Welfare Implications of Washington Wheat Breeding Programs

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Abstract

We calculate the welfare effects of the WSU wheat breeding programs for producers and consumers in Washington State, Oregon, Idaho, the United States and the rest of the world. We develop a partial equilibrium multi-region, multi-product, multi-variety trade model for wheat that provides consumer, producer and total surplus for each wheat class and region. Our results provide evidence suggesting that WSU wheat breeding programs have increased welfare in Washington State, in the United States and the rest of the world.

Keywords: welfare, wheat breeding programs, economic surplus, partial equilibrium.

JEL Codes: F14, F17, Q11, Q16, Q18.

Wheat is an important commodity for the United States and Washington State, both at the domestic and international levels. Land Grant Universities, such as Washington State University (WSU), invest in research to improve wheat characteristics that will benefit both producers and consumers. However, funds available for agricultural research are a scarce resource. To justify future spending in wheat breeding programs, the providers of the majority of funds, state and federal legislators, need to be assured that each dollar being spent in wheat breeding programs is being put to the most efficient use. Measuring the welfare effects of the WSU wheat breeding programs represents an important contribution in understanding the value of these programs.

The main objective of this study is to calculate the welfare effects of the WSU wheat breeding programs for producers and consumers in Washington State, Oregon, Idaho, the United States and the rest of the world. This study will make an important contribution to the literature since we extend previous work to examine a detailed multi-region, multi-product and multi-variety model that includes spill-over effects, and accounts for the limited substitution among wheat classes. Our framework and results will be useful to decision makers in the government since we provide justification for funding the WSU wheat breeding program by calculating the welfare effects of these programs and comparing them with the associated costs. Finally, this study will benefit producers and consumers through calculating the welfare effects for both groups. Consequently, this study will contribute to understanding the specific value of the wheat breeding programs to producers and consumers and provide justification for them.

There have been various studies examining the effects on welfare of different wheat breeding programs. Studies related to the impact of wheat breeding research started as early as the 1970s (Blakeslee, Weeks, Bourque and Beyers 1973; Blakeslee and Sargent 1982; Brennan 1984; Edwards and Freebairn 1984; Zentner and Peterson 1984; Brennan 1989; Brennan, Godyn and Johnston 1989; Byerlee and Traxler 1995; Barkley 1997; Alston and Venner 2002; Heisey, Lantican and Dubin 2002; Brennan and Quade 2006). Models have evolved and became more sophisticated and accurate with time. Most approaches focus on economic surplus measures, based on partial equilibrium or econometric models. These studies also differ in the representation of varietal improvement, with yield increase being the most popular.[1] Some work has been done regarding the use of new technologies, specifically the potential benefits of genetically modified wheat research (Berwald, Carter and Gruère 2005; Crespi, Grunewald, Barkley, Fox and Marsh 2005). However, none of these studies incorporate multiple regions, wheat classes, and wheat varieties jointly in their analysis.

In particular, most papers focus on the benefits for the specific area of study. For example, Blakeslee, Weeks, Bourque and Beyers (1973) provide an input-output study of the wheat producing sector in Washington State and its relationship with the State's economy.

[1] A popular study to follow when calculating yield increase is Feyerherm, Paulsen and Sebaugh (1984).

Blakeslee and Sargent (1982) calculate the internal rate of return as a measure of investment profitability for expenditures in wheat breeding research and extension in Washington State. Brennan (1984) evaluates the contribution of wheat breeders to the wheat industry in Australia, by evaluating three measures of varietal change and reporting an empirical examination of them. Brennan (1989) uses a discounted cash flow analysis to compare different wheat breeding methods to determine the changes in costs and benefits from some selected innovations that could reduce the period of time taken to produce a commercial wheat cultivar, also in Australia. Byerlee and Traxler (1995) examine the role of International Agricultural Research Center generated technology in the global system of spring wheat improvement, for the 1977-1990 period. They calculate the total economic surplus generated by wheat improvement research assuming linear demand and supply schedules and a parallel supply shift. Heisey, Lantican and Dubin (2002) use a constant elasticity of substitution production function to illustrate potential changes in wheat yield in farmers' fields, as well as changes in economic benefits that may be associated with an increase in experimental wheat yields. They study 36 developing countries.

Some studies incorporate different regions in their analysis. For example, Edwards and Freebairn (1984) develop a disaggregated commodity supply and demand model with separate sectors for the home country, and the rest of the world. The model is illustrated by estimating the gains to Australia, the rest of the world and the world from research into the wool and wheat industries. Barkley (1997) measures the impact of Kansas wheat breeding research on Kansas wheat producers and consumers, wheat producers outside of Kansas (including Argentina and Australia), and wheat consumers outside of Kansas (including China and Japan). A two-country model of supply and demand was used to estimate the impact of the research-induced supply shift on producer and consumer surpluses in Kansas and the rest of the world.

Brennan, Godyn and Johnston (1989) not only incorporate several regions, but they also incorporate quality aspects into an analysis based on a partial equilibrium framework for evaluating new wheat varieties. The analysis estimates the change in producer and consumer surplus in Australia and the rest of the world resulting from a research-induced shift in the supply curve. A study by Zentner and Peterson (1984) incorporates different wheat classes for Canada. This is an econometric analysis of whether public investment in Canadian wheat research has constituted socially profitable use of scarce public resources, and to what extent the social benefit from these research activities have accrued to producers and consumers. This article contributes to the literature by incorporating different regions, wheat classes and varieties into the model, which has not been done before.

Estimates of the benefits of wheat research programs due to yield improvements vary by time-frame, country and specific study. The average US farmer in 1980 could expect to receive additional $29 dollars per acre for wheat production (Blakeslee and Sargent 1982). Barkley (1997) suggests that while the costs of the Kansas State wheat breeding program averaged $3.8 million dollars per year for the period 1979 to 1994, average benefits per year to Kansas wheat producers were $52.7 million dollars, $190 thousand dollars to Kansas consumers, and $41.4 million dollars to rest of the world consumers. Surplus for wheat producers in the rest of the world decreased an average of $40.7 million dollars per year. In Canada, producers and consumers benefit from wheat research, with annual social benefits of $49 to $143 million Canadian dollars depending on the scenario considered (Zentner and Peterson 1984). Heisey, Lantican and Dubin (2002) estimate that returns to international wheat breeding research are $1.6 to $6 billion dollars in annual benefits given a total investment of $150 million dollars per year.

Our work complements and contributes to the literature by looking at the different wheat classes independently, assuming that they are differentiated products, and by calculating welfare effects for the different regions using wheat varieties developed by WSU (Washington, Oregon and Idaho) in particular. Thus, we are able to calculate the spillover effects onto Oregon and Idaho. Our results provide evidence of the value of the WSU wheat breeding programs for consumers and producers, not only in Washington State but also in Oregon, Idaho, the United States and the rest of the world.

The rest of the article proceeds as follows. The next section provides background on wheat production. This is followed by model development. We next present the data used for the analysis. Results are then presented. The article ends with some brief conclusions.

Background

Wheat ranks fifth in total production among all commodities in Washington State. In the United States, Washington State is the fourth largest producer of wheat. Washington State is one of the largest wheat exporting states, with 85 to 90 percent of its crop being exported (Washington Wheat Commission 2006). Due to favorable growing conditions soft white wheat is primarily grown in Washington. Wheat varieties in Washington are always being adapted to counteract disease and pest issues that affect producers yield such as fungi and insects, as well as to meet producer demand for higher yielding varieties.

In addition to helping producers by increasing yield and / or quality, new varieties should also maintain or improve consumer desired characteristics, such as milling properties and the characteristics required for good quality bread, cakes, cookies or pasta, depending on the specific wheat class. Thus, wheat breeding programs are important to both producers, flour processing, and consumers. However, it is not always easy to justify increased expenditure in wheat breeding research. One reason is the long period of time from the beginning of the trials to the adoption of these varieties by growers. Another is the fact that growers do not buy seed every year, but save some of the harvested grain to plant the following year or years (Heisey, Lantican and Dubin 2002).[2] Welfare implications of wheat breeding programs are relevant concerns for associated interest groups and the public in general.

The Crop and Soil Sciences Department at WSU has several plant breeding programs, one of which is wheat. The wheat research program at WSU is funded by a mix of state and federal funds, as well as contributions from the Washington Wheat Commission.[3] Varieties developed by the WSU wheat breeding programs account for the majority of the wheat acreage in the State (Jones 2006).

Table A1 in the appendix shows the number of acres planted to WSU varieties in Washington, Oregon and Idaho by wheat class from 2002 to 2006, as well as the acres to private varieties and the total number of acres. We can see a great amount of variation in the number of acres by origin and class over time. The main wheat class planted in Eastern Washington is soft white wheat. In 2002, 74 percent of soft white wheat acres was planted to varieties developed by WSU, compared to 61 percent in 2006.

Wheat is not a homogeneous product. The agronomic characteristics of the different varieties and consumer preferences determine the end use of wheat, making the different wheat classes differentiated products. For example, flour made from hard wheat is mainly used for bread, soft wheat flour is mainly used for cakes and cookies and durum wheat flour is mainly used for pasta. The United States produces five major wheat classes: hard red winter (HRW), hard red spring (HRS), soft red winter (SRW), soft white winter (SWW) and durum wheat

[2] It can take from 7 to 12 years to develop and market a new wheat variety.
[3] Funding levels vary by year and by source.

(DUR). Production of the different classes of wheat in the United States is highly segregated. HRW is grown mainly in Kansas and Oklahoma (Central Plains), HRS and durum wheat are grown mainly in North Dakota (Northern Plains), SRW is produced in the Corn Belt and Southern States, and SWW is grown in the Pacific Northwest, Michigan and New York (Koo and Taylor 2006). Given the limited substitutability for milling purposes among these wheat classes (Marsh 2005, Mulik and Koo 2006), it is important to analyze these different classes on their own when studying wheat for the United States. We specifically model each wheat class independently and then subdivide the classes corresponding to varieties developed at WSU into 7 different regions. For Washington, Oregon, and Idaho, we subdivide each state in varieties developed by WSU and Other, and the rest of the United States is comprised in the other region.

Model

We divide the model section in two parts. First we present the general model following Alston, Norton and Pardey (1995), what we call the ANP model. Second, we expand the ANP model to incorporate the different wheat classes and regions. Figure 1 presents a flow chart overview of the expanded model. We extend this model to include two main regions, the United States and the rest of the world, and we further divide the United States by wheat class to get a multi-product model. Furthermore, we subdivide the wheat classes that the WSU wheat breeding programs have developed varieties for (HRW, HRS, SWW) into Washington State, Oregon, Idaho and Other States to obtain a multi-region model, where each state studied is further divided into production due to WSU varieties and Other. In this way, we allow for spillover effects to Idaho and Oregon. We also incorporate cross commodity price effects to allow for limited substitution in demand among wheat classes. We call this model the WSU wheat breeding programs model.

The ANP model is also similar to the ones presented in Brennan, Godyn and Johnston (1989), Byerlee and Traxler (1995), Edwards and Freebaim (1984), and Voon and Edwards (1992), and it has been used in most studies measuring economic surplus of agricultural research (Barkley 1997; Crespi et al. 2005; Heisey, Lantican and Dubin 2002; Nalley, Barkley and Chumley 2006; etc.). Alston, Norton and Pardey (1995) provide a structured, detailed and well written overview of the methods used for economic surplus estimation, as well as the methods for agricultural research evaluation and priority setting. Consequently, we follow Alston, Norton and Pardey (1995) in the development of our theoretical equilibrium displacement model.

ANP Model

We start by defining the supply and demand equations that characterize the wheat market in general. By characterizing the supply and demand functions we can calculate the changes in consumer, producer and total surplus associated with a change in price due to a shift in the supply curve. We assume linear demand and supply functions. The model is divided in different regions: the region of interest (where the supply shift occurs), *W*, and other relevant regions to the study, $i=1, \ldots, R$. The corresponding supply equations are:

(1) $$Q_W = \alpha_W + \beta_W (P_W + k_W)$$

(2) $$Q_i = \alpha_i + \beta_i P_i, \quad i=1, \ldots, R,$$

where Q denotes the quantity of wheat supplied by the corresponding regions, W or i, P is the price for wheat, k represents a parallel shift down of the supply curve, α represents the intercept parameter and β the slope parameter. The demand equations are represented by:

(3) $$C_j = \gamma_j - \delta_j P_j, \quad j=W, 1, \ldots, R,$$

where C denotes the quantity of wheat demanded in the corresponding region j, γ represents the intercept parameter, and δ is the non-negative slope parameter. In equilibrium, total quantity supplied and total quantity demanded are equal, giving the following market clearing condition:

(4) $$\sum_j Q_j = \sum_j C_j, \; j=W, 1, \ldots, R.$$

We substitute $k=KP_0$, such that K represents the vertical shift of the supply curve as a proportion of the initial price, P_0. Totally differentiating equations 1 to 3 allows us to re-write these equations in terms of relative changes and elasticities:

(5) $$E(Q_W) = \varepsilon_W [E(P_W) + K_W]$$

(6) $$E(Q_i) = \varepsilon_i [E(P_i)], \; i=1, \ldots, R$$

(7) $$E(C_j) = \eta_j [E(P_j)], \; j=W, 1, \ldots., R,$$

where E denotes relative changes, that is, $E(Z) = dZ/Z = dlnZ$; ε is the price elasticity of supply, and η is the price elasticity of demand. Now the market equilibrium condition is:

(8) $$\sum_j ss_j E(Q_j) = \sum_j ds_j E(C_j), \; j=W, 1, \ldots., R,$$

where ss represents the corresponding supply share ($ss_j = Q_j / \sum_j Q_j$) and ds represents the corresponding demand share ($ds_j = C_j / \sum_j C_j$). This system of equations (5 to 8) can be solved to obtain the relative change in price:

(9) $$E(P) = \frac{-K_W ss_W \varepsilon_W}{\sum_j (ds_j \eta_j + ss_j \varepsilon_j)}, \; j=W, 1, \ldots, R.$$

Subsequently, equation 9 can be substituted into the region-specific supply and demand equations 5 to 7 to obtain specific effects on quantities. With this information we can calculate annual benefits from research-induced shifts in the wheat supply curve by estimating changes in consumer surplus (*CS*), producer surplus (*PS*), and total surplus (*TS*):

(10) $\Delta CS_j = -P_j C_j [E(P_j)][1+0.5E(C_j)]$

(11) $\Delta PS_j = P_j Q_j [E(P_j)+K_j][1+0.5E(Q_j)]$, $j=W, 1, \ldots, R$,

(12) $\Delta TS = \sum_j \Delta CS_j + \sum_j \Delta PS_j$

where PC and PQ represent the initial consumer and producer prices, respectively. In this way total surplus from the research-induced supply shift corresponds to the area below the demand curve and between the two supply curves. This area represents the sum of the cost saving due to the yield increase and the economic surplus due to the increment to production and consumption.

A main limitation of this model is that it assumes only a parallel shift in the supply curve. Additionally, it applies linear demand and supply functions to provide at best a first order approximation of economic surplus. However, the model is still general and flexible enough to accommodate a wide range of different market structures and characteristics.

WSU Wheat Breeding Programs Model

We can modify the ANP model to incorporate the different wheat classes and regions to build our own equilibrium displacement model. Our model represents partial equilibrium because it only looks at the wheat industry and assumes constant prices for all inputs used in wheat production. Since we are only interested in simulating the welfare effects due to yield improvements in WSU developed varieties, we hold all other yield improvements constant, including improvements due to technology, management practices and other wheat breeding programs.[4]

We extend the ANP model to include two main regions or submodels, the United States submodel and the rest of the world submodel, and we further divide the United States submodel

[4] It should be noted that other states could be using wheat varieties with similar yield improvements, and thus, spillover effects may wash out once other yield improvements are considered.

by wheat class to get a multi-product model. Furthermore, we subdivide the wheat classes that the WSU wheat breeding programs have developed varieties for (HRW, HRS, SWW) into Washington State, Oregon, Idaho and Other States to obtain a multi-region model, where each state studied is further divided into production due to WSU varieties and Other (WA-WSU, WA-Other, OR-WSU, OR-Other, ID-WSU, ID-Other). In this way, we allow for spillover effects to Idaho and Oregon. We also incorporate cross commodity price effects to allow for limited substitution in demand among wheat classes.

First we only analyze the US submodel, and we obtain the equilibrium prices and quantities for each wheat class, region and sub-region given a supply shift due to the yield improvement in WSU varieties. With those results, we get the aggregate effects for the United States submodel and we simulate the results of trading between the United States and the rest of the world. Thus, we can obtain results for the overall model. We then calculate the changes in consumer, producer and total surplus for each wheat class and region within the United States, as well as for the United States as an aggregate and the rest of the world associated with a change in price due to a shift in the supply curve for the regions using varieties developed at WSU. We assume that the shift is due to yield improvements obtained by using varieties developed by the WSU wheat breeding programs, holding everything else constant. That is, holding potential improvements due to other research programs and technology constant. The supply shift parameter, K, is calculated as the yield increase or improvement due to WSU varieties divided by the price elasticity of supply (Alston, Norton and Pardey 1995).

The specific supply and demand equations for the US submodel are:

(13) $E(Q_{i,a}) = \varepsilon_i[E(P_i) + K_{i,a}]$, *i = HRW, HRS, SRW, a = WA-WSU, OR-WSU, ID-WSU*

(14) $E(Q_{i,b}) = \varepsilon_i[E(P_i)]$, *b = WA-Other, OR-Other, ID-Other, Other States*

(15) $E(Q_j) = \varepsilon_j[E(P_j)]$, *j = SWW, DUR*

(16) $E(C_n) = \sum_c \eta_{nc}[E(P_c)]$, *n, c = HRW, HRS, SRW, SWW, DUR*

Given that prices among wheat classes are not the same, we have a market equilibrium condition for each wheat class. Equation 17 corresponds to the equilibrium condition for HRW, HRS and SWW classes, and equation 18 to SRW and DUR:

(17) $\sum_d ss_d E(Q_d) = \sum_d ds_d E(C_d)$,

d = WA-WSU, WA-Other, OR-WSU, OR-Other, ID-WSU, ID-Other

(18) $E(Q_j) = E(C_j)$

In the overall model we aggregate the change in quantities produced, quantities consumed, and prices to obtain the corresponding changes in quantity produced, quantity consumed and price for the United States. Then we allow trade to occur between the United States and the rest of the world to obtain equilibrium prices and quantities for the rest of the world. This overall model assumes that changes in production within the United States will change the equilibrium prices and quantities in the rest of the world (large country effect). We consider this a valid assumption given that the United States is a large player in the wheat world market. The United States is the largest wheat exporter in the world with almost half of the US wheat crop being exported (Vocke, Allen and Ali 2005). The demand and supply equations for the rest of the world (*ROW*), and the market equilibrium condition given trade between the United States and the rest of the world are:

(19) $E(Q_{ROW}) = \varepsilon_{ROW}[E(P_{ROW})]$

(20) $E(C_{ROW}) = \eta_{ROW}[E(P_{ROW})]$

(21) $\sum_h ss_h E(Q_h) = \sum_h ds_h E(C_h)$, *h = US, ROW*

Finally, we calculate changes in consumer, producer and total surplus for each region and wheat class. Change in producer surplus for each region and wheat class is calculated as in the general equation for change in producer surplus (equation 11). However, the calculation of change in consumer surplus is somewhat different given the cross product prices in the demand equation for the different US wheat classes. Following Marsh (2005) we account for the limited substitutability for milling purposes among the wheat classes. By allowing the different wheat classes to be substitutes in consumption we now have a general equilibrium demand function. Consumption of a particular wheat class responds to changes in its own price, while allowing other wheat classes' prices and demand to change according to the cross-price elasticities (Alston, Norton and Pardey 1995). Therefore, the welfare measures taken from the general equilibrium demand function will reflect changes in that particular wheat class market, and also in all the other wheat classes markets. In this case, the general equation for change in consumer surplus (equation 10) captures the change in consumer surplus plus the change in producer surplus for the regions without the shift in the supply curve (Alston, Norton and Pardey 1995). Thus, we calculate the change in consumer surplus for the United States by adding the change in consumer surplus for wheat classes with a shift in the supply curve (equation 22), and then subtracting the producer surplus for all regions without a shift in the supply curve (equation 23). Equation 10 is used to calculate changes in consumer surplus for HRW, HRS and SWW.

(22) $$\Delta CS_{US}^{*} = \Delta CS_{HRW} + \Delta CS_{HRS} + \Delta CS_{SWW}$$

(23) $$\Delta CS_{US} = \Delta CS_{US}^{*} - \sum_{l} \Delta PS_{l} \ ,$$

where l = *HRW-WAOther, HRW-OROther, HRW-IDOther, HRW-OtherStates, HRS-WAOther, HRS-OROther, HRS-IDOther, HRS-OtherStates, SRW, SWW-WAOther, SWW-OROther, SWW-IDOther, SWW-OtherStates, and DUR.*

Data

Annual wheat production data for Washington, Oregon and Idaho from 2002 to 2006 are available through the US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) website (http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/). Detailed information on acreage by variety by state over time was obtained through the NASS Statistical Bulletins by State. Annual data on price, production and consumption for the United States and the world are available through the USDA Economic Research Service Wheat Yearbook Tables (http://www.ers.usda.gov/data/wheat/). Annual prices were deflated to reflect 2006 dollars using the US consumer price index (CPI) obtained through the Bureau of Labor Statistics website (http://data.bls.gov/). The CPI was adjusted to represent 2006 dollars by changing the base year to 2006 instead of 1982-1984. Supply and demand elasticities are obtained from the literature as discussed below.

First hand consumption data are not available for Washington, Oregon and Idaho. For these states, we calculated consumption proportionally to the state's population based on consumption for the whole United States. Population data for the United States, Washington, Oregon and Idaho were obtained through the Census Bureau website (http://www.census.gov).

The yield improvement data to calculate the supply shift parameter were obtained from the NASS website. Yield improvement was calculated as the marginal change in yield trend for spring and winter wheat. Yield data was not available by wheat class, only by wheat type (winter or spring). We calculated quantity produced for Washington, Oregon and Idaho for varieties developed by WSU and others using the acreage data by variety by state over time from NASS. The varieties were matched to a cultivar list and cross reference guide put together by Dr. Craig Morris from the Western Wheat Quality Laboratory, USDA. This reference guide contains information regarding the variety name, release date, source and origin, among others. Even though this list is not comprehensive, it gives a lower bound on the amount of acres planted to WSU varieties in Washington, Oregon and Idaho. We multiplied acres times yield by wheat type to get quantity produced for each wheat class and sub-region.

Results

Changes in consumer, producer and total surplus due to a shift in the supply curve for producers are analyzed for WSU wheat varieties. It is assumed that the shift in the supply curve is due to the yield improvement provided by using WSU wheat varieties. We calculate a yield improvement of 1.27 percent for winter wheat (HRW and SWW), and 1.64 percent for spring wheat (HRS).[5] Changes in consumer, producer, and total surplus (equations 10-12, 22 and 23) are calculated for each region and wheat class, the United States and the rest of the world. Specifically, we use the supply and demand equations 13-16, 19-20 and the market clearing condition described in equations 17-18, and 21. We assume that the price elasticity of supply for the United States is 0.22 (DeVuyst et al. 2001 as taken from Benirschka and Koo 1995), and for the rest of the world is 1 (Brennan, Godyn and Johnston 1989). The price elasticity of demand for the rest of the world is assumed to be -1.4 (Voon and Edwards 1992). The own- and cross-price elasticities of demand for the US wheat classes are presented in table A2 (Marsh 2005). Table A3 contains quantity consumed and price per wheat class and region in million bushels and 2006 dollars per bushel, respectively; and table A4, quantity produced by wheat class and region in million bushels. We use GAMS (version 22.2) to solve for the equilibrium prices and quantities using the PATH solver for MCP models.

[5] Yield improvement was calculated as the marginal change in yield trend for spring and winter wheat in Washington State.

Changes in consumers' and total surplus are presented in table 1, and changes in producers' surplus in table 2. These changes in surplus are in million dollars, 2006. Tables 3 and 4 present surplus changes in 2006 dollars per acre. Our results suggest that producers using WSU varieties and consumers in all regions have increased surplus from the research-induced supply shift due to WSU wheat breeding programs. The specific increase in surplus depends on the region and level of production. The largest surplus increase for producers using WSU varieties, $11 to $13 million dollars per year, is observed for SWW in Washington State, which is the majority of the wheat grown in the Pacific Northwest. Surplus increases for producers using WSU varieties of SWW in Idaho range from $2 to $2.5 million dollars per year. In Oregon, producers using WSU varieties of SWW have increased surplus by $0.7 to $1.4 million dollars per year. Producers using WSU varieties gain due to the increased yield. Yield increase translates into increases in quantity supplied and decreases in prices. Even with lower equilibrium prices producers using WSU varieties still observe large gains due to higher yield.

Decrease in surplus to producers using other varieties ranges from $10 thousand to almost $4 million dollars per year for Washington, $10 thousand to almost $3 million dollars per year for Idaho, and less than $10 thousand to $3.5 million dollars per year for Oregon. Surplus for producers of SRW decreased by $500 to $900 thousand dollars per year, while surplus for producers of DUR increased by $400 to $860 thousand dollars per year due to the cross price effects among wheat classes. At an aggregate level, the effect on US producers depends on the specific year, with surplus increases in 2002, 2004 and 2005 of $40 to $600 thousand dollars per year, and surplus decreases in 2003 and 2006 of $10 to $450 thousand dollars per year. Surplus decrease for producers in the rest of the world ranges from $90 to $140 million dollars per year.

Producers using other varieties face decreased surplus given the lower prices and that they did not benefit from the higher yield due to using WSU varieties.

Changes in consumer surplus are positive in all regions, with the magnitude of the increase depending on the number of consumers in each region. Consumers in Washington have increased surplus by $51 to $63 thousand dollars per year, consumers in the United States by approximately $27 to $29 million dollars per year, while consumers in the rest of the world have increased surplus by approximately $99 to $160 million dollars. Consumers reap all the benefits of lower prices, and thus, increases in consumer surplus are dependent on the number of consumers in each region, and specific quantity consumed.

The net effect in each region is always positive for Washington, the United States and the rest of the world. Increases in total surplus for Washington State range from approximately $11 to $14 million dollars per year. For the United States increase in total surplus ranges from $27 to $29 million dollars per year, and for the rest of the world, from $2 to $19 million dollars per year. However, the change in total surplus is always negative for Oregon, and depending on the year, it could be negative or positive for Idaho. The decrease in total surplus is small compared to the overall benefits, as represented in the total surplus changes for the United States as an aggregate. Specifically, decrease in total surplus for Oregon ranges from approximately $1 to $2 million dollars per year. Net effects for Idaho are smaller in magnitude, with increases of $170 thousand dollars for 2003 and decreases of $60 to $520 thousand dollars per year, for the rest. Net effects reflect the balance between consumers, producers using WSU varieties and producers using other varieties, given that surplus increases for the first two groups but decreases for the third one. We observe positive net effects if the number of consumers and producers using WSU varieties outweigh producers using other varieties.

To provide some perspective about the magnitude of these surplus changes, we divide the change in surplus by the number of acres to get changes in surplus in dollars per acre. These results are reported in tables 3 and 4. Producers in Washington have increased surplus by approximately $4.5 to $6 dollars per acre per year, illustrating the high percentage of Washington producers using varieties developed at WSU. Producers in Idaho increased surplus by 3 cents per acre in 2003 and decreased surplus 15 to 50 cents per acre per year for the other years, which shows the variation in use of WSU varieties in Idaho. Producers in Oregon have decreased surplus $1.7 to $2.6 dollars per acre per year, revealing a lower proportion of producers using WSU varieties as compared to Idaho and Washington. On aggregate terms, producers in the United States have increased or decreased surplus in such small magnitudes that in dollars per acre the increase or decrease is very close to zero, showing the balance between producers using WSU varieties and other varieties. Rest of the world producers have decreased surplus by approximately 20 to 30 cents per acre per year, given that they experienced lower prices, but not higher yields.

Total surplus changes for Washington represent increases of $4.75 to $6.14 dollars per acre per year, for Idaho total surplus increases by 15 cents per acre for 2003, and decreases by 5 to 43 cents per acre per year for the other years. These results show that in Washington and Idaho most of the benefits go to producers using WSU varieties, since increases in total surplus are only slightly higher than increases in producer surplus. Given the large quantities of wheat produced in those states relative to the average consumption per capita this result is no surprise. In the case of Oregon, there are net decreases of $1.35 to $2.18 dollars per acre per year, showing that producers using other varieties have more to lose than the gains accrued to consumers and producers using WSU varieties. Net effects for the United States as an aggregate are increases in surplus of approximately 50 cents per acre per year. Overall, in the United States the gains to consumers and producers using WSU varieties are larger than the loses to producers using other varieties. Net effects for the rest of the world are quite small, with surplus increases of 0 to 4 cents per acre per year, showing that the benefits of lower prices to consumers outweigh the costs to producers using other varieties.

To formally evaluate the WSU wheat breeding programs it is important to compare to the costs incurred to fund these programs. As mentioned earlier, funds for the WSU wheat breeding programs come from a variety of sources including: state, federal, university and the Washington Wheat Commission. Given the public nature of these funds, it is a relevant policy question to ask if these funds are being used efficiently. We have presented a detailed analysis of the changes in surplus for several regions due to the use of varieties developed by WSU. Now we need to compare these net benefits with the cost of research.

Average estimates of expenditures in WSU wheat breeding research from 2002 to 2006 range from \$0.97 to \$2.28 dollars per acre, depending on a broad or narrow consideration of expenditure on wheat breeding research.[6] Specifically, narrow expenditures represent all accounts that have "wheat" in the title, while broad expenditures represent all projects where one of the investigators specializes in "wheat". The cost data does not reflect the lagged effect of wheat breeding research. It can take 7 to 12 years from the development to the marketing and adoption of a new wheat variety. However, these data provide an estimate to put the benefits obtained in perspective. Thus, the net social welfare (after considering the research costs) for Washington is on average \$3.37 to \$4.68 dollars per acre per year, depending on the narrow or broad version of expenditures. We obtain benefits of \$2.49 to \$5.84 dollars on average for each

[6] Based on calculations from expenditure data collected from the WSU College of Agriculture, Human, and Natural Resource Sciences and from representative price, cost and yield data for the state of Washington. Additional details are available from the authors upon request.

dollar invested in WSU wheat research from 2002 to 2006. Net welfare results for Washington are presented in table 5.

Furthermore, the average profit for wheat in the United States from 2002 to 2006 was $41.56 dollars per acre per year.[6] The increase in producer surplus for Washington represents on average about 13 percent of the average profit for wheat. The percentages for each year (2002 to 2006) are presented in table 6. These numbers provide further evidence of the benefits for Washington state wheat producers of using the varieties developed by the WSU wheat breeding programs.

Conclusions

This article presents welfare effects of the WSU wheat breeding programs under a multi-product, multi-region, multi-variety model including spillover effects to Idaho and Oregon. Given the specific characteristics of the different wheat classes and regions we believe that it is important to introduce these differences into the model to obtain more accurate results, since information is lost by aggregating all wheat classes and regions into one.

Overall, consumers in all regions and producers using WSU developed varieties have increased surplus from yield increases in wheat due to WSU wheat breeding programs. This is due to the combination of lower prices and higher yields due to WSU wheat breeding programs. However, producers using non-WSU varieties, in the rest of the world and of other wheat classes have decreased surplus due to lower prices and constant yields. It is important to note that this model is partial equilibrium and thus, we are holding constant all other potential yield increases due to technology or other wheat breeding programs to concentrate on the effect of WSU wheat breeding programs. Changes in total surplus are positive for all regions except for Oregon, and some years for Idaho. However, the surplus decreases in these two states are smaller relative to the increases in all other regions, and the net effects for United States and the rest of the world are positive.

We have analyzed an important question: if funds allocated to the WSU wheat breeding programs had a reasonable return. We compare the expenditures in the WSU wheat breeding programs to the benefits calculated with our model, and we find that for each dollar spent per acre, farmers obtained on average extra $7 dollars per acre from 2002 to 2006. It is also important to consider the lagged effect that investment in research has. It takes 7 to 12 years to develop and market a new variety. Our results are important for Washington State University and policymakers in general, because they provide justification for the current funds allocated the wheat breeding programs.

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Figures

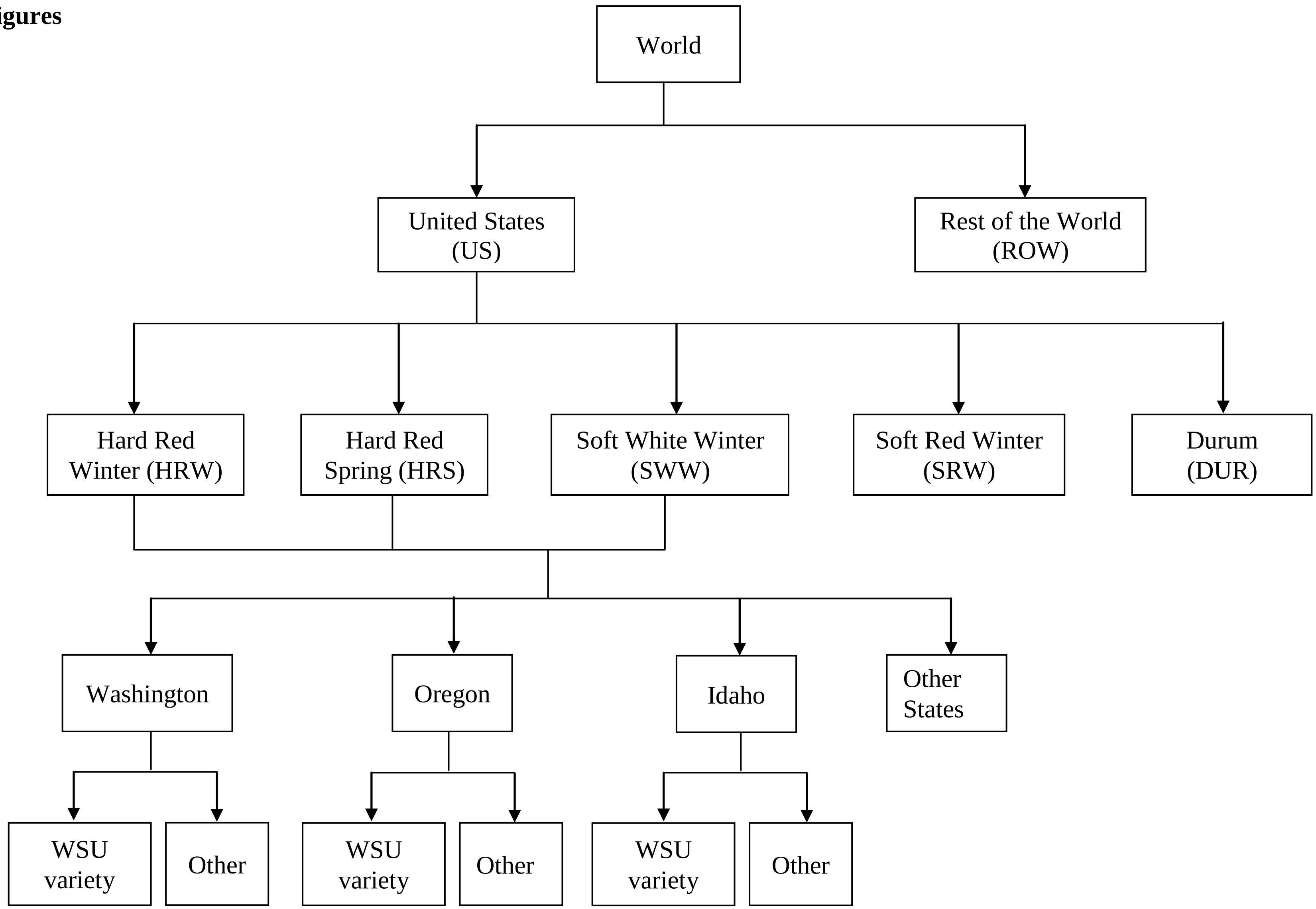

Figure 1: Flow Chart Overview of the WSU Wheat Breeding Programs Model

Table 1: Consumers' and Total Surplus Changes

Region	2002	2003	2004	2005	2006
	Change in Consumers' Surplus [a]				
Washington	0.57	0.61	0.57	0.51	0.63
Idaho	0.13	0.14	0.13	0.12	0.14
Oregon	0.33	0.35	0.33	0.29	0.36
United States	27.14	28.73	26.84	26.84	29.27
Rest of the World	98.55	157.70	120.28	127.39	126.48
	Change in Total Surplus [a]				
Washington	11.35	14.14	13.97	11.66	13.56
Idaho	-0.25	0.17	-0.06	-0.52	-0.47
Oregon	-1.13	-1.83	-1.61	-1.67	-1.84
United States	27.18	28.28	27.43	26.94	29.26
Rest of the World	8.47	18.70	1.91	6.14	9.32

[a] Units are million 2006 dollars

Table 2: Producers' Surplus Changes [a]

Region	Class	Origin	2002	2003	2004	2005	2006
Washington	HRW	WSU	1.37	1.22	1.44	1.36	2.28
		Other	-0.02	-0.02	-0.01	-0.01	-0.04
	HRS	WSU	0.80	0.82	1.22	0.70	1.28
		Other	0.01	0.01	0.00	0.01	-0.01
	SWW	WSU	11.26	13.72	13.17	11.58	13.02
		Other	-2.63	-2.21	-2.42	-2.49	-3.61
	All	All	10.78	13.53	13.40	11.15	12.93
Idaho	HRW	WSU	0.00	0.00	0.00	0.00	0.00
		Other	-0.06	-0.07	-0.07	-0.07	-0.10
	HRS	WSU	0.00	0.00	0.12	0.13	0.30
		Other	0.02	0.03	0.01	0.02	-0.01
	SWW	WSU	2.52	2.54	2.44	1.99	1.95
		Other	-2.86	-2.47	-2.70	-2.70	-2.75
	All	All	-0.38	0.03	-0.19	-0.64	-0.61
Oregon	HRW	WSU	0.00	0.00	0.06	0.09	0.08
		Other	0.00	0.00	0.00	0.00	-0.01
	HRS	WSU	0.01	0.00	0.04	0.04	0.02
		Other	0.00	0.00	0.00	0.00	0.00
	SWW	WSU	1.17	1.36	1.44	0.91	0.71
		Other	-2.64	-3.54	-3.48	-2.99	-3.01
	All	All	-1.46	-2.18	-1.94	-1.96	-2.20
Other States	HRW	All	-3.37	-4.28	-3.73	-3.91	-4.24
	HRS	All	0.39	0.71	0.32	0.50	-0.20
	SWW	All	-5.77	-8.23	-7.37	-5.38	-5.38
United States	SRW	All	-0.80	-0.89	-0.65	-0.53	-0.71
	DUR	All	0.65	0.86	0.74	0.86	0.42
	All	All	0.04	-0.45	0.59	0.10	-0.01
Rest of the World	All	All	-90.08	-139.00	-118.37	-121.25	-117.16

[a] Units are million 2006 dollars

Table 3: Consumers' and Total Surplus Changes

Region	2002	2003	2004	2005	2006
	Change in Consumers' Surplus [a]				
Washington	0.24	0.26	0.25	0.23	0.28
Idaho	0.12	0.12	0.11	0.10	0.12
Oregon	0.39	0.32	0.35	0.32	0.43
United States	0.45	0.46	0.45	0.47	0.51
Rest of the World	0.19	0.30	0.22	0.24	0.24
	Change in Total Surplus [a]				
Washington	4.75	6.03	6.14	5.24	6.09
Idaho	-0.23	0.15	-0.05	-0.43	-0.39
Oregon	-1.35	-1.69	-1.69	-1.87	-2.18
United States	0.45	0.46	0.46	0.47	0.51
Rest of the World	0.02	0.04	0.00	0.01	0.02

[a] Units are 2006 dollars per acre

Table 4: Producers' Surplus Changes [a]

Region	Class	Origin	2002	2003	2004	2005	2006
Washington	HRW	WSU	15.66	16.92	16.69	17.97	20.47
		Other	-0.35	-0.24	-0.21	-0.28	-0.44
	HRS	WSU	16.26	14.80	18.68	16.95	20.25
		Other	0.09	0.08	0.00	0.08	-0.05
	SWW	WSU	8.93	10.63	10.95	9.72	13.03
		Other	-5.92	-5.65	-5.30	-4.58	-5.58
	All	All	4.51	5.77	5.89	5.01	5.81
Idaho	HRW	WSU	0.00	0.00	0.00	0.00	0.00
		Other	-0.41	-0.35	-0.42	-0.40	-0.51
	HRS	WSU	0.00	0.00	28.57	27.66	29.41
		Other	0.07	0.10	0.04	0.10	-0.03
	SWW	WSU	11.85	13.08	14.70	13.22	15.23
		Other	-7.87	-6.94	-7.11	-6.21	-6.50
	All	All	-0.35	0.03	-0.16	-0.53	-0.51
Oregon	HRW	WSU	0.00	0.00	16.22	16.67	16.33
		Other	0.00	0.00	0.00	0.00	-0.65
	HRS	WSU	12.50	0.00	20.00	22.22	16.67
		Other	0.00	0.00	0.00	0.00	0.00
	SWW	WSU	6.47	8.35	9.96	8.86	10.52
		Other	-4.29	-4.43	-4.83	-4.17	-4.48
	All	All	-1.74	-2.02	-2.03	-2.19	-2.60
Other States	HRW	All	-0.11	-0.13	-0.12	-0.13	-0.15
	HRS	All	0.03	0.06	0.03	0.04	-0.01
	SWW	All	-4.37	-4.06	-3.68	-2.99	-3.87
United States	SRW	All	-0.10	-0.11	-0.08	-0.09	-0.10
	DUR	All	0.22	0.30	0.29	0.31	0.22
	All	All	0.00	-0.01	0.01	0.00	0.00
Rest of the World	All	All	-0.17	-0.27	-0.22	-0.22	-0.22

[a] Units are 2006 dollars per acre

Table 5: Cost and Social Welfare of WSU Wheat Breeding Programs [a]

	2002	2003	2004	2005	2006	Average 2002-2006
Broad Cost of WSU Wheat Programs	2.45	2.37	2.30	2.19	2.09	2.28
Narrow Cost of WSU Wheat Programs	1.05	1.01	0.98	0.94	0.89	0.97
Change in Total Surplus Washington	4.75	6.03	6.14	5.24	6.09	5.65
Net Social Welfare Washington (broad)	2.30	3.66	3.84	3.05	4.00	3.37
Net Social Welfare Washington (narrow)	3.70	5.02	5.16	4.31	5.20	4.68
Returns per dollar invested (broad)	1.94	2.54	2.67	2.39	2.91	2.49
Returns per dollar invested (narrow)	4.54	5.96	6.26	5.60	6.82	5.84

[a] Units are real dollars per acre

Table 6: Producer Surplus and Profit Comparison

	2002	2003	2004	2005	2006	Average 2002-2006
Real Average US Profits per acre	28.81	52.48	40.36	28.38	57.76	41.56
Change in Producers' Surplus for Washington, 2006 dollars per acre	4.51	5.77	5.89	5.01	5.81	5.40
Change in Producers' Surplus as Percentage of Profit	15.66	10.99	14.59	17.66	10.06	12.99

Appendix

Table A1: Number of Acres Planted by State, Wheat Class and Origin

State	Class	Origin	2002	2003	2004	2005	2006
		WSU	87,500	72,100	86,300	75,700	111,400
	HRW	Private	24,200	60,400	17,500	29,200	52,200
		Total	144,500	157,000	133,500	111,800	202,000
		WSU	49,200	55,400	65,300	41,300	63,200
Washington	HRS	Private	81,900	103,700	105,700	81,900	171,500
		Total	159,500	186,500	201,000	165,100	275,400
		WSU	1,261,283	1,290,583	1,203,017	1,191,450	999,517
	SWW	Private	140,783	143,500	174,333	186,700	155,600
		Total	1,705,500	1,681,500	1,659,500	1,735,000	1,647,000
		WSU	0	0	0	0	0
	HRW	Private	16,200	27,300	12,700	11,300	12,300
		Total	148,000	201,000	165,000	175,000	195,000
		WSU	0	0	4,200	4,700	10,200
Idaho	HRS	Private	16,200	27,300	12,700	11,300	12,300
		Total	148,000	201,000	165,000	175,000	195,000
		WSU	212,700	194,200	166,000	150,500	128,000
	SWW	Private	59,600	41,000	50,600	54,300	68,500
		Total	576,000	550,000	546,000	585,000	551,000
		WSU	0	0	3,700	5,400	4,900
	HRW	Private	0	3,400	0	0	6,700
		Total	4,200	8,200	4,600	9,400	20,400
		WSU	800	0	2,000	1,800	1,200
Oregon	HRS	Private	11,600	20,000	13,200	12,300	9,000
		Total	27,800	30,200	34,600	39,300	53,000
		WSU	180,733	162,883	144,533	102,700	67,517
	SWW	Private	1,400	2,500	24,900	4,200	17,400
		Total	795,800	961,800	865,400	820,400	739,500

Table A2: Own- and Cross-Price Elasticities of Demand [a]

	HRW	HRS	SRW	SWW	DUR
HRW	-0.864	1.522	-0.023	0.366	0.306
HRS	0.949	-1.712	-0.017	-0.373	-0.234
SRW	-0.009	-0.011	-0.028	0.024	0.071
SWW	0.066	-0.108	0.011	-0.036	-0.045
DUR	0.067	-0.082	0.04	-0.054	-0.118

[a] Source: Marsh (2005)

Table A3: Quantity Consumed and Price

	2002	**2003**	**2004**	**2005**	**2006**
Class / Region	**Quantity Consumed [a]**				
HRW	377.13	378.08	382.05	368.11	355.00
HRS	215.00	223.00	228.00	227.00	235.00
SRW	165.00	153.00	155.00	155.00	165.00
SWW	80.00	85.00	75.00	85.00	85.00
DUR	81.49	72.85	69.50	79.18	85.00
ROW	21068	20434	21224	21792	21537
	Price [b]				
HRW	4.75	4.54	4.36	4.70	5.44
HRS	5.01	4.80	4.97	5.14	5.41
SRW	3.81	4.01	3.21	3.23	3.98
SWW	4.43	4.33	4.19	3.69	4.87
DUR	4.76	5.82	5.97	6.17	6.49
ROW	5.46	5.28	4.90	5.01	5.92

[a] Units are million bushels
[b] Units are 2006 dollars / bushel

Table A4: Quantity Produced [a]

Class	Region	Origin	2002	2003	2004	2005	2006
HRW	Washington	WSU	5.08	4.69	5.78	5.07	7.35
		Other	3.31	5.52	3.16	2.42	5.98
	Idaho	WSU	0.00	0.00	0.00	0.00	0.00
		Other	11.40	16.08	14.85	15.93	15.02
	Oregon	WSU	0.00	0.00	0.23	0.33	0.26
		Other	0.00	0.00	0.05	0.24	0.82
	Other States	All	600.55	1044.71	832.14	905.83	652.65
HRS	Washington	WSU	2.12	2.27	3.27	1.82	3.16
		Other	4.74	5.38	6.79	5.45	10.61
	Idaho	WSU	0.00	0.00	0.33	0.34	0.74
		Other	17.94	19.47	22.34	14.35	21.52
	Oregon	WSU	0.03	0.00	0.10	0.09	0.06
		Other	0.97	1.21	1.56	1.95	2.59
	Other States	All	325.64	471.35	491.08	442.59	393.65
SWW	Washington	WSU	73.15	83.89	80.60	79.83	65.97
		Other	25.76	25.41	30.58	36.42	42.73
	Idaho	WSU	16.38	15.54	14.94	13.70	9.86
		Other	27.97	28.46	34.20	39.54	32.57
	Oregon	WSU	7.59	8.31	8.82	6.26	3.58
		Other	25.83	40.74	43.97	43.78	35.62
	Other States	All	56.49	94.67	93.25	78.63	63.66
SRW	All	All	320.97	380.44	380.31	309.02	390.17
DUR	All	All	79.96	96.64	89.89	101.11	53.48
All	ROW	All	19277	18042	20915	20771	19974

[a] Units are million bushels