But Are They Meritorious?

Productivity Gains under Plant IPR

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Abstract

Despite that recentness of intellectual property rights protection of plants in the US ,
documenting the productive merit of varieties associated with IPR protection has been
elusive. This paper using varietal trial data of soft white winter wheat from Washington
State found supporting evidence to the hypothesis that Plant Variety Protection has
contributed to the genetic improvement of soft white winter wheat in Washington State.

I.   Introduction

The Intellectual Property Rights (IPR) protection of plants in the United States is
relatively recent, dating variously to 1930 (Plant Patents; asexually propagated), 1970
(Plant Variety Protection, PVP)[1] and 1985 (utility patents)[2]. Despite that recentness,
documenting the productive merit of varieties associated with IPR protection has been
elusive. It has been possible to establish theoretically that IPR systems which enhance
the appropriability of benefits from inventions increases investment in inventive activities
(see e.g., Scherer, 2005). We know as well that following the adoption of PVP that the
amount of private investment in plant breeding has increased significantly.   Butler and
Marion (1985, p. 74) conclude that PVP "has stimulated the development of new

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[1] However, hybrids were not protectable until 1994.
[2] In contrast, the first general patent act was adopted in 1790.

varieties of soybeans and wheat." Plus a significant number of firms invested in plant

breeding since 1970 but there was no documentable effect on public plant breeding.

Perrin, Hunnings and Ihnen (1983, Tables 3 and 4) surveyed all known seed companies

and found private investment in cereal breeding rose from essentially nothing ($8,000) in

1960 to $ 4.3 m in 1979; similar trend results apply when computed on investment per

dollar of sales.

Foster and Perrin (1991, Table 1) document that soybeans and wheat received the largest

number of certificates of PVP through 1987, which they correlate to the crop market

value. They further report a single private sector soybean breeding program in 1970

rising to 34 in 1988, or, in terms of PhD breeders, six in 1970 and 70 in 1988

respectively. By 1994 the number of cereal breeders had risen to 892, of which almost 80

percent worked for the private sector. For wheat alone, the comparable numbers are 130

and 41.5 percent (Fry, 1996, Tables 1 and 5).

From this overview it is generally clear that, for wheat (and soybeans) at least, the private

sector has invested more in breeding since the advent of protection in 1970, and that as a

result, more varieties are available now than in the pre-PVP era. The public sector

continues to dominate many crops as the leading source of new varieties, with many now

protected under PVP. These results support the economic theory. What though is not

well documented is if the protected new varieties are more productive, or merely trivial

reformulations of existing materials. PVP systems are susceptible to such "cosmetic

breeding" as the 'Research Exemption' provision allows for the use and reproduction of

protected varieties in plant breeding and other bona fide research[3]. The absence of grow

out trials in the US and agronomic merit standards means the PVP system as applied in

the U.S. is particularly prone to cosmetic breeding (Lesser, 1994; Naseem, Oehmke and

Schimmelpfenning, 2005).

However, since agricultural crop seeds are an important input into commercial farming

operations and since the relative productivity of available varieties can be observed and

measured, the opportunity for seed firms to maintain market share with multiple 'me to'

varieties can be questioned. The objective of this paper is the evaluation of the effect of

PVP on the productivity merit of U.S. wheat varieties. As an exemplar, we use soft white

winter wheat varieties in Washington State, which are and have been available both

protected and unprotected under PVP from both the public and private sectors.

The U.S. Patent Office lists but 12 wheat variety utility patents granted meaning utility

patents are a trivial percentage of the 600+ certificates of PVP granted[4] and their presence

does not complicate the analysis. Conversely, utility patents in recent years are

dominating protection for soybean varieties (Lesser and Mutschler, 2002). Because

patent laws do not require the same variety denomination be used in all references to the

variety, it is often not possible to determine if a particular variety has been patented.

Public varieties are registered on the USDA GRIN website[5] from which the protection

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[3] PVPA Section 114, available at http://www.ams.usda.gov/Science/PVPO/PVPO_Act/PVPA2005.pdf
[4] Available at www.uspto.gov under 'search' patents; http://www.ars-grin.gov/cgi-bin/npgs/html/pvp.pl?Wheat,%20common
[5] http://www.ars-grin.gov/cgi-bin/npgs/html/csr.pl?WHEAT

status can be identified as well. That factor makes an analysis of the productive merit of soybean varieties not possible, leading here to the choice of wheat as the base of analysis.

II.   Literature Review

A. Studies based on variety trial data

Relatively few studies of the impact of PVP on crop productivity have been undertaken over the years so it is possible to examine here the available ones in some detail. Perrin, Hunnings and Ihnen (1983, pp. 34-37) did evaluate soybean performance over 1960-79 using variety trial data from North Carolina, Louisiana and Iowa. State variety trials are described in detail in the data section below. The methodology used was a simple 'hinge' function at 1970 with a variety yield as the dependent variable which allowed comparing the trend in yield improvement before and after the 1970 adoption of PVP. The year of variety release (or first entry into trials) was used as a control variable as older varieties are generally less productive.

The pre-PVP trend was essentially flat while the post figure was a positive .12 bu./acre/year, but only significant at the 16 percent level. From these results the authors conclude that the direction of change is consistent with the function of IPR and will have a cumulative effect over time. In analyzing these results, it should be noted that a new variety takes on the order of eight years to develop and likely longer for a newly entered private firm. Moreover the analysis implicitly assumes no positive aggregate productivity effects from say heavier use of fertilizers over time nor negative ones from

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drought or cold. And finally and most critically, since the tested varieties contain a mix of public and private entries as well as protected and unprotected ones, the hypothesis implicitly tested is that the existence of PVP would raise the average productivity of all varieties sufficiently to change the trend line. Stated differently, the test weights all varieties equally when in fact it is not clear but that PVP operates only through private releases, or protected releases. Thus, the small identified effect is not surprising but still the evidence is far from compelling.

Babcock and Foster (1991) again used variety trial data (in this case from North Carolina) to evaluate the effect of PVP on tobacco variety releases and yields over the period 1954-87. They used the same methodology as Perrin, Hunnings and Ihnen (1983) with two key differences. First, they vary the date of the intercept and slope shifters for each of the eight years following adoption of PVP. But one year, 1973, resulted in a significant (at the 5% level) yield effect, which they describe as "suggestive, but inconclusive". Again though the analysis of the trend implies the effect of PVP operates through the average of all varieties in contrast to weights or protected vs. unprotected, etc.

The other methodological modification though is of more relevance to the current study than the conclusion. Rather than using the nominal values of the yields as the dependent variable they used the yield difference with a 'reference' variety. A reference is a variety planted over multiple years to create a baseline comparison. For measuring annual change, the reference accounts for some of the annual differences – the fixed effects in the terminology of cross section time series analysis – which were implicitly assumed

constant by Perrin, Hunnings and Ihnen (1983). This approach then captures some broad annual factors like rainfall, assuming that the reference and new varieties respond similarly.

Alston and Venner (2002) also use state average variety trial data to evaluate the effects of PVP on wheat genetic productivity. The massive data set of over 20,000 observations for both hard red spring and hard red winter wheat covers nine states and years 1950-93 where an observation applies to the yield of a variety in a particular location. The PVP effect is measured by two dummy variables, one distinguishing public or private ownership and the second PVP status. Also unlike Babcock and Foster (1991), variables were added to year of trial, year of variety release (variety age), location, wheat price and an index of state-level precipitation and temperature data, as well as interaction terms between temperature and rainfall, and rainfall and fertilizer.

The variable of particular interest is the PVP dummy which is negative but highly insignificant across several specifications. Additionally, the rate of improvement derived from the continuous date variable is no higher and may be lower following adoption of PVP leading to the conclusion of a showing of "no discernable effect" of PVP on wheat yields. No importance however is attached to the positive and significant sign on the private variety variable, even though the existence of PVP is likely responsible for the involvement of private capital in wheat breeding. Our results (see below) suggest that the negative sign is a consequence of the high correlation between PVP and private. The degree to which private varieties are protected is not discussed.

Unlike Babcock and Foster (1991), Alston and Venner (2002) did not compute the dependent variable as the yield difference from a local reference. The use of actual variety yield figures means all adjustments for management and environmental effects on yields must be done through additional independent variables – in their case the state level temperature and rainfall indexes and interaction terms. However, as Carew and Devadoss (2003) analyze at some length using detailed insurance and survey data in their study of farm level canola yields in Canada, environmental and management issues are localized (although admittedly Canadian provinces are very large). For example, in Manitoba there are three identified 'risk regions' based on differences in soil quality, fertilizer use and rainfall. Moreover they add an additional weighted soil quality index. With the absence of more detailed adjustments for localized factors, the omitted variable effects on the Alston and Venner (2002) results spreading across two wheat types, nine states and 40+ years are difficult to evaluate.

B. Studies based on production function analysis

The three final studies to be considered here assess the effects of PVP using a crop production function approach expanding on the simpler methodology of Perrin, Hunnings and Ihnen (1983). The earliest of the three is Alston and Venner (2002) using many of the same data described above. Specifically, they model on the state level average wheat yields with variables adjusting for wheat price, fertilizer application, year, and as well as the precipitation and rainfall indexes. The PVP effect is measured both as the proportion of acres planted to PVP-protected varieties, and as a structural change (intercept shifter)

for 1976 (1981 for winter wheat which is said to take longer to develop). Results for the structural change test show no state to have a statistically significant coefficient (results for HRS are shown) while for the PVP share analysis, no state results are both positive and significant. These results have been widely reported.

In the case of the PVP share equations, the results are however a little ambiguous because there is evidence that the PVP-protected varieties are predominately semidwarfs[6]. With our data set (see below) we also find that PVP-certificated varieties are heavily concentrated into sub classes of wheat, that is, are not randomly distributed across types. That situation could directly affect the results if, for example, dwarf varieties grew best in low rainfall areas and while distinctly superior to non-dwarfs in those environments, yields were still below state averages, giving exactly the shown results. Moreover, the practice of wheat farmers to save seed further delays the diffusion of new varieties.

The objective of the Carew and Devadoss (2003) study of Canadian canola yields is more methodological than strictly empirical, that is determining if one or two-way fixed or random effects models using panel data better explain the unobserved region-specific variables correlated with the explanatory variables in crop production functions. There are other institutional aspects which distinguish their results from those done in the US, notable that Canada did not adopt PVP legislation until 1990, and that about 80 percent of canola varieties in recent years are genetically engineered for herbicide resistance, and often sold as hybrids. For the one-way models, the share of area planted to PVP-

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[6] That is, an "extreme positive correlation" was found between the semidwarf share and share of area planted to certificated varieties. Alston and Venner (2002).

protected varieties was positive and significant, but not so when the PVP effect is measured as a structural change factor (set at 1996). Neither variable is significant in the two-way models. These results provide some limited support for a positive effect of PVP on canola yields, but mostly serve to emphasize the data needs for a careful production function analysis for crops planted over wide areas with varying localized conditions.

Finally and most recently, Naseem, Oehmke and Schimmelpfenning (2005) use the production function methodology to evaluate cotton germplasm improvement under PVP legislation. They employ the Carew and Devadoss (2003) panel data methodology, made possible because the USDA published annual data on area plantings by variety. A difference though is the use of three PVP-related variables:

1. PP-planted acreage as % all cotton acreage,

2. # PVP varieties as % all varieties, and

3. PVP-planted area % x yield trend 1950-2000 over 14 states.

As conclusions, variable 1 was negative and significant, 2 negative and significant as well, and 3 positive and significant. However, when evaluated at their sample means, the net productivity benefit is reported as 58.77 lbs/acre. This strongly positive result compared to much prior work they attribute to the possible failure of prior studies to "control for important trend shifts".

III.   Testable Hypotheses and Methodology

A. Testable hypothesizes

Overall, the literature contains both positive and negative support for an hypothesis that

PVP legislation in the US contributed to the production of more productive varieties.

The results vary according to crop, time period and methodology making a consensus

decision not possible. That is the justification for the present analysis which can benefit

from the limitations of prior work. Specifically, the literature assessment is grounds to be

concerned about the limitations of the crop production function approach. Because soil,

rainfall and temperature conditions are very localized and changes in management

practices difficult to quantify, it is difficult to capture those effects with a few state-level

indexes, as Carew and Devadoss (2003) show. Hence, here we undertake the variety

trials data-based comparison approach.

Among the prior studies using this approach, we are convinced by the Babcock and

Foster (1991) justification for computing the dependent variable as the yield difference

between the target variety and that of a localized reference. Assuming that all test

varieties (including the reference variety) are affected proportionally by localized

growing conditions, this difference variable is a means of adjusting for those differences.

At the same time, experimental trial data include information on rainfall, temperature and

fertilizer applications for individual test sites which are further control variables.

Remaining then is a consideration of the hypothesizes to test.

We are convinced by the Alston and Venner (2002) approach of using a dummy variable to denote PVP-associated varieties and look for significant differences in yields. The alternative, as applied by Babcock and Foster (1991) and before them Perrin, Hunnings and Ihnen (1983), is a structural change measure hinged at the time PVP legislation can be anticipated to have began affecting germplasm quality. Arguably that point could extend from prior to the 1970 adoption of PVP legislation in the US[7] to 6 – 8 years following to allow for the development of new varieties. Identifying the exact time of structural change is often problematic and can introduce error into studies using that methodology.

At the same time, the structural change method implicitly assumes the varieties tested represent a near universe of available varieties, or at least a random sample from that universe. That assumption is often incorrect. On one hand, some varieties are included by the experiment stations which run them as part of the variety development process. That is, they are pre-release and may never justify release, at least in all areas tested. Conversely, private firms, which are typically charged for including their varieties in trails, may not and do not always include all their best varieties in the trials. They may believe their own proprietary tests better represent the potential of their materials. The ones which are included then represent exceptions for some firms and may for example show some potential outside the target sales area and so justify the cost of inclusion with a limited penalty to a firm's reputation if performance is not strong. At the same time,

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[7] Butler and Marion (1985) found private firms initiated breeding programs prior to 1970 in what they interpret to be anticipation of the passage of the legislation.

trials leaders may choose to included private varieties at public expense if for example a variety is popular, or growing in use. So for whatever reasons, varieties included in trials are not necessarily representative of varieties actually grown which makes the structural change methodology approach difficult to interpret. This 'sample' effect varies by crop and possibly by state; for example, fringe producing areas are more likely to include private varieties with a broader market area potential. Of course, the test designating protected varieties is not completely exempt from this sampling issue, but as with our data set (see below) which includes 99 percent of the wheat varieties grown in Washington State, the effect is minimized.

Within the PVP-impact approach, additional consideration must be given to the hypothesizes tested. They can be:

      a. PVP-protected varieties are more productive,

      b. Private varieties are more productive, or

      c. Both protected and private varieties are more productive.

The final option of course follows Alston and Venner (2002) but we find this problematic if one presumes private varieties are protected. That of course is a state and crop-specific empirical question. It does correspond with the theoretical expectation that private firms will invest in breeding activities when benefits are made appropriable through IPR legislation. Nonetheless there may be particular instances when private firms choose not to seek (or retain) protection. In the case of Washington State wheat variety trials, there

is a strong correlation between 'protection' and 'private' so that including both in the same equation would lead to multicollinearity (see below).

The question of which to use, the protection status or the public/private differential is more complex to answer as it goes to the heart of the issue about the motivational functions of IPR systems. For the private sector the matter is straightforward – the need for profit and the role of appropriability in garnering that profit. For the public sector other factors may apply. Public program may protect nearly universally or selectively so as to maximize net funds generated. Justifications for routine protection can include:

- Means of recognizing contribution of breeders,

- Protection against criticism if an unprotected variety turns out to be popular,

- Part of an agreement with funders under which a state program automatically licenses all varieties to the group in exchange for stabilized financial support for the breeding program.

Others considerations likely apply as well, and are largely a consequence of state level policy. But the point is that seeking PVP protection does not necessarily connote relative productivity compared to other public varieties.

For purposes here, we take a positive sign on 'private variety' to be the *strong* hypothesis as private varieties were essentially nonexistent prior to the existence of PVP legislation. That is, if private varieties have higher average productivity and under the assumption that private firms enter the open pollinated breeding business only when IPR is available, then PVP has indeed contributed to germplasm productivity. The hypothesis is 'strong'

because the private varieties *included in the trials* (recognizing the sampling issue

discussed above) must exceed in yield public ones, both protected and unprotected.

Public sector breeders are clearly highly accomplished so that the test is especially

onerous for wheat where the public sector remains the leading investor and supplier of

varieties.

A second test considers all protected varieties, which is to say protected public varieties

are added to the private ones. The interpretation of this test depends on the protection

policy followed by states. If all public released varieties are routinely protected from

some date (or dates, in the case when multiple state releases with different policies)

forward, then the effective hypothesis tested is one of structural change from that policy

date. Since the policy decision may be only partially associated with the breeding

program, we refer to this as the *weak* test. Alternatively, state(s) may choose to protect

selectively. Presumably, the superior (and more marketable) varieties are protected in

part as a revenue source. That means they exist in part as a consequence of the existence

of PVP so that a significant coefficient signifies a benefit from the existence of PVP.

However, since the causality association is less direct than for private varieties, we refer

to this as the *medium* hypothesis.

B. Model

Increase in crop yields are contributed by technological advances such as changes in

production practices and genetic improvement of new varieties. Genetic improvement of

crops is achieved by using plant breeding techniques in the development of new varieties.

In order to measure the contribution of genetic improvement to the yields of new varieties requires data on the effects of non-genetic factors such as production technology and changes in weather parameters on the yields of a reference variety[8] of the crop.

Let $Y_{i(=r,n)}(t,w)$ represents the yield of a variety which is a function of time index t, representing genetic and non-genetic technological advances, and w, which represents all other exogenous factors where, r stands for reference variety and n stands for new variety. Cordially fixed reference varieties respond to exogenous shocks and changes in production practices over a period of time, but not to genetic improvements. Yields of new varieties respond to genetic and non-genetic improvements and also to the exogenous shocks. Since a reference variety and new varieties are tested under the same agro-climatic conditions with the same production practices, the contribution of genetic improvement to the yield of the new variety can be obtained by subtracting the non-genetic contribution of reference variety from the total contribution of technological advances to new varieties.

Since genetic improvement does not affect the yield of a reference variety, $\dfrac{\partial Y_r}{\partial t}$ represents the non-genetic technological change on the reference variety. As mentioned earlier, $\dfrac{\partial Y_r}{\partial t}$ also represents the contribution of non-genetic improvements to the yields of new varieties. Hence, contribution of the genetic improvement to the yields of new varieties can be represented as $Y_{nt} - \dfrac{\partial Y_r}{\partial t}$, where Y_{nt} is yield of new variety.

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[8] Researchers use a reference variety to measure the relative performance of new tested varieties over a period of time.

We do not select a single variety or group varieties as new varieties; instead all the varieties tested except the reference varieties are considered as new varieties. Because yield performances are affected by agro-climatic conditions and technological advances over time and across trial locations, including all tested varieties in the analysis will capture the regional differences and gauge the relative performance over time. Including site specific information on weather parameters and production practices is more informative and useful than including averages across trial locations in a particular region.

As mentioned in Babcock and Foster (1991), one difficulty in using a reference variety is that research station tests on a single standard varieties are rarely carried over all the years in the sample. Typically, there will be overlap periods for reference varieties i.e. one reference variety is tested simultaneously with another reference variety. Hence, when a very old reference variety is being replaced by another reference variety, predictive equations can be estimated using observations on yield during the overlap periods for the reference varieties.

Since the data for the varietal trials are by sites and by particular variety, the general form of the model included in the analysis is given below.

$$Y_{ist} = a_0 + a_1 RF_{st} + a_2 Fert_{st} + a_3 t_i + a_4 \Pr iv_i + a_5 Zone_s + a_6 PVP_i$$

Where Y_{ist} is the additional yield growth due to genetic improvement of the tested variety i at site s at time t.

RF_{st} is the RF at site s at time t

$Fert_{st}$ is Fertilizer applied at site s at time t (mainly Nitrogen and Sulfur, we include both separately).

t_i is the time index representing the trial year

$\Pr iv_i$ is the dummy variable and equals 1 if variety i is private

$Zone_s$ is the dummy variable and equals 1 if the trial was at Zone s (we use the zone wise classification of the Pacific North West (PNW). PNW is classified into six agro-climatic zones based on some selected parameters. See the data section below.

PVP_i is a dummy variable, and equals 1 if variety i is protected under PVP (As mentioned above we do not include PVP_i and $\Pr iv_i$ together).

C. Data

Washington is one of the major wheat producing states in the Pacific North West (WA,OR & ID). Washington State University (WSU) is the main public wheat breeder in the region with wheat breeding dating back to the 1890s. Soft white winter (SWW) and Soft White Spring are the major classes of wheat produced in the region and especially in Washington (about 70%)[9] mainly because of the strong breeding program for soft white wheat at WSU. The private sector-initiated breeding programs in the late 80s (PVP was introduced in 1970). Based on our discussion with extension agronomists at WSU, in the low rainfall regions there is a strong tendency by farmers to keep their own seeds for planting in the following year. Private companies therefore target their varieties to medium/high rainfall regions, to enhance sales.

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[9] Hard white winter, Hard Red winter, Soft white spring, Hard white spring, and Hard Red Spring are the other classes of wheat grown in the state. Soft white wheat has a sub-class known as club mainly because of the appearance of its head. Hard Red is the second major wheat class in the state.

Private sector participation in the soft white breeding program is very limited because of the strong breeding program at WSU. Instead firms focus on classes with limited public sector participation such as Hard Red spring and high production zones. Since our objectives here are to test whether private varieties and/or protected varieties are more productive, we use varietal trial data since 1970.[10] However, in this preliminary paper we use data for the period 1994-2006 (excluding 1995, which are missing) and focus on soft white winter wheat only. We selected soft white winter wheat as it is the major type of wheat grown in the state.

According to the extension agronomists at WSU, the varietal trial data represents 99 percent of the varieties grown in the state. We compiled data from the uniform trials-meaning all the varieties under trial are tested at all the locations- from the Cereal Variety Performance Trial reports by Department of Crop and Soil Sciences at WSU (recent years available at www.needtoinserturl.com) . Since we require information on variety ownership and the PVP status, we identified the public varieties listed in GRIN [Germplasm Resource Information Network, available at http://www.ars-grin.gov/]. As mentioned earlier, many advanced lines of potential future public varieties are included in the trials, especially in recent years. Since there is uncertainty about their eventual approval, only public varieties registered with GRIN are included on their website (http://www.ars-grin.gov/cgi-bin/npgs/html/findpvp.pl). Only 13 varieties developed by WSU are protected.[11] All private varieties are included in the analysis even though they are not registered. We use Madsen as a reference variety for the period 1994-2006.

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[10] To see the pros and cons of using varietal trial data see Babcock and Foster (1991).

[11] Extension agronomist Mr. John Burns informed us that WSU is not protecting many of its varieties mainly as protection is not considered as a revenue generating source. Further, the Washington Wheat

Among the weather parameters, rainfall (precipitation) is the major factor influencing yield in this state. However, other parameters such as growing degree days (GDD) and soil depth are also important as soil moisture depends on these factors as well. Agronomic zones for the PNW based on rainfall, soil depth and growing degree days was reported in Douglas et al (1990). This classification has six agronomic zones. Since each of the trial locations in Washington falls in one of these zones, we used this zone-wise classification in the analysis to reflect localized agronomic conditions.

IV. Results

A. Private Varieties

Following, Babcock and Foster (1991) we used the log of the ratio of yields as the dependent variable capturing the contribution of genetic improvement in our analysis. Results of the analysis for private varieties are reported in Table 2. Private varieties have a positive effect on genetic improvement albeit not a significant one. It should be noted that WSU is well established in the soft white wheat breeding program making it difficult for private companies entering post-PVP to capture a significant market share.

Precipitation, one of the major weather parameters determining wheat yield in the PNW region (Douglas et al. 1990), has a positive effect. The negative and significant sign on the square term suggests a diminishing marginal return of precipitation. The fertilizer variables, nitrogen and sulfur, are significant; however, the negative sign of nitrogen is unexpected. It may be because of the poor interaction between nitrogen application and

Commission, the major donor for the WSU wheat breeding program is not very supportive of PVP protection. Other states follow different strategies.

rainfall occurrence (fertilizer application without adequate soil moisture is not efficient and effective). The positive and significant coefficient on the time index indicates rising genetic improvement over the study period, as expected from a quality breeding program. The annual rate of yield increase from genetic improvement can be calculated from the derivative of the dependent variable with respect to time, i.e. $\{\partial \ln[Y_n / Y_r] / \partial t\}$ giving an annual average of .04 percent.

As mentioned above, we control for other weather parameters by using the agro-climatic zones. All the trial locations in the data set could be classified into one of the six agro-climatic zones except for zone two. Zone six (which is hot and dry) is taken as the reference zone in the analysis. Hence the positive and significant effect of other zone variables relative to the reference zone in the model is as expected. The low R^2 value of the model is a consequence of the dependent variable ratio of the yields instead of actual yields. When we use actual yields instead of the log of the ratio we had R^2 values in the 44 to 45 % range (results not reported here).

We also conducted an analysis of each zone separately and the results are reported in Table 3. For zones four and five (zone six includes limited number of observations and is excluded) the coefficient of the private variable was negative but not significant. This is likely a consequence of private companies focusing their breeding programs on medium or high rainfall regions rather than low rainfall regions. Farmers in the low rainfall regions save seeds, making those areas a less profitable investment for private companies.

B. Protected Varieties

Results from the regression analysis testing whether protected varieties (both public and private) are more productive are presented in Table 4. All the variables have the same directional effect and significance as in Table 2, except for the protection variable (PVP protected). We find that protected varieties have positive and significant effect on the genetic improvement and thus support our *weak* hypothesis. However as in the case of former analysis, results from the zone-wise analysis (not presented here) showed that for zones four and five PVP has positive effect but is not statistically significant.

V. Conclusion

Our study using varietal trial data of soft white winter wheat from Washington State finds supporting evidence to the hypothesis that PVP has contributed to the genetic improvement of wheat. Contrary to the previous study using experimental yields of wheat (Alston and Venner, 2002), our study supports the hypothesis that protected varieties are more productive. Even though the public sector is well established in the soft white winter wheat breeding program and the private sector entered the market only in late 1980s (in response to PVP) our results show a positive effect of PVP on the contribution of genetic improvement to the yield of soft white winter wheat. In subsequent analysis, we expect stronger positive evidence for other classes of wheat such as Hard Red wheat where the public sector has a weak breeding program compared to the private sector.

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Table 1. Agronomic Zones classification of the PNW (Source:Douglas et al. (1990))

Zone	Description	Observations in the current sample	Criteria		
			GDD	Soil depth(in)	Annual precipitation(in)
1	Cold-moist	520	Under 700	all	Over 16
2	Cool-moist	0	700-1000	all	Over 16
3	Cool-deep-moderately dry	1285	700-1,000	Over 40	14-16
4	Cool-Shallow - dry	192	Under 1,000	Under 40	10-16
5	Cool-deep-dry	1195	Under 1000	Over 40	10-14
6	Hot-very dry	22	Over 1,000	all	Under 10

Table 2 Results from the regression analysis testing the effect of private ownership

Variables	Coefficient (Robust S.E)
Private	.001(.005)
Annual pptn	.03 (.005)**
Pptn square	-.0009(.0001)**
Nitrogen	-.0005(.0001)**
Sulfur	.002(.0007)**
Log time	.02(.003)**
Zone 1	.07(.01)**
Zone 3	.06(.02)**
Zone 4	.04(.02)**
Zone 5	.09(.02)**
Constant	-.31(.04)**

Note: ** significance at 5% level (one tailed)

Table 3 Results from the zone wise regression analysis testing the effect of private ownership

Varible	Zone1	Zone3	Zone4	Zone5
Private	.003(.01)	.008(.007)	-.004(.02)	-.003(.009)
Annual pptn	-.005(.03)	-.01(.01)	.31(.10)**	.007(.009)
Precipitation square	.0001(.0008)	.0002(.0003)	-.008(.003)**	.00005(.0003)
Nitrogen	-.0004(.0002)**	-.002(.0006)**	.006(.001)**	-.0006(.0003)*
Sulphur	.003(.001)**	.007(.002)**	-.03(.005)**	-.0009(.001)
Log time	.02(.008)**	.01(.006)**	-.03(.03)	.03(.007)**
Constant	.009(.2)	.16(.11)	-3.2(1.0)	-.09(.06)
R2	.03	.04	.15	.02
N	520	1285	192	1190

Note: Robust standard errors are reported in the parentheses

** significance at 5% level (one tailed)

Table 4 Results from the regression analysis testing the effect of PVP

Variables	Coefficient (Robust S.E)
PVP	.02(.005)**
Annual pptn	.03(.005)**
Pptn square	-.0009(.0002)**
Nitrogen	-.0005(.0001)**
Sulfur	.002(.0007)**
Log Time	.02(.004)**
Zone 1	.07(.02)**
Zone 3	.06(.02)**
Zone 4	.04(.02)**
Zone 5	.09(.02)**
Constant	-.313(.05)**

Note: ** significance at 5% level (one tailed)