Potential Economic Impacts

from the Introduction of Genetically Modified Wheat

on the Export Demand for U.S. Wheat

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Executive Summary

The United States is a dominant player on the world's wheat market. As such, U.S. wheat producers' use of cost-saving technology has worldwide importance. Of special interest to consumers in many parts of the world, however, is the usage of technology such as genetic modification. Unlike traditional cost-saving technologies, genetic modification is facing rather intense pressure from consumer groups and others opposed to its introduction into the food supply. While there are varied reasons for this opposition, the end result is the same and we are seeing more and more nations moving towards some type of segregation, if not outright blockage of genetically modified foods.

The effects of the usage of the genetic modification on producers' costs have been studied by economists, universities, and the biotech companies who are developing the new varieties. What has been less scrutinized is the effect upon the demand for these goods, especially in overseas markets and, in turn, the net effect on profitability when the cost-saving technology may harm demand. This study, funded by the Kansas Wheat Commission, investigates the potential impacts on the trade of U.S. wheat if genetic modification is adopted by U.S. wheat producers.

As genetically modified wheat has not yet been adopted, no data exist to discern the effect of the product on consumer demand and, hence, international trade. As such, this study utilizes an economic model of U.S. wheat trade that incorporates data and findings from previous

research on the wheat market in order to provide an "educated guess" about any potential trade impact. Once the model has been developed to simulate the current status of U.S. wheat trade in the absence of genetically modified wheat, counterfactual simulations are performed under two different trade scenarios.

Under the first scenario, both genetically modified and conventional wheat are mixed upon the world market. Under the second scenario, there is some type of segregation so that only wheat from the U.S. is implicated by the biotechnology adoption. In both of these scenarios, various hypotheses of cost-savings from the new technology are coupled with hypothetical demand changes overseas in both short- and long-run simulations.

The results show that if wheat is not segregated, the gains to U.S. wheat producers from the adoption of genetically modified wheat are more likely to be favorable than if the wheat is segregated. Specifically, if the cost savings are similar to what Monsanto has predicted, then the fall in importers' willingness to pay for mixed wheat must be rather large to erase U.S. producers' gains from using the technology. Even in a long-run scenario where U.S. wheat may be more substitutable, with per-unit cost savings greater than 10 percent, importers' willingness to pay for mixed wheat must fall by more than 42 percent before the profits to U.S. producers are erased. This seems to us to be a rather large and unlikely decline in willingness to pay for wheat and is greater than that predicted by other research.

On the other hand, if wheat is allowed to be segregated, then the utility of genetically modified wheat becomes questionable. Under this scenario, because U.S. wheat would be identifiable, the export demand for U.S. wheat is clearly more heavily implicated than in the no-segregation scenario. In this case, for example, if the per-unit cost savings are 10 percent, importers' willingness to pay for U.S. wheat need only fall a rather modest 15 percent in the long run in order to erase any profits from the adoption of the new technology. Even if cost savings are on the order of 20 percent per unit, given predicted willingness to pay declines of 35 percent in other studies, the adoption of genetically modified wheat appears unwise.

Of course, the two most important hypotheses in this study are based upon the two pieces of information for which the most uncertainty exists. Namely, how much will the cost savings be, and how much will demand be affected by the introduction of the genetically modified product into the food supply? In this study we investigate a variety of possibilities, but no one will know the real answer to these questions until the product comes to market. Obviously, this is true of any marketing enterprise. Because the potential gains as well as the potential losses are so large, perhaps caution and study are more prudent at this time. We recommend that while U.S. wheat producers continue to push biotech companies and research institutions for better and better data of the effects of genetic modification on yields and costs of production, producers should also seek more answers to demand-side questions. Funding studies that try to determine consumer acceptance and willingness to pay for genetically modified foods as well as funding greater education of the public about these foods seems like money well spent at this time.

1. Introduction

Monsanto Corporation had scheduled its introduction of Roundup Ready wheat into United States commercial markets by 2005 but reversed its decision citing a lack of industry coordination (Monsanto, 2004a). Monsanto's explanation of what it meant by a lack of coordination was vague, but one likely interpretation is skepticism on the part of U.S. wheat producers in the face of growing international consumer concern over the use genetically modified (GM) ingredients in food. The hard-red spring wheat that Monsanto developed is genetically modified to resist the Roundup herbicide. As such, the wheat was marketed to reduce production costs, clearly benefiting hard-red wheat growers. Nevertheless, a concern on the minds of many wheat growers is that there would be a decrease demand for U.S. wheat, especially from abroad, because of consumer uneasiness towards GM foods. Further, although Monsanto's GM wheat was one particular variety, given the difficulties of segregating wheat and the labeling restrictions where non-GM wheat could be "tainted" by a GM variety, the impact on demand logically extends well beyond this particular variety.

Grower concerns are well founded. Several countries that import large amounts of U.S. wheat have placed severe restrictions on genetically modified products. Further, while there are arguments as to whether or not these barriers are administrative trade barriers disguised as consumer concern or truly reflect the concerns of an importer's consumers, the results of these restrictions are the same: less demand for U.S. wheat. The idea that these concerns are simply masquerading trade barriers in violation of WTO, in our opinion, is overly simplistic.[1] Numerous surveys and studies of consumer sentiment towards GM products have been performed and the conclusion that many foreign consumers simply do not want genetically modified commodities in their food supply should be taken as a datum.[2] Detractors who argue that consumer sentiment is not the issue need only peruse reviews of the literature by McCluskey (2000), Senauer (2001), Barkley (2002), and a study by Lusk et al. (2005) which summarizes the research from 25 studies corroborating the finding of an overall consumer unease towards GM especially in Europe. We contend that in the story about producer profitability from the adoption of GM crops, the demand effect is an important, but often neglected element.[3]

Clearly, since production costs would be lowered after the adoption of the technology, if there is no change in demand for wheat in importing nations, the supply of wheat from the U.S. will increase. Given the large-country effect of U.S. wheat production, an increase in supply would lower world wheat prices, but this price drop would be offset by the cost savings leading to increased producer profits or "surplus," which we define explicitly later in this report.

However, should demand for wheat decrease because of a perceived "taint" of GM in those countries whose populations oppose GM wheat, the profitability becomes uncertain. It could very well be that the decline in the price for U.S. wheat due to consumer preferences for non-GM wheat may be greater than the cost savings from the adoption of GM wheat. Of course, such a result is impossible to predict, but before wheat producers adopt this new technology it is

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[1] Although we argue that consumer sentiment is well-established, we do wish to point out a very interesting hypothesis explaining Europe's resistance to biotech as proffered by Graff and Zilberman (2004). Graff and Zilberman argue that European farm chemical producers, who stand to lose greatly in the face of GM adoption, are leading the fight to keep borders closed to GM.

[2] It should be noted that the U.S. has brought a WTO case against the EU's GM policy citing it as a de facto trade barrier masquerading as a phytosanitary concern. The case certainly has merit. See for example Carter (2002) and Crespi and Marette (2003a).

[3] For example, in a recent study on adoption of GM rice in California, Bond, Carter and Farzin (2004, p. 4) show significant cost-savings to producers but admit, "this study does not thoroughly address market acceptance issues that may affect both domestic and export demand for conventional and GM rice."

valuable for them to consider the possibilities. *The objective of this research is to determine by how much demand would need to fall in overseas markets to offset any cost savings to U.S. GM wheat producers*.

In this study we seek to use an economic trade model under two different segregation scenarios to inform interested parties of the degree to which demand would have to fall to erase any producer profits gained by the lower cost of GM wheat production. In the first scenario, we presume that GM and non-GM wheat is mixed on the world market. This might be akin to the U.S. winning its WTO arguments allowing GM goods to be imported without need for labeling or other restrictions. Under the second scenario, we investigate the impact on U.S. exports of wheat under the presumption that GM products must in some way be segregated, for example with the use of a label or an administrative trade barrier. This second scenario is reality in many parts of the world today.

- Trade Scenario 1: GM Wheat is Mixed with non-GM wheat in Export Markets.
- Trade Scenario 2: GM Wheat can be Identified and Segregated from Non-GM wheat in Export Markets.

Simply, if we can show that producer profits can be easily erased with just a small decline in demand, it would likely be best to postpone the adoption of GM wheat until consumers find it more palatable. Conversely, if demand declines would need to be significant, such worries can be assuaged.

It is important to note that modeling an event that has not actually occurred is obviously difficult. Data cannot be observed, only educated approximations can be made. There are certain to be nuances in the market that will not be evident until GM wheat is actually produced.

Even so, it is important for producers to be as informed as possible about what effects GM wheat may have on wheat production and marketing systems.

The remainder of this paper is divided into the following sections. Section 2 presents a brief background on GM wheat and consumer sentiment toward genetic modification. Section 3 presents both a graphical and algebraic formalization of the international trade model that underlies the simulations. Section 4 presents the data and statistics used in the simulations. Section 5 presents the results of the analysis, and section 6 concludes.

2. Background: GM Wheat and Consumer Sentiment

The GM wheat developed by Monsanto is called Roundup Ready because it is resistant to the glyophosate herbicide, Roundup. The process of developing a strain of Roundup Ready wheat has taken many years. The first step taken by researchers when developing glyophosate-tolerant seeds is to insert the glyophosate-tolerant gene into the wheat cell. The researchers then conduct many tests to be sure the gene is adequately preventing the wheat plant from being harmed by the glyophosate herbicide (Metz, 2004). Test plots are planted to ensure proper growth and yield. In the spring of 2002 approximately 35 test acres of Roundup Ready wheat were planted in the U.S. (Monsanto, 2004b).

GM corn, soybeans, and cotton have already been released and produced in the U.S. As seen from the production of these crops, costs can be reduced in several ways from using GM seeds. Glyophosate herbicides are cheaper than many other herbicides, which decreases the production costs. Glyophosate herbicides do very little damage to the plants, increasing yields. Also, applying herbicide at a certain growth stage is not as critical, allowing producers a larger window to spray for post-emergent weeds. After the genetically modified crop is harvested, there is usually a relatively small amount of weeds left in the field and there is little carry-over allowing for more flexibility in crop rotation options (see the discussion in Taylor, DeVuyst, and Koo, 2003). Monsanto estimated that the increase in income from using Roundup Ready wheat could be as much as $6 to $11 per acre (*Farm Industry News*).

Although there are many benefits to producers from using GM wheat, it is important to determine if a decrease in export demand will negate these benefits. GM wheat may receive more opposition from anti-GM consumers than corn or soybeans because of the unique characteristics of the crop. Corn and soybeans go through many processes before being consumed by humans. Soybeans are processed into soybean oil, meal, and many other products. Corn can be used as a sweetener in the form of corn syrup and even has non-food uses. Also, large amounts of corn are used as livestock feed. Wheat, on the other hand, is a diet staple in many parts of the world and is used as flour for a variety of food products (Taylor, DeVuyst, and Koo, 2003). Many times there are few production processes that occur between production and consumption and because of this, consumers may be more concerned about the *perceived* health and safety of wheat as compared to corn or soybeans.

Another issue of concern when dealing with GM wheat is the process of segregation. Segregation refers to "the isolation of like products with particular attributes to avoid commingling" (Wilson, Jabs, and Dahl, 2003). A good argument has been made that if GM wheat is introduced into U.S. markets, an efficient segregation process must be in place to assure foreign trading partners. Some U.S. import customers will be more willing to buy U.S. wheat if they know a segregation system exists in the U.S. If segregation does not occur between GM and non-GM wheat, a large amount of non-GM wheat can be contaminated by a small amount of GM wheat.

This segregation issue is of especial concern to U.S. wheat producers given the GM labeling requirements of some countries whereby even trace elements of GM can be enough to cause a labeling requirement. In other words, non-GM wheat delivered by truck or stored in an elevator that previously contained GM wheat may be enough to cause the wheat to require a GM label (see Carter, 2002 and Crespi and Marette, 2003a, 2003b). Wisner (2004, p. 24) reports that in order to meet the concerns of EU consumers, the added segregation cost to U.S. producers could be from 21 to 54 cents per bushel based on a USDA survey of grain elevators. Further

Wisner speculates that given the processing of wheat and need for stringent segregation it may be very likely that all wheat products from the U.S. marketed in the EU would end up being labeled as containing GM wheat and, as such, Wisner argues that it is a truly possible scenario that EU consumers would reject all U.S. wheat given the prevalence of available substitutes from other non-GM wheat producing nations.

The extent of GM labeling requirements is varied and growing with more and more nations adopting mandatory labeling in recent years. Even in countries that do not have mandatory labeling, voluntary labeling is being adopted. In the European Union, a label is mandatory for all foods containing at least 0.9 percent of GM product (Dombey, 2002). Mexico also requires the labeling of GM products and Japan has recently required both GM and non-GM to be labeled (Reuters, 2000). In May of 2000, the United States Food and Drug Administration (FDA) decided against mandatory labeling, proposing instead to help producers who voluntarily wish to label their goods as GM-free (FDA, 2000 and Caswell, 2000). At this writing, Argentina and Canada are also considering voluntary programs for products that do not contain GM. Table 1 provides a listing of countries and their current labeling requirements.[4]

[4] An interesting side issue is whether there is a difference in the overall profit and consumer surplus depending on which good, the GM or the non-GM product, is to be labeled. Crespi and Marette (2003b) consider this issue and show that this subtle difference can have rather serious consequences because of who bears the cost of the particular label.

Table 1. Cross-Country Comparisons of Current and Proposed Labeling Laws

Country	*Current Mandatory Program*	*Current Voluntary Program*	*Proposed Mandatory Program*	*Proposed Voluntary Program*
Argentina				X
Australia	X			
Canada				X
Czech Republic	X			
European Union	X			
Hong Kong			X	
Hungary	X			
India			X	
Indonesia	X			
Japan	X			
Malaysia				
Mexico	X			
New Zealand	X			
Norway	X			
Russia	X			
South Korea	X			
Switzerland	X			
Thailand		X	X	
United States		X		

Sources: OECD (2001, pp. 11-12) and Carter (2002, p. 2).

Much research has been done to explore the acceptance of GM products worldwide. Although some of the strongest opposition to GM products has been in the European Union (Gillam, 2004), consumers in more and more nations are growing as vocal. Senauer (2001) compiled the results of several consumer surveys in the U.S. and Europe toward biotechnology. According to these surveys, Americans are much more accepting of GM products than Europeans are with only 21 percent of Americans feeling that GM foods posed "serious safety risks" compared with 65 percent of Swedish consumers, 62 percent of Portuguese, 60 percent of Austrians, 57 percent of Germans, 48 percent of Dutch, 39 percent of British, 38 percent of French and 30 percent of Italians. Norwegian consumers were closest to the American response rate with 28 percent expressing a distrust of GM foods. In Japan, as well, according to a poll by the national newspaper, *Yomiuri Shimbun*, 70 percent of Japanese consumers indicated hesitance toward the purchasing of GM foods but with an astounding 80 percent of Japanese consumers indicating a need to mandate GM labeling so that all consumers can make an informed choice. South Korean consumers have expressed similar concern about the purchase of such goods (see also Tomson, 2003 and McCluskey, Grimsrud, Ouchi and Wahl, 2003). Such consumer sentiment towards GM products in Europe and Asia must certainly be of special concern to U.S. wheat exporters. As seen in Table 2, the EU imported about 6 percent of the U.S.'s wheat in 2002/03 and Japan and South Korea imported roughly 14 percent and 6 percent, respectively. Mexico, the U.S.'s second-largest wheat consumer, as noted above, has also recently adopted GM labeling requirements.

Table 2. *Top 7 Importers of U.S. Wheat for the 2002/03 Marketing Year*

	Imports in thousand MT	*Percent of Total*
Japan	2,997.6	14%
Mexico	2,485.6	12%
Nigeria	1,659.7	8%
Philippines	1,559.7	7%
S. Korea	1,257.1	6%
European Union	1,236.3	6%
Egypt	1,107.0	5%
Total of Top 7	12,303.0	59%
Total U.S.	20,804.8	100%

Source: National Association of Wheat Growers (2004)

3. A Trade Model of GM Impacts on U.S. Wheat

Obviously a determination of the effect of a demand change (if any) on U.S. wheat exports is speculative prior to the product's introduction. Nevertheless, economic theory can prove valuable in formulating reasonable scenarios while rejecting implausible ones. In this section a theoretical analysis is developed to model the trade of U.S. wheat. After the model is derived, counterfactual simulations can then be conducted to determine potential changes in producer surplus (profits) after an introduction of GM wheat. The simulation analysis will benefit from years of studies of wheat markets by economists who have attempted to determine the price responsiveness (elasticities) of wheat demand and supply. Before proceeding with the mathematical analysis we provide a graphical explanation beginning with a discussion of how producer profit, or so-called producer surplus, is to be measured.

3.1 How Economists Measure Profit (Producer Surplus)

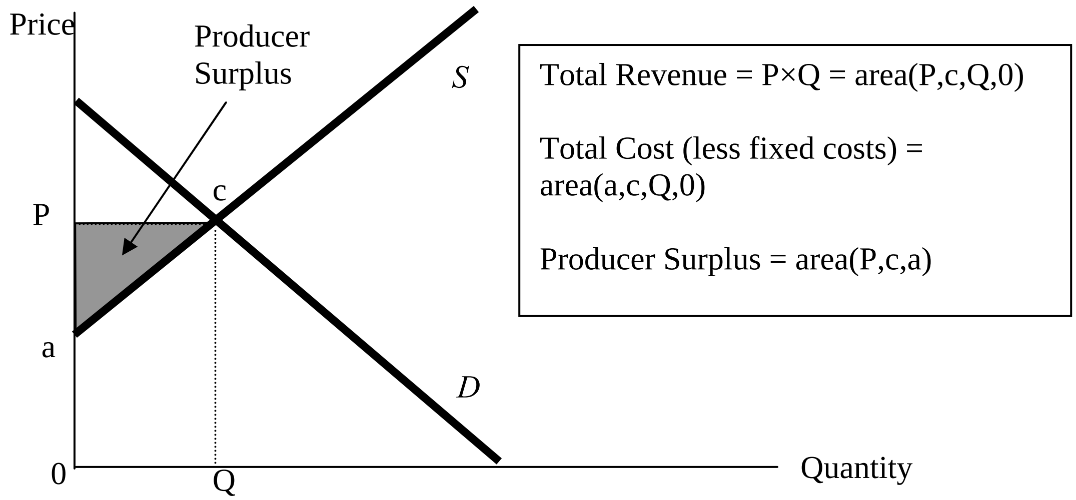
Producer surplus refers to the total profits (excluding fixed costs) for all of the firms in an industry. Simply, if one thinks of the supply curve as a measure of the minimum that a producer is willing to accept (WTA) for a product and still earn an (accounting) profit, then any price above this minimum willingness to accept is a surplus to the producer.[5] Another way of showing this is to recall that the supply curve for a producer is that producer's marginal cost curve, and the industry supply curve is the summation of all of the individual producers' marginal-cost

[5] Relatedly, "consumer surplus" refers to the additional welfare that consumers receive from the purchase of a good. Since the consumers' demand curve measures consumers' willingness to pay (WTP) for a good, the distance between what consumers are willing to pay and what they actually pay is a type of surplus or benefit to the consumer. A downward shift of the demand curve reflects a lowered willingness to pay or, identically, a lowered consumer surplus for the good, all else equal.

curves. Thus, the industry supply curve measures the lowest price for any given level of output that would result in a profitable transaction.[6] Consider figure 1 below. *S* denotes the aggregate producer supply curve and *D* denotes the aggregate consumer demand curve. Price times quantity is total revenue, thus the rectangular box formed by points P, c, Q and 0 is the total revenue in the industry from a sale of Q units at a price of P. For each unit produced, the distance *beneath* the supply curve to the horizontal axis is the per-unit cost of producing the good. Thus, the distance above the supply curve to the price measures total revenue less total cost (excluding fixed cost), or the industry profit. It is this triangular area (P,c,a) in figure 1 that economists label producer surplus.

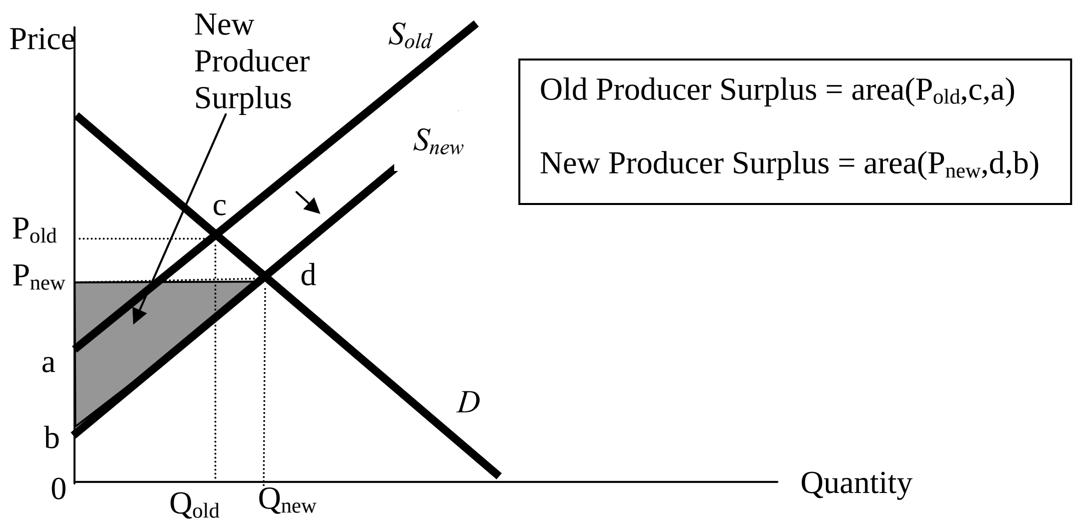
[6] As an aside, it should be noted that economists have a tendency to use the term profit to mean profit over and above the competitive level of normal or "accounting" profits. Thus, zero economic profit can still be a positive accounting profit or normal rate of return. Throughout this report we shall use the term "profit" in its lay definition of positive accounting profits.

Figure 1: *Producer Surplus.*



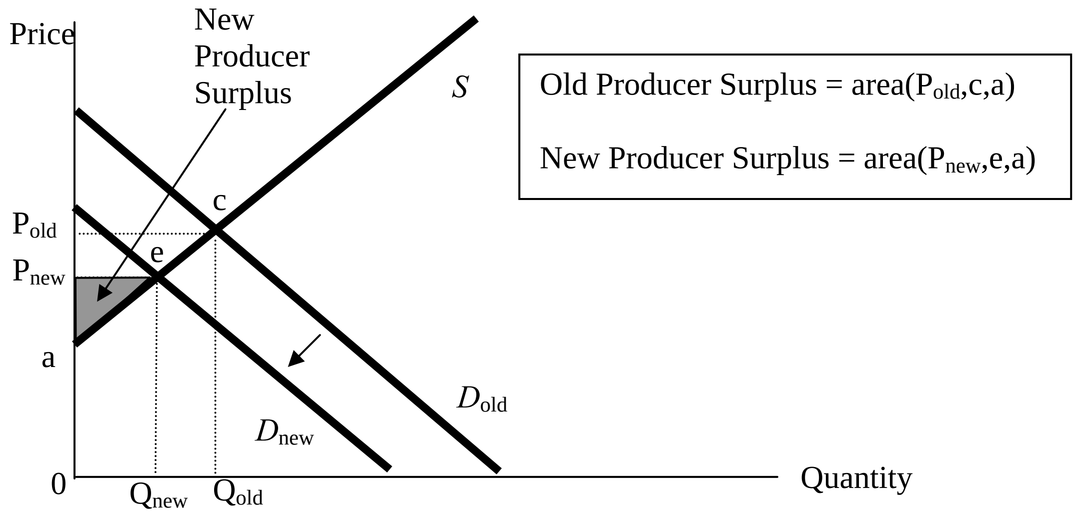
If producers adopt a cost-saving technology (like GM wheat), the result is a decline in the per-unit costs of production: a shifting downward of the supply curve. This results in a lowered price, but, if the cost-savings are profitable the decline in profit from the lowered price is more than made up for in an increase in revenue from greater sales. In figure 2, we show how producer surplus increases after the introduction of the cost-saving technology. The new producer surplus triangle, area(P_{new}, d, b), is larger than the previous surplus triangle, area(P_{old}, c, a) reflecting the cost savings from the introduction of the new technology. In the case of GM wheat, this is what is expected, provided, of course there are no changes in the demand for the wheat.

Figure 2: *Producer Surplus Increase after Adoption of Cost-Saving Technology.*



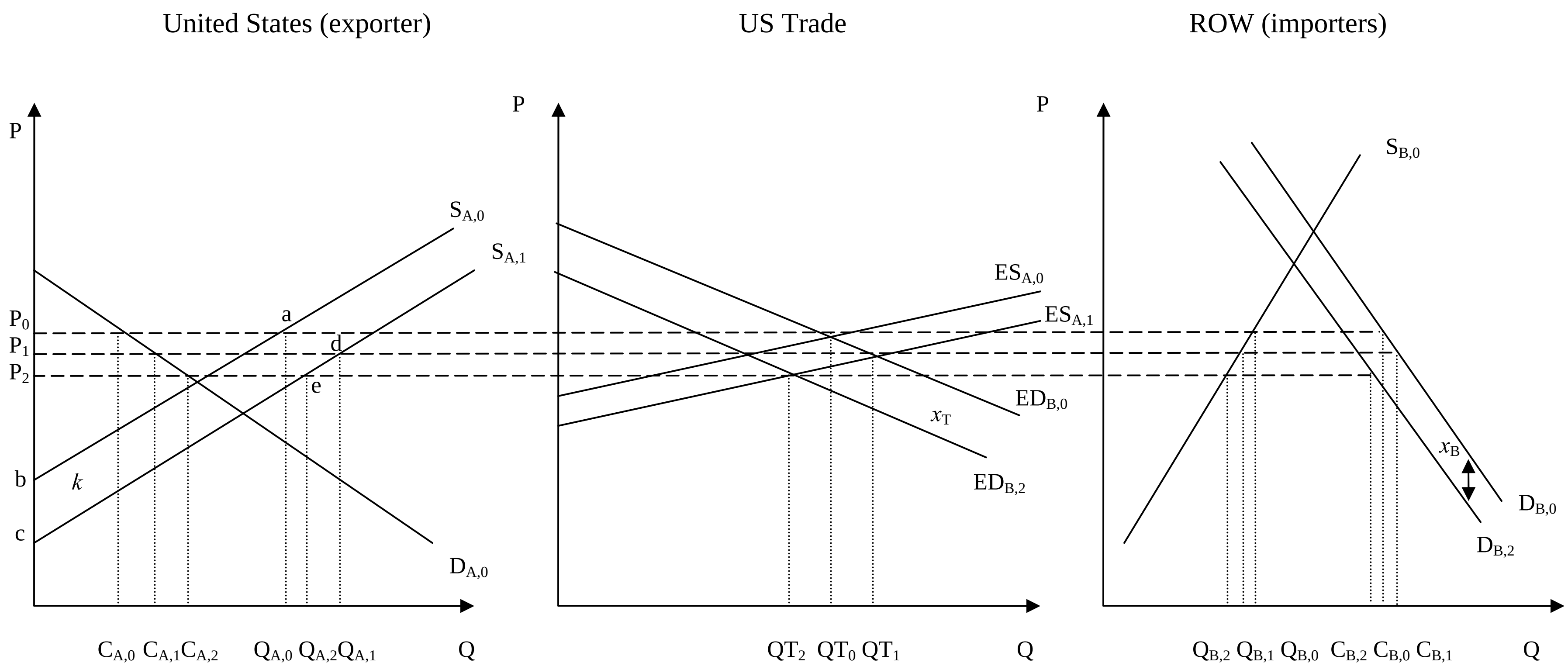
If consumers' willingness to pay for a product, as measured by the demand curve, declines, then the demand curve will shift downward. This can happen for many reasons. The availability of a substitute good could become greater or the substitute good's price could decline making the substitute more attractive thus causing consumers to switch. Or, consumers may switch from one good to another if their income changes: switching from hamburger to steak when income rises is one example. Or, in the case of GM wheat, it could be that consumers develop a lowered preference for the GM wheat after receiving information from an environmental group that delivers a poor image of biotechnology. For whatever reason, as shown in figure 3, the end result of a downward shift in the demand curve --from the producers' perspective-- is lowered profits as measured by the decreased producer surplus.

Figure 3: *Producer Surplus Decline after a Lowering of Consumer Demand.*



Figures 1, 2 and 3 are the essential features of the market model that we wish to develop analytically. What we are concerned with is the measurement of the change in producer surplus for U.S. wheat producers. The added complications in the analytical model are as follows. First, we must expand the above analysis to account for domestic and international trade of U.S. wheat. Second, we must allow for both a shift of the U.S. supply curve as well as the potential decline in demand overseas after this new product is introduced. Thus, we need a model that allows for both the demand and supply curves to shift so as to measure the total, potential change from an introduction of GM wheat, not just the potential cost savings. Figure 4 shows what is involved in the conceptual model.

Figure 4. *The Trade Model*



3.2 Adapting the Model by Incorporating Export Markets: A Graphical Analysis

In the trade diagram of figure 4 we show the market for U.S. wheat domestically and abroad. For the subscripts, we let "A" denote the U.S., "B" denote the "rest of the world" or ROW, and T denote the "Trade" arena. We consider the effects of shifts of supply and demand curves resulting in three different prices and quantities, denoted by the subscripts 0, 1 and 2. The first panel of figure 4 labeled "United States" represents the supply of wheat from U.S. producers and the domestic, U.S. demand for wheat. The points labeled C along the horizontal axis are the quantities of wheat demanded and those labeled Q are the quantities supplied for our three hypothetical prices of wheat (P_0, P_1, and P_2). In this first panel, domestic supply exceeds domestic demand, thus reflecting the fact that the U.S. is a net exporter of wheat. The last panel in figure 4 labeled "ROW" stands for the net, wheat importing nations in the "rest of the world." These nations import U.S. wheat as well as consume wheat from their own producers and also import wheat from other nations. Because of this, the supply curve represented in the ROW panel represents supplies of all non-US wheat. On the horizontal axis in the ROW panel, for any of the three prices we have denoted, Q is less than C showing that these ROW nations are net importers of wheat. The middle panel labeled "Trade" shows where the U.S. export demand (ED) and U.S. export supply (ES) curves intersect at the prices and quantities that will be exported (QT). The export demand and supply curves are particular to the trade in wheat of the United States. If something affects the U.S.'s production of wheat, the U.S. export supply curve will be affected. If something affects the demand for U.S. wheat overseas, then the U.S. export demand curve will be affected. Although it is difficult to see in this diagram as it is not drawn to scale, the total quantity exported by the U.S. is equal to the total quantity imported by the ROW, that is, $QT = Q_A - C_A = C_B - Q_B$.

Figure 4 shows the effect of a change from the introduction of GM wheat in U.S. production denoted as a shifting down by *k* dollars per unit of output. However, this downward shift will not entirely determine the new price. In other words, the new price is not simply the old price less *k*. The reason is that the new price is determined by the intersection of the supply and demand curves, not just the supply curve shift. Thus, the new price will lie somewhere between the old price, P_0, and P_0-*k*. The supply and demand elasticities are crucial to answering this question. While this seems trivial, it is important to understand for the analysis that follows and some researchers neglect the feedback mechanism involved in the determining of price.

Consider a hypothetical example to illustrate the basic trade model. Originally, the world price for wheat is P_0 as determined by the intersection of the original export supply ($ES_{A,0}$) and export demand ($ED_{B,0}$) curves in the trade panel. If U.S. producers adopt GM wheat, per-unit production costs are expected to decline leading to a new, lower U.S. supply curve, $S_{A,1}$ and, hence, lower export supply curve, $ES_{A,1}$ with a new price of P_1, U.S. domestic demand of $C_{A,1}$, U.S. wheat production of $Q_{A,1}$ and exported quantity QT_1. Likewise, overseas production will fall from $Q_{B,0}$ to $Q_{B,1}$ and quantity demanded overseas will rise from $C_{B,0}$ to $C_{B,1}$.

If there is no change in demand in ROW, then the new price remains at P_1. However, if demand changes in ROW because consumers are reluctant to eat GM wheat from the U.S., the result would be a drop in U.S. wheat demand overseas. As discussed above, how much this drop will occur is uncertain. To frame our analysis, we consider two possible scenarios. In scenario 1, we consider the possibility that GM and non-GM wheat are mixed: a no-segregation scenario. In scenario 2, we consider that the demand in the ROW is met with non-GM sourced wheat and the effect on GM wheat is only on the US wheat exports, not other wheat producers. Scenario 2 is the segregation case.

Under scenario 1, the effect on U.S. producers is traced back from the demand curve in ROW. Because consumers would have uncertainty over the content of their wheat under the no-segregation scenario, there may likely be a decline in their willingness to pay for all wheat products. Under scenario 1, we might expect a downward shift in the ROW demand curve by x_B dollars per unit corresponding to a movement in the ROW demand curve from $D_{B,0}$ to $D_{B,2}$. This, in turn, causes the export demand curve to fall from $ED_{B,0}$ to $ED_{B,2}$ and price to fall lower still to P_2, with U.S exported wheat falling to QT_2. Because less wheat is now going overseas, U.S. wheat production decreases from $Q_{A,1}$ to $Q_{A,2}$ although U.S. wheat consumption would increase from $C_{A,1}$ to $C_{A,2}$ as U.S. consumers purchase more wheat as the price declines.[7]

Under scenario 2, we essentially ignore the effect in the ROW panel because we presume that the ROW's demand for wheat will not change if the wheat can be segregated and non-GM wheat adequately sourced. In the segregation case, then, we simply look at the effect on a shifting of the U.S. export demand curve. For scenario 2, we can consider a hypothetical shifting down of the U.S. export demand by x_T dollars per unit. Here, we have drawn this shift to correspond with the discussion above under scenario 1, for ease of explication. Because of this, the change in overseas' demand that we show here will have the effect on the U.S. market as discussed above: U.S. wheat production decreases from $Q_{A,1}$ to $Q_{A,2}$.

For either scenario, producer surplus for U.S. wheat growers is measured off of the supply and demand figure in the first panel. Analysis of figure 4 indicates that the initial domestic demand in the U.S. is $C_{A,0}$; domestic supply in U.S. is $Q_{A,0}$ and U.S. producer surplus (PS_0) is equal to the triangular area (b,P_0,a) before the introduction of genetically modified wheat into U.S. production. With the introduction of GM wheat and no change in demand in the importing nations, $S_{A,0}$ shifts down to $S_{A,1}$ and $ES_{A,0}$ shifts down to $ES_{A,1}$. Therefore, U.S.

[7] We presume in this model that U.S. consumers are accepting of GM inputs.

producer surplus (PS_1) becomes area(c,P_1,d), where PS_1 is greater than PS_0. With the introduction of GM wheat and a decrease in demand in the ROW under either scenario where we have shown $ED_{B,0}$ decreasing to $ED_{B,2}$ and price falling to P_2, the new producer surplus (PS_2) becomes area(c,P_2,e). It is the difference in these areas that our change in producer surplus formula will calculate. The magnitude of the effects is purely conjecture in this diagram, but the constellation of effects from the perspective of U.S. producers can be simply deduced: 1) U.S. producers can be made better off, 2) U.S. producers experience no change, or 3) U.S. producers are made worse off after the introduction of GM wheat. Which of these will come to pass requires the reworking of figures 1-4 in an algebraic form making it easier to compute counterfactual scenarios.

3.3 The Algebraic Analysis

For the purpose of this analysis, we assume linear supply and demand curves and parallel shifts in these demand functions. Alston, Norton and Pardey (1995) discuss the benefits of such models because of their ease of use, especially when the usage of other functional forms is not expected to add much to the analysis. Because of arguably negligible consumer concerns about GM goods in the U.S., we assume that any shifts in demand from the introduction of GM wheat come from overseas.

The model used in this analysis is an augmented form of the model discussed in Alston, Norton, and Pardey (1995, p. 216).[8] Such models are standard shrift in the economic trade modeling literature having been used to study the adoption of technical change in a variety of settings. For example, Price, Lin, and Falck-Zepeda (2001) use a model of this type to examine the benefits of the adoption of GM cotton and soybeans. Lopez Andreu (2003) used such a

[8] More discussion of these models can also be found in Voon and Edwards (1991, 1992).

modeling technique to look at the adoption of GM corn. Barkley (2002) looked at the adoption of biotech in corn and soybeans. Our two scenarios require a slight alteration of the algebraic model depending on our hypotheses of segregation or no-segregation. However, the alteration is rather straightforward. Thus, we develop the full analysis for scenario 1 and then show the minor change for scenario 2.

Under scenario 1, our no-segregation scenario, our model for GM wheat can be represented by the following four equations, with lettering consistent with the trade diagram of figure 4:

U.S. Supply: $$Q_A = \alpha_A + \beta_A(P + k) = \alpha_A + \beta_A k + \beta_A P \quad (1)$$

U.S. Demand: $$C_A = \gamma_A - \delta_A P \quad (2)$$

ROW Supply: $$Q_B = \alpha_B + \beta_B P \quad (3)$$

ROW Demand: $$C_B = \gamma_B - \delta_B(P + x) = \gamma_B - \delta_B P - \delta_B x \quad (4)$$

Here, Q_A and Q_B are the quantities of wheat produced in the U.S. and the ROW, respectively. C_A is the amount of wheat consumed in the U.S. and C_B is the amount of wheat consumed in the ROW. P is the world price of wheat. k is the amount by which the per-unit costs are introduced into the supply function due to the cost savings from producing GM wheat and x is the decrease in demand due to the reluctance of U.S. trading partners to purchase GM wheat, measured as a per-unit price decline. This can be thought of as the decline in overseas consumers' willingness to pay for non-segregated wheat as discussed above. α and γ are intercepts and β and δ are slope parameters.

We can solve for the equilibrium price by setting total quantity equal to total demand: $Q_A + Q_B = C_A + C_B$. Doing so gives

$$P = (\gamma_A + \gamma_B - \delta_B x - \alpha_A - \beta_A k - \alpha_B) / (\beta_A + \beta_B + \delta_A + \delta_B). \quad (5)$$

When there is no supply shift k=0 and

$$P = P_0 = (\gamma_A + \gamma_B - \delta_B x - \alpha_A - \alpha_B) / (\beta_A + \beta_B + \delta_A + \delta_B). \qquad (6)$$

Defining K as the percentage change in per-unit cost savings such that $k=KP_0$, then when the supply increases due to the reduced costs of producing GM wheat, the new price will be

$$P = P_1 = (\gamma_A + \gamma_B - \delta_B x - \alpha_A - \beta_A KP_0 - \alpha_B) / (\beta_A + \beta_B + \delta_A + \delta_B). \qquad (7)$$

Therefore, the change in price after the introduction of GM wheat is

$$P_1 - P_0 = - \beta_A KP_0 / (\beta_A + \beta_B + \delta_A + \delta_B). \qquad (8)$$

The absolute value of the *relative* price change is denoted by Z:

$$Z_0 = -(P_1 - P_0) / P_0 = \beta_A K / (\beta_A + \beta_B + \delta_A + \delta_B). \qquad (9)$$

Multiplying Z_0 through by $P_0 /Q_{A,0}$ and adapting to elasticity form[9] gives

$$\begin{aligned} Z_0 &= -(P_1 - P_0) / P_0 \\ &= (\beta_A K)(P_0 /Q_{A,0}) / [(\beta_A + \beta_B + \delta_A + \delta_B) (P_0 /Q_{A,0})] \\ &= \varepsilon_A K / [\beta_A(P_0 /Q_{A,0}) + \delta_A(P_0 /C_{A,0})(C_{A,0} /Q_{A,0}) \\ &\qquad + (\beta_B + \delta_B)[P_0 /C_{B,0} - Q_{B,0})][(Q_{A,0} - C_{A,0} /Q_{A,0}]] \\ &= \varepsilon_A K/[\varepsilon_A + s_A\, \eta_A + (1 - s_A)\, \eta_B^E], \qquad (10) \end{aligned}$$

where ε_A is the U.S. supply elasticity for wheat, η_A is the absolute value of the U.S. demand elasticity for wheat, η_B^E is the absolute value of the U.S. export demand elasticity for wheat, and s_A is the initial share of U.S. wheat consumed domestically. Here we used the fact that $QT_0 = C_{B,0} - Q_{B,0} = Q_{A,0} - C_{A,0}$.

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[9] Interpretation of Elasticities: An elasticity measures the percentage change in a variable Y given a one percent change in another variable X; mathematically, $\frac{dY}{dX}\frac{X}{Y} = \frac{\%\Delta Y}{\%\Delta X}$. For instance, the elasticity of supply, $\varepsilon = \frac{dQ}{dP}\frac{P}{Q}$ gives the percentage change in the quantity supplied of a good following a one-percent change in the good's price. Thus, a supply elasticity of 0.4, for example, would mean that if the price increased (decreased) by 1%, the quantity supplied would increase (decrease) by only 0.4%. The price elasticity of demand is similarly derived but the price-quantity effects are in opposite directions. For example, a demand elasticity of -0.8 means that if the price increased (decreased) by 1%, the quantity demanded would decrease (increase) by 0.8%.

Similar manipulation must be done to determine the price change due to the decrease in demand in the ROW due to the reluctance of foreign consumers to purchase non-segregated wheat. When there is a U.S. supply shift but there is no ROW demand shift, x=0 and

$$P = P_1 = (\gamma_A + \gamma_B - \alpha_A - \beta_A K P_0 - \alpha_B) / (\beta_A + \beta_B + \delta_A + \delta_B). \qquad (11)$$

When the ROW demand decreases due to the introduction of GM wheat, defining $x=XP_1$ so that X denotes the percentage change in the willingness to pay for a unit of wheat yields

$$P = P_2 = (\gamma_A + \gamma_B - \delta_B XP_1 - \alpha_A - \beta_A K P_0 - \alpha_B) / (\beta_A + \beta_B + \delta_A + \delta_B). \qquad (12)$$

Therefore, the change in price after the introduction of GM wheat is

$$P_2 - P_1 = - \delta_B XP_1 / (\beta_A + \beta_B + \delta_A + \delta_B). \qquad (13)$$

The absolute value of this *relative* price change is

$$Z_1 = -(P_2 - P_1) / P_1 = \delta_B X / (\beta_A + \beta_B + \delta_A + \delta_B). \qquad (14)$$

Multiplying through by $P_0 / C_{B,0}$ and adapting to elasticities gives

$$\begin{aligned} Z_1 &= -(P_2 - P_1) / P_1 \\ &= [(\delta_B X)(P_0 / C_{B,0}) / [(\beta_A + \beta_B + \delta_A + \delta_B) (P_0 / C_{B,0})]](Q_{A,0} / Q_{A,0}) \\ &= (1 - s_A)\eta_B X / [\beta_A(P_0 / Q_{A,0}) + \delta_A(P_0 / C_{A,0})(C_{A,0} / Q_{A,0}) \\ &\qquad + (\beta_B + \delta_B)[P_0 / C_{B,0} - Q_{B,0})][(Q_{A,0} - C_{A,0} / Q_{A,0}]] \\ &= (1 - s_A)\eta_B X /[\varepsilon_A + s_A \eta_A + (1 - s_A)\eta_B^E], \qquad (15) \end{aligned}$$

where, again, ε_A is the U.S. supply elasticity for wheat, η_A is the absolute value of the U.S. demand elasticity for wheat, η_B is the absolute value of the ROW demand elasticity for wheat, η_B^E is the absolute value of the U.S. export demand elasticity for wheat, s_A is the initial share of U.S. wheat consumed domestically.

In order to capture the total price change when there is an increase in supply in the U.S. *and* a decrease in demand in the ROW we sum Z_0 and Z_1 to get

$$Z = Z_0 + Z_1 = [\varepsilon_A K + (1\text{-}s_A)\eta_B X\,]/[\varepsilon_A + s_A\,\eta_A + (1 - s_A)\,\eta_B^E]. \tag{16}$$

The change in U.S. producer surplus from the hypothetical changes in the supply and demand curves will be calculated using the following formula:

$$\textit{Change in PS} = P_0\, Q_{A,0}\, (K - Z)\, (1 + 0.5\, Z\, \varepsilon_A). \tag{17}$$

Under scenario 2, where U.S. wheat is segregated, the above steps are repeated, but in this case since the demand change is only on the U.S. export demand curve, the initial equations of importance are:

U.S. Supply: $Q_A = \alpha_A + \beta_A(P + k) = \alpha_A + \beta_A k + \beta_A P$ (1)

U.S. Demand: $C_A = \gamma_A - \delta_A P$ (2)

US Export Demand: $QT = \gamma_T - \delta_T(P + x) = \gamma_T - \delta_T P - \delta_T x$ (4’)

In equilibrium US Export Supply must equal US Export Demand, hence, $ES = Q_A\text{-}C_A = QT = ED$. Using this fact, we can derive the total price change when there is an increase in supply in the U.S. *and* a decrease in demand in the US export market only in the same fashion as above. In this scenario, the derived Z equation will be identical to that in equation (16), except for the replacement of the ROW demand elasticity in the numerator with the U.S. export demand elasticity and noting that x is now the change in the U.S. export demand curve rather than the ROW demand curve. Specifically, Z under scenario 2 is:

$$Z = Z_0 + Z_1 = [\varepsilon_A K + (1 - s_A)\eta_B^E X\,]/[\varepsilon_A + s_A\,\eta_A + (1 - s_A)\eta_B^E]. \tag{18}$$

And the change in U.S. producer surplus from the hypothetical changes in the supply and demand curves under scenario 2 are measured using equation (17) with the new Z from equation (18).

4. Data and Statistics Used for the Analysis.

The elasticities and other numerical values used in the estimation are presented in table 3. The world price in table 3 is the U.S. free-on-board (fob) Gulf price. Because wheat is not a homogeneous product, there is no true 'world price' but the U.S. fob Gulf price is a commonly used 'world price'. What are of crucial importance to our analysis are the elasticity measures, which we have gathered from the existing literature as noted in the table. Much work has been done on determining the supply and demand elasticities for wheat, and, yet, the literature still provides a great deal of disparity. While the supply elasticities are fairly constant in the literature, and we choose to use the supply elasticity of 0.22 as used by DeVuyst et al. (2001), the demand elasticities tend to be much more varied. Our values for the demand elasticities represent a typical range. This is, in part, reflective of the fact that some researchers are estimating long-run and others are estimating short-run demand parameters, hence we have labeled these as short- and long-run elasticities.

It is reasonable to assume that in the short run, demand elasticities, especially, would be what economists call "inelastic." Simply, an inelastic demand means that price movements must change a lot in order for quantities to change. This makes sense if it is difficult for consumers to switch to substitute goods. For example, in the column labeled "short-run", the -0.1 own-price elasticity of demand for wheat outside of the U.S. means that a one-percent increase in the price of wheat will result in a less than one percent (specifically a 0.1 percent) decrease in the quantity of wheat demanded. A similar story exists for the other demand elasticities in the short run. This is important for the analysis because these inelastic estimates suggest that movements in prices and/or quantities from either the introduction of GM cost-savings or from consumer aversion to GM wheat are not likely to have a great effect unless these changes are quite pronounced. On the contrary, the long-run price elasticity of demand is higher because consumers can source more substitutes in the long run. In the case of GM products, the terms may be confusing, however, as it is foreseeable that in the "short run" consumers may react to GM goods more than they will in the long run after they have come to accept them. Nevertheless, we maintain the nomenclature as stated here.

Table 3. *Description of Variables*

Variable	*Value* Short-Run (Inelastic S & D) Scenario	Long-Run (Elastic S & D) Scenario	*Units*	*Description*
Q_A	77.0[a]		Million metric tons	U.S. supply of wheat in 2003
Q_B	732.83[a]		Million metric tons	ROW wheat supply in 2003
C_A	58.25[a]		Million metric tons	U.S. wheat demand in 2003
C_B	621.38[b]		Million metric tons	ROW wheat demand in 2003
P	145[c]		U.S.$/ metric ton	World wheat price
η_A	-0.53[c]	-1.4[f]		U.S. price elasticity of wheat demand
ε_A	0.22[d]			U.S. price elasticity of wheat supply
η_B	-0.1[d]	-1.4[f]		ROW price elasticity of wheat demand
η_B^E	-0.6[e]	-4[f]		U.S. price elasticity of wheat export demand
s_A	32.39, 56% [a]		Million metric tons	Initial share of U.S. wheat consumed domestically

[a]Source: USDA
[b]Source: National Association of Wheat Growers (2004)
[c]Source: FAPRI (2004)
[d]Source: DeVuyst et. al. (2001) as taken from Benirschka and Koo (2001)
[e]Source: Haniotis, Baffes, and Ames (1988)
[f]Source: Voon and Edwards (1992)

5. The Results

As discussed, the question we want to address is: By how much would demand need to fall to offset the cost savings of producing GM wheat under our two segregation scenarios? Using the above equations along with published research and conjecture from other studies, we develop several counterfactual scenarios.

To place bounds on the analysis, we considered a "best-case" production scenario from the introduction of GM wheat and a "worst-case" demand scenario. For the best-case production scenario, we considered a per-unit cost savings of 23 percent (e.g. a downward shifting of the U.S. supply curve by 23 percent corresponding to K in equations (16), (17), and (18)) from the introduction of GM wheat. This was derived based upon our given wheat supply elastcity of 0.22 and a 5 percent increase in quantity based upon Monsanto's prediction of yield increases. The resulting cost saving was roughly 23 percent, consistent with the inelastic supply curve in our model. As this 23 percent cost saving is our upper bound, we also considered less optimistic scenarios: 1 percent, 5 percent and 10 percent downward shifts in the supply curve. Using the same rationale, these would correspond to yield increases of 0.22 percent, 1.1 percent, and 2.2 percent, respectively.

The demand movement is less straightforward. In order to account for a change of X in equations (16), (17), and (18), we need to determine the amount by which consumers in ROW would lower their valuation of wheat after the introduction of the GM attribute in both the segregated and non-segregated scenarios. Studies such as that performed by Neill (2004) are important for determining how much more consumers would pay for non-GM wheat. Wisner

(2004) deduced a 35 percent decline in price in the U.S. export demand due to a dropoff in consumer demand in those nations with GM labeling laws. The ROW demand curve represents the willingness to pay for wheat, thus this demand curve is a mixture of demand for all wheat: both from the US and from elsewhere. Thus, we use Wisner's 35 percent decline as our "worst case" for the total decline in the ROW demand under scenario 1 and as our best guess of the decline in the U.S. export demand curve under scenario 2 (this latter being in line with Wisner's hypothesis). Because of the differing elasticities of the ROW and US export demand curves (with the export demand curve always being more elastic), we expect the effect on producer surplus to be more pronounced under scenario 2. We also consider less extreme cases of 0 percent, 1 percent, 5 percent and 10 percent downward shifts in the ROW and export demand curves. Recall, a 0 percent decline would indicate that there is no change in the demand for wheat given the introduction of GM.

We also do not consider the fact that only one variety of wheat will have the GM trait and, essentially, treat all U.S. wheat as implicated by the introduction of GM wheat. There are two rationales for this. First of all, the intermediate values (0 percent, 1 percent, 5 percent, and 10 percent changes in supply and demand) can be thought of as average changes in supply and demand given that a portion of the U.S. wheat supply is genetically modified and given that not all overseas consumers are opposed to the technology. As we have no idea how much of the crop would be GM, this would seem to be a plausible method for seeking answers. The second rationale is that Wisner has argued that the lack of segregation, ease with which tainting can occur, and rigid standards for labeling may very well implicate all U.S. wheat. As Crespi and Marette (2003a) discuss, if consumers are uncertain about a product's quality, they may very well simply presume it to be GM. As such, implicating all GM wheat, as done here seems reasonable.

We perform eighty simulations, twenty for each of the short-run and long-run demand elasticity values under both the no-segregation and segregation scenarios. Tables 4-7 are the results of the no-segregation scenario. Tables 8-11 provide the results of the segregation scenario. We begin with a discussion of the results for scenario 1.

5.1 Results under the No-Segregation Scenario.

Tables 4 and 5 provide the results when demand is less elastic and tables 6 and 7 provide the results under the elastic scenarios. Tables 4 and 6 are the predicted changes in the farm-level price per metric ton and quantity of U.S. wheat produced. Tables 5 and 7 are the predicted changes in producer surplus.

The results of the analysis are interesting and show the difficulty in predicting equilibrium outcomes when many demand and supply curves are shifting at once. Tables 4 and 5 show how both prices and quantities sold decline for a given technology-induced cost savings as demand declines (reading left to right across columns). Likewise, for a given demand decline, as the supply curve shifts downward (reading downward across rows), prices drop and quantities rise. As long as per-unit revenues increase or decline less than per-unit costs, profits will increase as is shown by the producer surplus changes in tables 5 and 7. We note that the estimated price declines for the short-run scenario are consistent with those projected by Taylor, DeVuyst and Koo (2003, p. 25).

In general, comparing table 5 with table 7, the counterfactual simulations suggest that, in most of the hypothetical demand and supply changes considered, the introduction of GM wheat provides a gain to producers. In table 5, the only losses to U.S. producers occur when demand shifts by 35 percent and per-unit cost savings are small; on the order of 1 percent or less. As is expected, the potential for losses increases as we move from the inelastic, short-run cases of table 5 to the more elastic, long-run cases of table 7. By calculating gains and losses in profits and not just revenues, we also see a more accurate picture of the true value of GM wheat. For example, consider the case in tables 4 and 5 where we examined a 5 percent decline in demand coupled with a 5 percent per-unit cost savings. The results show that even though industry revenues are lower after GM wheat is adopted (11.1 billion compared with 11.2 billion prior to the GM adoptions), industry profits actually increase by 370 million dollars because of the cost advantages.

As far as potential losses are concerned, under the no-segregation scenario producer profits are most in peril in the long run when (1) ROW demand is more elastic and (2) the per-unit cost-savings for the GM technology are on the order of only 1 percent to 5 percent. In these cases, table 7 reveals net producer surplus losses ranging from 22 to 775 million dollars for the U.S. wheat industry. By comparison, in the short-run or inelastic demand curve response (table 5), producers only see a net loss if there is a demand decline in the ROW on the order of 35 percent and the cost savings from GM adoption are less than 5 percent.[10]

[10] Specifically, the supply shift must be less than 2.75% with a 35% decline in demand measured by consumers' willingness to pay in order for producers to be no better off with the GM technology.

Table 4. *Price and Quantity Changes in US Wheat under No Segregation Scenario: Base Price=$145/MT, Base Quantity=77.0 MMT: Inelastic Demand*

Supply Shift in U.S. (Per-Unit Savings)	Demand Shift in ROW (WTP decline) 0%	1%	5%	10%	35%
1%	$145	$145	$144	$144	$142
	77.1 MMT	77.1 MMT	77.0 MMT	77.0 MMT	76.8 MMT
5%	143	143	143	142	140
	77.6	77.6	77.5	77.5	77.2
10%	141	141	141	140	138
	78.2	78.2	78.1	78.1	77.9
23%	136	136	135	135	133
	79.8	79.8	79.7	79.7	79.4

Table 5. *Producer Surplus Changes, No Segregation Scenario: Inelastic Demand (Millions $)*

Supply Shift in U.S.	Demand Shift in ROW (WTP decline) 0%	1%	5%	10%	35%
1%	80.2	73.9	48.7	17.3	(140.3)
5%	401.4	395.1	370.0	338.6	181.3
10%	804.0	797.8	772.7	741.4	584.5
23%	1856.7	1850.5	1,825.6	1,794.5	1,638.6

Table 6. *Price and Quantity Changes in US Wheat under No Segregation Scenario: Base Price=$145/MT, Base Quantity=77.0 MMT: Elastic Demand*

Supply Shift in U.S. (Per-Unit Savings)	*Demand Shift in ROW (WTP decline)* 0%	1%	5%	10%	35%
1%	$145	$145	$143	$142	$134
	77.1 MMT	77.1 MMT	76.9 MMT	76.7 MMT	75.8 MMT
5%	144	144	143	141	133
	77.7	77.7	77.6	77.4	76.4
10%	144	144	142	141	133
	78.5	78.5	78.3	78.2	77.2
23%	142	142	141	139	131
	80.6	80.5	80.3	80.2	79.2

Table 7. *Producer Surplus Changes, No Segregation Scenario: Elastic Demand (Millions $)*

Supply Shift in U.S.	*Demand Shift in ROW (WTP decline)* 0%	1%	5%	10%	35%
1%	102.7	77.8	(21.7)	(146.4)	(774.5)
5%	513.8	489.1	389.9	265.6	(360.2)
10%	1,028.1	1,003.4	904.7	781.0	158.1
23%	2,367.3	2,342.9	2,245.4	2,123.2	1,507.8

5.2 Results under the Segregation Scenario.

When importing nations can keep GM wheat separate from non-GM wheat, the concern is simply about changes in the U.S. wheat export demand curve. As in the previous scenario, tables 8 and 9 provide the results when demand is less elastic, and tables 10 and 11 provide the results under the elastic cases for scenario 2. Tables 8 and 10 are the predicted changes in the farm-level price per metric ton and quantity of U.S. wheat produced. Tables 9 and 11 are the predicted changes in producer surplus when the US wheat is implicated by the GM technology.

With the exception of the no-demand shift cases (which are identical to the cases in the no-segregation scenario), the results under the segregation scenario are starker. As expected, the benefits from the introduction of the GM technology are not as great in this case. Price declines are larger in these scenarios, especially in the elastic demand cases because the export demand curve for U.S. wheat is more price responsive than the ROW demand curve. Likewise, quantity production is lower when compared to the no-segregation scenario, although perhaps not as much as might first be expected. This is because our model assumes that GM wheat that is not exported is still, mostly, consumed in the U.S. market. The result is that farmers still produce a good deal of GM wheat, but sell it at a lower price.

Comparing the producer surplus changes in tables 9 and 11, we see that there are more cases where producer profits become negative than in the no-segregation cases. Just like the no-segregation case, producer profits are most in peril in the long run, elastic demand cases. However, the results here are more striking. Tables 10 and 11 show that in the long run cost savings must be closer to Monsanto’s implied predictions (e.g. the 23 percent per-unit cost savings) in order for GM wheat to be of benefit to U.S. producers. Further, if Wisner is correct in his assessment that there would be a 35 percent drop in the willingness to pay for U.S. wheat, then table 11 shows that in the long run, there is no benefit to U.S. producers from the introduction of GM varieties given Monsanto’s implied cost savings. Depending on the short-run or long-run elasticities and the predictions of supply and demand changes, producer surplus losses in these tables range from $109 million to $2.4 billion.

Table 8. *Price and Quantity Changes in US Wheat under* <u>*Segregation*</u> *Scenario: Base Price=$145/MT, Base Quantity=77.0 MMT: Inelastic Demand*

Supply Shift in U.S. (Per-Unit Savings)		*Demand Shift in US Export Demand (WTP decline)* 0%	1%	5%	10%	35%
	1%	$145	$144	$142	$140	$127
		77.1 MMT	77.0 MMT	76.8 MMT	76.5 MMT	75.1 MMT
	5%	143	142	141	138	126
		77.6	77.5	77.3	77.0	75.6
	10%	141	140	138	136	124
		78.2	78.1	77.9	77.7	76.2
	23%	136	135	133	131	118
		79.8	79.7	79.5	79.2	77.8

Table 9. *Producer Surplus Changes,* <u>*Segregation*</u> *Scenario: Inelastic Demand (Millions $)*

Supply Shift in U.S.		*Demand Shift in US Export Demand (WTP decline)* 0%	1%	5%	10%	35%
	1%	80.2	42.5	(108.8)	(298.4)	(1,257.1)
	5%	401.4	363.7	212.8	23.6	(933.3)
	10%	804.0	766.5	615.9	427.7	(527.5)
	23%	1,856.7	1,819.4	1,669.8	1482.1	533.4

Table 10. *Price and Quantity Changes in US Wheat under* *Segregation* *Scenario: Base Price=$145/MT, Base Quantity=77.0 MMT: Elastic Demand*

Supply Shift in U.S. (Per-Unit Savings)	*Demand Shift in US Export Demand (WTP decline)* 0%	1%	5%	10%	35%
1%	$145	$144	$140	$136	$113
	77.1 MMT	77.0 MMT	76.6 MMT	76.0 MMT	73.4 MMT
5%	144	143	140	135	112
	77.7	77.6	77.2	76.7	74.0
10%	144	143	139	135	112
	78.5	78.4	78.0	77.5	74.8
23%	142	141	138	133	110
	80.6	80.4	80.0	79.5	76.8

Table 11. *Producer Surplus Changes,* *Segregation* *Scenario: Elastic Demand (Millions $)*

Supply Shift in U.S.	*Demand Shift in US Export Demand (WTP decline)* 0%	1%	5%	10%	35%
1%	102.7	31.7	(253.5)	(612.2)	(2,443.1)
5%	513.8	443.0	158.9	(198.5)	(2,022.8)
10%	1,028.1	957.6	674.8	319.0	(1,497.1)
23%	2,367.3	2,297.7	2,018.3	1,666.8	(128.0)

Table 12 presents the above information in a different manner. Table 12 shows the predicted amount by which demand would need to fall as measured in terms of consumers' willingness to pay for U.S. wheat in order to erase the given cost savings from a shift in the supply curve. Thus, if one expects that the per-unit cost savings will be on the order of 5 percent, under the inelastic demand case, no-segregation scenario, the ROW's willingness to pay for U.S. wheat would need to fall 64 percent.[11] By comparison, under the segregation scenario, the U.S. export demand would only need to fall by 11 percent to erase the same cost savings. Under the more elastic demand cases, with 5 percent cost savings, the no-segregation scenario implies that the ROW's willingness to pay for U.S wheat would need to fall 21 percent, while the U.S. export demand would only need to fall by 8 percent if wheat were segregated.

Table 12. *Percent Decline Needed in Willingness to Pay for Exported Wheat in Order to Eliminate GM Wheat's Per-Unit Cost Savings*

	No Segregation Scenario		*Segregation Scenario*	
Cost Savings	*Inelastic Demand*	*Elastic Demand*	*Inelastic Demand*	*Elastic Demand*
1%	13%	4%	3%	2%
5%	64%	21%	11%	8%
10%	100%[a]	42%	22%	15%
23%	100%[a]	95%	49%	33%

[a] Under the inelastic demand, no-segregation scenario, if cost savings were larger than 10%, consumers in the ROW would essentially need to have a 100% decline in their willingness to pay for wheat before the cost savings to U.S. producers are lost.

[11] Recall, this represents the demand from all nations, not just those opposed to GM wheat. In other words, the 64% could reflect, say, a 90% drop in value in Europe but little or no change elsewhere for an average drop of 64%.

6. Conclusion

While the analysis done here is worthwhile, the real market impacts of GM wheat are yet to be seen. When investigating the potential impacts of introducing GM wheat into the market there are many factors that cannot be analyzed until the GM wheat is actually on the market. As such, studies that approach consumers directly to asses their likelihood of purchasing GM products are very useful at this stage. In the absence of an actual market to examine and in the absence of more consumer studies, we must make due with hypothetical scenarios as we have done here.

What then are we to make of the results of this present study? Should U.S. farmers adopt the GM technology? The answer to these questions hinges on the answer to the most important question. *How much will the cost savings be?*

This study provided two scenarios to consider: first, where wheat is mixed on the world market and secondly, if the GM and non-GM wheat were segregated.

Under the first scenario, the results indicate that if the answer to the cost-savings question is that the per-unit cost savings are less than 5 percent, then perhaps U.S. producers may be taking a big gamble in adopting the new technology. The results of the counterfactual simulations suggest that it would only take a 21 percent decline in the willingness to pay for U.S. wheat abroad to erase any cost savings from adopting GM wheat. However, in our opinion, a 21 percent decline in the price of wheat as an input to a wheat product is actually not very much. Wheat, for example accounts for only 5 percent of the price of a loaf of bread, so if overseas millers are facing pressure to source non-GM goods they would not be burdened extensively by the share of this particular input in their production process. As such, this can easily put downward pressure on the price of U.S. wheat. On the other hand, if the cost savings are expected to be larger than 5 percent per unit, U.S. wheat producers would clearly have more latitude in their adoption of the GM technology as the cost savings from the technology would then make it quite profitable for U.S. producers to sell wheat into non-segregated markets.

Under the segregation scenario, however, the results indicate much more caution is warranted. If U.S. wheat is “tainted” in the minds of overseas consumers because of GM, then our predictions here show that cost savings must be much higher to overcome the demand-reduction effect. In fact, if Wisner’s prediction of a drop in the price of U.S. wheat on the order of 35 percent is reasonable, then our simulations suggest that in the long run there is little chance that GM wheat would be profitable, unless of course consumers’ reluctance is overcome.

Since the segregation scenario is the current state of the world, to some degree or another, this finding seems especially worrisome. Therefore, unless the U.S. can win its arguments in the WTO or convince consumers that GM wheat is no different from other wheat, there would seem to be good reason for going slowly at this time.

Nevertheless, there is still room for optimism, even in the face of segregation. As a perusal of the simulations show, the benefits for adopting GM wheat certainly exist and if consumer reluctance can be tempered over time so that demand shifts by10 percent or less, then there clearly are gains to be made from adopting the new technology.

7. References

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