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# Welfare Implications of Introducing Biotech Traits in a Market with Segments and Segregation Costs: The Case for Roundup Ready® Wheat

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## Abstract

Roundup Ready® Wheat (RRW) was one of the first genetically modified (GM) traits for the wheat sector and was under review by regulatory agencies in the United States and Canada when Monsanto withdrew it from further consideration. There are a multitude of issues associated with the *ex ante* evaluation of this decision. These include market acceptance and segregation, as well as the varying sources of cost savings and productivity gains. In this article, we develop a spatial partial equilibrium model of the higher-protein hard wheat market and assess the changes in the distribution of welfare associated with release and adoption of RRW. It incorporates segments for GM aversion in each market and segregation costs for each segment. Major conclusions indicate that in the most likely scenario, producer welfare increases by $301 million and consumer welfare increases by $252 million. Producers of hard red spring (HRS) wheat in the United States and Canada win, while hard red winter (HRW) wheat growers lose.

**Key Words:** genetically modified grains, welfare analysis, wheat

## Highlights

An important challenge confronting the hard wheat market in North America is development and commercialization of genetically modified (GM) wheats. There are a number of GM traits at varying stages of development including Roundup Ready®, fusarium resistant, drought resistant, and varying types of quality improvement. This study addresses issues about *Roundup Ready*® wheat (RRW). Even though it has been withdrawn from regulatory approval, there are numerous lessons and issues that were uncovered regarding GM wheat which are highlighted. RRW would have been the first GM trait for the wheat sector and was under review by the regulatory agencies in the United States and Canada. There are a multitude of issues associated with the *ex ante* evaluation of GM traits in wheat. These include market acceptance, segregation, as well as the varying sources of cost savings and productivity gains. All these are compounded by U.S.-Canada competition in domestic and international markets and their approach to adoption.

In this study, we develop a comprehensive welfare model of the higher-protein hard wheat market and assess the changes in the distribution of welfare associated with release and adaption of RRW. It is a partial spatial equilibrium model and incorporates segments for GM aversion in each market and segregation costs for each segment. The domestic and international markets consist of segments with respect to GM aversion. Suppliers are allowed to adopt or not adopt depending on location and financial incentives to do so, and handlers are allowed to segregate GM from non-GM at different tolerance levels at different costs. Finally, the model determines equilibrium adoption rates, prices, and price differentials among segments, as well as trade flows. Sources of productivity gains and cost savings, some of which vary geographically, are included. The equilibrium is compounded by the spatial distribution of production and demands and domestic and international competition.

Some of the important facts that have an impact on the results include:

» Supply and Demand for High Protein Hard Wheat: High protein hard wheat is used to blend with and improve lesser quality wheat or in the manufacturing of highly specialized food and bakery products. Exportable supplies of high protein hard wheat are largely from the United States and Canada with limited supplies available in Australia, Argentina, and France. Customers with strong aversion to biotech wheat would confront procurement challenges in substituting for the volume of high protein hard wheat currently supplied by either (or certainly both) the United States or Canada.

» Supply Function Shifts: In each of the major hard wheat producing states and provinces in North America, there have been significant shifts in the supply functions during the 1990s. In all cases, these were leftward shifts with the exception of Montana. These are likely due to the combined impacts of the changes in U.S. farm legislation and the concurrent introduction of competing crops, which in most cases have been GM.

» Productivity Gains: RRW has a yield advantage ranging from 11-14% compared to conventional varieties and competing treatments. This is comparable to the initial gains associated with biotech corn and is the first major technology breakthrough for hard red spring (HRS) wheat since the introduction of semi-dwarf wheats in the early 1970s.*

- <u>Cost Savings:</u> Costs savings associated with adoption related to labor and management savings and other non-pecuniary costs range from $8.30 to $11.57/acre across regions. These are in addition to gains related to yield and reduction in dockage removal costs. In addition to these, non-adopter cost savings due to reduced competing chemical costs are in the area of $2.28/ac.

- <u>Market Acceptance</u>: Each market consists of segments with respect to GM aversion. We considered 4 potential segments in each country. Taken together, these imply that about 10% of the North American domestic market would require some form of segregation, and about 43% of the offshore market would require segregation.

The welfare model was solved and used to identify changes in welfare, the distribution of welfare changes, prices and differentials, and equilibrium adoption rates associated with the introduction of RRW. Major conclusions indicate:

- In the most likely scenario which we define as *segmented market acceptance*, producer welfare increases by $301 million, and consumer welfare increases by $252 million. These are comparable to the expost estimates of GM traits on other grains.

- Producers of HRS wheat and Canadian Western Red Spring (CWRS) wheat gain, and Hard Red Winter (HRW) wheat growers lose welfare. The reason for this is due to the technology being available to spring wheat growers and not HRW wheat growers. Further, (as noted below), there is an overall price decline which is less than the cost savings to HRS wheat growers, that adversely impacts HRW wheat.

- Consumers in countries and segments allowing GM gain in welfare, and those with restrictions, notably the European Union (EU) and Japan, have reduced welfare. Reasons for this are that their purchases are of a higher cost wheat that would not incur the technology savings, due to their segregation requirements and due to minor changes in origins. All other countries enjoy increases in consumer welfare.

- If there was full market acceptance (i.e., as if there was no GM aversion or market segments in any of the countries), total welfare increases to $787 million, and in this case there is a greater increase in consumer welfare.

- Any form of restricted introduction results in a lesser gain in welfare. Release in the United States only (or, only in Canada), results in a much lesser increase in producer welfare and negligible increase in consumer welfare. The United States would serve the domestic market, which is largely non-averse, and many of the smaller international

* Technically, breeders introduced semi-dwarfs into their breeding programs prior to the 1970s. Norman Borlaug is credited with identifying the semi-dwarf wheat 'Norin' in Japan in 1961 and starting what is called the "green revolution." These semi-dwarf materials were in the hands of CIMMYT in the 1960s which found their way to breeders programs in the spring wheat region.

markets. Canada would serve most non-GM market segments, albeit at a higher cost in order to increase supplies and conduct segregation.

If Japan were to shift all its purchases from the United States to Canada, there would be a substantial reduction in welfare gains. In this case, Japan is served by Canada at a higher cost, in part due to increase supplies and in part due to segregation costs. The United States serves the domestic market and most of the rest of the world market, in some cases at a higher cost. The combined impacts of these are for a large reduction in both producer and consumer welfare.

In the segmented market acceptance scenario:

» Adoption is greatest in the United States and North American supplies increase by 4%.

» Export market shares are largely unchanged.

» Price levels decline in all likely scenarios associated with introduction of this technology. Results indicate prices decline in the area of $5 to $10/mt. This is as expected and is due in part to the cost reduction of RRW of adopters. The change in prices varies across scenarios and by wheat class. However, for those markets averse to GM content, prices increase in the area of $9 to $12/mt.

» Price differentials emerge in each market and market segment approximately equal to the differentials in costs of production and marketing. These are the differentials likely to confront competitors within each country.

Numerous sensitivities were conducted including those related to technology fees, yield changes, and demand assumptions and implications are drawn for public organizations and private firms.

# Welfare Implications of Introducing Biotech Traits in a Market with Segments and Segregation Costs: The Case for Roundup Ready® Wheat

**William W. Wilson, Eric A. DeVuyst, Won W. Koo, Richard D. Taylor, and Bruce L. Dahl***

## 1. Introduction and Overview

There are several initiatives for the development of Genetically Modified (GM) wheats. In North America, these have been primarily on the *Roundup Ready*® trait, though there is extensive research elsewhere on a wide range of GM traits in wheat (e.g., fusarium resistance by Syngenta, drought resistence by DuPont, among others). Virtually all developments in North America are currently on Hard Red Spring (HRS) wheats though there is some effort on drought resistance in hard red winter (HRW) wheat. Experimental trials have been planted in South Dakota, North Dakota, and Minnesota, as well as in selected Canadian prairie provinces.

This study addresses issues about *Roundup Ready*® wheat (RRW) and even though it has been withdrawn from regulatory approval, there are numerous lessons and issues that were uncovered regarding GM wheat which are highlighted. RRW would have been the first GM trait for the wheat sector and was under review by the regulatory agencies in the United States and Canada. There are a multitude of issues associated with the *ex ante* evaluation of GM traits in wheat. These include market acceptance, segregation, as well as the varying sources of cost savings and productivity gains. All these are compounded by U.S.-Canada competition in domestic and international markets and their approach to adoption.

Even though RRW has been withdrawn from regulatory approval in Canada (Monsanto 2004; Sosland Publishing 2004), other GM wheat traits are under development. Policymakers will have to confront issues related to those traits as/if these move closer to commercialization decisions. Monsantos' decision to "deferring all further efforts to introduce Roundup Ready® wheat" (Monsanto 2004) and to "withdraw regulatory submissions outside the United States" (Sosland Publishing 2004) is particularly important. This decision was made for a multitude of reasons, but were influenced by apparent resistance by grower groups and others on the inability to segregate GM from non-GM wheat which was the maintained assumption of several aggregate level analyses (Furtan, Gray, and Holzman 2005; Furtan, Burden, Scott 2003; Wisner 2003).

Development of GM wheats has lagged other grains and oilseeds for varying reasons. Most important is likely the more complex genetics. Other contributing factors include: 1) wheat is a smaller volume crop within North America; 2) exports are of greater relative importance; 3) import country regulations vary much more for wheat and are less well defined;

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and 4) competition amongst exporting countries is likely more intense and compounded by radically different marketing systems regarding quality and trade practices, etc.

If a trait is approved in the United States and/or Canada, there would be no limits on the adoption of these traits, except for the extent that individual companies may impose a limit or tolerance. If the traits are approved in Japan, wheats can be imported, but subject to labeling laws. Since this trait is not (yet) approved in the European Union (EU), it would imply a nil tolerance. The new EU policy (Commission of the European Communities 2003a,b) would allow approved traits, but would require product labeling and traceability (using a yet to be specified system) if the level of adventitious presence exceeds 0.9%. Developments in these countries are pending and will impact the evolution.

RRW [1] is an example of 1st stage benefits. The 2nd and 3rd stage effects will not be accessible until 2007 and beyond.[2] In the case of wheat, 2nd stage effects include enhanced protein quality, novel starch types (functionality), enhanced nutritional content, reduced allergens, and improved freshness and shelf-life for baked products. These observations were echoed by Biane indicating that consumer benefits in the case of wheat include extending shelf life, improved nutrition, and reduced allergens. Pressures for adopting GM wheat, specifically RRW, come from a combination of yield increase, cost reduction, reduced dockage, increased profitability of competing crops (being recipients of GM technology), and the prospect of 2nd and 3rd stage benefits associated with GM wheats.[3]

A recent study evaluated the composition of RRW (Obert et al. 2004) to its non-transgenic parent and to conventional wheats. That study indicated that MON71800 was *substantially equivalent* to its non-transgenic parent and commercial wheat varieties and that MON71800 is as safe and nutritious as commercial wheat varieties. In closing, they indicated:

> *Considering the principle of substantial equivalence as articulated by the World Health Organization, the Organization for Economic Cooperation and Development, and the United Nations Food and Agriculture Organization, these data, along with the safety of the CP4 EPSPS protein and the safe history of use of wheat as a common source of animal feed and human food, demonstrate that glyphosate tolerant wheat MON71800 is as safe and nutritious as conventional varieties of wheat currently on the market.*

This is a significant finding that is the first refereed evidence about the substantial equivalence of RRW. Many of the existing studies we refer to below proceeded without this set of facts.

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[1] Monsanto decided to defer further commercialization of RRW for several reasons (Kilman 2004). On July 29, the United States Food and Drug Administration informed Monsanto that RRW "is as safe as conventional wheat for all food and feed uses."

[2] Bloomer (2001) originally suggested that 1st stage benefits should be commercially available by 2005. However, Monsanto has indicated these would not be released until certain milestones have been achieved. Syngenta suggested a date of availability for their fusarium resistant wheat for 2007, but it is unclear about the firmness of this date.

[3] Much of this background material is described in greater detail in Wilson, Janzen, and Dahl (2003).

The problem in wheat is compounded by the fact that most of the effort is focused, at least initially, on HRS which is the primary wheat class grown in northern tier states and Canada. Thus, Canada's position and adoption will have a critical impact of the post-adoption competition. Most important is that the mechanisms to facilitate adoption of GM wheats in Canada differ from those in the United States (e.g., variety approval process, variety kernel distinguishability, contract calls, the ability to add/create subclasses of wheat with specific characteristics).

The purpose of this study is to analyze the distribution of welfare changes associated with adoption of this trait. Though Monsanto has announced their deferral of commercialization of RRW, the results are still pertinent as to the factors that impact the market and distribution of welfare. As well, the methodology provides a way to evaluate welfare distribution for other GM traits and those in the hard wheat market in particular. The first section below describes previous studies that analyze welfare distributions of GM crops in general and of HRS in particular. Section 3 provides a detailed discussion of the major issues impacting welfare distributions associated with RRW in HRS. The analytical model is described in Section 4 and results are presented in Section 5. Finally, Section 6 provides a summary and discusses policy implications. The appendices contain background data, a description of the market for wheat protein, and other assessments.

## 2. Studies on Welfare Distributions and GM Crops

Introduction of biotechnology traits into GM crops and oilseeds have been subject to a number of studies. One strain of these focuses on the distribution of welfare gains amongst producers, consumers, and technology providers. This section summarizes some of these studies. The first section focuses on recent studies on grains, oilseeds, and cotton. The section that follows provides detail to the few studies that have addressed welfare implications of GM wheat.

### 2.1. Welfare Studies on GM Crops

Since the introduction of GM technology, a number of studies have analyzed the distribution of welfare gains attributable to these technologies. Generally, these use fairly aggregated models, make assumptions to facilitate calculations, and usually analyze impacts of traits that have already been introduced. Introduction of a trait, in this case an output trait, has the impact of increasing productivity and production, shifts the supply function, reduces prices, and increases demand by consumers. Then the analysis proceeds to evaluate the distribution of these gains amongst producers, consumers, and technology providers. Examples of some of these are summarized below.

Falck-Zepeda, Traxler, and Nelson (2002) modeled Bacillus Thuringiensis (Bt) cotton in 1996 with no technology spillovers assuming linear demand and supply and parallel shifts from adoption of the new technology. Two sectors were included, the United States and the Rest of the World (ROW). Differences in production costs were derived from surveys. Yield differences were converted into equivalent cost savings. Simulation was used to capture distributions for elasticity of demand, supply, and exports in the United States, and supply elasticity for the ROW. They found that the benefits were distributed as: 59% increase in producer surplus for U.S. farmers; 9% increase in consumer surplus for U.S. consumers; 21% increase in producer surplus from technology fees to Monsanto; 5% increase to Delta and Pineland; and 6% increase for the ROW.

Qaim and Traxler (2005) examined farm level and aggregate welfare effects of Roundup Ready® (RR) soybeans in Argentina (Table 2.1). Their analysis utilized a partial equilibrium model with international technology spillover. The model assumes linear supply response for a three-region model (United States, Argentina, and ROW). Farm level differences were elicited by surveying Argentine growers (late 2001). Respondents were asked to respond for the last three years (as most had stopped growing non-RR soybeans within the last two years). Data were analyzed to determine differences between RR and non-RR budgets and if farm size influenced effects.

They found seed costs were higher with RR in Argentina. Chemical costs were higher for non-RR soybeans as two to three chemicals were utilized vs. glyphosate for RR and the fact that glyphosate was cheaper than alternatives. Operating costs for own machinery and custom operations were lower with RR technology (faster harvest time). They estimated cost savings at $21/HA. No yield advantage was found. Prices for alternative herbicides dropped 32% on average from 1996-2001.[4] Bias was found where small farms accrue larger cost savings than large farms (higher pesticide savings than larger farms and lower average price markup for RR seeds due to lower use of certified seed).

**Table 2.1. Economic Surplus Generation and Distribution: Argentine Soybeans**

| | Change in Producer Surplus | Change in Consumer Surplus | Technology Revenue | Total Surplus |
|---|---|---|---|---|
| | ---------------- | ----------$mil---------- | ---------------- | |
| Argentina | 303 | 4 | 28 | 335 |
| United States | 145 | 149 | 393 | 687 |
| ROW | -291 | 498 | 0 | 207 |
| Total | 158 | 652 | 421 | 1, 230 |

Source: Qaim and Traxler (2005).

Several studies have analyzed the impact of GM technology in the U.S. soybean complex. Moschini, Lapan, and Sobolevsky (2000) derived increases in U.S. producer surplus ranging from $135 million to $396 million from the adoption of GM soybeans. Consumer surplus in the United States increased from $9 to $25 million. Total world surplus increased ranging from $804 million to $2.2 billion.

[4] This is close to the 38% to 40% price declines found elsewhere–see Section 3.6 of this report.

The U.S. Department of Agriculture (USDA) compared welfare benefits of adopting Bt cotton, herbicide tolerant (HT) cotton, and HT soybeans in 1997 (Price et al. 2003). Their welfare model assumed linear supply and demand functions and a parallel shift in supply due to biotech innovation for Bt cotton and HT cotton and HT soybeans for 1997. Several sources were used to quantify farm level impacts of biotechnology including the Agricultural Resource Management Survey (ARMS) and the Enhanced Market Data (EMD) (used for Bt cotton model only). Econometric models were developed to estimate effects of yields and pest control costs. Elasticities used in their analysis and results are summarized (Table 2.2) for base cases with linear demand and supply functions.[5] Results illustrate that welfare benefits of these biotech traits are $213 million, $232 million, and $308 million, for Bt cotton, HT cotton and HT soybeans, respectively (Table 2.3), and the distribution of these gains among producers, consumers, and technology companies varies.[6]

There are a number of important contrasts of these studies and approaches to the issues and challenges confronting welfare impacts of GM wheat traits. These include market segments and segregation costs, international competition, spatial dimensions of trade, and impacts of adoption, and each was conducted post-introduction of the trait. A critical item was that all these studies were of approved GM traits. These contrast with the analysis of the proposed GM wheat which has to rely on perceived benefits.

**Table 2.2. USDA Baseline Elasticities**

| | 1997 Bt and Herbicide Tolerant Cotton | 1997 Herbicide Tolerant Soybeans |
|---|---|---|
| U.S. Supply Elasticity | 0.47 | 0.28 |
| U.S. Demand Elasticity | -0.50 | -0.50 |
| Net Export Demand Elasticity | -0.97 | -1.21 |
| ROW Supply Elasticity | 0.15 | 0.30 |
| ROW Demand Elasticity | -0.15 | -0.25 |

Source: Price et al. (2003).

These studies are summarized in Table 2.4 with respect to their assumption.

[5] Price et al. (2003) also notes two other studies with non-linear supply and demand functions and non-parallel shifts in supply.

[6] Sensitivity was conducted to evaluate the impacts of non-linear demand and supply functions.

**Table 2.3. Estimated Welfare Effects for Selected Biotech Crops**

| | Bt Cotton | | Herbicide Tolerant Cotton | | Herbicide Tolerant Soybeans | |
|---|---|---|---|---|---|---|
| | $mil | percent | $mil | percent | $mil | percent |
| U.S. Farmers | 61 | 29% | 10 | 4% | 62 | 20% |
| U.S. Consumers | 30 | 14% | 132 | 57% | 16 | 5% |
| Monsanto | 62 | 29% | 11 | 5% | 86 | 28% |
| Delta & Pine Land/ Seed Companies | 13 | 6% | 4 | 2% | 124 | 40% |
| ROW Producers | -135 | | -733 | | -35 | |
| ROW Consumers | 181 | | 809 | | 55 | |
| Net ROW | 46 | 22% | 76 | 33% | 20 | 6% |
| World Benefit | 213 | | 232 | | 308 | |

Price et al. (2003).

**Table 2.4. Comparison of Model Assumptions Used in Biotech Welfare Analysis**

| | Falck-Zepeda et al. (2002) | Qaim and Traxler (2005) | Moschini, Lapan, and Sobolevsky (2000) | Price et al. (2003) Base Case | Price et al. (2003) Sensitivity |
|---|---|---|---|---|---|
| Crop | Bt Cotton | RR Soybeans | RR Soybeans | Bt Cotton, RR Cotton, RR Soybeans | Bt Cotton, RR Cotton, RR Soybeans |
| Year | 1996 | 1996-2001 | 1999 | 1997 | 1997 |
| Supply and Demand Functions | Linear | Linear | Linear | Linear | Non-linear |
| Technology Shift | Parallel | Parallel | Parallel | Parallel | Non-parallel |
| Efficiency of Technology Transfer | 0 | 100 | 100 | 50 | |
| Number of Sectors | 2 (U.S., ROW) | 3 (U.S., Arg., ROW) | 3 (U.S., S. Am., ROW) | 2 (U.S., ROW) | 2 (U.S., ROW) |

## 2.2. Welfare Studies on GM Wheat

There are numerous issues important in GM wheat that were not problematic in other studies of GM traits. Most important is that the trait(s) are not yet approved, there will be market segments with respect to GM aversion, segregation costs are important, and there is intense intercountry competition.

*Aggregate Impacts of GM Grains on the Upper-Midwest (NCFAP).* A comprehensive study quantified the farm income, food production, and reductions in pesticide use that may result from wider use of agricultural biotechnology in the United States (Gianessi et al. 2002). The study was based on 40 case studies of 27 crops across 47 states. The report is limited to cases for which successful transformation has occurred and for which there are at least preliminary results on performance for pest management. It compares observed and potential impacts of biotech crops versus conventionally bred crops, including only biotech cultivars to be used in pest management.

The study included two different case studies on wheat: viral resistant and herbicide tolerant varieties. The study on HT wheat was conducted in the four states that account for 92% of U.S. spring wheat acreage -- Montana, Minnesota, North Dakota, and South Dakota. In the case study on HT wheat, it is estimated that 33% of spring wheat in the above four states is not treated with herbicides to control Canada thistle, a key weed problem, because cost outweighs benefits, resulting in an average yield loss of 4 bu/ac. It is estimated that glyphosate tolerant wheat would control all major weeds in wheat and enable growers to increase their income by $12 per acre. The potential economic gains in North Dakota rank second only to California. The total economic impact of biotech crops in the four states is summarized in Table 2.5.

**Table 2.5. Impact of Biotech Crops by State**

| State | Added Income ($mil)* | Pesticide Reduction (lbs active ingredients) |
|---|---|---|
| Minnesota | 156 | 5,145,888 |
| Montana | 21 | 37,000 |
| North Dakota | 185 | 86,732 |
| South Dakota | 74 | 291,444 |

* Combines value of increased production and lower production costs if all biotech varieties studied are adopted.

Two recent studies used real options to analyze the optimal timing of the release of RRW in Canada. Though these are not comprehensive welfare analysis, they do capture the key sources of uncertainties associated with the irreversible decision of releasing a trait. Results from Furtan, Gray, and Holzman (2005) were based on the inability to segregate RRW from conventional wheat and concluded that releasing RRW would be akin to the market for lemons. Carter, Berwald, and Lyons (2004a) allowed for segregation at reasonable costs and refined other assumptions and found that it would be optimal in virtually all cases to release RRW.

- » Price levels decline in all likely scenarios associated with introduction of this technology. Results indicate prices decline in the area of $7mt. This is as expected and is due in part to the average cost reduction of RRW of adopters in the area of $14/mt. The change in prices varies across scenarios, and by wheat class as expected.

- » Price differentials emerge in each market and market segment approximately equal to the differentials in costs of production and marketing. These are differential likely to confront competitors within each country.

Numerous sensitivities were conducted including those related to technology fees, yield changes, and demand assumptions.

### 6.3. Implications

There are many implications of these results including those for public and private policies and inter-country implications.

The welfare gains of RRW are comparable to the estimated expost welfare gains on like traits introduced in soybeans and cotton in magnitude. Due to the increased productivity and market segments, prices decline. The distribution of welfare gains are neither universal nor symmetric. Producers in regions with greater adoption have a greater gain in welfare than others. Producers of HRS and CWRS wheat benefit, but HRW wheat producers lose. The reason for this is that the latter do not benefit from the technology but suffer from the price decline. There are also differential impacts across consuming countries. Those with large segments which are GM tolerant benefit the most. However, those that restrict GM imports, notably the EU and Japan, suffer due in part to the higher costs of production and segregation and to a minor extent the geographic shift in procurement.

Besides the differential impacts among producers and consumers, there are two areas that may be influenced by public policy. One is to improve, however possible, acceptance of GM wheat. In these results, the non-GM market segments comprised about 10% of the domestic market and 44% of the export market. Welfare improvement of full versus segmented market acceptance is about $234 million. This is sizable and results in improvements for all sectors. If other traits are commercialized, its impact would become even more important. While we recognize efforts are underway to improve and facilitate acceptance, there is certainly room for greater concentration of initiatives toward this end.

The second relates to segregation costs. We allow for reasonable costs of segregation in determining our equilibrium results. However, a number of requisites are necessary to achieve these, including the availability of low-cost repeatable tests, certification, and mechanisms to facilitate variety declaration. Each of these can be influenced by the public sector. Looking beyond the equilibriums presented here, an important area of intercountry competition will be the countries' ability to perform these functions at lower costs than their rivals. Again, the ability to do so can be influenced by policies and initiatives.

Three sets of private sector implications are discussed. Growers will be confronted with another production choice that has implications for farm management. These will also affect marketing decisions and will be impacted by price differentials, contracting mechanisms and obligations, the prospective need to maintain segregations and assure improved variety purity. Handling firms and exporters will compete in this bifurcated market based on segregation costs and risks. Further, non-GM buyers with tight tolerances will likely require closer buyer-seller relationships and be less transactional versus conventional marketing. Finally, inter-segment competion amongst processors will be intensified with the introduction of GM wheat. Notably, processors of products requiring non-GM or limited amounts of GM for marketing purposes, will confront greater competition from those that do not due in part to the lower cost ingredients available to the latter.

Finally, there are strategic implications for intercountry competition between the United States and Canada. Regions within these two countries already have different institutional mechanisms that facilitate quality and marketing and compete vigorously in most markets. If both countries adopt, both gain comparably, with Canada gaining slightly more due to its large acreage. Export market shares are largely unchanged. If one adopts and the other does not, the results change drastically.[26] If there were asymmetric adoption, the more likely case would be the United States adopting first.

One way to view this strategic rivalry would be that of tough commitments when prices are strategic complements (Bulow, Geanakopolos, and Klemperer 1985) in 2-stage games. In stage 1, the United States adopts a cost reducing technology. In the second stage, Canada and the United States compete, most likely on prices. A strategic commitment such as a technology that is cost reducing is thought of as "tough" (i.e., any commitment that would be bad for competitors, but it must be transparent and irreversible). Any such commitment has what would have direct and strategic price effects. The characteristics of the commitment (tough or soft) and 2nd stage competition impacts the longer-run equilibrium.

The asymmetric release and adoption by the United States would be interpreted as a tough[27] commitment to both reduce costs and segregate non-GM. Conceptually, this would be equivalent to a leftward shift in the U.S. reaction function in Bertrand competition, assuming prices are strategic complements. The impact of this would be reducing prices in each country, but a larger price reduction on its own price. The strategic side effect of the commitment is for a price reduction in both countries. In this case, the negative strategic effect is less than the direct effect. Fudenberg and Tirole (1991) refer to this as a "Mad Dog" strategy–i.e., with strategic complements, making a tough commitment is akin to an "attack to become top dog, invite battle heedless of costs." Both the direct and strategic effects should be considered in assessing how such decisions will affect future competition.

Results from our models can be used to interpret these strategic effects. If the United States adopts and Canada does not, the former makes a tough 1st stage commitment. This has the

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[26]An alterative strategic representation would be that of vertical differentiation. This would suggest that the two countries would chose to compete based on the vertical differentiation with respect to aversion to GM content. This is an appealing representation but is not pursued here.

[27] A soft commitment, in contrast, would be one that would result in less production than otherwise would have been the case–which is not the case here and would lead to higher prices.

impact of reducing costs by about $14/mt on average for adopters. Equilibrium prices in the 2nd stage drop by about $7/mt. Thus as the mad dog, the United States would accrue a cost advantage greater than the reduced equilibrium price change (i.e., the strategic effect would be negative, but not as great as the direct effect). Canadian and HRW wheat growers would be adversely impacted by having to compete against a lower cost competitor. This differential advantage would give the United States a first mover advantage and would be retained until Canada adopts similarly at which time it would diminish.

Of course, there are many other impacts of such an asymmetric release which are not considered here. One is the assurance that proposed segregation mechanisms will serve needs of buyers. The second is that in such a bifurcated market, Canada gains in the large stable Japanese market (assuming Japan would allow itself to be subjected to a bi-lateral monopoly structure for purchases), and the United States gains in other markets, which are typically smaller and more volatile.

## 6.4. Limitations

All of the assumptions and relationships used in this study are based on recent, and in most cases, refereed published sources and should be accepted as plausible. Hence, most of the limitations relate to factors not allowed in the welfare model. There are several which are acknowledged.

The model does not consider impacts on other small grains and organics. As production of GM HRS and CWRS wheat improves in profitability due to this technology, other sectors not benefitting from the technology will be adversely impacted. These include other small grains, notably durum wheat, malting barley, etc., and the organic production of HRS wheat. These sectors will suffer in part because their opportunity cost will increase, much like has occurred between these and other current GM row crops, as well as between HRS and HRW wheat as illustrated in this analysis. They will also suffer to a minor degree to the extent that they may require more onerous segregation and/or certification processes to assure their purity when grown or handled in non-specialized farms and facilities.

A second consideration is that it disallows emergence elsewhere in the world for non-GM higher-protein hard wheat as a substitutute. We view this as somewhat unlikley. While minor amounts of higher-protein APH are exported from Australia, the overall protein level has been declining in that country for many years despite attempts to reverse its decline. Other countries do not export notable volumes of higher-protein wheats with the functional characteristics of HRS wheat. If these countries could competitively produce these wheats, one would have thought they would have already done so given their value. The Former Soviet Union (FSU) and other eastern European countries are somewhat of a wild card on their ability to export wheats competitive with those in North America. Nevertheless, the approach here is not limiting because GM averse buyers are allowed to substitute the higher cost of segregation from the United States and Canada for the lower cost GM wheats. Finally, from a practical matter, we have to acknowledge that some of these competing regions are developing GM wheats, though their release is not imminent.

Third, we assume the market equilibrium is determined competitively. Strategic behavior of suppliers is ignored both on the part of importers and exporters. While we recognize there may be alternative assumptions on this topic, it seems reasonable. Essentially, we allow a large number of competing regions to compete among one another through a competitive export industry to supply to a large number of independent and spatially separate demanders that are assumed to be atomistic. Other approaches could be considered, but to do so would be by assumption and we do not have access to data that would allow verification of alternatives. Hence, the competitive assumption used here is retained and defendable.

Finally, we consider only one GM trait, that being RRW which has already been deemed as substantially equivalent to conventional varieties. There are other GM traits under development but their release is years away and measures of their potential productivity gains and/or cost savings do not exist.

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# Appendix A: Supply and Demand for Protein in Hard Wheats

This Appendix provides and documents the major sources of supply and demand elements for HRS and CWRS wheat. Demand is discussed first, followed by supply.

## A.1. Import Demand for HRS and CWRS

The United States exports about 50% of its HRS wheat. Major importers are illustrated in Figure 3.2. Major importers from the United States are (in rank order) Japan, Philippines, Taiwan, Italy, and South Korea. Beyond these, there are 70 countries that import levels ranging from 6 million bushels per year to less than 50,000 bushels. Imports by protein are shown in Figure A.1.1. These data illustrate that from the United States, about 95% of its exports of HRS are 13% or greater. Technically, the most common is for 14% or better.

Canadian CWRS wheat (Figure 3.4). [28] The largest importers of CWRS wheat are, in rank order: Japan, United States, Iran, and Mexico. In comparison, Iran does not import U.S. HRS wheat and China imports only a minimal volume, but the volumes have increased in recent years. Finally, about 60% of CWRS wheat exports are >13% protein, though this has not been reported in recent years. This is in contrast to the United States from which 95%of HRS wheat exports are >13%.[29]

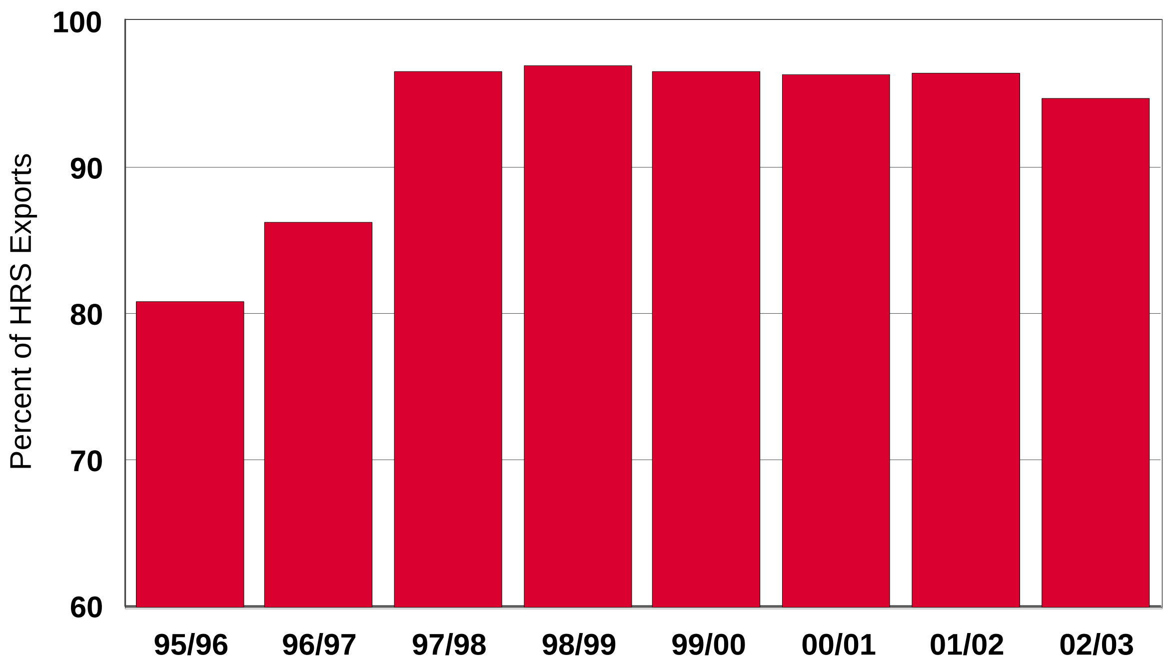


**Figure A.1.1. U.S. Spring Wheat Exports Protein > 13%, 1995/96-2002/03.**

[28] Comparable detailed quality data is not publicly available in Canada as in the United States.

[29] Data are not routinely reported for more recent years on the percent exported by class/grade/protein.

## A.2. Supply for HRS and CWRS

Major points from these figures/data (Figures A.2.1-A.2.6) are:

Production of this class of wheat is concentrated in the North Central portion of the continent with the greatest concentration in Saskatchewan and the Northern counties of North Dakota. However, production of HRS is scattered throughout many other states. There have been declining acres in each of the major growing regions. In North Dakota this is likely due to a combination of the Freedom to Farm, and concurrent adoption of competing crops, notably corn, soybeans, and canola. In Saskatchewan this is most likely due to shifts into canola and other specialty grains/oilseeds.

In total, this can be interpreted that the competing crops have gained in agronomic competitiveness relative to HRS wheat. Yields in the primary growing regions do not show significant trends.

There are some interesting comparisons between U.S. and Canada HRS/CWRS wheat production which are apparent in these figures: Acres planted in Canada have fallen much more than that in the United States over the past decade; HRS wheat yields are comparable until 2001 when U.S. yields were 5 bu/ac greater.

Supply of protein (Figure A.2.4) shows that HRS wheat has substantially greater protein than HRW wheat, average protein for HRS wheat in North Dakota exceeds that in Canada, and both have been tending upwards since 1995. In fact, that in 2001 suggests a notable upward shift in protein supplies. Estimates were derived of production of HRS and CWRS wheat with protein greater than 13% (Figures A.2.5-A.2.6). These illustrate that North Dakota and Saskatchewan are by far the largest concentration of production with about 200 million bushels each. Production with >13% in the United States is about 400 million bushels, and that in Canada is about 500 million bushels. The amount in Canada increased over the 5 years prior to 2002, and that in North Dakota decreased through 2002 and increased in 2003.

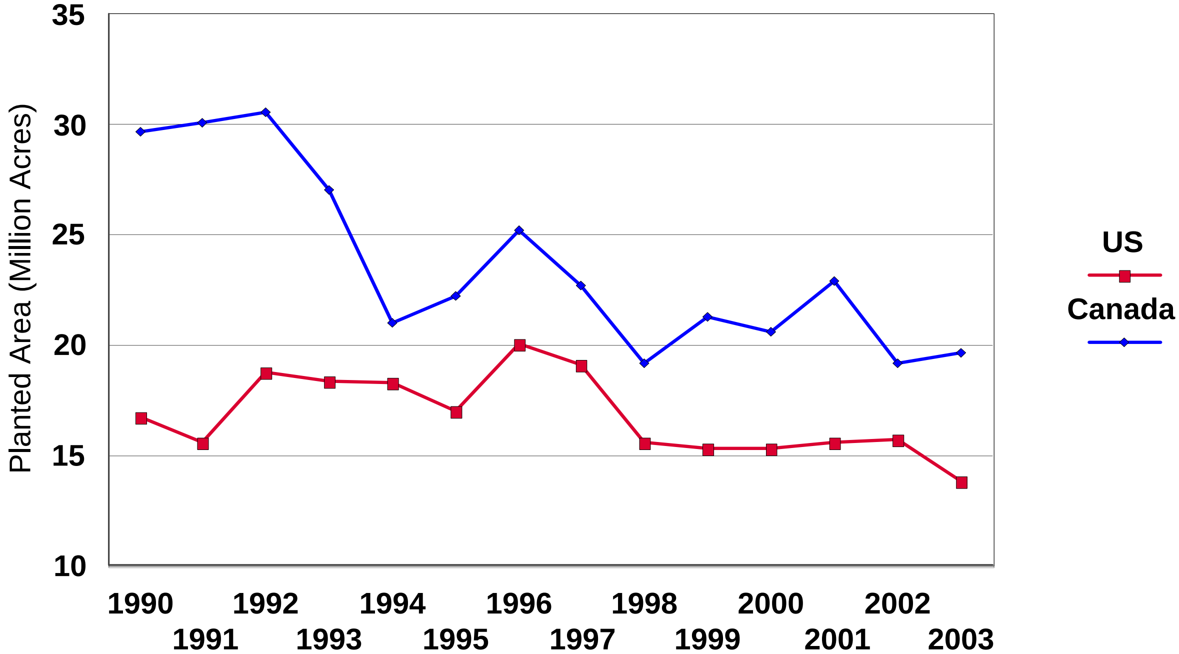


**Figure A.2.1 HRS Planted Acres, 1990-2003.**

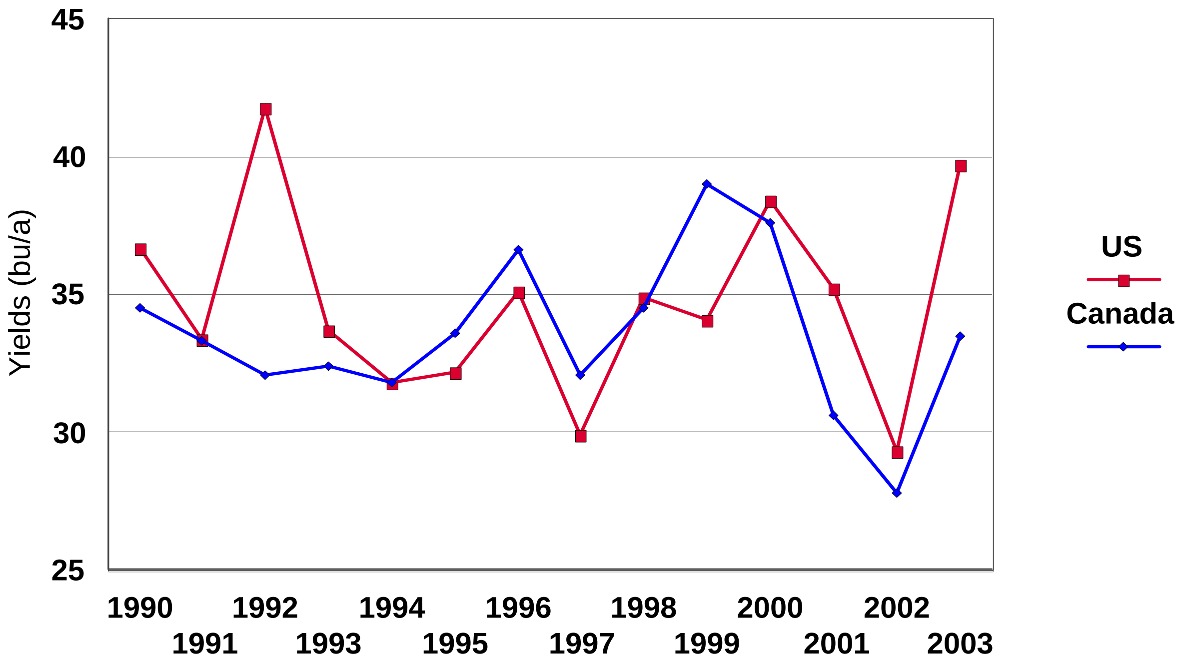


**Figure A.2.2 HRS Yields, 1990-2003.**

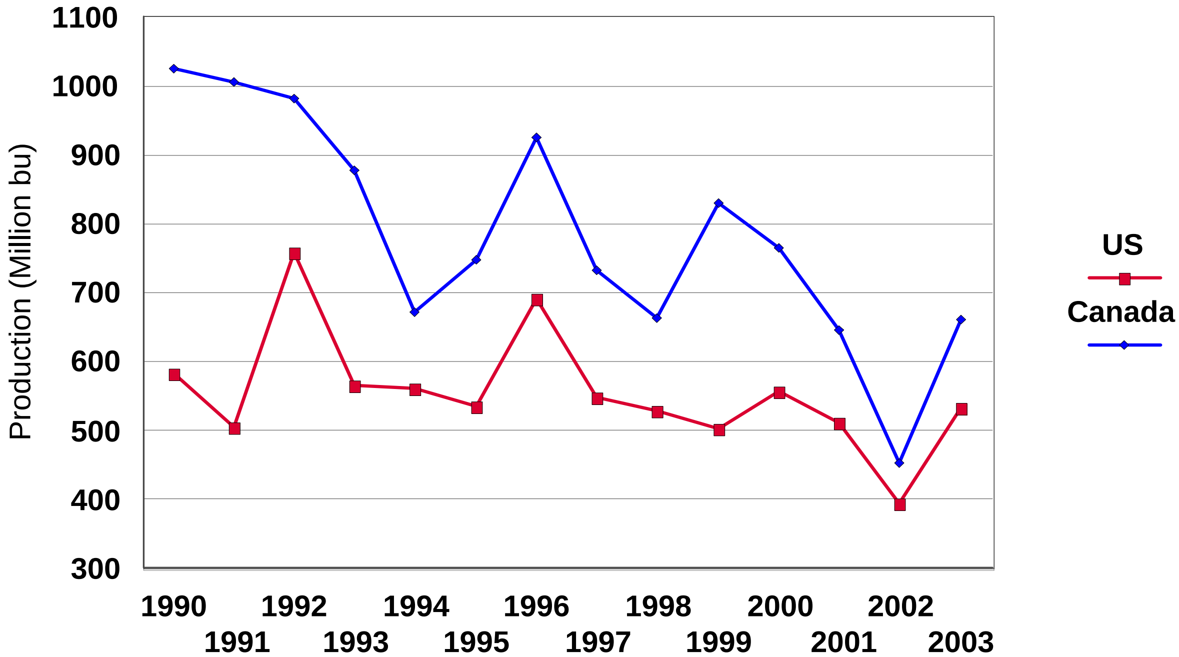


**Figure A.2.3. HRS Wheat Production, 1990-2003.**

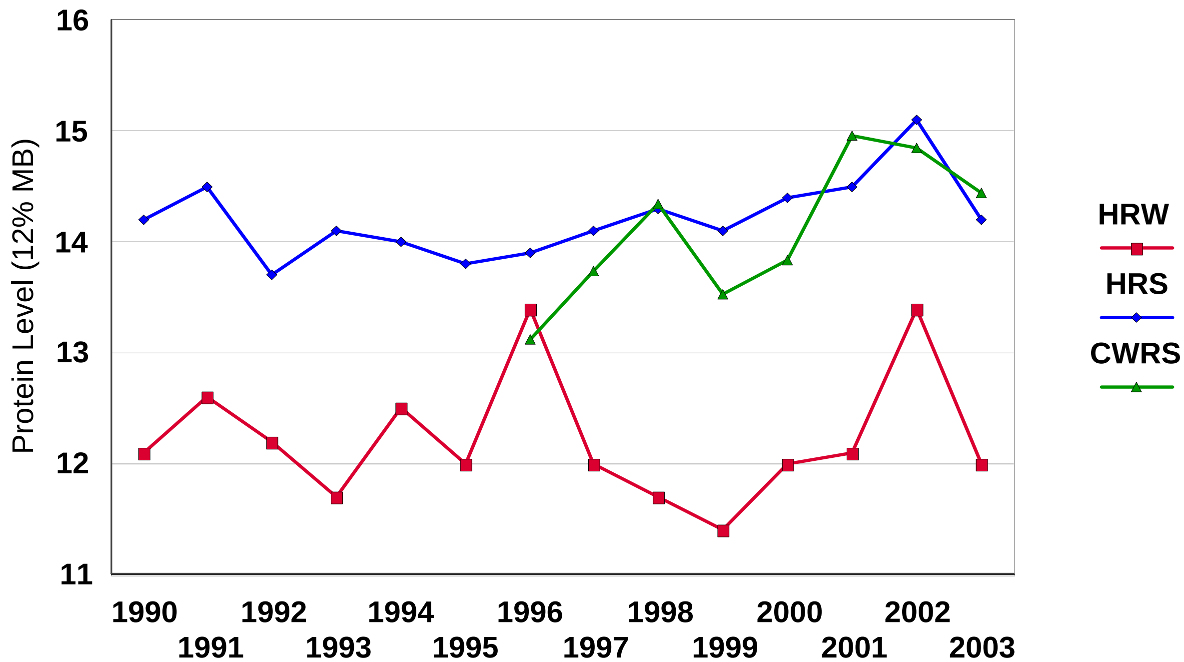


**Figure A.2.4. Protein Levels for HRS and HRW Wheat Production, 1990-2003.**

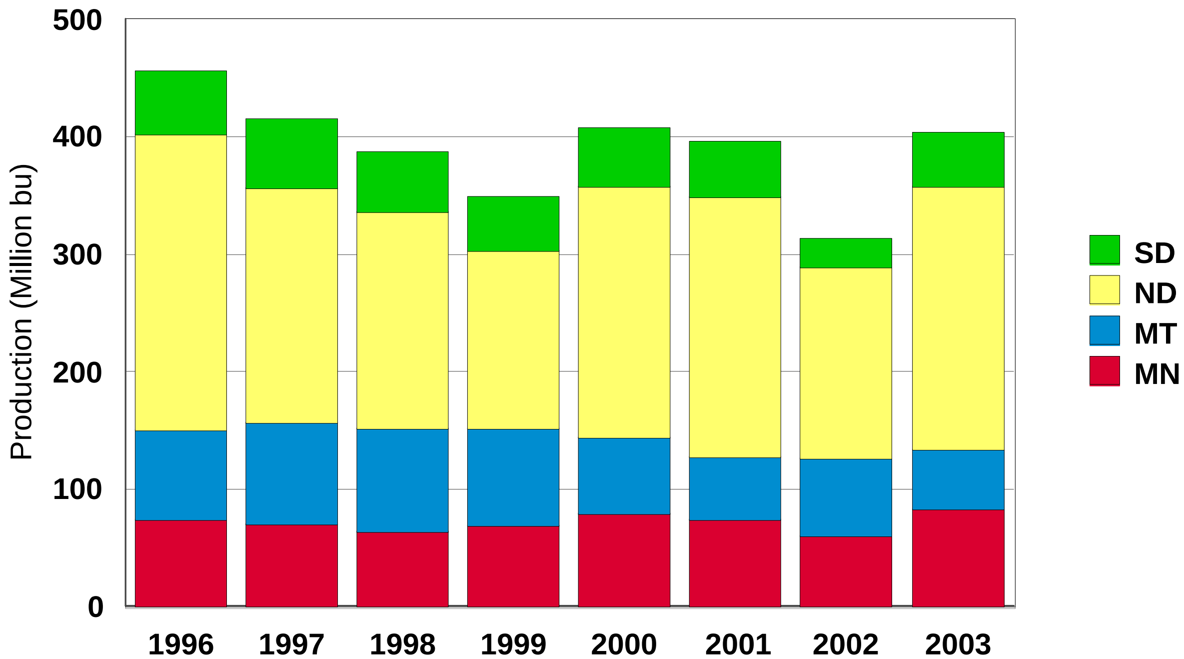


**Figure A.2.5. U.S. Spring Wheat Production Protein > 13% by State, 1996-2003.**

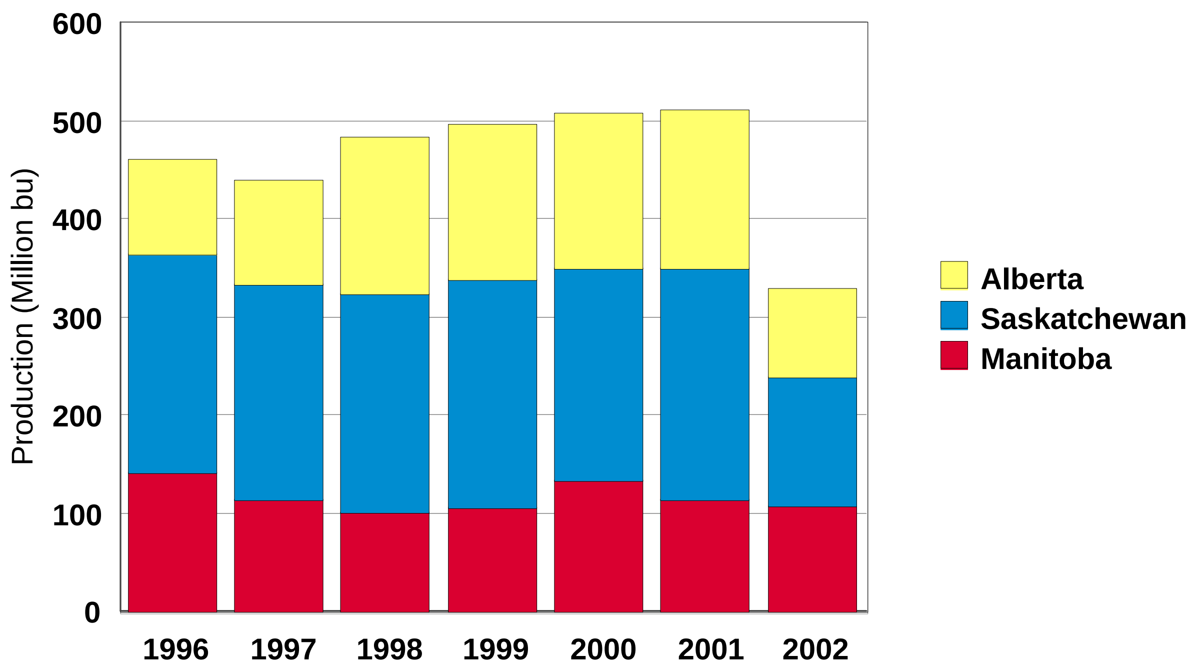


**Figure A.2.6. Canadian Spring Wheat Production Protein > 13% by Province, 1996-2002.**

## A.3. Supply/demand for Competitors to These Classes

This section provides a summary of production in each of these competing countries.[30] Focus is on those regions/classes which prospectively could compete with HRS wheat >13%. The only potential competitors for HRS and CWRS wheat in the world market, besides HRW, is from Australia, and potentially from Russia and the FSU countries.

In France, annual production of hard wheat >13% is about 400,000 mt, or 1% of total. Exports are nil. In fact, France imports higher-protein hard wheats.

In Argentina, most wheat production is in the 12% protein range. There is virtually no ability for segregation due in part to past marketing practices, use of infrastructure for corn marketing, and likely due to past buyer demands. Barriers to expanded production of higher-protein wheats are mostly inability to segregate and store.

Supply and demand for all wheat in Australia are shown in Figure A.3.1. Production has been increasing from around 500 million bushels in the early 1990s, to more recent years in the area of 800-900 million bushels. Only a minor component, about 200 million bushels, are used domestically. The majority is exported, at about 600 million bushels.

The major classes of wheat in Australia are ASW (Australian Standard White) and Feed (General Purpose and Feed). There has been concern that over the past 10 to 20 years there has been a general decline in the protein level of the domestic crop. In response, the AWB has created more classes, segregation, and payments for protein.

That class closest to the end-use characteristics of HRS wheat 13% is what is Australian Prime Hard (APH). Exports of that class have been in the area of 10% of total exports, but in more recent years has fallen to less than 5%. In volume, exports of this class has fallen from a peak of 60 million bushels, to about 30 million bushels in recent years (Figures A.3.2.). This is in part caused by increased use for domestic purposes and due to overall reduced production.

APH is about 3% of total market. The Australians are trying to reverse declining trend in protein (variety marketing, protein premium, etc.) for several years, but there has been minimal progress. Premiums necessary to increase protein are thought to be in the $20/mt range (i.e., 25 c/bu) and farmers would expand nitrogen usage. The maximum production potential would be in the 1 mmt range. The primary export markets for this class are, in rank order, Indonesia at about 13 million bushels, Japan at 8 million, and then Malaysia, Italy, Thailand, and China.

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[30] Observations made in this section are from communications with Wilson and selected contacts in each of the countries of interest. Though not comprehensive, these are provided here for perspective on the world supplies of higher-protein wheats.

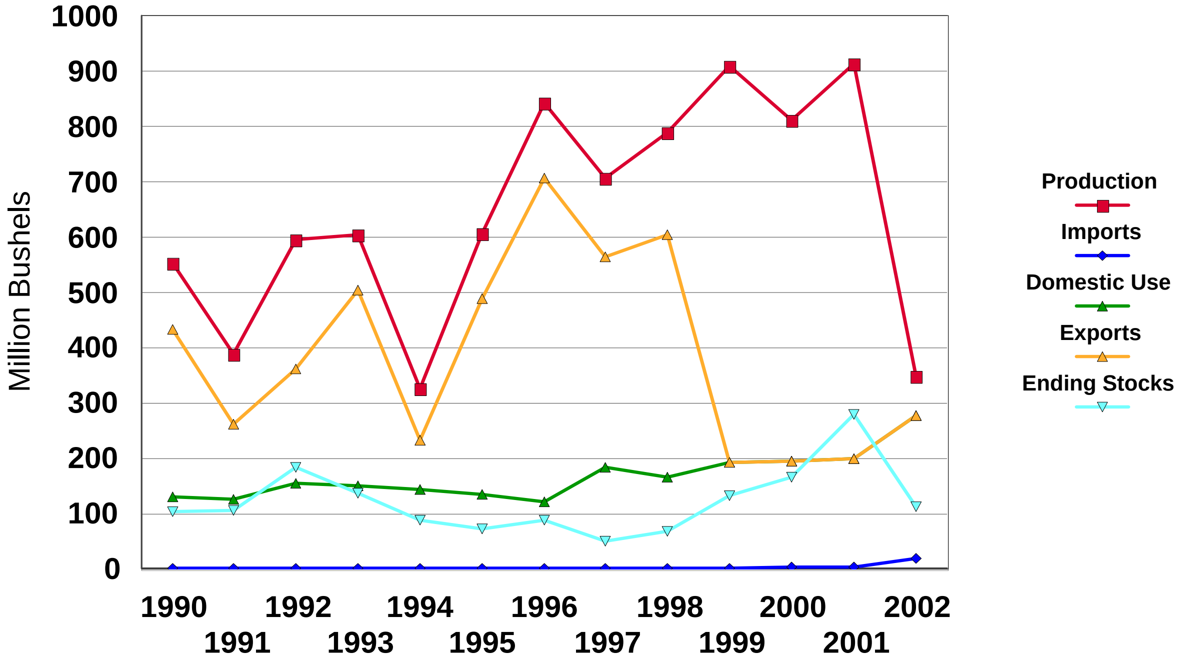


**Figure A.3.1 Australia Supply and Demand for Wheat, 1990-2000.**

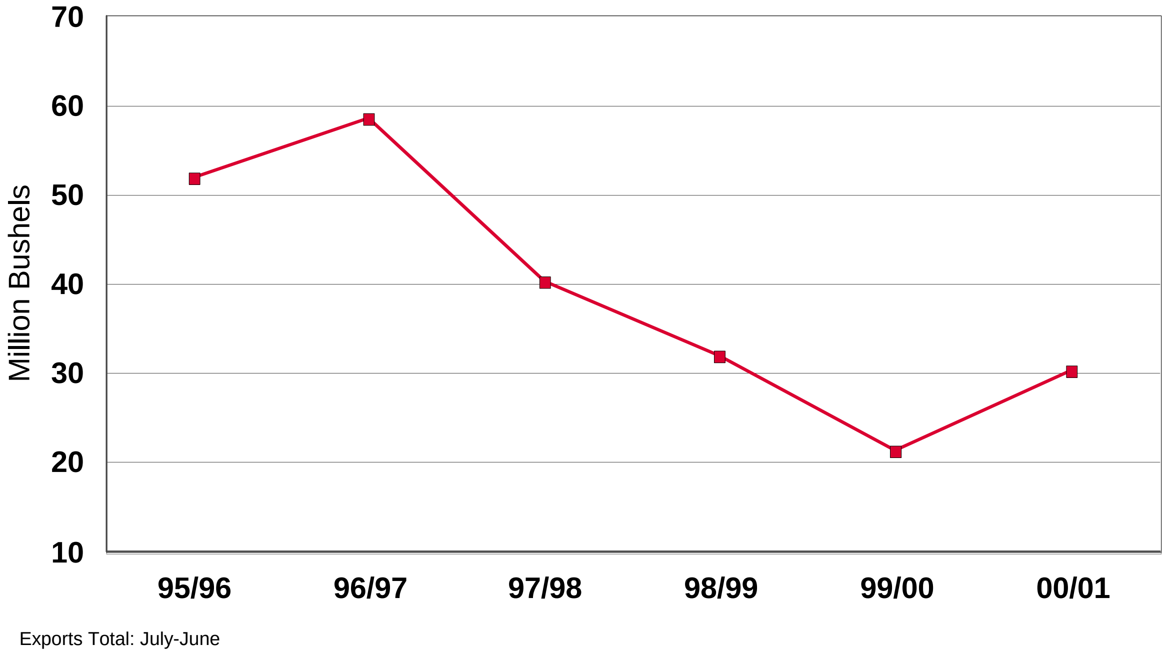


**Figure A.3.2. Total Exports of Australian AHP, 1995/96-2000/01.**

Production in Russia had been declining in the FSU from the 4 billion bushel range in 1990 to about 2.5 billion bushels in the later 1990s, but as is well known, expanded sharply in recent years. Only a very small amount is exported. It is thought that about 30% of the production exceeds 12% protein. This is mostly in the North Caucasus regions (about 65%) and any and all higher-protein would be used domestically and not exported. Basically, Russia is short of higher gluten wheats. The ability to expand would require major changes in the marketing system, premiums paid, technology, and grain storage/segregation system.

### A.4. World Production and Exports of Higher-protein HRS Wheats

Using these data, we sought to develop estimates of production and trade for what is defined as higher-protein hard wheats defined as >13% protein.

Production.[31] We defined percent of production as: U.S. HRS, about 88% of production (for crop years 1999-2003); Canada is CWRS and about 80% of production; Australia is APH, at about (3-6%) of production; Argentina=8% of production; France is nil at about 400,000 mt (net importer); and Russia/FSU 30% >12%.

These results are shown in Table A4.1. Canada is the largest producer at about 538 million bushels, followed by the United States at 400 million. Then, distantly is the production in Australia and Argentina, each with less than 50 million bushels, and France with less than 15 million. The United States exports a greater percentage of HRS wheat exports at >13%; Canada is 60%, and the other countries are an inconsequential percent. In volume, Canada exports 312 million, followed by about 230 million from the United States.

U.S. production and consumption (assuming 100% of HRS wheat use is of this quality) suggests the United States is slightly deficit. This is due in part to the years used in the average reported and is likely a contributing reason for the 38+ million bushels of imports (from Canada). The other countries are essentially inconsequential in terms of production or trade. On balance, trade in this quality is about 550 million bushels, mostly from Canada and the United States.

---

[31] These were derived using varying sources and manipulations of data on production and distributions (means and std.) on protein levels. In the northern region of the United States (Montana, North and South Dakota, and Minnesota), we have data from the annual crop quality survey from which we can estimate the mean and standard deviation for protein for HRS wheat. Estimates for means and standard deviations are available by province for Canada from the Canada Grains Council. Using these parameters and assuming a normal distribution of protein, the probability of protein equal to or greater than 13% is estimated for each state/province. The percent of production with >13% protein is then multiplied by state/province production and these are aggregated to arrive at totals for the United States Northern Region and Canada. Combining these, we derived estimates of production of HRS>13%. Technically, this would be for the states of Minnesota, Montana, South Dakota, and North Dakota; and the Canadian prairies.

**Table A.4.1. Production, Use, and Exports for Higher-protein (>13%) Hard Wheats (HRS, CWRS, and APH)**

| | U.S. HRS | Canada CWRS | Australia-APH | Argentina | France | Total |
|---|---|---|---|---|---|---|
| | -----------------------million bushels---------------------------------------------- | | | | | |
| Production | 400 | 538 | 50 | 42 | 5 | 1,035 |
| Domestic Use | 250 | 101 | 40 | 40 | 5 | 6 |
| Excess Supply | 150 | 438 | 10 | 0 | 0 | 599 |
| Imports | 30 | | | | | |
| Exports | 230 | 312 | 10 | 0 | 0 | 552 |
| Exp>Ex. Sup. | -80 | 125 | 0 | 0 | 0 | ≈47 |

* These are approximations, based on results/derivations presented earlier. Production is that portion of production with protein >13% and represents a 5-year average; domestic food use of HRS and CWRS wheat in the United States and Canada are assumed to be 100% of protein>13%.

## A.5. Summary

World production of higher-protein (>13%) hard wheats is concentrated in the northern tier regions of the United States and Canada. Both produce surpluses of these hard wheats (150 million bushels in the United States and 400 million in Canada) most of which is exported. It is clear that Canada has a greater excess supply but the excess supply in the United States is close to nil. The major importers of HRS 13%+ protein wheat are Japan, Iran, China (from Canada), Philippines, Taiwan, Korea, Venezuela, and Italy. This is followed by more than 70 other countries that import this type of wheat.

There are few competing classes for this type of wheat. The only notable one would be Australia APH, but production of that class has declined in recent years and exports have fallen to less than 30 million bushels. CWRS and HRS wheat are technically near-perfect substitutes from a functional quality perspective. Characteristics of greatest importance to end-users (domestic) are: consistency, absorption, and then followed by numerous other characteristics that varied by millers and bakers.

**Table A.4.2. Average Exports of Hard Wheats by the United States, Canada, and Australia, by Importer (Selected Countries)**

| Importer | U.S. HRS | CWRS | APH | Total |
|---|---|---|---|---|
| | -----------------------------------------000 bushels----------------------------------------- | | | |
| Algeria | 526 | 4,005 | | 4,531 |
| Bangladesh | 552 | 2,253 | | 2,805 |
| Belgium | 5,973 | 1,507 | | 7,480 |
| Bolivia | 504 | 1,050 | | 1,554 |
| Brazil | 575 | 18,393 | | 18,968 |
| Cameroon | 1,079 | 534 | | 1,613 |
| Chile | 607 | 5,512 | | 6,119 |
| China | 3,258 | 58,353 | 1,125 | 62,736 |
| Columbia | 3,426 | 15,852 | 588 | 19,866 |
| Costa Rica | 3,339 | 703 | | 4,042 |
| Dominican Rep. | 6,844 | 344 | | 7,188 |
| Ecuador | 4,740 | 5,443 | 367 | 10,550 |
| Egypt | 1,054 | 387 | 99 | 1,540 |
| El Salvador | 2,902 | 419 | | 3,321 |
| Ghana | 4,579 | 2,807 | | 7,386 |
| Guatemala | 2,086 | 7,899 | | 9,985 |
| Indonesia | 4,214 | 29,632 | 12,787 | 46,633 |
| Iran | | 64,183 | | 64,183 |
| Italy | 9,031 | 7,217 | 2,352 | 18,600 |
| Japan | 44,245 | 48,784 | 8,490 | 101,519 |
| South Korea | 12,992 | 4,863 | | 17,855 |
| Kuwait | 240 | | 1,121 | 1,361 |
| Malaysia | 1,559 | 6,827 | 3,312 | 11,698 |
| Mexico | 2,968 | 19,287 | | 22,255 |
| Nigeria | 1,845 | 4,053 | 220 | 6,118 |
| Norway | 1,349 | 485 | | 1,834 |
| Panama | 2,637 | | | 2,637 |
| Peru | 3,817 | 8,567 | | 12,384 |
| Philippines | 36,846 | 9,995 | 656 | 47,497 |
| Rep. S. Africa | 5,546 | 5,434 | | 10,980 |
| Spain | 6,073 | 3,260 | 456 | 9,789 |
| Sri Lanka | 1,509 | 4,254 | | 5,763 |
| Taiwan | 17,674 | 1,526 | 985 | 20,185 |
| Tanzania | 387 | 66 | 37 | 490 |
| Thailand | 5,190 | 4,261 | 985 | 10,436 |
| Turkey | 4,833 | 2,667 | 897 | 8,397 |
| UK | 3,198 | 11,724 | | 14,922 |
| US | | 31,066 | | 31,066 |
| Venezuela | 11,391 | 13,145 | | 24,536 |

# Appendix B: Comparison of Studies on Import Country GM Aversion

This appendix reports findings from other studies on countries with GM aversion. Tables B1 and B2 summarize the results of surveys by U.S. Wheat Associates (Forsythe 2002) and the Canadian Wheat Board (CWB). Wisner indicated that 6% of HRS wheat exports likely go to countries not requiring labeling of GM. This same percent was applied to durum where exports have been predominately to the EU (66%).

Table B3 provides a summary that is fairly current of market interventions by country. This was abstracted from the recent publication by Foster, Berry, and Hogan (2003).

**Table B.1. Countries and Previous Assumptions on GM Aversion**

| Country | U.S. Wheat I[a] | U.S. Wheat II | CWB[b] |
|---|---|---|---|
| Algeria | | | Reject[c] |
| Brazil | | | Reject |
| Canada | | | Reject |
| China | Not Averse | Reject | Reject |
| Taiwan | Not Averse | Reject | |
| Colombia | | | Reject |
| Ecuador | | | Reject |
| Egypt | | | Reject |
| EU | Averse | Reject | Reject |
| Indonesia | | | Reject |
| Iraq | | | Reject |
| Japan | Averse | Reject | Reject |
| Malaysia | | | Reject |
| Mexico | | | Reject |
| Philippines | Averse | | Reject |
| South Africa | | | Reject |
| Sri Lanka | | | Reject |
| Thailand | Not Averse | | Reject |
| US | | | Reject |
| Bangladesh | | | Not Reject |
| Chile | | | Not Reject |
| CIS & Baltices | | | Not Reject |
| Costa Rica | Not Averse | | |
| Cuba | | | Not Reject |
| Dom. Republic | Not Averse | | |
| El Salvador | Not Averse | | |
| Ghana | Not Averse | | |
| Honduras | Not Averse | | |
| Iran | | | Not Reject |
| Jamaica | Not Averse | | |
| Libya | | | Not Reject |
| Morocco | | | Not Reject |
| Nicaragua | Not Averse | | |
| Panama | Not Averse | | |
| Peru | | | Not Reject |
| Poland | | | Not Reject |
| South Korea | Averse | Reject | Not Reject |
| Sudan | | | Not Reject |
| Tunisia | | | Not Reject |
| Turkey | | | Not Reject |
| Venezuela | Not Averse | | Not Reject |
| Vietnam | | | Not Reject |

[a] U.S. Wheat I and U.S. Wheat II refer to surveys published in Forsythe (2002) and as reported by Gilliam (2002) and USDA-FAS (2004), respectively.
[b] CWB refers to CWB as reported in Kuntz (2001).
[c] Reject means that the buyers would reject wheat with GM (or RRW) content, not that it would reject all wheat.

**Table B.2. "At Risk" Markets for Canadian Spring Wheat**

| "At Risk" Countries | Volume of Canadian Spring Wheat Exports* | % of Total CWRS Exports |
|---|---|---|
| Algeria | 55 | 0.4 |
| Brazil | 833 | 6.3 |
| Iran | 1,048 | 7.9 |
| Italy | 186 | 1.4 |
| Japan | 1,322 | 10.0 |
| Malaysia | 114 | 0.9 |
| Morocco | 19 | 1.0 |
| South Korea | 345 | 2.6 |
| United Kingdom | 264 | 2.0 |
| Venezuela | 257 | 1.9 |
| TOTAL | 4,443 | 33.0 |

Notes: *Volume derived as a 10-year average, 1989-98, 000's of tonnes.
Source: Kuntz, University of Saskatchewan (2001); Canada Grains Council.

## Table B.3. Sources of Known or Intended Restrictions on Grain (Wheat) Imports

| Country | Sanitary/ Phytosanitary | Tol. | Labeling | Tol. | Adventitious Presence | Tol. |
|---|---|---|---|---|---|---|
| EU | Prior to 2003 only 3 corn varieties approved | | 1998 all GM, 2000-2003 all human food > 1%, now all food, oils, and animal feed over 0.9% from GM sources | 0.9% | Scientifically safe, but no final approval | .5% |
| China | Food safety certificates required. Temp. certificate from 3rd or origin assessments, permanent requires China field tests | None set yet | All foods containing GMOs | | | |
| Australia | | | All foods or ingred. except where novel DNA or protein removed | 1% | | |
| Brazil | | | All food for human consumption over tolerance | 01-03=4% 2003 = 1% | | |
| Taiwan | | | Products derived from GMOs that do not contain detectable DNA or proteins do not require label | 5% by weight | | |
| Japan | | | List of foods containing GM exceeding tolerance. Initially 24 foods on list, now 44 excluding oils as no method for verifying content. To be labeled Non-GM must be able to show IP from producer through processing. | 5% | | |
| Korea, South | | | All products with GM as major input except those where novel DNA or protein removed. | | | 3% reduced to 1% at some later date |
| Russian Federation | | | All foods and med products derived from GM except those that do not contain novel DNA or protein. | | | |
| Thailand | | | Food products that contain any GMO ingredient of at least 5% as one of top three ingredients. | 5% | | |

| Country | Sanitary/ Phytosanitary | Tol. | Labeling | Tol. | Adventitious Presence | Tol. |
|---|---|---|---|---|---|---|
| Argentina | CONABIA and SENASAS provide safety assessments. Decision to import is by Sec of Ag. | | None | | | |
| India | | | None | | | |
| Indonesia | | | Food derived from biotechnology must be labeled. Plans to extend to GM feeds. | | | |
| Malaysia | | | Mandatory labeling may be introduced in 2004. | 3% by volume | | |
| Philippines | | | Voluntary labeling | | | |
| Saudi Arabia | | | Mandatory on all imported and locally produced processed products containing GM ingedients. Extended in 2003 to animal feed, seed, fruits, vegetable, and other products under authority of MOC. | Appears to be 1% | | |
| United States | | | Not required unless consumers must be alerted to safety issue. | | | |

Source: Foster, Berry, and Hogan (2003).

# Appendix C: Mathematical Specification of the Analytical Model

A model of trade in higher-protein hard wheat was developed to measure changes in welfare and the distribution of welfare. It is a spatial partial equilibrium model that incorporates market segments for GM aversion and segregation costs for each segment. This is distinguished from Furtan, Gray, and Holzman (2002) and others that use non-spatial models and disallow segregation, amongst others. Other features of the model that distinguish it are that it simultaneously determines adoption rates, trade flows, prices, and price differentials by segment and includes adopter and non-adopter cost savings and dockage removal cost savings. Competition is assumed and the model is solved by maximizing the sum of producer and consumer surpluses. Results are used to derive equilibrium adoption rates, prices and price differentials, spatial flows, and production and marketings of GM and non-GM wheat, subject to varying tolerances.

An implicit price formulation is employed and prices paid and received are computed post-optimality. An important feature of our model is demand and supply for wheat by protein level. Protein in wheat is one of the more important hedonic characteristics and clearly distinguishes HRS and Canadian western red spring (CWRS) wheat from most other wheats and from most of hard red winter (HRW) wheat. Indeed Ghoshray found these to be a sub-market which is not substituted by other classes. In our case, we use protein quantities rather than wheat quantity in the demand model (described below) and substitutability is allowed within the higher-protein wheat market segment.

The implied protein demand equations are given as:

(1) $$Q_i = a_i + b_1 \cdot P_i$$

where the subscript *i* denotes the country. Protein quantities consumed are summed across the three wheat classes w∈{*HRW, HRS, CWRS*} across the four market segments t∈{*GM*, 5% *GM*, 0.9% *GM*, 0% *GM*} and producing region *j* as:

(2) $$Q_i = \sum_j \sum_w \sum_t q_{ijwt} \ .$$

The implied supply equations are given as:

$$Q_j = d + e \cdot P_j \ .$$

Protein quantities produced are summed across classes and GM content adopted, and consuming region as:

(3) $$Q_j = \sum_i \sum_w \sum_t q_{ijwt} \ .$$

The objective function, summing surpluses, is given mathematically as

$$
(4)\quad \begin{aligned}
&\sum_i \left( -\frac{Q_i^2}{2b_i} - \frac{a_i Q_i}{b_i} \right) - \sum_j \frac{(Q_j - d_j)^2}{2e_j} \\
&-\sum_i \sum_j \sum_w \sum_t q_{ijwt} \cdot trans_{ij} \\
&+\sum_i \sum_j \sum_t q_{ij\,hrs\,t} \cdot gmsavings_{jt} \\
&-\sum_i \sum_j \sum_w \sum_t q_{ijwt} \cdot segfee_{jt} \ .
\end{aligned}
$$

The value given in the parentheses in the first line of (4) is the total of areas beneath the individual consuming region's demand function. The second summation on the first line of (4) is the area beneath the individual producing region's supply function, or total costs. The second line subtracts transportation costs from producer *j* to consumer *i* ($trans_{ij}$). The third line sums the various savings associated with the GM wheat in each type of wheat ($gmsavings_{jt}$ – zero for 0 percent GM). And, the fourth line subtracts the costs of segregating each type of wheat from producer *j* ($segfee_{jt}$) . Markets are allowed to have different preferences for GM aversion which is defined by tolerance, and producing regions are allowed to produce GM and non-GM, as well as to ship different segregations with respect to GM content. The model determines these equilibrium values.

Three additional constraints are imposed to reflect relative demands for each type of wheat by consuming region. From Table B3, the percentage of total protein demands by type are used to constrain the minimum quantities of each wheat type. Using $mintype_{i,t}$ to denote the minimum percentage of wheat by type, we impose:

$$
(5)\quad \sum_j \sum_w q_{ijw\,NonGM} \geq mintype_{i\,NonGM'} \cdot Q_i
$$

Finally,

$$
(6)\quad \sum_j \sum_w \left( q_{ijw\,NonGM} + q_{ijw\,0.9\%GM} \right) \geq \left( mintype_{i\,NonGM'} + mintype_{i\,0.9\%GM} \right) \cdot Q_i \ .
$$

$$
(7)\quad \sum_j \sum_w \sum_{t \neq GM} q_{ijwt} \geq \left( \sum_{t \neq GM} mintype_{it} \right) \cdot Q_i \ .
$$

These three equations restrict a consuming region's demands with respect to aversion to GM content. In addition, higher quality wheat types can be used to satisfy demands for lower types, but not *vice versa.*

We also restrict the ability to substitute HRW for HRS and CWRS. Given process technology and preferences, HRW wheat is allowed to have limited substituitability with HRS wheat. Specifically, we allow HRW wheat demand as a percentage of total demand to increase to no more than10 percent above the baseline, or

$$\sum_j q_{ij,HRW,NonGM} \leq Q_i \cdot (wintperc_i + 0.1) \tag{8}$$

where $wintperc_i$ is the percentage of baseline total protein demand satisfied with winter wheat.

In Figure C.1, the partial equilibrium quantity, price paid, and price received are depicted. The difference between price paid and received is due to transportation and segregation costs. The area under the demand function given by a-f-Q-e is the first term on the first line of equation (1). The area given by e-g-Q is the second term on line one of equation (1). The area given by price paid-f-g-price received is the total segregation and transportation costs minus GM savings as in lines two through four of equation (1). The GM savings has the effect of shifting the supply function out. In net, equation (1) gives area a-f-price paid plus area price received-g-e, or total surplus.

Equilibrium prices are defined for each market and segment. These are derived from inverse supply and demand equations. Or, producer price received is computed as:

$$P_j = \frac{Q_j - d_j}{e_j} \tag{9}$$

and consumer price paid is computed as:

$$P_i = \frac{Q_i - a_i}{b_i} \quad . \tag{10}$$

The model is one of vertical market differentiation, and there are a number of computational difficulties not encountered in non-spatial models without segments and segregation. We use the protein equivalent within the hard wheat classes and allow limited substitutability between spring and winter wheats. Partitions exist amongst the four market segments with respect to GM acceptance, and we allow the model to determine the allocation to each from the origins. Non-GM is allowed to substitute in GM segments, but not vice versa in markets with partial/no-GM acceptance. We derive the implicit equilibrium price at each market for each segment and from this derive the producer prices at each origin. The GM savings have the effect of shifting the supply function, lowering equilibrium prices to GM market segments, but increasing the differential for non-GM segments. Price differentials between import markets exist due to both transportation costs and segregation costs for each market segment.

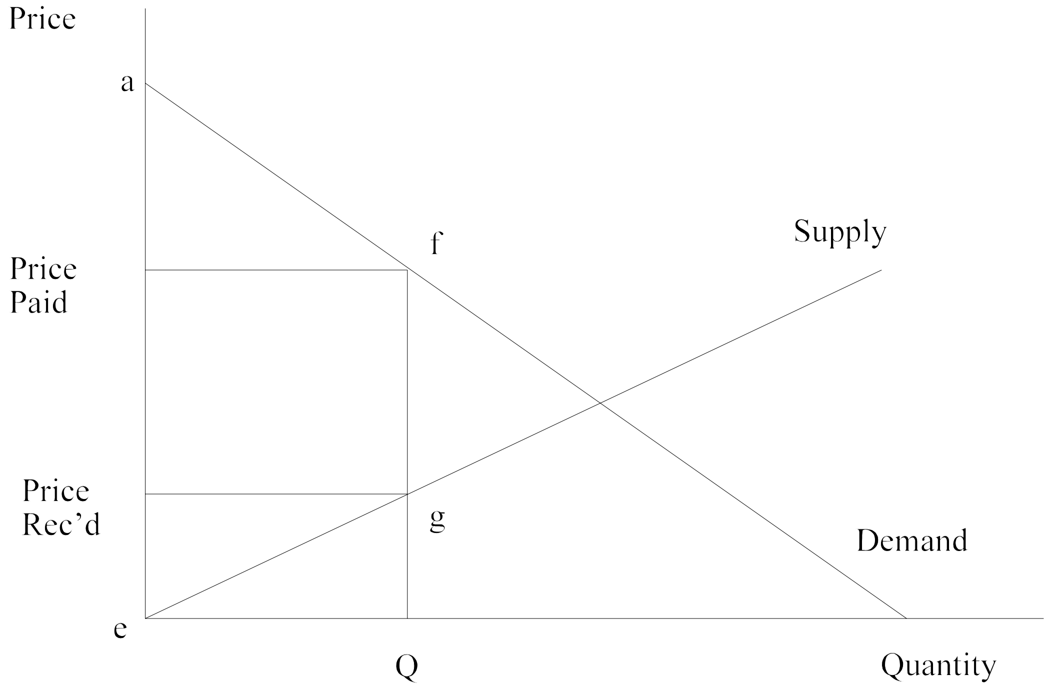


**Figure C.1. Partial Equilibrium with Transportation Costs and Segregation Costs**.

## Appendix D: Approach and Assumptions in Wisner's Analysis: *Market Risks of RR Wheat Introduction* [32]

***Introduction and Overview***

This study sought to analyze potential impacts of introducing GM HRS wheat on export markets, in the short term (interpreted as 2-6 years). It is largely descriptive and an assessment in the authors' views of the potential impacts of introducing GM into HRS wheat in North America. There are three major issues in that analysis deserving of comment and each are addressed below.

*Segregation Costs*. The underlying assumption of the study is that it is not possible to segregate. The specific approach to segregation is summarized in Table D.1. Costs were used based on a University of Illinois survey of specialty corn growers. These costs were inclusive of premiums for the product (75% of the cost cited, the other costs taken together are 6 c/bu), in addition to other costs associated with IP and testing. These supplemental costs were inclusive of testing of 100% of the product in the market, underutilization of elevators, the requirement of new elevators, and that GM could not use shuttle trains.

Discussion is made that there are risks associated with cross-pollenation and volunteers in wheat, though these are less than corn referring to the VanAcker, Brule-Babel, and Friesen (2003) studies and concludes that "these problems are a substantial risk." This is even though these risks are fairly negligible and translate to the equivalent of .009 for normal planting rates and decline through time. Pollen drift is also negligible at less than 1% (Hucl and Matus-Cadiz 2001).

These are all unlikely given the marketing system in the HRS wheat producing regions. First, segregation is a routine part of grain handling for many factors. Handlers can and will segregate if possible and if there are incentives (i.e., premiums$\geq$marginal costs). Second, inclusion of premiums for grain attributes by definition overstate the cost of segregation and should not be attributed to segregation costs. Third, testing would likely be applied more selectively, would only be applied for that portion of the market requiring a tolerance, and could be supplemented by varying contractual mechanisms to improve shippers, knowledge of the product content. Fourth, there are adequate elevators and storage capacity in the region and new construction to accommodate segregation would be highly unlikely.

Other recent studies in Canola (Foster, Berry, and Hogan 2003) indicate "there is no clear evidence to suggest that there is currently a premium for non-GM canola" (p.16). They do indicate a narrowing in the spread between Canadian (GM) and Australian (non-GM) canola prices. However, there could be a number of explanations for this including increased reliability of supply of Australian canola, problems in disposing of excess Canadian supplies, and changes in relative currencies. They indicated premiums of $US5-10/mt (after IP costs) for containerized canola trade predominately with Japan. For soybeans they provide an average spread between

[32] Study prepared for the Western Organization of Resource Councils. A full report is available at www.worc.org.

Japanese futures contracts for non-GM and U.S. source soybeans on the Tokyo Grain Exchange. They indicate that the spread (premium) for non-Gm soybeans averaged 7.3% for 2002-03. However, volume of trade in the non-Gm soybean contract was equivalent to 1% of Japan's annual soybean imports. For corn, the non-GM premiums were derived from a U.S. Grains Council survey of U.S. elevators which reported average premiums of 3.5% of the value of corn. These are summarized in Table D.2.

**Table D.1. Segregation Costs Analysis/Critique**

| Feature | Wisner Assumption | Critique/Impact |
|---|---|---|
| Base cost elements | University of Illinois survey on speciality corn inclusive of: product premium and testing. | IP-type costs are not what will be required by buyers averse to GM content. Product premium is for indigenous quality and demands for processing traits and should not be a component of IP cost. |
| Supplemental costs | Additional costs imputed as required by Wisner for wheat (numerical values not shown): 100% of product tested, shuttles preclude GM, underutilization of elevators, requirement of new elevators. | Testing should vary by geography, time, and autonomous to individual buyers, and testing every load would be unnecessary and costly; testing only required on shipments to buyers requiring limits on GM; shuttles facilitate GM marketing; excess capacity in elevators, etc., would facilitate specialization of handling without new construction. |
| Wheat of other classes would suffer | Buyers of durum, SRW, and other classes would be adversely impacted. | U.S. Grade standards has "wheat of other classes" that can be specified to control levels of HRS in these classes; and visual distinguishability assures integrity. |
| Canada has comparative advantage in segregating | Claim | Unlikely and not supported by evidence. |
| Starlink impacts | Assertion on inability of market to segregate. | Starlink was released based on feed approval, not for food use; industry uninformed, pre-planting contract differences not apparent;<br>None of these are analogous in RRW. |
| Tokyo Grain Exchange price differential | The price differential reflects impact of market discount for GM content. | Differential implied in these two contracts is due to IP specifications inclusive of product quality specifications. |

**Table D.2. Evidence of Non-GM Premiums**

| | Canola | Soybeans | Corn |
|---|---|---|---|
| Bulk Non-GM | - None - | 7.3% of value (Japan Futures Contract) ($16.09/MT or 44 c/bu assuming price of $6/bu) | 3.5% of value (Survey of U.S. Grain Handlers) ($3.86/MT or 9.8 c/bu assuming price of $2.8/bu) |
| Containers | US$5-10/MT (after IP costs) | | |

Source: Foster, Berry, and Hogan (2003).

*Market Acceptance*. Claims are made about importing countries' aversion to GM wheat. Presumably, this observation is based on a pre-regulatory approval of the trait, and no provision is allowed for post-regulatory acceptance. Mention is made of 37 countries currently requiring labeling of GM content above thresholds, but documentation is not provided. Wisner indicates that 10 countries are considering membership into the EU which currently has labeling requirements (none of these are importers of HRS or CWRS wheat). Also, allegedly, new countries may consider adding labeling requirements fueled by recent ratification of Cartagena Protocol on Global Biosafety (operational September 11, 2003) and prospects for greater range and numbers of GM grains being adopted.

*Aggregate Market Analysis*. The study proceeds to assess the market impacts of these issues. No model or framework is provided. No allowance or consideration is made for yield increases, cost reductions for adopters and non-adopters, dockage removal costs, etc., and no provision is allowed for buyers specifying limited GM content in their purchases (Table D.3).

Finally, and critically, the assumption is made that the excess supplies of RRW would be made in the feed market, at those market values.

**Table D.3. Aggregate Market Assessment**

| Feature | Wisner Assumption | Critique/Impact |
|---|---|---|
| Analytical framework | No description | |
| Yield increase due to RRW | Not allowed | Likely increase 11-14% |
| Cost reduction due to RRW | Not allowed | Cost reduction in the $9/acre range |
| Supplies (world) of non-U.S./Canada origin high protein | Assumed adequate to meet demands | Incorrect |
| Disposal of excess supply of RRW HRS wheat | U.S. Feed market | Unlikely |
| Market acceptance: U.S. | Assumed not accepted | U.S. consumers already consume bread products with GM ingredients; aversion is near nil; some segments (about 7%) may be averse and require segregation. |
| Demand elasticities | None provided | |