Wheat Yield Response: On-farm Management versus Breeder Contributions

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ABSTRACT

Data from the WSU wheat variety test program along with spatially interpolated historic weather records present a unique opportunity to compare wheat variety performance across time and Washington State geography. A key assumption in this analysis takes wheat variety to be genetically constant year-over-year. This assumption allows us to separate breeding versus farm-level productivity gains. Furthermore, across the wide variety of climate regions within Washington State, productivity gains can be measured for different climate regions, allowing a unique contribution to the body of literature attempting to differentiate the various technology contributions to farm productivity.

Analysis of breeder contributions to wheat productivity gains are then applied to state-wide USDA productivity data and determine the economic benefit provided by the wheat variety improvements to average $1.60 per bushel (2010 dollars).

DATA

Wheat variety yield data is sourced from the WSU Uniform Cereal Variety Testing Program. The WSU variety test program's stated mission is to provide growers with "comprehensive information on the adaptation and performance of winter and spring wheat varieties across the different climate regions and management practices in eastern Washington." Digitized data records covering harvest years 1979-2010 include 4,000-6,000 yearly experimental test plots in specific locations and coded by experimental category, including plots that were planted specifically to mimic standard farming practices. From over 540,000 available test plots over 70,000 meet the requirements characterized as standard farming practices.

This wheat variety data was matched with a spatially and temporally interpolated historic weather records present a unique opportunity to compare wheat variety performance across time and geography. A key assumption in this analysis takes wheat variety to be genetically constant year-over-year. If the same variety is observed improving in yield year-over-year, that measurable improvement, controlled for location and weather conditions, is attributed to on farm management improvements. Likewise, a difference in yield between varieties, controlling for location and weather conditions, allows a measure a performance between varieties. Using both of these measures we compare contributions to year-over-year gains in yield from breeder selection versus on farm management only.

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OVERVIEW

Data from the Washington State University (WSU) wheat variety test program along with spatially and temporally interpolated historic weather records present a unique opportunity to compare wheat variety performance across time and geography. A key assumption in this analysis takes wheat variety to be genetically constant year-over-year. If the same variety is observed improving in yield year-over-year, that measurable improvement, controlled for location and weather conditions, is attributed to on farm management improvements. Likewise, a difference in yield between varieties, controlling for location and weather conditions, allows a measure a performance between varieties. Using both of these measures we compare contributions to year-over-year gains in yield from breeder selection versus on farm management only.

METHOD

Three different linear regression models were used to estimate gains in yield due to improved on-farm management and improved varieties. The regression models are titled, "Heat Index Model", "Evapotranspiration Model" and "Modified Thompson Model" and emphasize different methodological ways of measuring the effects on yield from moisture, temperature, wind, snow coverage, location, time and other factors. The basic analysis for each of the three models is described in general here:

On farm management contribution to gains in yield were estimated by regressing yield for each wheat variety, i, location j, and harvest year t, using a combination of temperature, location and weather variables represented by the matrix Xij. These models allow each variety a unique slope representing the year-over-year gain in yield (or loss) in yield as a result of on farm management. The example model follows:

\[ Yield_{ijt} = \beta_0 + \beta_1 YR_t + \beta_2 Raint + \beta_3 Raint^2 + \beta_4 Wjt + e_{ijt} \]

Differeniating variety yield with respect to year results in a unique year-over-year change in yield for each variety. Because we assume each variety’s unique genetics to remain constant the derivative describes year-over-year changes in yield resulting from on-farm management only.

\[ \frac{\Delta \text{Yield}}{\Delta \text{YR}} = \beta_1 \]

In order to measure breeder contributions to yield a modified version of the model excludes the variety-year, interaction term. In this case each variety is forced to have the same slope while the variety dummy variables describe intercept differences and as such, compare average yield differences between varieties. Ordering variety yield by release year allows a trend estimate on breeder contributions to gains in yield. The basic variety comparison model follows:

\[ \Delta \text{Yield}_i = \beta_1 YR_t + \beta_2 V_i + \beta_3 V_i \times YR_t + \beta_4 Wjt + e_{ijt} \]

Climate predictions for Eastern Washington suggest a modest increase in average annual rainfall of 4% for the thirty year period 2020-2050 compared to the period 1971-2000. To account for modest increases in moisture a quadratic model is developed to estimate optimal annual rainfall totals for each wheat class. An example quadratic model follows:

\[ \Delta \text{Yield}_i = \beta_1 YR_t + \beta_2 \text{Rain}_t + \beta_3 \text{Rain}_t^2 + \beta_4 Wjt + e_{ijt} \]

Furthermore, two models based on the heat index and modified Thompson approaches are developed to estimate variety response to marginal increases in moisture. An example of these models follow:

\[ \Delta \text{Yield}_i = \beta_1 YR_t + \beta_2 \text{Rain}_t + \beta_3 \text{Rain}_t^2 + \beta_4 Wjt + e_{ijt} \]

RESULTS

For the wheat class winter white common, the most widely cultivated wheat class in Washington State covering 60-70% of all wheat acreage, aggregate results estimate 25% of average year-over-year gains in yield derive from improved wheat varieties. Analysts by precipitation zone shows breeder contribution to gains are proportionally higher in drier regions (30-40% of all year-over-year gains attributable to variety improvements) and proportionally less for the wettest region (only 12% of all year-over-year gains attributable to variety improvements). Results for other wheat classes are also estimated.

From the analyses of breeder contributions to wheat productivity gains are applied to state-wide USDA annual wheat yield records to determine the economic gains attributable to wheat variety improvements. Annual economic gains are estimated to average about $1.4M for winter wheat and $0.4M for spring wheat. Combining all wheat classes the aggregated state-wide annual average economic gain from improved wheat varieties is about $1.8M (2010 dollars). These value estimates are gross monetary returns on the price per bushel received on the average increase in yield attributed to improved varieties. This value does not include costs associated with harvesting, storing and managing the additional yield nor does it account for any increase in seed price that may be associated with higher performing varieties.