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IDENTIFICATION AND ESTIMATION

OF UNDERLYING MARKET SUPPLY FUNCTION PARAMETERS

FOR A COMMODITY WITH MANDATORY OUTPUT CONTROLS

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Tobacco

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ABSTRACT

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Data on lease rates for transferable output quotas allow implicit measurements of marginal costs. Regression of these costs on quantities of quota allows identification and estimation of parameters of the marginal cost function. Econometric analysis of sixty tobacco counties for eight recent years yields implied supply elasticities of about 3.3.

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Many agricultural industries operate with governmentally regulated supply. Among the most severe form of regulations are mandatory output quotas as have been used, for example, in the U.S. flue-cured tobacco industry for over two decades. Recently the idea of mandatory controls has been suggested as a solution for oversupply problems in the food and feed grains industries (as in the Harkin-Gephardt alternative to the 1985b Farm Security Act).

Governmental supply restrictions complicate our understanding of supply conditions because they replace some producer responses to economic conditions with the responses of program legislators or administrators. In particular, with a mandatory quota program, observed market price and quantity combinations are not "on" the relevant supply curve and so cannot be used directly to estimate the underlying market supply elasticity, a necessary parameter in analysis of the impact of the program.

This paper shows how to use data on quota lease rates to identify and estimate those supply function parameters needed for analyzing the impact of the mandatory control program. The next section briefly reviews a simplified model of quota as applied to the tobacco industry. We then develop our model for estimation and discuss the data and econometric issues. The statistical results provide estimates of an intermediate-run supply elasticity relevant to questions regarding the impact of deregulation and the social costs and transfers from the program. In the final section the results are interpreted in the context of this policy analysis.

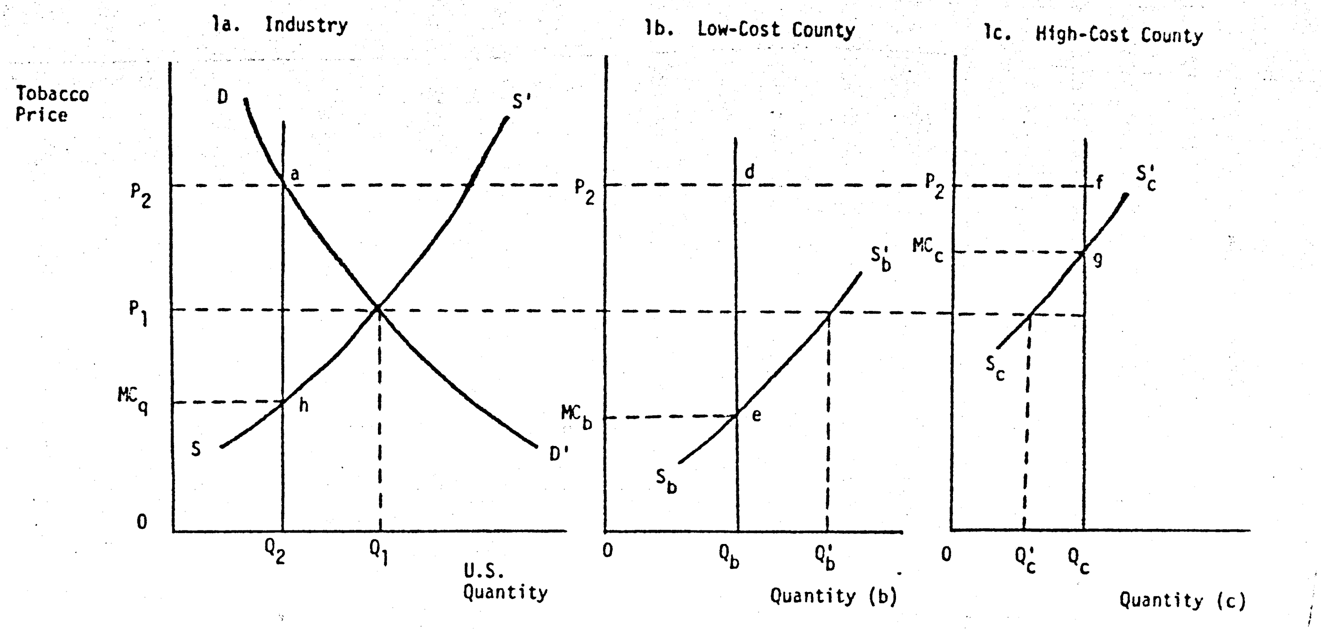
The Standard Model of a Quota Program

Figure 1 shows a conventional representation of the effects of a production quota system. Panel 1a represents the total U.S. tobacco market. Since tobacco quota is not transferable among counties, the effects differ among counties. Panels 1b and 1c represent counties that have relatively low and relatively high costs of producing tobacco. The axes refer to prices and quantities of tobacco.

In figure 1, DD' represents the aggregate demand for U.S. tobacco at the farm level, holding all other prices constant. It is the sum of the derived demands for U.S. tobacco for export and domestic use. SS' represents the long-run industry supply function that would prevail in the absence of the tobacco program: the industry marginal cost function. In the absence of price supports and quotas, competition would yield a price of P_1 and output of Q_1. A production quota that restricts total output to Q_2 results in a higher price, P_2. If the quota were freely transferable, it would be allocated among producers so the marginal costs of producing tobacco would be minimized: the aggregate marginal cost would still be represented by SS' and the marginal cost of producing the quota quantity would be MC_q. The difference between this marginal cost and the market clearing price (P_2-MC_q) would be quota rent yielding total industry income to quota represented by the area P_2ahMC_q.

Currently, tobacco quota is transferable within but not between counties so costs are minimized within but not among counties. The marginal cost of producing tobacco within any county depends on the total quota for that county and on the cost curve for that county. Panel 1b represents the tobacco market in a county that has relatively low costs (MC_b) of producing its quota quantity (Q_b), whereas panel 1c represents a county that has relatively high costs (MC_c) of producing its quota quantity (Q_c). The supply (marginal cost) curves in the two counties are S_bS_b' and S_cS_c'. In the absence of quotas the two counties would produce Q_b' and Q_c' at the tobacco price, P_1, that is given exogenously to any particular county. That is, output would be smaller in the higher cost county but larger in the lower cost county. The quota rents in the two counties are P_2-MC_b and P_2-MC_c.

Figure 1. Effects of Eliminating Quotas on the Tobacco Industry at the Aggregate and County Levels



It is useful for the econometric work--and for seeing the results of policy changes--to express figure 1 algebraically. Equation (1) represents the tobacco supply function that would prevail in the absence of the tobacco program, corresponding to SS′ in figure 1, and equation (2) represents the tobacco demand function, corresponding to DD′. Equation (3) represents the wedge between marginal costs (net of quota lease) and price.

(1) $d\ln Q_s = \epsilon d\ln P_s$

(2) $d\ln Q_d = \eta d\ln P_d$

(3) $d\ln P_d = (1-\rho) d\ln P_s + \rho d\ln R$

where Q_s = quantity supplied, P_s = the tobacco price net of quota lease or, more precisely, the minimum marginal cost of producing the total quota quantity (MC_q in figure 1a), η = the elasticity of supply, Q_d = quantity demanded (=Q_s by assumption), P_d = the tobacco price, η = the elasticity of demand, R = the price wedge: the difference between the market price for the quota quantity and the marginal cost (P_2-MC_q) in figure 1a), and ρ = the price wedge as a share of the price of tobacco (R/P_d). These equations are all in log differential or percentage change terms (that is, dlnX = dX/X). Equating (1) and (2) eliminates quantity, and we solve for the percentage change in the tobacco price as a function of the elasticities of supply and demand, the current price wedge, and the percentage change in the price wedge.

$$(4) \quad dlnP_d = \frac{\rho\epsilon}{(1-\rho)\eta - \epsilon} \times dlnR.$$

Substituting (4) into (2) yields the percentage change in output:

$$(5) \quad dlnQ_d = \frac{\eta\rho\epsilon}{(1-\rho)\eta - \epsilon} \times dlnR.$$

Quota rents are key data we use to identify (i) income and wealth associated with quota ownership and (ii) marginal costs of producing current output. To discover the unregulated equilibrium price and quantity or the impact of other regulatory change, estimates of the elasticities of supply and demand are required. Sumner and Alston (forthcoming 1987) consider tobacco demand in detail. The next section focuses on the supply elasticity.

Empirical Model

Under a mandatory supply control program, the cost of the commodity includes the costs associated with normal production and marketing and additional costs of owning or acquiring the right to produce. With no mandatory controls for tobacco there would be no implicit or explicit quota lease payments. Marginal costs would then be (roughly) current costs net of lease rates. In competitive agricultural industries without supply restrictions, output price tends to equal the marginal cost of production. Since tobacco quota markets are restricted to operate within counties, for a county i in year t, marginal cost may be represented as in equation (6).

(6) $C'it = (Pit - Rit) = C'(Qit, Xit, Uit)$,

where C' represents marginal cost, P is the expected price of tobacco, R is the lease rate per unit of output quota, Q is the quantity of output quota available, X is a vector of observable input prices and other cost shifters, and U represents unobserved variables.

The market for tobacco quota is settled in the spring of each year, before actual market prices and quantities are determined but after the announcements of effective quotas and the national average price floor have been made. Whereas C' itself is unobservable, we do have good information on the expected county average price for the coming season and the county lease rate for quota. On the right side of equation (6), the quantity of effective output quota available in the county depends on the national basic quota set by the federal program administrators and the previous year's over- or under-production. Growers also have reasonable information on other cost determinants (such as past yields and labor costs) at the time quota lease rates are determined.

Equation (6) is essentially a supply function specified in price dependent form. This is appropriate because effective quota for county i in year t is exogenously determined by past weather and demand conditions filtered through the administration of the national tobacco program.

There are three further issues to mention before we proceed to the data analysis. (1) Elimination of the tobacco program would allow production to shift across county lines for the first time in half a century. Some of the high cost areas would therefore become less important in tobacco markets; data related to them may not be relevant to the supply parameters under deregulation. We have therefore presented some estimates that have excluded areas thought to be the most likely to lose tobacco production (see Pugh and Hoover, Hoover and Todoulos and Grise).

(2) The elimination of county restrictions also means that supply would adjust to price changes along this "extensive" margin that is not available under the current program. This additional scope for flexibility suggests that estimates that ignore intercounty adjustment are biased downward as estimates of the supply elasticity relevant to the unrestricted market. However, we doubt that this bias is large because tobacco currently uses only a small proportion of the agricultural resources even in the most intensive counties.

(3) There is one final reason to believe that the supply elasticity estimated here is somewhat smaller than that appropriate to the question of deregulation. Our estimates are associated with year-to-year movements of quota and lease rates. The change in the lease rate bid in response to a change in the available quota is made with certain factors of production essentially fixed. Tobacco inputs such as bulk curing barns or harvesting equipment might fall into this category. But the movement to a new equilibrium output level following a major policy change is essentially a long-run response that would be made with almost all inputs considered as variable. In the final section we discuss how one or more short-run elasticities may be useful to the question of policy change.

Data

The data used in this analysis consists of annual observations over a cross section of 60 North Carolina tobacco producing counties covering the years 1977 through 1984. Data on the lease rates for transferable tobacco marketing quotas were summarized by Sparrow from a survey of county extension agents (Sparrow, 1986).

All price and wage variables are deflated by the producers' price index to place them in real terms. The marginal cost variable is calculated by subtracting the quota lease rate from the support price and adjusting the costs for differences across counties by adding the average differential between county market prices and the national support price, and removing any tobacco producer assessments.

The combined cross-sectional time series data contains 480 observations. There are 12 missing values of the quota lease rate variable that are proxied by predicted values from a regression of the lease rate on tobacco-type dummy variables, year dummy variables, and the county adjustment factor.

A subset of the data consisting of observations on counties that produce Type 11A tobacco was excluded from portions of the analysis. This type of tobacco represents production in a region of typically higher costs.

The means and standard deviations for each variable used in the analysis are presented in Table 1. This table also contains the means and standard deviations for the logarithmic forms of the variables used in regression analyses and the units of measurement for each variable.

Discussion of Results

The empirical investigation consists of four linear regressions on the logarithmic forms of several conceptually relevant variables. This approach yields elasticities directly in the form of regression parameters. The dependent variable for all four equations is the log of adjusted marginal costs. Explanatory variables include a county size variable of a county's basic tobacco quota in 1976, the county's effective quota, the yield per acre of tobacco for the county, and the nonfarm wage rate in the county.

The regression results are presented in Table 2. The first three equations include the entire sample; Model IV considers only the "low cost" region of tobacco production. The supply price elasticities are presented in inverted form as the parameters on the log of effective quota. The resulting elasticities are 3.21, 3.37, 3.16, and 2.52 for models I, II, III, and IV, respectively. The variances of the elasticity estimates are calculated by raising the elasticity estimate to the fourth power and multiplying it by the variance of the estimated inverse of the elasticity. These elasticities are all highly significant. It is important to note that this inverted price-dependent estimation procedure is not totally unbiased for estimating elasticities. However, good asymptotic properties are maintained in that these estimates converge in probability to the true value, and the sample size used for estimation is quite large in all cases. These results reveal that the supply elasticity for tobacco in North Carolina is in the neighborhood of 3.3, and when the higher cost counties are excluded, the elasticity drops to 2.5. This result probably arises from short-run fixities and greater mechanization in the lower cost counties.

The county size scale variable is significant in all equations with a negative sign. This reflects the fact that quota levels were initially based on the historical production levels of the last free market period of tobacco production, the 1930s. It would be expected that those counties having the highest levels of production during this period, and thus the highest levels of recent tobacco quotas, were the lower cost counties.

The yield variable is significant in each model in which it appears, because tobacco production is exogenously constrained by production quotas. Higher yields will therefore reduce the amount of land devoted to tobacco production, thereby lowering costs.

The nonfarm wage rate variable represents the opportunity cost of management expertise and labor. This variable is significantly negative in each model in which it appears. This effect is maintained because higher nonfarm wages must be met by a higher payment to labor and management, thus increasing costs.

Model III contains a set of 60 county dummy variables. These variables represent an attempt to remove all county-to-county variation not accounted for by the regressors of the models. The only variable significantly affected is nonfarm wages. This may suggest that once this cross-sectional variation is accounted for, the role of wages in determining costs is more clearly defined.

In all, the models appear to yield reasonable estimates of the supply elasticity of tobacco. The inclusion of additional factor price variables has only a small effect on the estimated parameters. Exclusion of the higher cost counties appears to lower the elasticity of supply considerably. Including dummy variables to eliminate cross-sectional effects has little effect on the parameters of the model.

Interpretations and Conclusions

The estimates in Table 2 provide evidence that the marginal cost of tobacco production is sensitive to yields, wage rates and the quantity produced. The most important result is that marginal costs rise by about three percent for a ten percent increase in quantity. The implied "intermediate-run" supply elasticity is in the range of three. This is above that used by Johnson and Norton for flue-cured tobacco and also is well above the supply elasticity found in econometric studies of other crops. There are features of this industry and its policy, however, that make the relatively high elasticity reasonable. Unlike some other commodities, such as wheat or cotton, flue-cured tobacco faces no obvious barriers to expansion in the major input markets with potentially limited supplies (Sumner and Alston, 1986, Chapter 4).

A relatively large supply elasticity, combined with a demand that is also elastic (due to the importance of competition with foreign producers;

see Sumner and Alston, forthcoming 1987) implies that taking off the mandatory controls would imply large output expansion relative to the price change. Previous estimates of the supply elasticity underestimated the potential expansion of the industry.

Table 1. Means and Standard Deviations of Variables Included in the Analysis of Tobacco Marginal Costs.[a]

Variable	Whole Sample			Low Cost Region[b]		
	n	Mean	Std. Dev.	n	Mean	Std. Dev.
Lease Rate (¢/lb.)	468	.136	.015	344	.149	.036
Adjusted Support Price (¢/lb.)[c]	480	.589	.026	344	.593	.026
Adjusted Marginal Costs (¢/lb.)	480	.445	.049	344	.436	.044
Log of Adjusted Marginal Costs	480	-.816	.109	344	-.835	.100
Basic Quota, 1976 (acres)	480	13.916	11.977	344	15.871	12.998
Log of County Size	480	15.95	1.141	344	16.087	1.162
Yield (lbs./acre)	480	1985.667	234.643	344	2043.474	204.177
Log of Yield	480	7.586	.125	344	7.617	.106
Effective Quota (million lbs.)	480	11.864	11.464	344	12.917	10.562
Log of Effective Quota	480	15.805	1.111	344	15.896	1.142
Non-Farm Wages ($/wk.)	480	72.649	11.221	344	71.058	11.304
Log of Non-Farm Wages	480	4.274	.149	344	4.252	.152

[a]All price variables deflated by the Producer's Price Index.

[b]Excludes counties in Type 11A tobacco growing region.

[c]Adjusted for county differences by including the average differential between county market prices and the national support price.

Table 2. Tobacco Marginal Cost Equation Regression Results.

Variable	Model I	Model II	Model III[a]	Model IV[b]
Intercept	-.337	.127		.131
	(.048)	(.240)		(.288)
County Size	-.339	-.324		-.422
	(.016)	(.016)		(.024)
Log of Effective Quota	.312	.297	.317	.397
	(.016)	(.016)	(.017)	(.026)
Supply Price Elasticity	3.205	3.367	3.155	2.519
	(.027)	(.033)	(.067)	(.027)
Log of Yield		-.078	-.074	-.078
		(.028)	(.034)	(.035)
Log of Non-Farm Wage		.030	.189	.025
		(.023)	(.065)	(.026)
R-Square	.547	.556	.637	.555
F-Statistic	286.87	148.58	11.80	105.55
n	480	480	480	344

[a]Model III includes dummy variables for counties (sixty counties).

[b]Model IV is comprised of observations taken from the "lower cost" counties. These are counties outside of the Type 11A tobacco growing region.

References

Grise, Verner N. "Trends in Flue-Cured Tobacco Farming." Agricultural Economic Report No. 470, Economics and Statistics Service, USDA, June 1981.

Hoover, Dale M. and Sophia I. Efstratoglou Todoulos. "Economic Effects of Intercounty Transfer of Flue-Cured Tobacco Quota." Economics Research Report No. 23, North Carolina State University, March 1973.

Johnson, Paul R. and Daniel T. Norton. "Social Cost of the Tobacco Program Redux." American Journal of Agricultural Economics 65 (1983): 117-119.

Pugh, Charles R. and Dale M. Hoover. "Lease Rates in North Carolina Counties under the Program for Flue-Cured Tobacco." Presented at the 29th Tobacco Workers Conference, Lexington, Kentucky, January 1981.

Sparrow, D. Arthur. "The Structure of North Carolina Flue-Cured Tobacco Enterprises." Unpublished M.S.M. paper, Dept. of Economics and Business, North Carolina State University, December 1986.

Sumner, Daniel A. and Julian M. Alston. Effects of the Tobacco Program: An Analysis of Deregulation. AEI Occasional Paper. Washington, D.C.: American Enterprise Institute, 1986.

Sumner, Daniel A. and Julian M. Alston. "Substitutability for Farm Commodities: The Demand for U.S. Tobacco in Cigarette Manufacturing." American Journal of Agricultural Economics, forthcoming 1987.