, and exports, the subsidy causes greater deadweight loss. The efficient quantity, Q_e is determined by the intersection of the International Price and Social Cost curve, which in turn is the marginal cost (Supply Curve) plus the $1 per gallon subsidy. Given our assumptions $Q_s – Q_e$ is 200 million gallons per year, and the deadweight loss from too much production is ½x(200)x$1 or $100 million dollars per year. This represents the additional cost of domestic production when biodiesel was available from international producers at a resource cost equal to the international price.

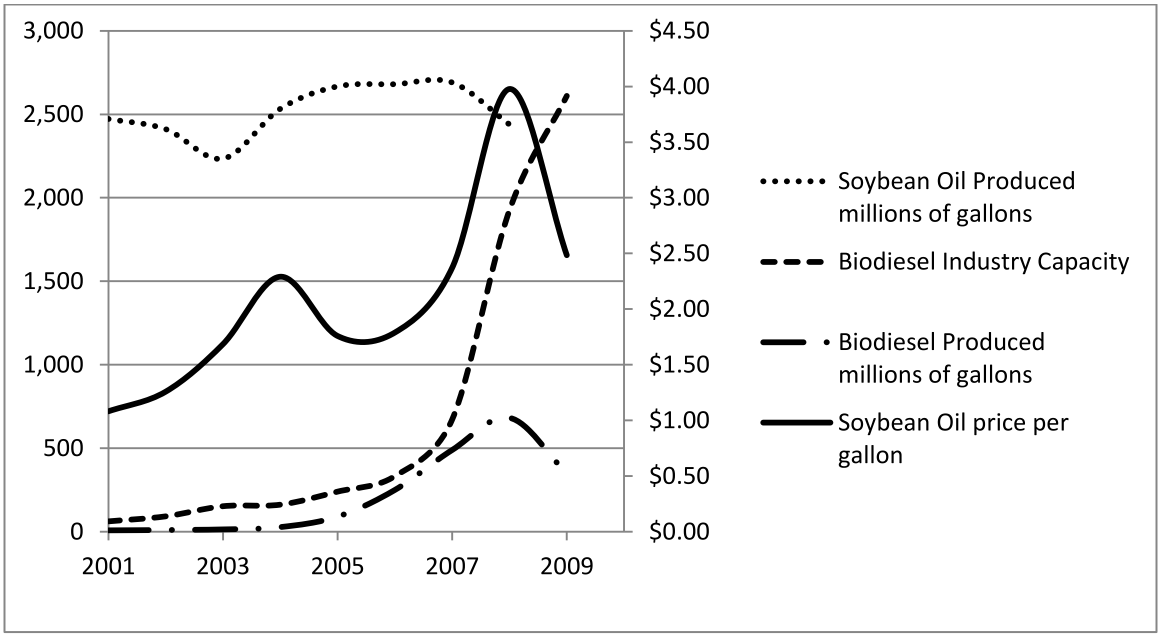

Figure Five C: Prices and quantities of biodiesel and soybean oil over time.

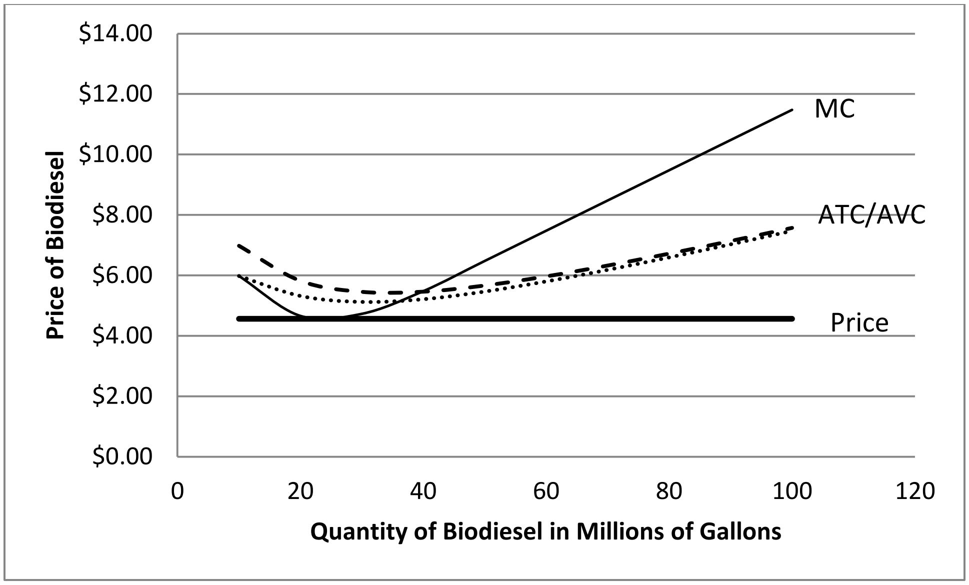

Figure Five D: 2008 Imperium Cost Curves. The increase of input prices makes production unprofitable in spite of the biodiesel subsidy and high market price. Imperium shuts down production.