

## Does Plant Variety Intellectual Property Protection Improve Farm Productivity? Evidence from Cotton Varieties

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The plant variety protection (PVP) system has been criticized by some authors as being nothing more than a marketing tool and not having much effect on productivity. We investigate this issue for the case of cotton in the United States, first by examining trends in cotton varieties planted and then by quantifying the effect of PVP varieties on cotton yields. Our analysis suggests that PVP has led to the development of more varieties and that these varieties have had an overall positive impact of PVP on cotton yields.

**Key words:** cotton, intellectual property rights, plant variety protection.

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### Introduction

In a recent decision focusing on utility patents for plants and seeds (*J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred International, Inc.*, 2001), the United States Supreme Court made room for plant variety protection (PVP) alongside the expanded applicability for utility patents provided by the decision. PVP was described as providing “limited patent-like protection for certain sexually reproduced plants.” The plant breeder’s rights provided by PVP are limited in that they contain a research exemption (Kesan, 2001) and an exemption that allows farmers to save and replant seeds. The effectiveness of PVP in promoting the development of improved varieties will likely influence US farm productivity through yield and other advantages and is also relevant internationally, as World Trade Organization (WTO) countries are increasingly adopting some form of PVP to meet their obligations under the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement.

Initial empirical evidence has failed to find support for the hypothesis that PVP has a positive influence on crop yields. Each of the studies investigating this relationship considered a different crop: Alston and Venner (2002) investigated wheat; Babcock and Foster (1991), flue-cured tobacco; Perrin, Hunnings, and Ihnen (1983), soybean; and Carew and Devadoss (2003), canola. Janis and Kesan (2002) expanded the crop coverage of the debate (without providing any new yield-impact evidence) by discussing soybeans and corn and made the conclusion that their “results indicate that the Plant Variety Protection Act (PVPA) rights are burdensome to acquire, and yet the expected post-issuance licensing and enforcement activities... are virtually non-existent” (Janis & Kesan, 2002, p. 754) and that PVP serves “primarily as a marketing tool” (Kloppenborg, as cited in Janis & Kesan, 2002, p. 775). The lack of impact of

PVP on yields is intriguing as there is evidence that PVP has provided the necessary incentives for breeding research. For example, in an early evaluation of the PVP Act, Perrin et al. (1983) found that both the absolute number and expenditure of nonhybrid crop breeding programs increased substantially after 1970; they attributed this change to the incentives created by the PVP Act. They found that the rate of improvement of yields released after the PVP Act was higher than those released before, although this result was significant only at the 16% level. Butler and Marion (1985) concluded that the “PVPA has stimulated the development of new varieties of soybean and wheat” (p. 75), but were unable to conclude that total R&D activity had increased. Knudson and Pray (1991) and Pray and Knudson (1994) also found that PVP has effects on private-sector research priorities and breeding activity but did not relate PVP to yields. Likewise, Srinivasan (2004) and Diez (2002) have found that the impact of Plant Breeder’s Right in Europe has been to increase the incentives for private firms to develop new varieties, but they too did not relate the effect of those new varieties on yields.

The primary contribution of this paper is quantification of the effect of PVP varieties on cotton yields. It is somewhat anomalous that cotton has not been previously examined, as cotton is a major US row crop and relies heavily on PVP certificates for intellectual property (IP) protection. In contrast to corn and soybeans, which in recent years have been protected primarily by utility patents (Lesser, this issue), by 2001 only two cotton varieties were protected by utility patent (United States Department of Agriculture [USDA] Economic Research Service, 2005). PVPs are not widely used for tobacco and canola, with fewer than 100 PVP certificates granted for either crop, as opposed to 600 for cot-

**Table 1. Summary statistics of key variables; unit of observation is (state, year, variety).**

Variable	N	Mean	SD	Min	Max
Yield, excluding CA & AZ (lb/ac)	10,436	501.68	160.65	103.87	901.11
Yield, all states (lb/ac)	11,792	547.06	224.70	103.87	1,354.32
Area (thousand acres)	11,792	1,622.23	2,212.64	45	13,315
Number of varieties planted	11,792	28.98	23.65	1	112
Number of varieties planted with valid PVP cert. (post 1970)	9,377	22.94	18.23	0	81
Percent of area planted to PVP varieties (post 1970)	9,377	69.10	31.71	0	100

ton varieties (USDA Plant Variety Protection Office, 2005). Approximately one third of the wheat varieties in Alston and Venner (2002) had PVP protection (J. Alston & R. Venner, personal communication, July 14, 2005). PVP remains the primary mechanism to protect the IP of new cotton varieties.

This study first presents descriptive and econometric empirical evidence on cotton yields and the use of PVP certificates to protect cotton varieties. After describing the data and an empirical yield model, it provides, for the first time, empirical results of the impact of PVP on cotton yields. The study then addresses the policy issue of whether PVP is useful. An important consideration is the decline in PVP certificate use over the past five years, suggesting further investigation into the Janis and Kesan (2002) hypothesis that PVP certificates are becoming more burdensome to acquire because of backlogs and delays at the PVP office. We provide empirical evidence on this issue for cotton PVP applications. The last section provides some possible explanations for differences between the empirical results obtained by different studies and makes some tentative conclusions.

## Empirical Evidence on PVP Activity and Cotton Productivity

### Data and Descriptive Analysis

Since 1950, for the cotton growing states, the USDA Agricultural Marketing Service (AMS) has collected and published annually the names of the varieties planted and their respective acreage (USDA AMS, various years). The variety name allows us to match it with the information on PVP certificates for cotton that is compiled and published by the USDA Plant Variety Protection Office (2005). Each PVP certificate contains information on the name of the protected variety, the application and grant dates, and information on the name of the applicant. By matching the names in the AMS cotton variety planted dataset with those in the PVP dataset, we are able to ascertain the number and percentage of acreage planted to protected varieties at

the state level as well as other variety and state-specific information (such as yield for each state, the number of transgenic varieties planted, and the number of new varieties introduced).

Our panel data cover 50 years (1950–2000) across 14 cotton-growing states in the United States. (See Table 1 for descriptive statistics of key variables.) We identify 658 distinct varieties that were planted in the United States, of which 292 were protected by PVP certificates. Figure 1 shows the growth in the number of varieties planted since 1950 along with the trend in the number of protected varieties. A striking feature of the trend is the significant increase in the number of different varieties that are planted first in 1970 and then again 1994, which may not be entirely coincidental. The PVP Act was enacted in 1970 and amended in 1994 to make protection stronger (notably limiting the farmer's exemption provision). Prior to the act, the number of different varieties that were planted stayed almost constant at an average of 34 different varieties planted per year, increased to 74 in the period 1970–1994, and further increased to 160 in 1994–2000. Of significance is also the increase in the percentage of varieties planted protected by the PVP Act (Figure 1), such that by 2000, 69% of varieties that were being planted were protected. The number of new varieties that have been introduced each year has also increased in the years after the act (Figure 2), while at the same time the life of each variety planted (i.e., the number of years it is planted before its use discontinued) has decreased, more so in the 1990s. These trends would imply that breeders might be responding to the PVP Act not only by introducing more varieties each year into the market but also by introducing them more often, thereby providing farmers with more varietal choices.

Did the new varieties—the majority of them protected by PVP—result in higher productivity? To address this question it is useful to first examine the state-level data. Arkansas represents a state with a fairly typical pattern of cotton yield growth and PVP use (Figure 3). Arkansas cotton yields grew slowly from the mid

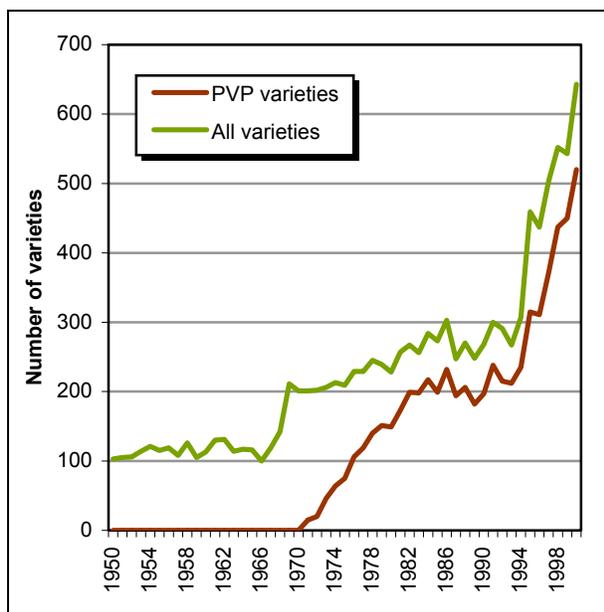


Figure 1. Number of cotton varieties planted (total and those with PVP certificates), 1950–2000.

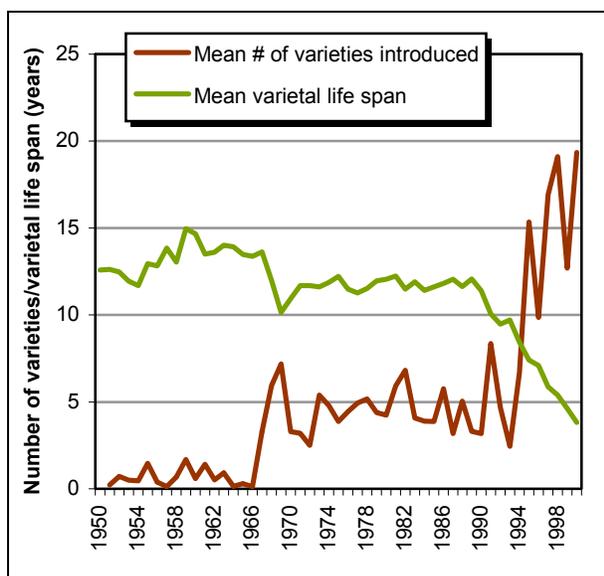


Figure 2. Number of new varieties introduced (mean for all states) and mean varietal life span (all states), 1950–2000.

1950s to about 1980. From 1980 to 2000 there was an apparent one-time upward shift in the yield profile and/or the emergence of a different trend line with more rapid yield growth. During the period of slow yield growth, the area planted to all varieties in Arkansas decreased from a high in the early 1950s to a low in approximately 1982 (Figure 4). After 1982, the total

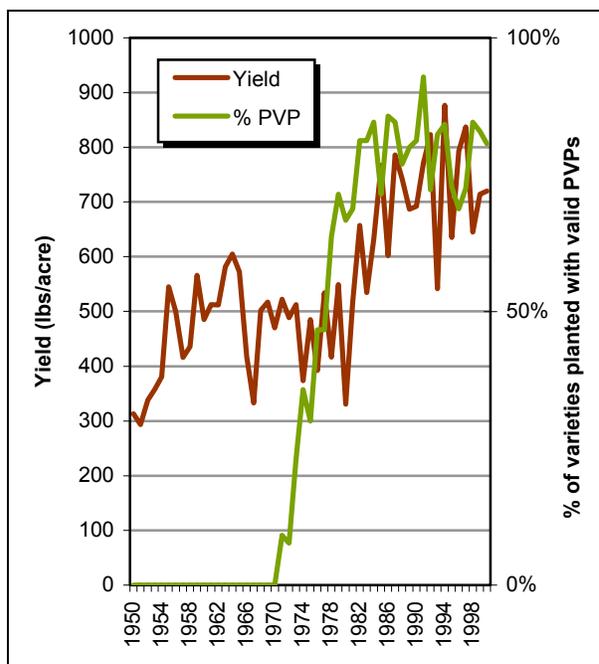


Figure 3. Cotton yields and proportion of varieties with PVP certificates, Arkansas, 1950–2001.

area planted increased along with the area planted to cotton varieties with PVP protection.

As early as the mid-1970s, seed companies began to take advantage of the IP protection afforded by PVP certificates. (Figures 3 and 4 both show when protected varieties began to be grown.) By 1982, most of the cotton varieties grown in Arkansas had PVP certificates (Figure 3, bottom panel). This high level of PVP protection continued until very recently, when the development of genetically modified varieties increased reliance on utility patents, probably reducing reliance on PVP certificates for intellectual property protection. It should be emphasized that regardless of the relative importance of patents and PVP certificates in protecting new crop varieties, intellectual property rights (IPRs) will be key to continued introduction of new varieties.

The remaining upland cotton growing states follow somewhat similar patterns. (California and Arizona, which are also pima-cotton states, follow somewhat different trajectories. California also had variety restriction laws which limited new variety development.) In each state, PVP certificates were widely used from the early 1980s through the end of the sample period, with some decline in use in recent years. The biggest difference among the upland cotton-growing states is the strength of the trend break in the early 1980s. For example, Figure 5 shows Louisiana cotton yields. It is unclear

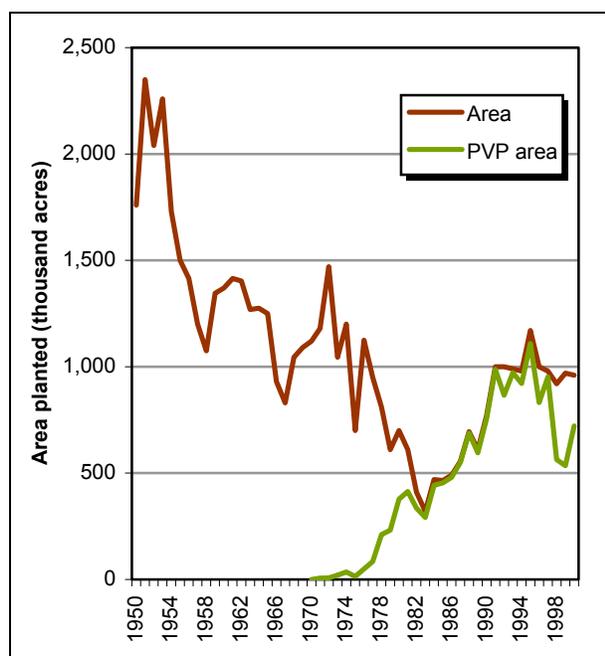


Figure 4. Total area planted to all cotton varieties and varieties with PVP certificates, Arkansas, 1950–2000.

whether these yields have grown more rapidly after 1982 than before 1982. Determining the existence and magnitude of possible trends and trend breaks across the main cotton-producing states, as well as the relationship between PVP certification and yield growth, becomes an issue that needs to be addressed by econometrics.

### Econometric Evidence

Following Carew and Devadoss's (2003, p. 383) panel-data approach to modeling the relationship between cotton yields and plant breeders' rights, we consider an empirical production relationship of the form

$$Yield = f(\text{Plant Breeders' Rights, Technical Change, Regional/State Characteristics, Area Planted}), \quad (1)$$

where observations are available for several states over a period of time. The data used are those described in the prior section. The ending period of the dataset was truncated to 1996 to avoid complications caused by the release of transgenic cotton varieties, which tend to have different IP protection issues than do traditionally bred varieties.

A number of preliminary regressions were estimated to facilitate testing of model specification. Due to the emergence of transgenic cotton varieties in the late 1990s, observations after 1996 were dropped. The pre-

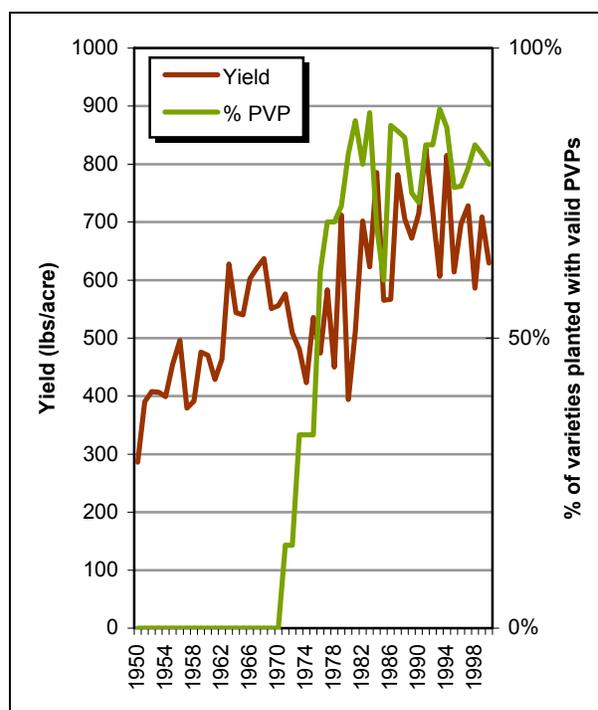


Figure 5. Cotton yields and proportion of varieties with PVP certificates, Louisiana, 1950–2000.

liminary testing included the usual Hausmann tests of fixed effects and Hausmann tests of econometric exogeneity of selected variables. It also included determining the time of the trend shift by trying different years and selecting the year that generated the highest log-likelihood value for the regression. Tests of separate trends and trend shifts for each state failed to show statistically significant trend differences or different shifts across states. Examination of the error structure led to the determination that residuals were heteroskedastic across states and that the residuals contained state-specific auto-regressive (AR(1)) components, and the final model was estimated with state-specific AR(1) parameters. Preliminary regressions and diagnostics are not reported here for brevity. The final regression was for a panel of the main upland cotton-producing states (Alabama, Arkansas, Georgia, Louisiana, Missouri, Mississippi, North Carolina, South Carolina, Tennessee, and Texas; inclusion of Arizona, California, and Oklahoma has little effect except on the trend shift variable).

The regression procedure used was (iterated) feasible generalized least squares available in the software package STATA. The results are reported in Table 2. They show that cotton yields exhibit an upward trend over the sample period: the coefficient on the trend variable of 5.4 ( $p < 0.01$ ) indicates that cotton yield is

**Table 2. Feasible generalized least squares (FGLS) regression analysis of cotton yields.**

Explanatory variable	Coefficient	p
Constant	372.8996	0.000
Intercept shift—1982	6.2817	0.855
Trend	5.3683	0.000
Trend shift—1982	-18.7975	0.018
Area	-0.0363	0.000
Area squared	0.0013	0.031
PVP area as % of total area	-5.9783	0.008
Number of PVP varieties as % of all varieties planted	-89.3218	0.035
PVP area (%) * trend	0.2122	0.003
N	460	
Log likelihood	-2571	
Wald $\chi^2$	204.01	
Prob > $\chi^2$	0.000	

Note. State-level fixed effects not reported.

expected to increase by 5.4 lb/acre/year, *ceteris paribus*. There is a statistically significant shift in this trend in 1982. The coefficient on the trend shift variable of -18.8 indicates that after 1982, cotton yield is expected to decline by 18.8 lb/acre/year, *ceteris paribus*. Since both the trend and trend shift variables are in effect after 1982, the net effect of these two variables is that expected cotton yields decrease by  $5.4 - 18.8 = 13.3$  lbs/acre/year after 1982 over the sample states, *ceteris paribus*. This decline represents trend effects only and may be offset by positive contributions from other variables; also, we do not include the interaction term between PVP and trend in this calculation. Cotton area has a quadratic effect on yield. As expected, the linear area term has a negative effect on yields that is statistically significant at the 1% level ( $p < 0.01$ ). The quadratic term is statistically significant at the 5% level ( $p = 0.03$ ) and positive. Evaluated at the sample mean, the net effect of the linear and quadratic area coefficients is negative, reflecting the fact that yields were increasing even while acreage planted generally declined. One explanation for this is Acreage Reduction Programs that were begun in 1982. Up until 1990, producers fallowed between 12.5% and 25% of their land through an acreage-reduction program that was tailored to meet a postharvest stock target of four million bales. Because marginally productive land would usually be fallowed, the likelihood of higher yields on the remaining land increased. Another possible explanation is that area expansion brings less productive land into production, leading to lower average yields.

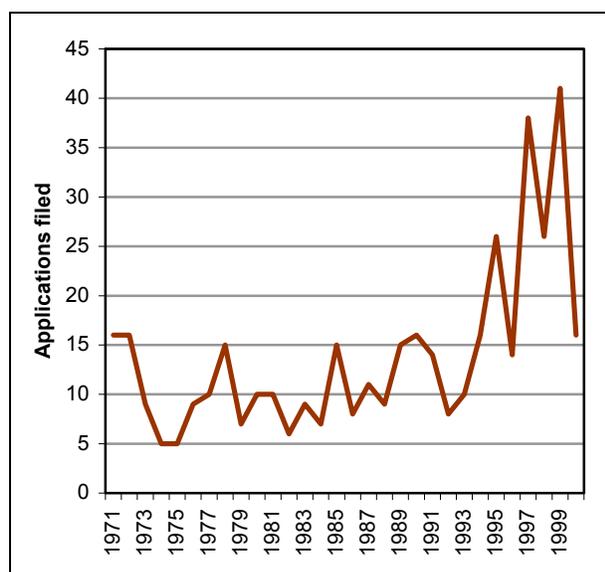
The primary variables of interest are the three PVP variables. The overall effect of the PVP comprises three individual effects. The impact of the use of PVP varieties (as measured by the proportion of cotton area planted to varieties with a PVP certificate) on cotton yields across the states is negative and statistically significant at the 5% level ( $p < 0.01$ ). The impact of PVP varieties when measured as the proportion of all cotton varieties planted that were protected by PVP certificates is negative and statistically significant at the 5% level ( $p = 0.04$ ). The coefficient on the interaction between the proportion of cotton area planted to PVP varieties with the trend term is positive and statistically significant at the 5% level ( $p < 0.01$ ). Because the PVP impact comprises the three effects, we evaluated these three effects at their sample means. The combined impact of the three PVP variables, evaluated at their sample means, is a positive 58.77 lbs/acre.<sup>1</sup> These results indicate that previous empirical work may have failed to control for important trend shifts (for a more general discussion of trend shifts, see Oehmke & Schimmelpfennig, 2004) and interactions between trends and PVP effects, or the impact of PVP may be different in other crops, or possibly both may be true.

## Policy Issues

The empirical evidence presented in the above section indicates that PVP certificates helped improve cotton yields over the 1982–2000 period. However, extrapolating this directly to policy prescriptions for the 21<sup>st</sup> century requires additional investigation. Two forces in particular might be expected to mitigate the importance of PVP certificates for protecting intellectual property in cotton varieties in the near future: increasing time lags between PVP applications and grants (the congestion effect discussed by Janis and Kesan, 2002), and increasing use of utility patents to protect biotech cotton varieties.

For corn and soybeans, Janis and Kesan (2002) report that issuing durations—the average time lag between PVP application and grant—had risen since the 1970s but had fallen since 1999 when applications began to drop. Since 1999 they describe “a significant

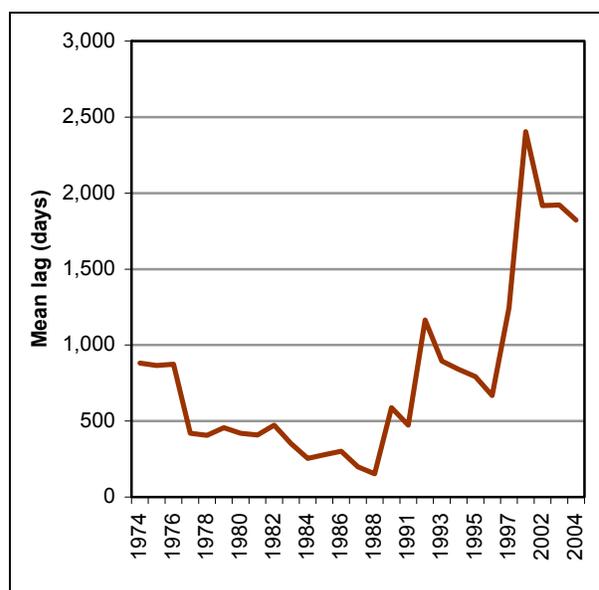
1. This calculation includes both area and number-of-varieties effects: The hypothetical experiment is a 1% increase in the number of PVP protected varieties that translates into a 1% increase in the proportion of cotton area planted to PVP protected varieties; as a result of these increases in PVP protected varieties and areas, yields increase almost 59 lbs/acre.



**Figure 6.** Number of PVP applications filed by year of application.

decline in the number of applications” (p. 760) with the implication that PVP had fallen out of favor. Examination of the cotton data reveals a different picture of PVP grant congestion. The number of cotton applications changed little between 1970 and 1993, remaining around 10 or 11 per annum, but took off between 1994 and 2000 reaching a high of more than 40 applications in 1999 (Figure 6). With numbers of PVP certificate grants remaining roughly constant (except for some especially productive years between 2002 and 2004), the mean lag between application and grant for cotton PVP has shown an upward trend since 1998 (Figure 7).

The conclusion implied by Janis and Kesan (2002) is that longer durations added to the cost of obtaining PVP until in 1999. Companies decided that the costs of this “weak” form of IP exceeded the benefits and applications dropped. This story does not fit very well with the congestion effects for cotton PVP, however, as cotton applications remained high even as the delays grew. Several factors could be contributing to making cotton the exception to the rule. There were several strong years of cotton PVP certificate production after 2002 (as just mentioned); this might have heartened companies to continue making applications. The companies might have reasoned that if the grant rate stayed high, they were less likely to get caught in application congestion in the future, particularly if they thought (or heard) that other companies might be making fewer cotton applications. The benefits to the companies of obtaining PVP might also have been higher for cotton than for other



**Figure 7.** Mean lag between application and granting of PVP in days.

*Note.* Applications that are pending, denied, or withdrawn are excluded.

crops; this could be related to firm concentration or market structure questions that are beyond the scope of this paper.

There are other factors which are harder to reconcile with Janis and Kesan’s (2002) discussion of issuing durations. They call PVP certificates “burdensome” to acquire, but this is probably not related to the fees charged, which average around \$1,500. Their observation that the process is “laborious, time-consuming, and not inexpensive” is probably more related to issuing durations, but they do not discuss provisional protection status. Applications are checked relatively quickly for missing pieces, and if the main categories of information are present, most are awarded provisional protection. After achieving provisional status, the probability of a PVP application being denied is extremely low. In fact, only one of the 904 corn PVP applications that were filed was found to be ineligible. For soybean applications it was seven out of 1,343. Once a firm is awarded provisional protection, it has a very good chance of getting the PVP certificate. The issuing delay could then have a negligible effect on seed producers who can mark their products with statements that provisional PVP prohibits unauthorized duplication.

In considering possible PVP congestion effects, it might also be important to consider differences in uses of intellectual property between the major crops. Lesser and Mutschler (2002) point out that there are very few

utility patents for cotton and few patents on “lines, varieties, or hybrids” of crops other than corn and soybeans.

An alternative hypothesis is that the emergence of Bt and Roundup Ready cotton varieties has changed the nature of available cotton protection. US patent law allows protection of genetically modified varieties by utility patent. (Individual genes of genetically modified varieties can also be protected by utility patent.) In 2004, 80% of US cotton area was planted to genetically modified varieties (James, 2005). This suggests that the use of utility patents may be replacing PVP certificates as the IP protection of choice in cotton.

## Conclusions

Rather than the “sound and fury, signifying nothing” conclusion for plant variety protection drawn by Janis and Kesan (2002), our analysis of cotton varieties may be yielding a different Shakespeare quotation: “We must take the current when it serves, or lose our venture.” In this paper we have found that the PVP Act was the current that served the cotton industry well, particularly when other forms of IP protection were unavailable or unused. Analysis of the relationship between PVP and cotton yields requires consideration of trends in yields (and trend shifts), changes in total area planted and area planted to PVP varieties, numbers of protected varieties planted, and the interaction of PVP area planted with trend. There has been an increase in the number of new varieties released annually since the PVP Act, and econometric results indicate a positive effect on yields. We conclude that at least for cotton, the PVP Act has served to encourage a greater flow of innovation and the development of more productive cotton varieties.

However, our conclusions are not without some caveats that have important implications for future work. Because we have not accounted for other factors that may influence yields, an extension of this study should incorporate the influence of weather, insect pressure, and changes in management practices on yields. For example, if pest pressure in some periods reduced yields, the impact of new yield-enhancing varieties would not be apparent, especially if the yield-reduction effect (from the pests) were greater than the yield-increasing effect (from the new variety). Similarly, unfavorable weather would also put downward pressure on yields, masking any positive effects of new yield-increasing varieties. On the other hand, changes in management practices and better technology (such as transgenics) would overestimate the PVP effect. One way to finesse this issue is to use test plot data that control for

confounding effects, but test plot data often overstate the yields obtained in farmer’s fields.

Looking to the future, we conclude that some form of intellectual property protection will be necessary for the continued introduction of improved cotton varieties. With the advent of transgenic cotton varieties, it is possible that the desired form of protection will shift from PVP certificates to utility patents.

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