Commodity Policy, Price Incentives, and the Growth in Per-Acre Yields

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Abstract

We estimate the influence of policy-induced price changes and of technology supply on North Carolina flue-cured tobacco yields. The decline in land rent and effective output price that accompanied a 1965 policy change from acreage allotments to poundage quotas caused a 12 percent decrease in yields. Farmer yields were more responsive to yield-increasing technologies under acreage allotments than under poundage quotas. Annual yield growth was 0.5 percent under poundage quotas and 4.32 percent under acreage allotments. The growth rate decline is attributable to changes in relative prices and to a slowdown in the supply of available technologies.

Key Words: commodity policy, endogenous yield growth, flue-cured tobacco, technical change.

Government programs affect agricultural supply through their influence on farmer incentives. Studies of the supply effects of U. S. commodity policy have focused on land diversions and aggregate acreage response (e.g., Lee and Helmberger; Houck and Ryan; and Tegene, Huffman, and Miranowski). The influence of commodity programs on per-acre yields commonly is considered temporary, with yields changing as differing land qualities are diverted (Love and Foster; Hoag, Babcock, and Foster; Rausser, Zilberman, and Just; Weisgerber). The relation between government-altered incentives and long-term yield growth due to the adoption of new technologies has received little empirical attention.

Our objective is to determine how government programs affect levels and growth rates of commodity yields. We investigate whether yield growth imputed to technical change depends upon policy-induced changes in relative prices. We use an index of available technology derived from research-station data to account for technical change. This index is used instead of the usual time trend because a simple trend captures the influence of both innovation supply and adoption rates. An index of available technology allows us to separate the influence of new technologies from the effects of new technologies and adoption decisions.[1]

Tobacco is well-suited to this investigation. Because the tobacco program is the only commodity program with criminal penalties for noncompliance, it is the only program with complete participation. Therefore, empirical evidence of government influence on yields should be more evident for tobacco than for other commodities. And, flue-cured tobacco serves as an ideal case study to measure the response of yields to policy change. The federal flue-cured tobacco program has undergone a number of important changes since its inception in 1938 (Grise and Griffin). Foremost is the 1965 change from acreage allotments to poundage quotas as the principal means of controlling supply. Additionally, a focus on North Carolina flue-cured tobacco, which accounts for 65 percent of U. S. output, allows the use of Babcock and Foster's (1991) measures of the supply of yield-increasing technologies. We use

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these measures along with factor prices, some influenced by government intervention, to estimate a derived yield-supply function for North Carolina flue-cured tobacco from 1955 to 1987. The estimated function is used to determine how government intervention affects yields over this period.

The Growth in Tobacco Yields: 1954-1987

Between 1954 and 1987, per-acre tobacco yields in North Carolina increased at an average rate of 1.9 percent per year. In contrast, the average annual growth of North Carolina corn yields over the same period was 5.3 percent. Given the ample evidence of changes in tobacco farming practices (e.g., Johnson, pp. 73-95), one may attribute much of the growth in tobacco yields to development and adoption of technological advances, in much the same way as previous studies explained increases in corn and in other crop yields (e.g., Griliches). As demonstrated in figure 1, the pattern of growth between 1954 and 1987 for tobacco yields clearly is different from that of corn yields. Tobacco yield growth rates were markedly higher in the period before 1965 (averaging 4.1 percent per year) than in the period after 1964 (0.8 percent per year). In contrast, before 1965 corn yields increased at an average rate (5.7 percent) very similar to that after 1965 (5.0 percent).

One explanation for the decline in yield growth rates for tobacco is that the potential gains from adopting previous major innovations were exhausted, and no new major advances were developed. Traditionally, one represents the growth of a commodity's per-acre yield, in response to the introduction of a technical advance, as following an S-shaped adoption curve (Davies; Griliches; and Mansfield). Diffusion of the advance across producers (and thus growth in aggregate yields) begins slowly, proceeds rapidly, and slows as the advance reaches all potential adopters. In any year, minor technical innovations may shift the diffusion curve upward, but without continual major advances growth rates of aggregate yields eventually decline as diffusion slows. The exhaustion of previous innovations in tobacco production and a slowdown in discovery of new innovations would lead to a decline in yield growth rates.

An alternative explanation for the decline in yield growth lies in the microeconomic response of the tobacco producer to changes in government policy. One specific change is the focus of this article. Before 1965, the federal program for flue-cured tobacco controlled market supplies by restricting the amount of land planted to tobacco both nationally and within individual counties (Grise and Griffin). Growers could alter the scale of their tobacco enterprises by buying and selling acreage allotments within their county until 1963 and, beginning in 1963, they also could lease allotments for one year. Rents generated by supply restrictions were reflected in the amount that growers were willing to pay for tobacco land allotments. In 1965, the program adopted the present direct supply-control system using poundage quotas that restricts the extent of marketings both nationally and by producers within a county. Since the program change, growers have been able to alter the scale of their enterprises by buying, leasing, or selling pounds of quota.[2] After the program change, economic rents no longer were tied to land. Rather, they were bid into the quota lease value.

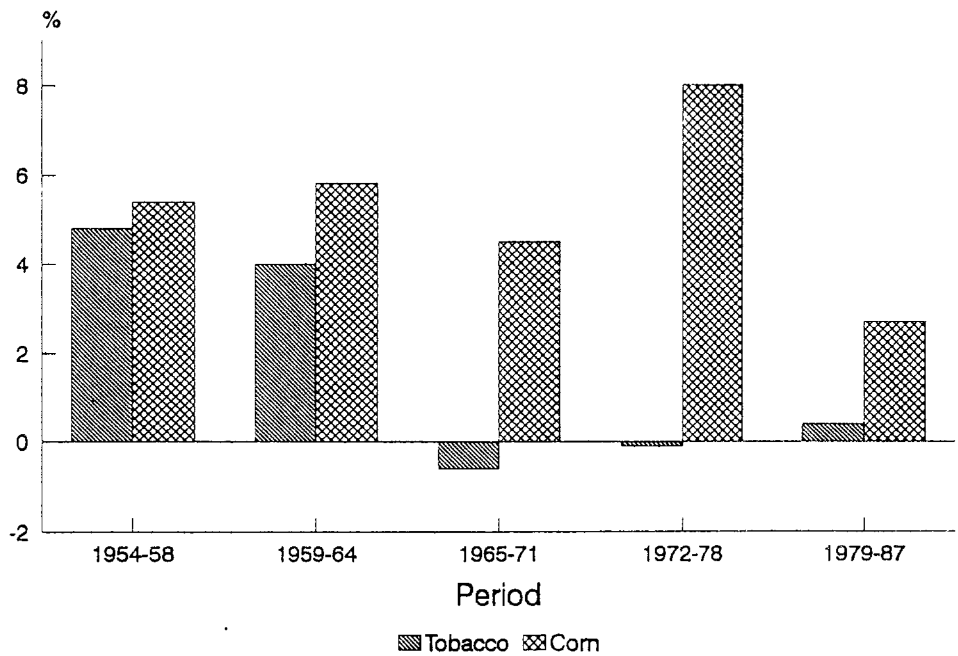
The first explanation for the continual decline in yield growth rates was rejected by Foster and Babcock. Time series evidence supports the hypothesis that a sudden decline in both yield levels and growth rates commenced in 1965. The economic incentives causing this sudden change are the focus of this investigation, the first step of which is the development of a conceptual model of producer decisions under government intervention.

Per-acre Tobacco Yields and Policy Change

Yields respond to price changes and to changes in available technologies. The extent to which newly-available, yield-increasing technologies are adopted and alter actual yields may depend upon prices, which are, in turn, influenced by government policy. In an environment of exogenous technology supply, policies that change incentives affect yields in two ways. First is the direct effect of changes in relative prices when available technology is held constant. Second is the altered response of actual yields to exogenous technological advance.

More formally, let $Y(P \mid \tau)$ be the farmer's optimal yield at prices, P, given the set of

Figure 1. Average Annual Growth Rates for Tobacco and Corn in North Carolina.



Source: North Carolina Department of Agriculture. *North Carolina Agricultural Statistics*, various years.

exogenously available technologies, τ. Three comparative static results are of interest: a) The effect of a change in some price P_i for a given technology, $\partial Y/\partial P_i$; b) the effect of a change in available technology for constant prices, $\partial Y/\partial \tau$; and c) the change in the yield response to technology with respect to a change in a price, $\partial^2 Y/\partial \tau \partial P_i$.

We consider first the effects of government policy changes on yields when technology is held constant. A tobacco grower's net revenue, NR, can be represented as

$$NR = A[P_T Y - C(Y,A \mid \tau) - r], \qquad (1)$$

where A is acreage planted, P_T the effective price per-unit of output, $C(Y, A \mid \tau)$ the minimum per-acre cost of producing Y on A acres with available technology τ, and r the per-acre rental rate of tobacco-growing land. We assume that $C(Y, A \mid \tau)$ is locally convex in Y and A, conditional on available technology, τ. Before 1965, land rental rates, r, captured the rents generated from supply controls. Following Moschini and Babcock and Foster (1992), we decompose the effective price facing the producer, P_T, into the difference between market price, P_m, and per-pound quota rent, q: $P_T = P_m - q$. Before 1965, there was no market for quota poundage ($q = 0$): thus, the effective output price was simply the expected market price. After the program change, quota lease rates, q, capture the program rents. The effects of moving from acreage restrictions to poundage quotas can be represented by a decrease in r and a concurrent increase in q.

In any given year, the grower maximizes NR through choice of Y and A. Thus, the marginal conditions $P_T = \partial C/\partial Y$ and $[\pi(P_T,A \mid \tau) - r] = A\partial C/\partial A$ are implied, where $\pi(P_T,A \mid \tau)$ is the grower's per-acre return over nonland costs for a given level of acreage and a given technology: $\pi = P_T Y - C(Y, A \mid \tau)$. Note that $\partial \pi/\partial P_T = Y$ when the marginal conditions are met. In equilibrium, P_T and r will be such that there are zero rents earned by a grower—$\pi(P_T,A \mid \tau) = r$—a relation implying that costs per acre are minimized: $\partial C/\partial A = 0$. The maintenance of this equilibrium condition implies a relation between output prices and land rental rates, which is found by totally differentiating the equilibrium condition $\pi(P_T,A \mid \tau) = r$:

$$\frac{\partial \pi}{\partial P_T} dP_T + \frac{\partial \pi}{\partial A} dA = dr \, .$$

The zero-profit condition and the solution to the grower's optimization problem, $\partial\pi/\partial A = -\partial C/\partial A = 0$, imply that $dP_T/dr = 1/Y$. The following comparative static results follow immediately:

$$\frac{dY}{dr} = \frac{Y^{-1} C_{AA}}{\Delta} > 0, \text{ and} \tag{2}$$

$$\frac{dA}{dr} = \frac{-Y^{-1} C_{YA}}{\Delta} \gtrless 0 \text{ as } C_{YA} \lessgtr 0, \tag{3}$$

where $\Delta = C_{YY} C_{AA} - C_{AY}^2 > 0$ from the assumed convexity of the cost function.

When it is assumed that land rental rates and output prices adjust to maintain zero grower profits, a relaxation of acreage allotments with a subsequent increase in output price results in an unambiguous decrease in per-acre yield. The sign of the acreage effect due to decreased rental rates is ambiguous, however: it depends upon how acreage affects per-acre marginal costs. If they decrease (increase) with an increase in land cultivated, then a decrease in land rental rates results in a decrease (increase) in acreage. These results give the total effect on yields and on acreage levels from a change in rental rates with a corresponding change in expected output price to maintain equilibrium.

The partial effects of changing rental rate and output price at an initial zero profit equilibrium are as follows:

$$\frac{\partial Y}{\partial P_T} = \frac{C_{AA} - C_{YA} Y/A}{\Delta} \, , \tag{4}$$

$$\frac{\partial Y}{\partial r} = \frac{A^{-1} C_{YA}}{\Delta} \, , \tag{5}$$

$$\frac{\partial A}{\partial P_T} = \frac{C_{YY} Y/A - C_{YA}}{\Delta} \, , \text{ and} \tag{6}$$

$$\frac{\partial A}{\partial r} = \frac{-A^{-1} C_{YY}}{\Delta} \, . \tag{7}$$

Note that the partial effects on yields and on acreage levels from a change in effective output price depend, in part, upon how per-acre marginal costs change with total acres. The necessary condition ($C_{YA} < 0$) for yield levels to decrease with increased land rental rates (holding P and τ constant) is the sufficient condition for both yield and acreage levels to increase with effective output price (with r and τ held constant). Coefficient estimates obtained by regressing yields on rental rates and on output prices while controlling for available technology and for other variables can be interpreted as the partial changes given by (4) and (5).

In a competitive market for tobacco acreage allotment, tobacco land rental rates would fall *ceteris paribus* with the elimination of acreage restrictions. With a decrease in land rental rates, growers would earn economic profits without a corresponding decline in the net price that they receive for their output (if all other factors have perfectly elastic supplies). Three responses may occur to decrease grower prices: the production of individual growers may increase, which would increase aggregate production and thus lower market price; the number of growers may increase, which would lead to the same expansion; and growers may bid up the poundage lease rates (effectively lowering their output price). If aggregate production is fixed annually by policy, as it has been since 1965, then equilibrium is reattained by increased poundage lease rates, thus the per-unit effective price received by growers is decreased, and all growers, the number of whom is variable, once again would receive zero profits.

Restricting the total amount of land available for production increases the per-unit cost of tobacco land relative to the cost of other inputs.

When the index of available technology is held constant, a higher price for tobacco land (with a subsequently increased output price to maintain zero profits) gives growers the incentive to use their land more intensively by applying greater per-acre amounts of nonland inputs and by increased *adoption* of available yield-increasing technologies. Moving from restrictions on total land use to restrictions on total amount of tobacco that can be sold would reduce the price of land relative to nonland inputs and decrease the effective output price (consumer price less quota lease rate). The altered incentives facing individual growers would induce increased use of land and decreased use nonland resources to produce the same amount of aggregate output.

It is less evident how price changes affect the responsiveness of yields to new technologies becoming available over time. If adoption rates are independent of prices, as is commonly assumed in empirical work (e.g., Ball), then $\partial^2 Y/\partial\tau\partial r = 0$. Rejection of this independence hypothesis would be evidence supporting the idea that policies affect the rate at which yield-increasing technologies are adopted, as hypothesized by Rausser, Zilberman and Just. The extent to which tobacco yields are altered by relative price changes for given technologies and by responses to newly-available technologies is determined in the subsequent empirical analysis.

Estimating the Growth in Tobacco Yields

In the preceding conceptual analysis, we concentrated on the yield effects of changes in land rental rates and in output price—the two price variables most directly influenced by government policy—and of available technologies. In the subsequent regression analysis, we also include wage rates and an index of all other input prices. The per-acre tobacco yield data, output and input prices, and technology-related data are presented in table 1. The yield data are county-average yields for 10 representative counties in North Carolina.[3] County yields are an appropriate level of aggregation because the tobacco program forbids cross-county sale or lease of flue-cured tobacco allotments. Thus, growers within a county face a common rental rate for tobacco land before 1965 and a common grower output price after the 1965 program change.

Beginning in 1954, North Carolina State University began its Official Flue-cured Tobacco Cultivar Variety Trials (NCOVT). Data became available documenting new varietal development, i.e., genetic innovations, and changes in prevailing production technologies i.e., non-genetic input innovations.[4] Babcock and Foster (1991) developed measures of the *potential* effects of technical change on flue-cured tobacco yields using NCOVT data. From these data we derive an index for use in a seemingly unrelated regression analysis to explain the contribution of available technology to *actual* county yields before and after the change from acreage allotments to poundage quotas. The index is derived as follows.

For each growing region, variety trials are conducted on research-station plots. Production practices on the stations are updated periodically to reflect prevailing practices within the different growing regions. These changes in production practices on the research stations have increased yields independently of the development of new varieties (Bowman, et al.; Babcock and Foster [1991]). Region-specific technology indexes (equal to 1 in 1955) were obtained from Babcock and Foster's (1991) regression coefficients relating logged yields of new varieties to logged time. The index values for a year are associated with the next year's actual production to reflect that new varieties tested in one year are available for release the next year. This index is a comprehensive measure of available technology, and reflects the contribution of both genetic and non-genetic innovations.

We obtained pre-1963 rental rates for North Carolina tobacco acreage from Seagraves' *ex post* analysis of the Eastern Belt for 1954 to 1962. Relevant land rents for this analysis are actual per-acre rental rates determined before planting. These *ex ante* rental rates are based most appropriately on expected prices and on expected weather that will occur during the growing season. Because support prices are announced before planting, there is little uncertainty about output price, so we made no price adjustments. But. *ex post* return data are influenced greatly by yields, which in turn depend upon the realization of growing season weather. Therefore, we transformed Seagraves' *ex post* data to *ex ante* data by eliminating weather variations from Seagraves' yield data. The resulting estimates of

Table 1. Data Used in the Regression Analysis[a]

Year	Yield[b] (lbs/ac)	Output Price[b] ($/lb)	Land Rent[b] ($/ac)	Wages ($/wk)	Technology Indexes[c] East	Border	Old
1955	1473.9	1.28	352.25	62.55	1.00	1.00	1.00
1956	1666.5	1.30	316.02	68.14	1.10	1.10	1.16
1957	1496.6	1.30	368.81	68.03	1.17	1.17	1.26
1958	1709.4	1.35	452.08	63.38	1.22	1.22	1.34
1959	1517.9	1.36	464.23	67.92	1.26	1.26	1.41
1960	1830.0	1.37	545.69	68.66	1.29	1.29	1.46
1961	1791.8	1.36	646.36	70.01	1.32	1.32	1.51
1962	1909.4	1.37	537.06	72.37	1.35	1.35	1.55
1963	1979.4	1.36	569.12	71.61	1.37	1.37	1.59
1964	2281.6	1.38	579.47	76.50	1.39	1.39	1.63
1965	1797.6	1.21	45.26	78.96	1.41	1.41	1.66
1966	1837.5	1.18	43.65	83.44	1.43	1.43	1.69
1967	2025.3	1.22	43.17	90.38	1.45	1.44	1.72
1968	1820.5	1.22	40.97	100.04	1.46	1.46	1.75
1969	1799.0	1.24	37.73	105.43	1.48	1.47	1.78
1970	2042.5	1.20	36.75	108.47	1.49	1.49	1.80
1971	2097.5	1.16	35.29	111.95	1.50	1.50	1.82
1972	1970.0	1.12	33.97	106.95	1.52	1.51	1.85
1973	2088.0	0.99	28.85	97.85	1.53	1.52	1.87
1974	1958.0	0.93	28.16	96.96	1.54	1.53	1.80
1975	1909.0	0.88	26.08	94.71	1.55	1.55	1.91
1976	2025.5	0.90	26.48	99.66	1.56	1.56	1.93
1977	1838.5	0.96	32.65	100.00	1.57	1.57	1.94
1978	2024.5	0.87	28.62	104.94	1.58	1.58	1.96
1979	1875.0	0.71	26.59	98.67	1.59	1.58	2.98
1980	1945.0	0.72	24.90	96.27	1.60	1.59	2.00
1981	2126.0	0.74	22.83	91.70	1.61	1.60	2.01
1982	2098.5	0.68	22.96	98.66	1.62	1.61	2.03
1983	1916.5	0.62	23.85	99.31	1.62	1.62	2.04
1984	2159.0	0.57	22.78	104.15	1.63	1.63	2.06
1985	2193.5	0.71	27.05	109.11	1.64	1.63	2.07
1986	2058.0	0.77	22.08	123.35	1.65	1.64	2.08
1987	2037.5	0.70	17.92	130.55	1.65	1.65	2.10

[a]All prices are deflated by the producer prices paid index, 1977 = 100.

[b]Average of 10 counties.

[c]1954 = 1.00.The Eastern Belt counties are Johnston, Pitt, Lenoir, and Halifax. Cumberland and Robeson are the two Border Belt counties, and Wake, Stokes, Granville, and Guilford are the Old Belt counties.

per-acre rental rates are based on net revenue calculations: they reflect no actual transaction data and may exclude some relevant costs. We therefore calibrated the adjusted Seagraves' estimates with data from a 1962 survey of acreage rental rates (Bordeaux, Hoover and Toussaint). This calibration was accomplished by multiplying the deweatherized Seagraves estimates by 0.63.[5] Data for 1963 come directly from 1963 survey data (Bordeaux, Hoover and Toussaint). No land rental rate data were available for 1964, so the 1963 level was adjusted upward according to the percentage increase in average flue-cured tobacco prices from 1963 to 1964.

The adjusted and extended Seagraves rental rate data represent the per-acre returns to tobacco growing in a typical Eastern Belt county. To obtain county-specific rental rate data requires estimation of the relative return to tobacco growing in each county in the sample. We used post-1964 poundage lease rates to estimate county-specific acreage rental rates for 1955 to 1964. Per-pound lease rate data (discussed in detail below) are available beginning in 1965. These lease rates reflect per-pound production cost differences between counties. Average per-pound lease rates for 1965 to 1967 for each county were multiplied by average yields from 1955 to 1964 for each county to obtain county-specific estimates of per-acre net revenues. Estimates of county-specific acreage rental rates from 1955 to 1964 were obtained by multiplying the adjusted and extended Seagraves series by the ratio of a county's net revenue, as indicated by average yields and per-pound lease rates, to Pitt County's net revenue estimate.[6] Pitt County was selected as the numeraire county because it has the greatest estimated net revenue.

Discussions with tobacco extension specialists at North Carolina State University led us to conclude that there is no shortage of land suitable for growing flue-cured tobacco in North Carolina. Furthermore, many soil types are suitable. Thus, the relevant land rental rates after the change from acreage allotments to poundage controls in 1965 is the prevailing rental rate for all agricultural crops. Average North Carolina farmland rental rates for the period 1965-87 were obtained from USDA publications (USDA, ERS a,b). County adjustments were made by multiplying the state average by the ratio of county average corn yields to state average corn yields from 1965 to 1987.[7]

Average agricultural field work wages were obtained from NCDA. An index of all other input prices served as a deflator. This index is the USDA producer prices paid index for all production items, excluding wages and interest rates.

The appropriate grower output price is the expected effective price of tobacco with the expectation taken before planting. Before the 1964 program change, grower price was expected market price. After the change, the appropriate price was expected market price less the per-pound quota lease rate, which is known before planting.

Expected market price over this period is fairly certain because the support price of tobacco is known prior to planting. Regressing observed market price, P_{mt}, on support price, S_t, and lagged market price yields this estimated prediction equation (with t-statistics in parentheses) for the expected market price, P^e_t:

$$P^e_t = \underset{(2.89)}{0.05} + \underset{(0.64)}{0.07}P_{mt-1} + \underset{(8.55)}{0.95}S_t \quad R^2 = 0.99 .$$

Per-pound quota lease rates for the 10 counties for 1966-69 and for 1977-87 are from Pugh and Hoover, and from Toussaint. Estimates of lease rates for 1965 were obtained from Hoover's estimates of lease rate averages for the tobacco growing belts. Estimates for the missing data for 1970-76 were obtained by regressing known lease rates against tobacco support prices, land rental rates, real wages, a time index, and county-specific intercept terms. Predicted values from the regressions were used for 1970-76. The data set was not extended beyond 1987 because transactions costs of off-farm leasing of tobacco increased when the lease and transfer provision of the tobacco program was eliminated.

To account for a portion of the yield variation caused by random variables, monthly rainfall amounts were included in the regressions. Rainfall-squared terms also were included to account for possible decreasing returns from rainfall. Because of the high probability of correlated error terms across counties, the 10 yield equations were estimated as seemingly unrelated regressions (SUR). The null hypothesis of a diagonal covariance matrix between equations was rejected at the 0.01 significance level. The quadratic functional form was used to allow for interaction between prices and technology. No interaction terms involving the rainfall variables were included. County-specific differences not accounted for by the explanatory variable are captured by county-specific intercepts. The response of yields to rainfall, prices and technology was restricted to be the same across the 10 counties.

Results

The estimated coefficients from the quadratic function using SUR for the 10 counties are presented in table 2. The county-specific intercepts and the R^2 values are reported in table 3. The ten-county average of actual and expected yields from the regression results are illustrated in figure 2. Expected yields in figure 2 were obtained by fixing rainfall variables at mean levels. Expected yields increased rapidly from 1955 to 1964, increasing at an average annual rate of 4.3 percent. In 1965, expected yields decreased by approximately 250 pounds. After this 12 percent decline, expected yields increased at an average annual rate of 0.5 percent. Note that over the entire sample, expected and actual yields attained their maximum value in 1964, immediately before the program change. The null hypothesis that yields are determined solely by technology and rainfall is strongly rejected (χ^2 = 43.61 with 12 degrees of freedom). We now turn to a discussion of price and technology components contributing to this path of yield growth.

Table 2. Seemingly Unrelated Regression Results

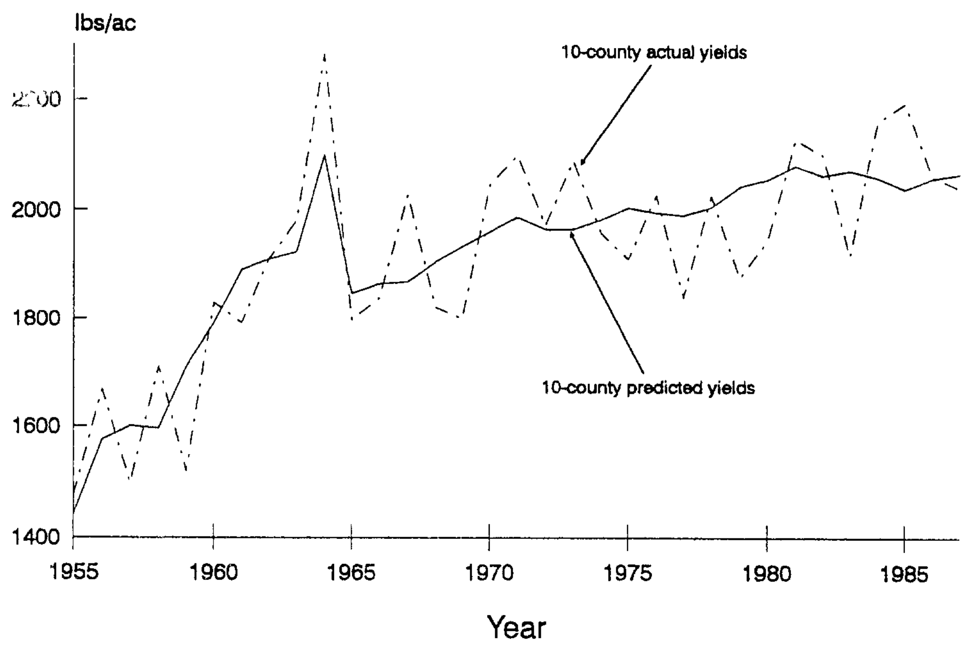
Variable[a]	Estimated Coefficient	t-statistic
τ	-333.8	0.22
τ^2	178.44	0.43
r	-9.189	2.38
r^2	0.00053	1.27
P_T	-1803.0	1.64
P_T^2	-42.641	0.17
w	-38.931	1.33
w^2	0.1266	1.14
$r \cdot \tau$	1.018	2.32
$w \cdot \tau$	-0.772	0.17
$P_T \cdot \tau$	108.11	0.29
$P_T \cdot r$	3.4315	1.16
$P_T \cdot w$	14.395	1.85
$r \cdot w$	0.0425	2.42
May	9.512	0.88
May^2	-2.260	2.05
June	12.973	1.98
June^2	-1.894	3.66
July	40.858	6.05
July^2	-2.764	5.64

[a] The variable definitions are: Y - tobacco yields per acre; P_T - the effective per-pound price of tobacco; r - the per-acre rental rate for tobacco-growing land; τ - an index of available technologies, and w - weekly price of agricultural labor.

Table 3. Constant Terms and Individual County R^2's

County	Intercept	*t*-statistic	R^2
Wake	4790.7	2.25	0.78
Cumberland	4917.9	2.30	0.75
Robeson	5019.7	2.35	0.74
Johnston	5043.9	2.36	0.76
Guilford	4669.4	2.20	0.65
Pitt	4984.3	2.33	0.51
Lenoir	5105.3	2.39	0.50
Stokes	4620.6	2.17	0.59
Granville	4578.0	2.15	0.53
Halifax	4985.2	2.33	0.50

Figure 2. Predicted and Average North Carolina Tobacco Yields



Note: Predicted yields were calculated at the mean values of the rainfall variables.

To gain insight into the comparative statics results in equations (2), (4), and (5) we test the statistical significance of the derivatives of yields with respect to output and input prices. Of particular interest is the hypothesis that $dY/dr > 0$, i.e., allowing grower output price to equilibrate. We are also interested in the signs of $\partial^2 Y/\partial\tau\partial P_i$, where P_i represents output and input prices. Certain statistical tests require that test statistics be evaluated at a set data point. One obvious setting would be to fix the data at their mean values for the entire sample period 1955-87. But average levels of the data are a combination of two quite different policy regimes. It is reasonable to expect that the response of yields to the exogenous variables depends upon the prices existing in each policy regime. The pre-1965 regime had high land and grower output prices; whereas the post-1964 regime had low land and output prices. An alternative method of testing the hypotheses is to evaluate the null hypotheses at average land and tobacco prices under each of the two regimes. Results of these tests for the two policy regimes and the entire sample period are given in table 4. The two alternative data points are the sample mean prior to 1965 for land rental rates and tobacco prices, and the sample mean for years after 1964 for land rental rates and tobacco prices. The price of labor and the technology index are held constant at their sample means for all hypothesis tests.

As can be seen in table 4 the sign of $\partial Y/\partial P_T$ is not significantly different from zero at the pre-1965 level of data; it is significantly negative after 1964; but it is not significantly different from zero for the entire sample. These test results should be contrasted with the null hypothesis that P_T has no explanatory power in the regression, a hypothesis rejected at the 0.10 significance level (χ^2 = 9.46 with five degrees of freedom). These empirical results indicate that the marginal cost of per-acre yields increases with acreage, ($C_{YA} > 0$ from equation [4]) only from 1965 to 1987.

The sign of $\partial Y/\partial r$ is ambiguous. It is positive but statistically insignificant at standard confidence levels under the 1955-64 regime of high land rental rates and tobacco prices; it is negative and statistically insignificant under the 1965-87 regime of low rental rates and tobacco prices; and it is negative and insignificant over the entire sample. But the null hypothesis that r has no explanatory power in the regression is rejected at the 0.01 significance level (χ^2 = 38.37 with five degrees of freedom). These results suggest that if C_{YA} is positive, it also is small.

The sign of $\partial Y/\partial\tau$ is significantly positive over the entire sample period and for the subsample from 1955 to 1964; for the period 1965 to 1987, it is smaller with a larger confidence interval. The null hypothesis that τ has no explanatory power in the regression is rejected at the 0.05 significance level (χ^2 = 12.88 with five degrees of freedom). The implied elasticity of yields with respect to the index of available technology is 0.54 for the early period and 0.23 for the latter, a fact implying that the responsiveness of yield to available technology is about half as great after the 1965 program change as it was before.

Although we have no comparative statics-based hypotheses regarding the relation of yields with wage rates, w, $\partial Y/\partial w$ is positive and significant between 1955 and 1964, but insignificant for the latter subperiod and for the entire sample. The null hypothesis that w has no explanatory power in the regression is rejected at the 0.05 significance level (χ^2 = 11.22 with five degrees of freedom).

From these results, we can conclude that the rapid growth in yields from 1955 to 1964 (figure 2) can be attributed to increasing land prices, wage rates, and yield potentials of available technology (see table 1). The abrupt decline in expected yields in 1965 was coincident with a 92 percent decline in land rental rates with the corresponding drop in grower output price of 12 percent. The comparative statics shown in equation (2) imply that decreases in land rental rates result in decreased yields when output prices adjust to maintain zero profits. To calculate the equilibrium effects of changes in rental rates or expected output price, note that

$$\frac{dY}{dr} = \frac{\partial Y}{\partial r} + \frac{\partial Y}{\partial P}Y^{-1} = \frac{dY}{dP}Y^{-1} .$$

This theoretical finding is strongly supported empirically by using the mean land rent and the output price for 1955 to 1964, with a t-

Table 4. Hypothesis Tests for the Seemingly Unrelated Regression Model[a]

Null Hypothesis:	$\partial Y/\partial P_T = 0$	$\partial Y/\partial \tau = 0$	$\partial Y/\partial w = 0$	$\partial Y/\partial r = 0$	$dY/dP_T = 0$	$dY/dr = 0$
Period[b]	Nonequilibrium Changes[c]				Equilibrium Changes[d]	
1955 - 1987						
Test Value	124.46	408.67	3.04	-0.323	-495.93	-0.26
t - Statistic	0.34	2.41	0.99	-0.25	-0.23	0.23
1955 - 1964						
Test Value	1083.3	729.11	19.076	0.908	2824.2	1.47
t - Statistic	0.91	3.45	2.89	1.43	4.67	4.67
1965 - 1987						
Test Value	-292.14	270.24	-3.825	-0.833	-1890.4	-0.99
t - Statistic	-2.71	1.40	-0.99	-0.52	-0.61	-0.61

[a]Variable definitions are given in table 2.

[b]The data levels used in the test statistics are the mean levels over the entire sample for all variables with the exception of the price of tobacco and land rental rates which are set to their mean over time period indicated

[c]Nonequilibrium changes are those where all other variables are held constant.

[d]Equilibrium changes are those where the zero-profit condition is maintained.

statistic of 4.66 (table 4). The point estimate of dY/dr at the average land rent and the output price for the years immediately before and after the policy change (1964 and 1965) is 1.42 with a t-statistic of 3.92. This is strong evidence that the concurrent decreases in land rent and output price that were brought about by the policy change decreased yield levels. Cheaper tobacco-growing land, caused by the move from acreage allotments to poundage quotas, lowered the cost of extensive production (use of more land) relative to that of intensive production (increasing yields).[8] After the program change, increases in rental rates had insignificant effects on yields. After the drop in yield levels in 1965, expected yields continued their upward trend. The yield increases after the program change can be attributed to continued, but slower, increases in potential yield as measured by the index of available technology.

Under the null hypothesis that the response of yields to changes in available technology is independent of policy, the interaction term between land rental rates and technology is zero. The coefficient of this interaction term is 1.018 with a t-statistic of 2.32. Thus, we can conclude that when quotas are tied to acreage (with concurrent increases in land prices), the response of yields to changes in available technology is greater than when quotas are not tied to land. This finding is consistent with the hypothesis that adoption rates of yield-increasing technologies are correlated positively with the price of land relative to other factor prices. As can be seen in table 2, the estimated coefficients on the interaction terms between the technology index and both output price and wages are insignificantly different from zero. This result implies that the determining factor in the responsiveness of yields to available technology is land rents.

Conclusions

In this paper, we demonstrated how changes in federal tobacco policy affected levels and growth of flue-cured tobacco yields. We investigated whether yield growth attributed to technical change depends upon policy-induced changes in relative prices. This study is relevant to other commodities when government intervention influences land and output prices. We used an index of available technologies that was derived from research-station data and that allowed us to distinguish yield effects of new technologies supplied and overall effects of new technologies and adoption decisions.

To summarize the empirical results, tobacco yield levels and the responsiveness of yields to changes in available technology depend upon price effects of program design. Specifically, the

1965 drop in land rents and output price, resulting from the shift from acreage allotments to poundage quotas, decreased yield levels by 12 percent. In addition, the movement to poundage quotas decreased the responsiveness of yields to changes in available technology. These findings are consistent with the hypothesis that high land prices lead to high adoption rates of yield-increasing technologies. The growth of expected yields declined from an annual rate of 4.32 to 0.5 percent because of a change in relative prices, a slowdown in the rate of increase of available technologies, and a decrease in the responsiveness of yields to those technologies.

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Endnotes

1. In this paper we do not address the issue of induced innovation, that is, the effect of changed incentives on the supply of newly available technologies. We take the supply of available yield-increasing technologies for tobacco as exogenously given, an assumption supported by the empirical findings of Babcock and Foster (1991). We consider only endogenous adoption rates, which depend implicitly upon levels of output and input prices. Two examples of related theoretical work on the connection between government-altered price distributions and technological adoptions are Kim, Hayes, and Hallam, who show that the stabilization of output prices will increase adoption rates of yield-increasing technologies for risk-averse firms, and Miller and Tolley, who address the question of optimally choosing price supports and input subsidies to affect the profitability of the new technology relative to an old technology, thus increasing adoption rates.

2. Beginning in 1987 the "lease and transfer" provision of the flue-cured tobacco program was eliminated. Since then, growers who lease tobacco quota must grow it on the farm of the quota owner.

3. The three primary growing regions or "belts" are represented by the 10 counties in this study. Pitt, Johnston, Lenoir and Halifax Counties represent the Eastern Belt; Stokes, Guilford, Wake and Granville Counties represent the Old Belt; and Robeson and Cumberland Counties represent the Border Belt.

4. The results from the NC OVT are published annually as a Department of Crop Science Research Report, North Carolina State University.

5. Surveyed rental rate data for Pitt County in 1962 was $297, for Wilson County, $327, for an average of $312. The weather-adjusted Seagraves estimate for 1962 is $495.75.

6. The resulting ratios are 0.92, 0.73, 0.74, 0.57, 0.61, 0.67, 0.91, 1.00, 0.97, and 0.73 for Robeson, Cumberland, Wake, Guilford, Granville, Stokes, Johnston, Pitt, Lenoir, and Halifax Counties.

7. The hypothesis of time-invariant ratios of county corn yields to state corn yields could be rejected only for Pitt County. The constant ratios used to adjust state farmland rental rates for Robeson, Cumberland, Wake, Guilford, Granville, Stokes, Johnston, Lenoir, and Halifax Counties are 0.99, 0.94, 0.78, 0.82, 0.71, 0.79, 0.87, 1.07, and 0.96. Fitted values from the following regression equation were used to adjust farmland rental rates for Pitt County: $Y_P/Y_{NC} = 1.601 - 0.00726 \cdot T$, where Y_P is the county corn yield in Pitt County, Y_{NC} is the average state yield, and T is an annual time index that equals 65 in 1965. The t-statistic on the time coefficient was -2.75.

8. A similar output effect was found by Beck for the case of laying hens in Australia. The imposition of a hen quota in 1972 resulted in a 9.5 percent increase in the per-hen production of eggs.