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VARYING-PARAMETER SUPPLY FUNCTIONS AND THE SOURCES OF ECONOMIC DISTRESS IN AMERICAN AGRICULTURE, 1866-1914

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Abstract

The agrarian unrest in the United States at the end of the nineteenth century is examined. This unrest is often viewed as stemming from the inability of farmers to adapt to changing conditions in world agriculture. This hypothesis is tested in the context of a distributed lag supply function. Varying parameter estimation methods are used to trace the history of the parameters in the supply function and to decompose observed prices into permanent and transitory components over time. The patterns of variation are tested for conformity with a model of rational price-expectation formation. The conclusion is that farmers behaved as economic theory would predict, but that neither theory nor practice gave them relief from the troubles which plagued them.

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"[W]hen we speak of 'rational behaviour' or of 'irrational behaviour' then we mean behaviour which is, or which is not, in accordance with the logic of the situation. In fact, the psychological analysis of an action in terms of its (rational or irrational) motives presupposes...that we have previously developed some standard of what is to be considered as rational in the situation in question."

---Karl R. Popper [1966]

I. Introduction

Few questions of American economic history are as intriguing as those surrounding the transformation of American agriculture between the Civil War and World War I. The reversal of the relative weights of agriculture and industry is well known, with agriculture employing 52.5% of the labor force and producing 57% of commodity-production value added in 1870 but employing only 31.4% of the labor force and producing 38% of the commodity-production value added in 1910 [Lebergott 1966, p. 119; Gallman and Howle 1971, p. 26. The value added figures are for 1869 and 1909]. But in addition, this period seems to have marked a once-and-for-all shift in the consciousness of the farming population. The years prior to World War I marked the emergence of the "farm bloc" attitudes which have persisted to the present day. The Granges, Wheels, Alliances, and cooperatives were proving grounds for the tactics of special interest politics. Unlike the antebellum proslavery minority, the farming minority managed to avoid being swamped in the political triumph of its rivals. The reason for the farmers' survival as a political force may originate, paradoxically, in the decisive defeat they suffered in the Bryan debacle of 1896 and their simultaneous loss of organizational autonomy. The Republican victory coupled with the dismantling of the Populist political machinery guaranteed that the farming interests could never again seriously contend for national hegemony. Secure in its victory, the business establishment could afford to grant the farmers special privileges almost as a consolation.

Whatever conclusions might be drawn about the politics of the era of protest and unrest that began in the 1870's, the sources of that unrest remain obscure. Because of the deep current of special pleading that flows through all the farmers' manifestoes, the modern historian is unwilling to accept them at face value. And because of the Populist intellectuals' ignorance of economics (any doubts concerning this can be laid to rest by brief attendance at Coin's Financial School [Harvey 1895]), the articulated grievances of the farmers are similarly suspect. When the viewpoints and prejudices of the contemporary observers are put aside, most of the alleged economic foundations of the farmers' unhappiness fail to pass modern tests of necessary or sufficient cause. Railroad rates, exploitation in the Southern labor market, high interest rates, and adverse movements in the agricultural terms of trade are all inadequate as explanations of either the pattern or timing of the upheavals [Higgs 1970, DeCanio 1974a, Bowman 1965, North 1974]. Even so, it would be foolishly premature to assert that the farmers were not somehow oppressed in their economic role. To claim otherwise risks being forced to argue that the entire era of protest and organization, which left a permanent imprint on the political style of the agricultural minority, was nothing but the product of the fevered imaginations of misfit reformers, or of the systematic misperceptions of the farmers themselves.

Economic historians have recently inclined towards the view that while the farmers were not victimized by trusts and markets in the ways they thought they were (monopoly exploitation, falling terms of trade, speculation in futures, etc.), they were nevertheless suffering the burden of adjustments to changes in the economic environment. For example, Mayhew has hypothesized that the unrest of the Grangers and Alliancemen was not so much a response to a worsening of their overall economic position as instead a reaction to the commercialization of agriculture. This commercialization probably increased farm incomes, but it also made the farmers subject to impersonal and mysterious market forces. Farmers' discomfort with the demands of the market environment was thus the true source of their discontent [Mayhew 1972]. A somewhat different but related view was expressed by North:

> What was fundamentally at stake in the farmer's discontent was, first of all, that he found himself competing in a world market in which the fluctuations in prices made no apparent sense to him. The bottom might drop out of his income because of a bumper crop at the other side of the world, in Argentina or Australia. When he suffered a period of drought and poor crops, the higher prices he had learned to expect in such a case might still not be forthcoming (if other areas had a good crop year).... [North 1974].

Implicit in the motivations for Populism proposed by both North and Mayhew is the idea that farmers' perceptions of the economic reality were awry; that in some fundamental sense the operation of the markets for agricultural products presented farmers in the late nineteenth century with a puzzle beyond their ability to solve.

Against this approach may be counterposed the results of recent studies on the responses of cotton and wheat farmers to changes in the relative prices of alternative crops in the late nineteenth century. Although these supply studies are based on a relatively simple specification of the farmers' response functions, they do indicate a reasonable degree of flexibility in the behavior of agriculturalists in those regions of the United States where the great cash crops were grown. Price movements elicited output changes in the proper direction, and the speed of farmers' responses was rapid enough to guarantee substantial adjustment to permanent price changes in a fairly short length of time [Fisher and Temin 1970, DeCanio 1973].

Nevertheless, doubts linger that conventional estimation of distributed lag supply functions will reveal those aspects of the farmers' underlying behavior required to unravel the origins of their distress. Even if producers' price responsiveness is a key indicator of their adaptability, the fifty-year span from the end of the Civil War to the outbreak of World War I can not reasonably be characterized as a period during which agriculture in the United States was untouched by structural change. Yet all the econometric models employed until now to estimate the parameters of farmers' response functions assume an unchanging structure. If changes in the behavior, psychology, organization or outlook of the farmers were responsible for the boiling up of the protests, then the estimates of constant parameters of distributed lag supply functions may be incapable of revealing those causes. The commercialization of wheat farming and the bitter experience of the sharp cycles of the 1870's and 1890's may have altered the manner in which farmers formulated their expectations. In the South, a general flexibility in switching between cotton and alternative crops may have gradually succumbed to the demands for cotton by monopolistic furnishing merchants. In either region, specialization may have required increasing investment in crop-specific capital, thus reducing opportunities for choice of crop. Changes in the relative proportions of farmers exhibiting different types of behavior could change the weights appropriate for aggregation. In any of these cases, the 1866-1914 average estimates of the price elasticities and speeds of adjustment could easily reveal normal responses by the farmers for the period as a whole, while remaining mute on the magnitude and direction of the all-important <u>changes</u> in these parameters.[1]

Recent developments in the theory of models with varying parameters allow these issues to be attacked directly [Cooley 1971; Cooley and Prescott 1973a, 1973b, 1973c, 1974; Rosenberg 1973]. These new techniques not only enable identification of changes in the parameters over time, but also permit fresh speculation concerning the origins of the changes. This paper explores the outcome of applying one such technique to the data analyzed in the previous wheat and cotton supply studies. The results reveal a surprising combination of influences operating on American agriculture at the turn of the century. The farmers seem to have behaved according to standards of optimal decision-making, but despite their best efforts their freedom of action was curtailed by the development of world commodity markets. The farmers' difficulty was not so much that they failed to understand their condition, but that they were unable to do anything to alleviate it. In such a situation, the pursuit of chimeras may have offered the only hope. Populism and its related organized uprisings may be seen in this light not as unsuccessful attempts to right economic wrongs, but as doomed efforts by the farmers to deny what could not be changed. In the dollars and cents matters involving farm management and crop choice, the farmers behaved as economic theory would have led them to behave, but neither theory nor practice offered any realistic relief from the problems which plagued them. They were more successful in adapting to an inherently unpleasant situation than in proposing or implementing reforms to change that situation in any fundamental way.[2]

II. The Model.

The model employed by Fisher and Temin [1970] and DeCanio [1973] in their studies of wheat and cotton is a version of the dynamic adjustment model of Nerlove [1958]. The basic model assumes the form

$$S_t = \beta_1 + \beta_2 P_{t-1} + \beta_3 S_{t-1} + \beta_4 S_{t-2} \qquad (1)$$

where S_t denotes the share of acres planted in wheat or cotton in year t, P_t denotes the relative price of cotton or wheat compared to an an index of the prices of the alternative crops in year t, and the β's are coefficients to be estimated.[3] The theoretical motivation for this model has implications about the interpretation of the coefficients β_i. The suppliers are assumed to base their desired share of acreage (S_t^*) on the expected relative price (P_t^e):

$$S_t^* = \alpha_1 + \alpha_2 P_t^e \qquad (2)$$

In the studies referred to above, actual acreage is assumed to respond to desired acreage with some speed of adjustment μ, and price expectations are assumed to adjust to experience with some speed of adjustment θ.

$$S_t = S_{t-1} + \mu (S_t^* - S_{t-1}) \qquad (3)$$

$$P_t^e = P^e_{t-1} + \theta (P_{t-1} - P^e_{t-1}) \qquad (4)$$

With some manipulation equations (2)-(4) lead to empirical relations of the form (1) where the β's depend on the speeds of adjustment μ and θ and the elasticity of desired supply with respect to expected price (α_2). Both the studies of nineteenth-century agricultural supply referred to above found that either μ or θ was equal to unity, which implies $\beta_4 = 0$.[4] For this reason, and because we are interested primarily in testing hypotheses about the mechanism of price expectation formation, we will follow the previous studies in estimating

$$S_t = \beta_1 + \beta_2 P_{t-1} + \beta_3 S_{t-1} \tag{5}$$

Nerlove argues that these coefficients are likely to be relatively constant in the short run, but that the conditions which lead to the formation of expectations are not likely to be constant in the long run.[5] As we have argued in the introduction the time period spanned in this study is not only quite long but was probably characterized by a wide variety of structural changes. Such changes are likely to have influenced the expectations of farmers. Thus, even within the context of received doctrine there are strong reasons to believe that the supply functions we are concerned with are subject to change over time.

One objective of the present study is to determine empirically the extent to which such structural change actually did take place over the period 1866-1914. In addition, however, we wish to probe beneath the surface of the distributed lag supply response model to determine whether or not any changes which did take place conformed to the types of parameter variation which might be predicted by economic theory. Theoretical attempts have been made to relate the parameters of distributed lag specifications to optimal decision processes at the micro level, both with respect to the formulation of price expectations and the rapidity with which actual levels of the dependent variable are brought into conformity with "desired" levels [Griliches 1967]. While it would be best to test both types of structural change hypotheses, the data required to investigate fully the origins of changes in the speed of adjustment of actual to desired acreage shares are not available.[6] On the other hand, the data required to compare farmers' behavior against standards of optimality in price expectation formation is immediately accessible, since the requisite historical price information is already contained in the price series used to estimate the lagged adjustment supply functions.

For this reason, we will concentrate on testing the theory of optimal expectation formation proposed by Muth [1960]. Thus we will assume that farmers were not prevented from achieving their desired crop mix. (This amounts to assuming that $S_t = S_t^*$ or $\mu = 1$.) Instead of simply positing a lagged adjustment of the expected price to past values of the price, Muth derives the optimal adjustment parameters as functions of certain characteristics of the price history itself. To test this economic theory of expectation formation, changes in the structural parameters that actually occurred will be compared with the changes predicted by the theory, given the changes taking place in the price series over time.

To make this approach a bit more transparent, let us consider in more detail the decision problem facing the farmer. Since $\mu = 1$, the relationship between actual supply and the expected price is given by

$$S_t = \alpha_1 + \alpha_2 P_t^e \qquad (6)$$

Following Muth, let us also make the reasonable assumption that the price the farmer observes is the sum of a permanent component $(\overline{P}_t)$ and a transitory component (η_t)

$$P_t = \overline{P}_t + \eta_t \tag{7}$$

We shall assume that the transitory components are independently and identically distributed with mean zero and variance σ_η^2. The permanent components can be assumed to follow a moving average process

$$\overline{P}_t = \overline{P}_{t-1} + \varepsilon_t \tag{8}$$

where the ε's are independently distributed with mean zero and variance σ_ε^2. The essence of the farmer's decision problem is to forecast the price for time period t given the information available up through $t-1$. Muth shows that the price prediction P_t^e which minimizes the error variance $E(P_t - P_t^e)^2$ given the information up to time t is

$$P_t^e = \sum_{k=1}^{\infty} (1-\lambda)\, \lambda^{k-1}\, P_{t-k} \tag{9}$$

where λ depends in a known way on the variances of the permanent and transitory components of the price:[7]

$$\lambda = 1 + (1/2)(\sigma_\varepsilon^2/\sigma_\eta^2) - (\sigma_\varepsilon/\sigma_\eta)[1 + (1/4)(\sigma_\varepsilon^2/\sigma_\eta^2)]^{1/2} \tag{10}$$

A Koyck transformation after the substitution of equation (9) into equation (6) leads to an empirical relationship of the form

$$S_t = \alpha_1 (1-\lambda) + \alpha_2 (1-\lambda) P_{t-1} + \lambda S_{t-1} \tag{11}$$

which gives the interpretation of the β_i of equation (5) which will be followed throughout.

If the price itself is subject to exogenous influences because of changing conditions in the markets for agricultural products, then λ will change, provided the farmers perceive the changes in the characteristics of the observed prices and modify their decision rule accordingly. In section IV we test this hypothesis about farmers' behavior in some detail and find that the pattern of variation in the coefficients of (5) is quite consistent with this view of rational behavior.

Equation (5) is identical to the form of the supply functions estimated by Fisher and Temin [1970] and DeCanio [1973], except that (5) does not include a time trend as an additional variable. The main justification for inclusion of the trend in the original studies was that it picked up effects of omitted variables. We feel that a significant time trend may actually be indicative of the type of structural change which the varying-parameter estimation technique is explicitly designed to capture.[8] Also, since there are good reasons for expecting the parameters to vary over time it may be that the empirical form (as distinct from the structural parameters) of the model changes over time as well [David 1971]. Tentative results obtained when we extended the data series through World War I to 1925 suggest that the basic form of the relationship may indeed have changed. We found several instances of negative or statistically insignificant price elasticity coefficients when the samples were extended to 1925. It was decided to end the sample in 1914 to maintain comparability with the previous studies and to avoid having to change the basic specification of the estimated equation.[9]

III. Estimation Method.

The estimation method used in this study has been developed in [Cooley 1971; Cooley and Prescott 1973c and 1974]. While theoretical and other reasons suggest that the parameters in our relationship are likely to change over time, they do not suggest the precise pattern of the variation. For this reason we assume that the parameters are subject to a rather general process that is capable of detecting parameter variation from a variety of sources. The coefficients are assumed to be subject to both permanent and transitory changes over time:

$$\beta_t = \beta^p_t + u_t$$
$$\beta^p_t = \beta^p_{t-1} + \omega_t \tag{12}$$

The vector β^p_t represents the permanent component of the parameters at time t. The u_t and ω_t are independent and identically distributed random variables with zero mean vectors and covariance matrices which are specified as

$$\text{Cov}(u_t) = (1-\gamma)\,\sigma^2\,\Sigma_u$$
$$\text{Cov}(\omega_t) = \gamma\,\sigma^2\,\Sigma_\omega \tag{13}$$

The matrices Σ_u and Σ_ω specify the relative magnitude of the parameter changes and are assumed known up to a scale factor. In the current analysis we assume

$$\Sigma_u = \Sigma_\omega = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{14}$$

The implication of this assumption is that the β coefficients will vary at the same rate. The choice of this particular specification of the covariance structure was essentially arbitrary, except that all parameters were allowed to vary and no a priori assumption was made about the relative magnitudes of the variations. Extensive experiments were carried out with alternative specifications of Σ_u and Σ_ω, including matrices with unequal diagonal elements and ones with both positive and negative off-diagnoal elements. Comparisons of the Bayesian posterior odds [Zellner 1971, pp. 291-302] did not indicate that any particular specification of the Σ matrices was superior to the others. In addition, the parameter histories traced out with the alternative specifications were all very similar, with extremely high correlations between both the values of the parameters at different base periods (see below) and changes in the parameter values from one base period to the next, for all the alternative covariance structures tested. Thus, the analysis presented below is quite robust with respect to alternative Σ specifications.

The parameter γ (which is constrained to lie between zero and one) specifies the relative variance of the permanent and transitory components of the changes in the β's. If γ is significantly different from zero, then the β's are subject to permanent changes over time.

Since we are interested in the permanent component of the parameter process and, in particular, specific realizations of the process, we normalize the equation around a specific time period.[10] If we let τ represent such a period, then

$$\beta^P_\tau = \beta^P_{\tau-1} + \omega_\tau$$
$$= \beta^P_t + \sum_{j=t+1}^{\tau} \omega_j \tag{15}$$

From equation (12) we can write

$$\beta_t = \beta^P_\tau - \sum_{j=t+1}^{\tau} \omega_j + u_t \tag{16}$$

Letting X_t' represent the row vector of independent variables $(1, P_{t-1}, S_{t-1})$, we can rewrite the supply equation as

$$S_t = X_t' \beta^P_\tau + \pi_t \tag{17}$$

The error vector π_t is distributed normally with mean zero and covariance matrix

$$\text{Cov}(\pi) = \sigma^2[(1-\gamma)R + \gamma Q] \equiv \sigma^2\Omega(\gamma) \tag{18}$$

The matrix R is a diagonal matrix which depends on Σ_u and X, while Q is a matrix which depends on X, Σ_ω and the period on which the parameter process is normalized.

If γ were known, estimation would be a trivial application of Generalized Least Squares. The object of the estimation procedure is to obtain a consistent estimate of γ which will yield the asymptotically efficient estimates of the β's. The formal details of the estimation technique and the asymptotic properties of the estimates are developed fully in [Cooley 1971 and Cooley and Prescott 1974]. In this study we present the Bayesian estimates of the parameters. We have assumed priors which are sufficiently diffuse so that the sample information dominates. Our prior knowledge (or ignorance) about the parameters is represented by the independent distributions:

$$p(\gamma)\ d\gamma \propto d\gamma \qquad 0 \leq \gamma \leq 1$$

$$p(\beta)\ d\beta \propto k\ d\beta \tag{19}$$

$$p(\sigma)\ d\sigma \propto (1/\sigma)\ d\sigma$$

The marginal posterior density for σ can be shown to be

$$p(\sigma;s) \propto |\Omega(\gamma)|^{-(1/2)}|(X'\Omega(\gamma)X)|^{1/2}\ \hat{\sigma}^{-(T+k)/2} \tag{20}$$

where $\hat{\sigma}$ is the generalized sum of squared residuals, k is the number of independent variables, and T is the number of observations. The parameters β have the posterior density (conditional on γ)

$$p(\beta;s,\gamma,\sigma) \sim N\{B(\gamma),\sigma^2(X'\Omega(\gamma)X)^{-1}\} \tag{21}$$

where $B(\gamma)$ is simply the Aitken estimator of β. The first moment of the posterior density for β is obtained by numerical integration

$$E(\beta;s) = \int B(\gamma)\ p(\gamma;s)\ d\gamma \tag{22}$$

In the subsequent discussion we report as estimates of β the first moment of the posterior density. The parameter γ is only estimated once for each state and the estimates of β at five year intervals are obtained conditional on γ.

IV. Results.

Estimation of (5) and tracing the parameter histories over the entire period at 5-year intervals reveals the existence of substantial parameter variation as measured by $\hat{\gamma}$, as well as several interesting patterns in the variation of the different parameters. Table 1 gives the values of the Bayesian estimates of the parameters at a year close to the beginning of the sample period (1874) and at the end of the period (1914).

{Insert Table 1}

Table 2 gives the estimates of γ for each state with the associated standard errors $\hat{\sigma}_{\gamma}$. The small sample distribution of $\hat{\gamma}$ is not known, but the asymptotic distribution of $\hat{\gamma}/\hat{\sigma}_{\gamma}$ is derived in [Cooley and Prescott 1974].

{Insert Table 2}

Examination of the parameter histories (of which the estimates given in Table 1 are the endpoints) reveals several interesting findings. Allowing variation in the constant term is a general way to provide for shifts in the supply functions. The Fisher and Temin and DeCanio specifications parameterized such potential shifts by inclusion of a trend term. Table 1 reveals that for the cotton states, the constant increased over the period for all states but

Florida and Louisiana. These two states and Mississippi were the only states whose trend coefficient was negative in [DeCanio 1973]. For the wheat states, the constant drifted downward for all states but Kansas, Maryland, and Missouri. In the Fisher and Temin regressions, the trend was negative for all states but Kansas, Maryland, Virginia and Nebraska, and in the cases of both Virginia and Nebraska, they found a negative trend when relative yield was included as an explanatory variable. It appears that both specifications indicate similar movements in the intercepts of the supply functions over the period.

This similarity is reassuring, but there are important differences between the fixed parameter and varying parameter models' results. In both the cotton and wheat states, the varying-parameter estimates of β_3, the coefficient of the lagged share, are generally lower than the estimates of this coefficient in the fixed-parameter models. Now it is well known that misspecification of either the disturbance process or the explanatory variables can lead to biased estimates of the coefficient of a lagged dependent variable [Johnston 1972]. This bias is likely to be positive if the omitted variables exert an influence on the dependent variable which persists over several periods. In agricultural supply it seems likely that factors tending to stimulate wheat or cotton production might exert a persistent influence over a period longer than one year. Such omitted variables might include relative prices of crop-specific inputs, forces leading to a revision of the price-expectation behavior of the farmers, or other factors too erratic to be adequately parameterized by the trend coefficient in the fixed-parameter functions. The varying-parameter technique is specifically designed to capture permanent changes in the structural coefficients which might be associated with movements in omitted variables, and it is also a more general alternative to the specification of a first-order autocorrelated disturbance [Cooley and Prescott 1973c, p. 468]. On both grounds then, the varying-parameter technique is less susceptible to the possibility of a upward bias in the coefficent of the lagged share. This is consistent with the comparisons between estimation methods exhibited in Table 3. This table displays the end-point values of $\hat{\beta}_3$ from the varying parameter regressions, the fixed-parameter estimates with first-order autocorrelated disturbance, and estimates taken from a naive OLS regression without a trend variable. The β_3 estimates in the naive model are typically the highest, followed by the autocorrelated model with trend, followed by the varying-parameter estimates.[11]

{Insert Table 3}

Leaving aside comparisons with the previous work, the time pattern of the coefficient estimates leaves no doubt that the conditions of agricultural supply were undergoing significant modification during the period. Table 4 shows the simple correlation coefficients between the parameter values calculated at 5-year intervals and a simple trend. The pattern for the wheat states is unambiguously clear: β_2, the short-run price elasticity, declined over time, while β_3, the coefficient of S_{t-1} increased. There are only two exceptions to this pattern for β_2 and three exceptions for β_3. The long-run price elasticity, α_2, shows a negative trend in 15 of the 17 wheat states. If β_3 is interpreted as the parameter λ of equations (9) and (11), the implication is that as time went on the farmers in the wheat states tended to put greater weight on the whole history of the relative wheat price in formulating their predictions, while the relative weight they gave to more recent observations of this price declined.

For cotton the picture is somewhat less clear. Five states of ten show β_2 declining over time, and the correlations seem, if anything, a bit stronger in the states with increasing β_2. Eight of the ten states show a declining β_3, indicating an increasing relative weight on recent prices in formulating the price prediction. The long-run price elasticity is negatively correlated with the trend in six of the ten states.

{Insert Table 4}

The picture presented by the wheat estimates is one of declining flexibility on the part of the farmers. Fifteen out of seventeen states showed a fall in both the long-run and the short-run price elasticity, and this decline was so severe that by 1914 four states (California, Illinois, Missouri and Indiana) exhibited negative short-run price elasticities. (Of course, negative price elasticities are highly implausible, but in no case are these estimates significantly different from zero.) At the same time the price elasticities were declining, the estimates of β_3 are indicative of decreasing reliance on recent prices in forming the forecast of the relative price. The increasing commercialization of wheat farming does not appear to have led to more elastic price-responsiveness on the part of western and northern farmers.

The parameter trends for the cotton farmers cast further doubt on the possibility that they became increasingly committed to cotton and unable to shift into alternative crops [DeCanio 1973]. If an increasing proportion of farmers were "locked in" to cotton production, the aggregate short-run price elasticity might have declined in reflection of the changing aggregation weights of the free and constrained farmers. No such uniform decline over the entire South is observed; five of the states exhibit declining β_2's, five increasing β_2's. It is difficult to see how the increasing short-run price elasticities of South Carolina, Georgia, Alabama and Texas could be reconciled with the traditional hypothesis of increasing involuntary specialization in cotton throughout the South due to credit conditions.[12]

These overall trends in both the wheat and cotton parameter histories should not obscure the fact that there are substantial variations within the trends. Along the lines of inquiry suggested in Section II, it might be asked whether the patterns of parameter variation reveal aspects of farmers' behavior more subtle than the simple response to changes in the relative price. Nerlove [1958] examined parameter differences across distinct groups of farmers (defined by the different crops they grew), but our 5-year interval parameter histories enable us to examine changes in the response parameters of given groups of farmers defined by their geographical location. Following Nerlove, we first examine the influence of differing degrees of price variability.

Obviously, there is no unique way to measure changes in the variability of the price over time, so the method chosen carries no claim to any ideal properties. With this qualification, define V_t as sample variance of the price variable computed over the 5-year interval ending in year t. Denote this V_t as the "temporary variance" of the price. Define $v_t = V_t^{1/2}$ as the temporary price standard deviation over the same period. These v_t were computed for each state's price series, for each 5-year interval ending in one of the base years for which the historical parameter values were calculated.[13] For each state, the first differences of the v_t were correlated with first differences of the β_2 and β_3 estimates calculated at the 5-year base intervals. First differences were used to eliminate potentially spurious correlations due to the presence of common trends possibly arising from different sources. The resulting correlations indicate the degree to which changes in price variability were matched by changes in the parameter values.

{Insert Table 5}

The pattern of the correlation coefficients is initially puzzling. Both the cotton states and the wheat states show a strong association between changes in the parameters and in the v_t. However, the patterns of change in the two regions are mirror images of each other. In the cotton states, increases in price variance are associated with increases in $\hat{\beta}_3$ and with decreases in $\hat{\beta}_2$, while in the wheat states increases in v_t are associated with decreases in $\hat{\beta}_3$ and increases in $\hat{\beta}_2$. There are only two exceptions to the pattern among the cotton states, and only three exceptions to the pattern out of the seventeen wheat states. Before these results are judged to reveal conclusive evidence of a fundamental difference in the behavior of wheat and cotton farmers (and, by implication, the irrationality of one group or the other), it is necessary to investigate further the link between price variability and the structural parameters which would be predicted by theory.

Recall from equations (9)-(11) of Section II that λ $(= \beta_3)$ represents the rule used by farmers to "discount" the information contained in past prices when forming their prediction of the harvest-time price. A low λ means that past prices are taken very little into account in forming the optimal predictor; a high λ means that information from the more distant past is given a relatively high weight in predicting the current price. It can be shown from equation (10) that λ is a decreasing function of $\rho = \sigma_\varepsilon^2/\sigma_\eta^2$, the ratio of the variance of the permanent component to the variance of the transitory component of the price.[14] This is plausible, for as Muth states [changing his notation to conform]:

> If the changes in the permanent component are small relative to the "noise," then λ will be very nearly unity. The forecast then gives nearly equal weights to all past observations in order that the transitory components tend to cancel each other out. The forecasts then do not depend very much on recent information because it says very little about the future. On the other hand, if changes in the permanent component are large relative to the noise, λ would be small so as to weight the recent information heavily [Muth, 1960, p. 304].

Decomposition of the price into permanent and transitory components suggests that the relationship between price variability and β_3 will not necessarily be unidirectional.

$$V_t = \mathrm{Var}[\eta_t + \sum_{i=1}^{t} \varepsilon_i] \qquad (23)$$

from (7), (8) and the definition of V_t. Thus

$$V_t = \sigma_\eta^2 + t\,\sigma_\varepsilon^2 \qquad (24)$$

since $\sigma_{\eta\varepsilon} = 0$ and ε_i and ε_j are independent for $i \neq j$. Thus changes in V_t may come about as a result of either changes in σ_η^2 or changes in σ_ε^2, or both. And since λ depends on $\sigma_\varepsilon^2/\sigma_\eta^2$, a change in the V_t might be associated either with an increase or a decrease in λ. That differences in the source of change in the v_t might be important in explaining the different patterns of change in β_3 associated with change in v_t is suggested by a comparison of the $\sigma_\varepsilon^2/\sigma_\eta^2$ ratios for the cotton and wheat states. This ratio can be estimated for each state's price series by application of the varying-parameter technique to a regression of the price on a simple constant, specifying $\Sigma_u = \Sigma_\omega = [1]$. This procedure generates estimates of $\gamma = \rho/(1+\rho)$ for the price series of each state. These $\hat{\gamma}$ displayed in Table 6 show clearly that the cotton price series differ from the wheat price series in having smaller ratios of $\sigma_\varepsilon^2/\sigma_\eta^2$.

{Insert Table 6}

Although most southern states have ratios of $\hat{\gamma}/\hat{\sigma}_\gamma$ suggestive of some permanent variation, the average $\hat{\gamma}$ for the wheat states is more than four times the average of $\hat{\gamma}$ for the cotton states. Permanent changes in the wheat price series were relatively more important than were permanent changes in the cotton price series.

The analysis can be pushed even farther, and a direct test of the Muth hypothesis (i.e., that farmers were rational in the Muth sense) performed.

The direct test involves estimating the value of γ or ρ for 5-year segments of the relative price series of each state. These estimates for the 5-year period ending in year t will be referred to as measures of the "temporary relative variance" of the price series, and will be written as γ_t and ρ_t, in analogy with the 5-year temporary variances V_t. These successive γ_t capture the changing decomposition of the price into permanent and transitory components only imperfectly, but they should nevertheless contain some information on the relative contributions of permanent and transitory changes. Correlations of the temporary relative variances with the parameters estimated at the successive base years, as well as correlations of the first differences of these estimates, are contained in Table 7.

{Insert Table 7}

It is immediately seen that the Muth hypothesis is confirmed. In both the cotton states and the wheat states, the overwhelming majority of correlations between the temporary relative variance and the β_3 estimates are negative, exactly as required by the Muth analysis (since $d\lambda/d\rho < 0$). There is one exception to the predicted pattern of first differences out of the 10 cotton states, and five exceptions out of the 17 wheat states. The undifferenced correlations show two exceptions in the cotton states, and either three or four exceptions for the wheat states, depending on which measure of temporary relative variance is used.

Up to this point, the discussion has been primarily concerned with the interaction between the price variable and β_3, the coefficient of S_{t-1}.

Examination of the estimated form of the supply function shows why β_2 (the coefficient of P_{t-1}) and β_3 might be expected to move in opposite directions. From equations (5) and (11), $\beta_3 = \lambda$ and $\beta_2 = \alpha_2(1-\lambda)$. If α_2 were constant, the correlation between the $\hat{\beta}_2$ and the $\hat{\beta}_3$ would be -1. However, given independent variation in the long-run elasticity α_2, the correlation between the $\hat{\beta}_2$ and the $\hat{\beta}_3$ will not be perfect. Thus while the various measures of temporary price variability (v_t, γ_t and ρ_t) might be expected to be correlated with the $\hat{\beta}_2$ in the opposite direction from their correlation with the $\hat{\beta}_3$, the correlations with $\hat{\beta}_2$ may not be as unambiguous as those with $\hat{\beta}_3$. The correlations between γ_t and ρ_t with $\hat{\beta}_2$ are generally in the expected direction, although the associations are somewhat weaker than the associations with $\hat{\beta}_3$ in both the cotton and wheat states. This is consistent with the fact that the Muth hypothesis makes no prediction of the direction of the relationship (or even the existence of a relationship) between α_2 and ρ, in contrast to the unambiguous connection predicted between β_3 and ρ.

It should also be pointed out that the negative correlation between $\hat{\beta}_3$ and $\bar{\rho}$ does not appear to hold <u>across</u> states. It would be too much to expect that the structural parameters of each state's supply function were determined entirely by Muth-type considerations. Differences in the crop mix, aggregation weights, and other underlying conditions of supply can be expected to condition the values of the structural parameters, leading to variation in those parameters across states and regions. The unique advantage of the varying parameter estimation method in this context is that it allows a test of the Muth hypothesis <u>within</u> each state.

This is equivalent to controlling for all the other structural differences between states. Indeed, such strong empirical evidence of the Muth effect could hardly have been developed without the varying parameter estimation methods.

It might be thought that the evidence for the validity of the Muth hypothesis is not overwhelming on the basis of the correlations of Table 7, particularly for the wheat states. A two-tailed binomial test of the null hypothesis of equiprobability of positive and negative signs of the correlations gives the following probability-values:

{Insert Table 8}

The calculated probability-values are low for every sign count, especially if all 27 states are joined into a single sample. But even in the wheat states, the probability-values are low enough to provide strong support for the Muth hypothesis. This is particularly so in light of all the things that could go wrong with the test. Consider the following sources of "noise" in the correlations: (a) There is no a priori reason for choosing a 5-year interval for the successive estimates of γ_t. This choice was made arbitrarily for computational convenience. The relevant period over which price variations influence the structural parameters might be either shorter or longer. (b) The varying parameter estimates calculated on a base period are weighted averages of the permanent components for periods both before and after the base year [Cooley and Prescott 1974; see also footnote 10 above]. The weights assigned to distant years decline, but nevertheless the estimated values of the structural parameters include information from the "future" occuring after each base period. Needless to say, this information could not have been possessed by the farmers, and it is not included in the estimates of the γ_t. (c) The wheat model may be less well specified than the cotton model because of the problem of aggregating winter wheat and spring wheat. The timing of the model matches the timing of the decisions to plant spring wheat, but the price (P_{t-1} is the December 1 price in year t-1) is only correlated with the price information available to farmers making decisions about planting winter wheat [Higgs 1971, Fisher and Temin 1971]. Thus, as winter wheat became a more important part of the wheat crop, the specification of the wheat model becomes poorer. (d) As is obvious from equation (10), β_3 $(=\lambda)$ is not a linear function of either ρ or γ. This nonlinearity will tend to reduce the linear correlation coefficient between $\hat{\beta}_3$ and ρ_t, or between their first differences. (e) In addition to all these difficulties, the correlations are all based on relatively small samples---eight observations for the first-difference correlations and nine for the undifferenced correlations. Thus, a substantial amount of pure sampling error might be expected.

Aside from any of these probabilistic points, however, the strongest support these correlations provide for the existence of the Muth effect is the way they totally eliminate the need for separate explanations of the parameter trends and variations for the cotton and wheat states. The results of Table 7 show that the behavior of both cotton and wheat farmers is consistent with the same model of price prediction, a model based on a natural optimal decision rule. There is no need for ad hoc theorizing concerning the origins of structural variation. Differences in observed responses on the part of the two major groups of farmers may therefore be identified as stemming from differences in the structure and operation of the output markets for wheat and cotton.

Given these strong indications of the presence of the Muth effect and of the influence of price variability on the decision-making process, two questions remain: (1) Exactly what was perceived by the farmers in their scrutiny of the price history for their products? (2) Is there any way to account for the difference in the nature of the relative cotton price series from that of the relative wheat price series? When these two questions are answered, or at least when plausible answers are sketched, it will be possible to draw some final conclusions regarding the origins and course of the agrarian unrest of the 1880's and 1890's.

It is, of course, patently obvious that no nineteenty-century farmer spent his time decomposing the time series of relative crop prices into permanent and transitory components or mathematically computing variances and standard deviations of the price over its recent history. However, the farmers are likely to have been aware of price fluctuations, and of certain qualities of those price fluctuations which appear in the mathematical treatment as the permanent and transitory components of variation. Permanent changes in the price are just that---changes whose effects persist over time. A high ratio of the variance of the permanent component of the price to the variance of the transitory component represents a relatively large amount of permanent change in the price history as compared to the transitory fluctuations. Is it likely that the farmers would have been aware of this distinction?

In reality, low ρ would be manifested in a price series that fluctuated "randomly." Since the variance of the component of permanent change would be small, almost all price fluctuations would be due to the transitory component, the effects of which do not persist. On the other hand, if ρ were large, the price series would be characterized by large shifts that would persist over time, and the magnitude of these shifts would be large relative to the transitory fluctuations of the price. One characteristic of a price series with low ρ would be that it would display hardly any autocorrelation of the residuals around its mean value, while a series with substantial permanent variation would display substantial autocorrelation of its residuals. In fact, the cotton and wheat price series exhibit exactly the pattern of autocorrelation that would be expected, given their γ [and ρ] values of Table 6. Table 9 lists the Durbin-Watson statistics computed for the residuals of the relative price series for each state when regressed on a simple constant.

{Insert Table 9}

It can be seen from this table that only the price series for North Carolina and Tennessee of the cotton states show significant autocorrelation at the 5% level, while only California, North Dakota and South Dakota of the wheat states fail to show a significant degree of autocorrelation.[15]

How would such price histories appear to the farmers? With small values of ρ and slight (if any) autocorrelation, the relative cotton price would appear to fluctuate randomly. There would be no tendency for a year of high cotton prices (relative to the long-term average) to be followed by another good year, or for a year of low cotton prices to be followed by another poor year. Any large increase in the variability of the cotton price would be interpreted (by an observant farmer) as only a larger-than-average temporary fluctuation. Thus, for cotton farmers the optimal prediction of the future price would tend to discount the information contained in recent values of a widely-fluctuating price. The relative price of wheat, on the other hand, was subject to permanent shifts. A year of higher-than-average price was often followed by more years of higher-than-average prices. The observant farmer might well expect a large fluctuation in the wheat price to persist, so his optimal prediction of the future price would heavily weight the information of a recent fluctuation.

This pattern of wheat price fluctuations has been commented upon before, but the conclusion has always been drawn that farmers were confused and bewildered by the behavior of the prices [See quotation from North 1974 given in Section I; Gray and Peterson 1974, p. 320]. But the existence of the Muth effect shows that at least a substantial number of both wheat and cotton farmers were well aware of the price fluctuations for their crops, as well as the pattern of those fluctuations, and acted accordingly. Wheat farmers did weight current information more heavily just after a large fluctuation, and cotton farmers tended to discount such information in predicting the future price. Both groups of farmers discounted recent information when the variance of the transitory component of the price was increasing relative to the variance of the permanent component of the price. In short, the results confirm that a sizeable number of nineteenth-century farmers were keen observers of not only the levels of relative prices for their products, but also of the patterns of price variability. Agriculturalists in both the wheat producing states and the cotton South were conscious of far more of the information contained in the price histories of their outputs than they have hitherto been given credit for utilizing.

Even if farmers were able to incorporate the information contained in the price histories in making planting decisions, the source of the difference in the behavior of the relative price series of the two regions remains to be explained. Why did the wheat price show substantially higher permanent variation than the cotton price? No final answer can be given here, but an informed guess is possible. It is first necessary to digress for a brief consideration of the economic forces affecting the price of an agricultural commodity.

For any commodity produced under competitive conditions and traded in a world market (as both wheat and cotton were after the Civil War), the price in any given year is determined by supply and demand. For these agricultural products, supply at the end of any crop year depends on the price which had been expected to prevail at harvest time (which influenced the planting decisions of farmers) and weather conditions determining yields in the current crop year. (We will ignore carry-over stocks and inventories to simplify the discussion.) The year's crop will normally be thrown onto the market and the market-clearing price will be determined by the intersection of the nearly vertical short-run supply curve with the demand curve. From year to year, the short-run supply curve will shift according to the forces listed above but the demand curve will be shifting as well, due mainly to demographic changes, long-term economic growth, and income variations associated with the business cycle.

Now suppose that one set of price-responsive suppliers produces most of the world's output of a commodity. An exogenous and unforseen increase in demand (due, for example, to a cyclical boom) will increase the price in the current year, thereby stimulating increased production in the succeeding years. If the expansion in demand does not persist, the observed annual price of the commodity will fluctuate randomly. Even if demand shifts do persist, the increased production elicited by them will to some extent cancel out the price increases brought about by the increases in demand. The same process applies to decreases in demand. Thus even persisting demand shifts will not necessarily elicit large permanent changes in the price of the commodity. On the other hand, suppose the subset of price-responsive producers contributes only a small portion of the world's supply. In this case, persisting shifts in demand would tend to be associated with larger and longer-lasting deviations of the world price from its average or trend value.

Just as the persistence of fluctuations in the commodity's price depends upon the degree of price-responsiveness of the producers, the volatility of demand and variance of yields will condition the mixture of "permanent" and "transitory" components of price variation. Rapid and random shifts in demand will tend to produce transitory price fluctuations, while factors which reduce the yield variance of the agricultural commodity will increase the ratio of permanent variance to transitory variance in the price. These factors provide the key to explaining the difference in the behavior of the cotton and wheat price relatives.

First, wheat constituted one of the major food crops of the world, and it is natural to think that demand for it would be less susceptible to cyclical fluctuations in income than would be the demand for cotton products. Second, wheat was grown all over the world, while cotton production was concentrated in the United States and a few other countries. This geographical dispersion of the wheat crop may have tended to reduce the weather-associated yield variance of the world wheat crop relative to the world cotton crop, since cotton production was much more localized. Finally, both wheat and cotton producers in the United States were price-responsive, but while U.S. cotton constituted the majority of the world's output after the Civil War, U.S. wheat production amounted to only around one-quarter of the world's crop.

{Insert Table 10}

It is not implausible to think that wheat producers in the other countries of the world were less price-responsive than American producers. American agriculture in the late nineteenth and early twentieth centuries was surely more progressive and commercialized than the agriculture of the non-European wheat producers.

Even if European producers were as price-responsive as their American counterparts, European governments began erecting high tariff walls around their wheat farmers after 1880. By 1900, the effective levels of protection in France and Germany amounted to 40¢ per bushel, and in Italy to over 20¢ per bushel [Malenbaum 1953, p. 162]. These tariffs were substantial in comparison to the wheat price of 62.1¢ per bushel received by American farmers in 1900 [Agricultural Statistics 1937, p. 9], and France, Germany and Italy accounted for an average of 56% of total European wheat production (excluding Russia) over the period 1894-1899 [Computed from Malenbaum 1953, p. 238-239].

Given a specific tariff of ψ on a bushel of wheat, an x% increase in the world price per bushel P results in only an $x/(1 + (\psi/P))$% increase in the price in the protected region.[16] The tariff therefore is responsible for a less-than-proportional price increase in the protected countries. The effect is to reduce the magnitude of the supply response from the protected countries, even if the elasticity of response of the farmers in those countries were identical to that of United States wheat producers. This effect is likely to have been important, since over the years covered in Table 10, United States wheat production accounted for only an average of 34.8% of European (excluding Russia) plus United States output.

It is highly likely then, that differences in world market conditions were responsible for the disparate characteristics of the price histories of American wheat and cotton. This source of patterns in the price histories coupled with Muth-optimal behavior on the part of both cotton and wheat farmers suggest some new interpretations of the economic basis of Populism and its related agrarian distress.

V. Concluding Speculations.

The results of the previous section support the predictions of economic theory in explaining farmers' response to price. Farmers were neither unresponsive to price changes nor insensitive to the history of fluctuations in the prices of their agricultural products. Enough farmers behaved optimally in the Muth sense to enable their reactions to be detected at the state-wide level of aggregation. Of course, the rational behavior of a substantial number of farmers does not preclude bewilderment or sub-optimal reactions on the part of many other farmers. But in a larger sense, even the farmers who were fully aware of their situation may not have been immune from economic distress.

For the wheat producers, the existence of permanent changes in the price of their cash crop presented them with unique problems of response. Autocorrelation of the relative wheat price opened the possibility of obtaining a real advantage by quick action in the event of a price change. Since price increases could be permanent, a "bonanza" approach to expansion of wheat acreage could pay large dividends. On the other hand, not all price fluctuations were permanent, so some farmers who rapidly revised their price expectations in response to some of the fluctuations must have been disappointed. Even if rapid expansion were temporarily successful, a period of greater-than-average prices could be followed by a period of less-than-average prices with distressing suddenness. And bad years associated with world business cycles might induce acreage contraction without any subsequent price increase following the reduction in American supply. The autocorrelated price series indicates that both good and bad years tended to come in clumps. Painful experiences due to this fact may have been responsible for the overall decline in price-responsiveness by farmers over the entire period, but in any case, awareness of these possibilities and attempts to adapt to them would not necessarily have guaranteed even the most intelligent farmers security from disaster.

As for the cotton farmers, it is possible that their preoccupation with the issue of cotton "overproduction" [DeCanio 1973 and 1974b] was derived from their awareness of the fact that the South dominated world cotton supply. Perceptive men must have realized that if only Southern farmers had been able to act in concert, they could have eliminated the depressing impact of the increased production that inevitably followed a year or years of high cotton prices. The very price-responsiveness of Southern farmers prevented them from realizing the full benefits of demand-induced booms.[17]

It was not the farmers' ignorance or irrationality that led to their difficulties. On the contrary, all evidence points to a remarkable degree of sophistication in their evaluation of the historical market data available to them. The perception of and adaptation to risks does not make those risks easier to bear, especially when practicable alternatives are severely limited. Despite the best efforts of the farmers to preserve their situation, the ultimate outcome for American agriculture was its reduction to the status of one sector among many, although it inherited its minority position with a rich patrimony of special economic privileges. In the process of the transition, many individual farming enterprises failed and their owners or operators were driven to other occupations in the urban centers. But the sufferings and discontents accompanying the final full commercialization of agriculture were not the result of the farmers' inability to function well in a demanding market environment. Populist America would have had to transcend somehow its market institutions in order to distribute equitably both the risks and gains offered by the technology and organization of agricultural production, and it was this challenge which the Populists and all their contemporaries ultimately proved unable to meet.

Notes

1. For a discussion of the possible types of structural change in models spanning extended periods of historical time, see [David 1971, pp. 464-467]. A recent discussion concerning parameter change in agriculture in the context of a model slightly different from that employed in the present paper is contained in [Sahi and Craddock 1974]. Lucas [1973] argues that dynamic economic theory implies that macro-economic parameters are unlikely to be stable over time.

2. In the subsequent section we shall clarify our view of "rational behavior" on the part of farmers; our only purpose here is to set the task and to anticipate some of the major findings and possible interpretations of the statistical results. It goes without saying that the econometric results stand independent of the interpretations that may be placed upon them. The data and estimates derived from them give good advice in the writing of history; it is the historians who are responsible for all remaining errors.

3. All variables are in natural logarithms. For a discussion of the data and its sources, see [Fisher and Temin 1970 and DeCanio 1973 and 1974]. The only difference in the data used in this paper and the data used in the previous studies is that the cotton price series was extended backward from 1882 to 1870 by substituting an average U.S. cotton price [Historical Statistics 1949, Series E 220, p. 108] for the unavailable state cotton prices used after 1882. The correlation between the U.S. price and the state prices was quite high after 1882, because of the competitiveness of the national cotton market, and it is unlikely that any substantial error is introduced by use of the national price for the years prior to 1882.

4. [Fisher and Temin 1970 and DeCanio 1974] estimated values of β_4 from equations similar in form to (1) which were not significantly different from zero, and the estimates of β_4 together with the estimates of the other coefficients would, if taken at face value, have implied values of μ and θ which were either imaginary or outside the zero-to-one range.

5. Nerlove also finds it plausible "that the elasticity of expectations is a decreasing function of the typical variance of prices....The result indicates that the behavior parameter β [which is analogous to θ of equation (4) in our notation] may be subject to a number of influences over time some of which are related to the characteristics of the market under investigation [Nerlove 1958, p. 59]." In addition to citing confirmation of an inverse relationship between the coefficient of expectations (β) and the variability of the outcomes found by Modigliani and Sauerlender [Nerlove 1958, p. 59], Nerlove himself finds the same inverse relationship between his coefficients of expectations and the year-to-year variability of the prices of the various crops [Nerlove 1958, p. 221]. Nerlove does not explicitly provide an optimizing theory of this relationship, however.

6. At a minimum, the required data would include information on changes in the costs of being out of equilibrium and changes in the costs of shifting from one crop to the other. Furthermore, models relating partial adjustment to maximizing behavior on the micro level have not "fared as well" as adaptive expectations formulations [Griliches, pp. 42-43].

7. According to Muth, it is not necessary to assume that ε_t and η_t are uncorrelated. "If $E\varepsilon_t\eta_t = \sigma_{\varepsilon\eta}$ and $E\varepsilon_t\eta_s = 0$ $(t \neq s)$, it is only necessary to replace the ratio $\sigma_\varepsilon^2/\sigma_\eta^2$ in [equation (10)] by $\sigma_\varepsilon^2/(\sigma_\eta^2+\sigma_{\varepsilon\eta})$ [Muth 1960, p. 304]."

8. Cooley and Prescott [1973a, p. 254] report the results of Monte Carlo experiments which lend support to this view.

9. It may be that the break which seems to have occurred around World War I is one of those historical instances alluded to by David which require a "succession of working models, each appropriate to a particular social, temporal and technological setting [David 1971, p. 466]." In any case, work is currently being planned to enlarge the model and extend the sample even beyond 1925.

10. Estimation in this context resembles exponential smoothing with observations distant in time from the base period receiving small weights.

11. If the β_3 coefficients estimated by the varying-parameter technique are least affected by misspecification bias, it follows that the estimated "speeds of adjustment" $(1-\beta_3)$ of the fixed-parameter models are probably too low. The implication is that distress and temporary overproduction resulting from sluggishness in the response of farmers to relative price changes is even less likely than might have been thought on the basis of the previous results.

12. It may also be noted that if $1-\beta_3$ is interpreted as the "speed of adjustment" as in [DeCanio 1973], the fact that β_3 decreases in eight of the ten Southern states suggests increasing flexibility in farmers' adjustments to price changes.

13. Except for the 1869 base year for the wheat states, since prices for the 5-year period ending in 1869 were not available.

14. $\lambda = 1 + (1/2)\rho - \rho^{1/2}(1+(1/4)\rho)^{1/2} = 1 + (1/2)\rho - (\rho+(1/4)\rho^2)^{1/2}$

$d\lambda/d\rho = (1/2) - (1/2)(\rho+(1/4)\rho^2)^{-(1/2)}(1+(1/2)\rho)$

Let $h(\rho) = (1+(1/2)\rho)(\rho+(1/4)\rho^2)^{-(1/2)}$

Is $h(\rho) > 1$ for all $\rho > 0$?

First, $h(\rho)$ is a monotonic function. This is true because h is continuous and $h' \neq 0$. For if $h'(\rho) = 0$,

$$h' = (1+(1/2)\rho)(-1/2)(\rho+(1/4)\rho^2)^{-(3/2)}(1+(1/2)\rho) + (1/2)(\rho+(1/4)\rho^2)^{-(1/2)} = 0$$

Multiply both sides by $(\rho+(1/4)\rho^2)^{1/2}$:

$$(1+(1/2)\rho)^2(-1/2)(\rho+(1/4)\rho^2)^{-1} + (1/2) = 0$$

Multiply by $(\rho+(1/4)\rho^2)$:

$$(-1/2)(1+(1/2)\rho)^2 + (1/2)(\rho+(1/4)\rho^2) = 0$$

$$-(1+\rho+(1/4)\rho^2) + (\rho+(1/4)\rho^2) = 0$$

$-1 = 0$, a contradiction.

So $h'(\rho) \neq 0$ for any ρ, and h is a monotonic function.

Now, as $\rho \to 0$, $h(\rho) \to \infty$.

As $\rho \to \infty$, $h(\rho) = ((1/\rho)+(1/2))((1/\rho)+(1/4))^{-(1/2)} \to 1$

So as $\rho \to \infty$, $h(\rho) \to 1$ from above, so $h(\rho) > 1$ for all $\rho > 0$.

Thus $d\lambda/d\rho < 0$.

15. It should also be noted that the observations for North and South Dakota span a shorter period then the other wheat states, reducing the likelihood of finding significant autocorrelation in their price series.

16. $x = \Delta P/P$, so if $y =$ the percentage change in the protected country, $y = \Delta(P+\psi)/(P+\psi) = \Delta P/(P+\psi) = (\Delta P/P)/(1+(\psi/P)) = x/(1+(\psi/P))$.

17. In addition, slow growth in total demand for American cotton may have contributed to the relative stagnation of the postbellum Southern economy [Wright 1974].

TABLE 1

VARYING-PARAMETER ESTIMATES, $\sum_u = \sum_v = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

COTTON STATES, 1870-1914; WHEAT STATES, 1867-1914

State	Base Year	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\alpha}_2$
North Carolina	1874	-1.466 (.193) -7.600	.273 (.066) 4.118	.537 (.131) 4.090	.590
	1914	-1.390 (.184) -7.563	.331 (.062) 5.349	.445 (.142) 3.131	.596
South Carolina	1874	-.583 (.102) -5.742	.119 (.039) 3.079	.641 (.127) 5.051	.332
	1914	-.542 (.095) -5.717	.150 (.032) 4.661	.605 (.136) 4.446	.379
Georgia	1874	-.717 (.121) -5.920	.119 (.048) 2.472	.518 (.148) 3.502	.248
	1914	-.646 (.114) -5.673	.158 (.042) 3.720	.465 (.158) 2.937	.295
Florida	1874	-1.094 (.186) -5.898	.161 (.044) 3.645	.164 (.170) .964	.193
	1914	-1.191 (.198) -6.012	.064 (.046) 1.399	.236 (.153) 1.544	.084
Tennessee	1874	-1.663 (.271) -6.132	.287 (.067) 4.291	.518 (.154) 3.371	.596
	1914	-1.638 (.273) -6.004	.294 (.069) 4.245	.465 (.149) 3.122	.550

TABLE 1 (Continued)

State	Base Year	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\alpha}_2$
Alabama	**1874**	-.734 (.099) -7.398	.083 (.032) 2.578	.309 (.150) 2.067	.120
	1914	-.687 (.095) -7.198	.116 (.032) 3.647	.286 (.156) 1.836	.163
Mississippi	**1874**	-.620 (.082) -7.525	.107 (.030) 3.571	.379 (.142) 2.658	.172
	1914	-.591 (.083) -7.116	.084 (.031) 2.692	.376 (.141) 2.658	.134
Arkansas	**1874**	-.954 (.130) -7.363	.181 (.041) 4.353	.389 (.152) 2.557	.296
	1914	-.896 (.130) -6.895	.189 (.042) 4.497	.340 (.153) 2.223	.286
Louisiana	**1874**	-.528 (.119) -4.425	.142 (.049) 2.926	.566 (.185) 3.064	.328
	1914	-.560 (.121) -4.642	.107 (.059) 1.809	.589 (.149) 3.945	.261
Texas	**1874**	-.600 (.104) -5.775	.101 (.035) 2.892	.551 (.146) 3.779	.225
	1914	-.494 (.090) -5.469	.145 (.033) 4.435	.490 (.158) 3.097	.284

TABLE 1 (Continued)

State	Base Year	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\alpha}_2$
Iowa	1874	-1.099 (.243) -4.519	.196 (.051) 3.807	.783 (.113) 6.956	.899
	1914	-1.130 (.259) -4.366	.153 (.074) 2.061	.806 (.094) 8.560	.790
California (1869-1914)	1874	-.349 (.406) -.859	.040 (.089) .444	.735 (.125) 5.864	.149
	1914	-.367 (.407) -.901	-.031 (.097) -.322	.744 (.106) 6.988	-.122
Kansas	1874	-1.588 (.380) -4.178	.168 (.109) 1.552	.430 (.182) 2.357	.295
	1914	-1.548 (.391) -3.961	.288 (.121) 2.371	.359 (.213) 1.684	.449
Nebraska	1874	-.788 (.156) -5.058	.100 (.035) 2.889	.487 (.132) 3.683	.195
	1914	-.805 (.171) -4.705	.033 (.052) .640	.499 (.136) 3.673	.067
Minnesota (1868-1914)	1874	-.725 (.118) -6.146	.148 (.027) 5.475	.750 (.104) 7.179	.592
	1914	-.747 (.123) -6.087	.096 (.035) 2.731	.766 (.099) 7.721	.412
Illinois	1874	-2.409 (.397) -6.065	.091 (.078) 1.165	-.232 (.183) -1.266	.074
	1914	-2.451 (.402) -6.095	-.039 (.098) -.403	-.202 (.167) -1.213	-.033

TABLE 1 (Continued)

State	Base Year	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\alpha}_2$
Maryland	1874	-.566 (.139) -4.068	.048 (.023) 2.053	.687 (.114) 6.039	.152
	1914	-.563 (.139) -4.061	.056 (.024) 2.331	.684 (.114) 5.975	.178
Michigan	1874	-1.770 (.333) -5.314	.285 (.067) 4.278	.584 (.132) 4.428	.686
	1914	-1.795 (.336) -5.349	.223 (.079) 2.830	.608 (.118) 5.140	.568
Missouri	1874	-1.018 (.246) -4.137	.004 (.043) .090	.439 (.139) 3.154	.007
	1914	-1.004 (.251) -4.008	-.001 (.053) -.019	.399 (.143) 2.785	-.002
Wisconsin	1874	-1.658 (.422) -3.930	.322 (.090) 3.594	.807 (.106) 7.617	1.671
	1914	-1.683 (.427) -3.944	.241 (.101) 2.381	.830 (.083) 10.040	1.413
Indiana	1874	-1.630 (.431) -3.786	.055 (.094) .583	-.190 (.182) 1.040	.046
	1914	-1.663 (.432) -3.849	-.064 (.110) -.582	-.168 (.167) -1.010	-.055
Virginia	1874	-.812 (.185) -4.385	.075 (.025) 2.959	.668 (.115) 5.803	.226
	1914	-.813 (.186) -4.369	.075 (.030) 2.542	.669 (.114) 5.896	.227

TABLE 1 (Continued)

State	Base Year	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\alpha}_2$
Pennsylvania	1874	-1.143 (.229) -5.002	.062 (.026) 2.427	.466 (.139) 3.361	.117
	1914	-1.150 (.230) -4.998	.041 (.030) 1.348	.475 (.135) 3.513	.077
New York	1874	-2.289 (.451) -5.079	.122 (.056) 2.183	.317 (.149) 2.131	.179
	1914	-2.302 (.453) -5.079	.064 (.062) 1.037	.347 (.138) 2.520	.099
Ohio	1874	-1.398 (.306) -4.572	.119 (.067) 1.771	.413 (.162) 2.553	.203
	1914	-1.412 (.307) -4.598	.096 (.078) 1.228	.416 (.157) 2.655	.164
North Dakota (1883-1914)	1884	-.767 (.268) -2.862	.137 (.060) 2.290	.226 (.180) 1.255	.177
	1914	-.784 (.270) -2.904	.083 (.059) 1.403	.229 (.177) 1.293	.107
South Dakota (1883-1914)	1884	-.572 (.181) -3.169	.067 (.038) 1.764	.594 (.153) 3.879	.166
	1914	-.586 (.182) -3.220	.035 (.041) .840	.608 (.151) 4.018	.089

Notes: The numbers in parentheses just to the right of the parameter estimates are the standard errors of the estimates; the numbers directly below the standard errors are the t-ratios of the parameter estimates to their standard errors.

TABLE 2

ESTIMATES OF γ AND σ_γ IN SUPPLY FUNCTIONS, WITH $\hat{\gamma}/\hat{\sigma}_\gamma$ RATIOS

Cotton State	$\hat{\gamma}$	$\hat{\sigma}_\gamma$	$\hat{\gamma}/\hat{\sigma}_\gamma$
North Carolina	.5131	.2148	2.389
South Carolina	.2578	.2018	1.278
Georgia	.3455	.2416	1.430
Florida	.3266	.1823	1.792
Tennessee	.3796	.2255	1.683
Alabama	.3098	.2117	1.463
Mississippi	.5251	.2213	2.373
Arkansas	.2832	.2139	1.324
Louisiana	.6833	.2052	3.330
Texas	.3224	.2262	1.425

Note: Sample period 1870-1914, $\Sigma_u = \Sigma_\omega = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

TABLE 2 (Continued)

ESTIMATES OF γ AND σ_γ IN SUPPLY FUNCTIONS, WITH $\hat{\gamma}/\hat{\sigma}_\gamma$ RATIOS

Wheat State	$\hat{\gamma}$	$\hat{\sigma}_\gamma$	$\hat{\gamma}/\hat{\sigma}_\gamma$
Iowa	.5373	.2222	2.418
California	.3207	.2201	1.457
Kansas	.3390	.2699	1.256
Nebraska	.5691	.2283	2.493
Minnesota	.6557	.2032	3.227
Illinois	.3808	.1958	1.945
Maryland	.3554	.2288	1.553
Michigan	.2671	.1903	1.404
Missouri	.4999	.2558	1.954
Wisconsin	.1838	.1551	1.185
Indiana	.2190	.1397	1.568
Virginia	.4496	.2376	1.892
Pennsylvania	.3980	.2767	1.438
New York	.4153	.2709	1.533
Ohio	.2126	.1992	1.067
North Dakota	.3989	.2390	1.669
South Dakota	.4178	.2496	1.674

Note: Sample period 1867-1914, except California, 1869-1914; Minnesota 1868-1914; North and South Dakota, 1883-1914.

$$\Sigma_u = \Sigma_\omega = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

TABLE 3

COMPARISON OF VARYING-PARAMETER, OLS, AND FIRST-ORDER AUTOCORRELATED DISTURBANCE ESTIMATES OF β_3

Wheat State	Varying-Parameter Estimates Base Year 1874	Varying-Parameter Estimates Base Year 1914	OLS	Autocorrelated Disturbance
Iowa	.783	.806	.940	.848
California	.735	.744	1.022	.933
Kansas	.430	.359	.897	.746
Nebraska	.487	.499	.937	.929
Minnesota	.750	.766	1.020	.765
Illinois	-.232	-.202	.737	.720
Maryland	.687	.684	.899	.815
Michigan	.584	.608	.922	.755
Missouri	.439	.399	.803	.590
Wisconsin	.807	.830	.976	.728
Indiana	-.190	-.168	.580	.0682
Virginia	.668	.669	.826	.784
Pennsylvania	.466	.475	.884	.909
New York	.317	.347	.908	.848
Ohio	.413	.416	.809	.789
North Dakota	.226	.229	.845	.650
South Dakota	.594	.608	1.004	.880

Notes: (1) The OLS regressions did not include a trend; sample period 1868-1914; except 1869-1914 for California and Minnesota; 1883-1914 for North Dakota and South Dakota.

(2) The autocorrelated disturbance regressions did include a trend; the sample period was 1867-1914. These estimates are taken from [Fisher & Temin 1970].

TABLE 3 (Continued)

COMPARISON OF VARYING-PARAMETER, OLS, AND FIRST-ORDER AUTOCORRELATED DISTRUBANCE ESTIMATES OF β_3

Cotton State	Varying-Parameter Estimates Base Year 1874	Varying-Parameter Estimates Base Year 1914	OLS	Autocorrelated Disturbance
North Carolina	.537	.445	1.029	.591
South Carolina	.641	.605	.954	.576
Georgia	.518	.465	.967	.589
Florida	.164	.236	.912	.464
Tennessee	.518	.465	.700	.747
Alabama	.309	.286	.862	.539
Mississippi	.379	.376	.826	.453
Arkansas	.389	.340	.564	.560
Louisiana	.566	.589	.942	.679
Texas	.551	.490	.978	.457

Notes: (1) The OLS regressions did not include a trend; sample period 1870-1914.

(2) The autocorrelated disturbance regressions did include a trend, and the sample period was 1883-1914. These estimates were taken from [DeCanio 1973].

TABLE 4

SIMPLE CORRELATIONS BETWEEN VARYING-PARAMETER ESTIMATES AND TREND

Cotton State	Corr($\hat{\beta}_2$, t)	Corr($\hat{\beta}_3$, t)	Corr($\hat{\alpha}_2$, t)
North Carolina	.599	-.928	-.454
South Carolina	.593	-.953	.255
Georgia	.578	-.980	.237
Florida	-.891	.883	-.893
Tennessee	-.466	-.672	-.897
Alabama	.817	-.967	.782
Mississippi	-.388	-.480	-.433
Arkansas	-.244	-.951	-.575
Louisiana	-.544	.688	-.505
Texas	.911	-.993	.823

Notes: (1) Sample period 1870-1914; parameters estimated at five-year intervals, beginning in 1874 and ending in 1914. Number of base years at which parameters estimated = 9.

(2) $\hat{\alpha}_2 = \hat{\beta}_2/(1-\hat{\beta}_3)$

(3) $\Sigma_u = \Sigma_\omega = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

TABLE 4 (Continued)

SIMPLE CORRELATIONS BETWEEN VARYING-PARAMETER ESTIMATES AND TREND

Wheat State	Corr($\hat{\beta}_2$, t)	Corr($\hat{\beta}_3$, t)	Corr($\hat{\alpha}_2$, t)
Iowa	-.676	.731	-.510
California	-.902	.842	-.898
Kansas	.850	-.921	.812
Nebraska	-.727	.568	-.725
Minnesota	-.961	.985	-.950
Illinois	-.895	.748	-.893
Maryland	.671	-.784	.663
Michigan	-.908	.930	-.890
Missouri	-.687	-.904	-.687
Wisconsin	-.967	.950	-.962
Indiana	-.945	.904	-.945
Virginia	-.221	.509	-.194
Pennsylvania	-.826	.846	-.824
New York	-.931	.925	-.928
Ohio	-.619	.498	-.627
North Dakota	-.950	.812	-.951
South Dakota	-.787	.971	-.775

Notes: (1) Sample period 1867-1914 except California (1869-1914), Minnesota (1868-1914), and North and South Dakota (1883-1914). Parameters estimated at five-year intervals beginning in 1869 and ending in 1914. Number of base years at which parameters estimated = 10 (7 for N. and S. Dakota).

(2) $\hat{\alpha}_2 = \hat{\beta}_2/(1-\hat{\beta}_3)$

(3) $\Sigma_u = \Sigma_\omega = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

TABLE 5

SIMPLE CORRELATIONS OF FIRST DIFFERENCES OF VARYING-PARAMETER ESTIMATES AND FIVE-YEAR TEMPORARY PRICE STANDARD DEVIATIONS

Cotton State	$Corr(\Delta\hat{\beta}_2, \Delta v_t)$	$Corr(\Delta\hat{\beta}_3, \Delta v_t)$
North Carolina	-.606	.627
South Carolina	-.745	.641
Georgia	-.704	.481
Florida	-.456	.104
Tennessee	-.189	.223
Alabama	.029	-.100
Mississippi	-.343	.172
Arkansas	-.344	.160
Louisiana	.436	-.470
Texas	-.316	.337

Notes: (1) Δ represents first differencing operator.

(2) Sample period 1870-1914. Parameters estimated at five-year intervals beginning in 1874 and ending in 1914. Number of first differences correlated for each state = 8.

TABLE 5 (Continued)

SIMPLE CORRELATIONS OF FIRST DIFFERENCES OF VARYING-PARAMETER ESTIMATES AND FIVE-YEAR TEMPORARY PRICE STANDARD DEVIATIONS

Wheat State	Corr($\Delta\hat{\beta}_2$, Δv_t)	Corr($\Delta\hat{\beta}_3$, Δv_t)
Iowa	.816	-.662
California	.748	-.637
Kansas	.469	-.459
Nebraska	.505	-.484
Minnesota	.793	-.622
Illinois	-.328	.290
Maryland	.447	-.431
Michigan	.597	-.524
Missouri	.398	-.526
Wisconsin	.339	-.448
Indiana	-.192	.092
Virginia	.563	-.545
Pennsylvania	.006	-.010
New York	.417	-.349
Ohio	.346	-.415
North Dakota	-.107	.035
South Dakota	.125	-.023

Notes: (1) Δ represents first differencing operator.

(2) Sample period 1867-1914, except California, 1869-1914; Minnesota, 1868-1914; North and South Dakota, 1883-1914.

(3) Parameters estimated at five-year intervals beginning in 1874 and ending in 1914, except North and South Dakota, which begin in 1889.

(4) Number of first differences correlated for each state = 8 (5 for North and South Dakota).

TABLE 6

ESTIMATES OF RELATIVE VARIANCE OF PERMANENT AND TRANSITORY COMPONENTS OF THE OBSERVED PRICE

Cotton State	$\hat{\gamma}$	$\hat{\sigma}_{\gamma}$	$\hat{\gamma}/\hat{\sigma}_{\gamma}$
North Carolina	.152	.094	1.613
South Carolina	.040	.058	.700
Georgia	.098	.081	1.212
Florida	.129	.101	1.279
Tennessee	.153	.095	1.609
Alabama	.081	.076	1.069
Mississippi	.050	.062	.802
Arkansas	.064	.065	.985
Louisiana	.084	.078	1.080
Texas	.048	.063	.751
Unweighted Average	.090		

Note: The equation $P_t = \beta_0$ was estimated by the varying parameter technique. The sample period was 1870-1914.

TABLE 6 (Continued)

ESTIMATES OF RELATIVE VARIANCE OF PERMANENT AND TRANSITORY COMPONENTS OF THE OBSERVED PRICE

Wheat State	$\hat{\gamma}$	∂_{γ}	$\hat{\gamma}/\partial_{\gamma}$
Iowa	.200	.220	.908
California	.079	.114	.698
Kansas	.131	.141	.925
Nebraska	.214	.197	1.084
Minnesota	.254	.228	1.114
Illinois	.412	.303	1.359
Maryland	.597	.242	2.465
Michigan	.421	.291	1.448
Missouri	.147	.162	.908
Wisconsin	.589	.299	1.972
Indiana	.584	.279	2.093
Virginia	.644	.222	2.896
Pennsylvania	.792	.166	4.786
New York	.764	.175	4.361
Ohio	.573	.276	2.079
North Dakota	.168	.205	.820
South Dakota	.203	.233	.869
Unweighted Average	.398		

Note: The equation $P_t = \beta_o$ was estimated by the varying parameter technique. The sample period was 1867-1914, except California, 1869-1914; Minnesota, 1868-1914; and North and South Dakota, 1883-1914.

TABLE 7

SIMPLE CORRELATIONS BETWEEN PARAMETER ESTIMATES AND MEASURES OF THE TEMPORARY RELATIVE VARIANCE OF PERMANENT AND TRANSITORY COMPONENTS OF THE PRICE

Cotton State	$Corr(\Delta\hat{\beta}_3, \Delta\rho_t)$	$Corr(\Delta\hat{\beta}_3, \Delta\gamma_t)$	$Corr(\hat{\beta}_3, \rho_t)$	$Corr(\hat{\beta}_3, \gamma_t)$
North Carolina	-.355	-.320	.079	.049
South Carolina	-.118	-.112	-.403	-.404
Georgia	-.120	-.095	-.298	-.261
Florida	-.257	-.289	-.348	-.310
Tennessee	-.079	-.078	-.095	-.038
Alabama	-.419	-.451	-.425	-.397
Mississippi	-.389	-.423	-.376	-.387
Arkansas	-.129	-.146	-.265	-.249
Louisiana	.880	.823	.843	.807
Texas	-.607	-.628	-.433	-.444

otes: (1) $\rho_t = (\sigma_\varepsilon^2/\sigma_\eta^2)_t$, the ratio of permanent to transitory components of variance in the price series, estimated by the varying parameter technique, for the five-year period ending in year t. Note that $\rho_t = \gamma_t/(1-\gamma_t)$

(2) Δ represents first-differencing operator

(3) Sample period is 1870-1914. Parameters estimated at five-year intervals beginning in 1874 and ending in 1914

(4) Number of first differences correlated for each state = 8; number of undifferenced estimates correlated for each state = 9.

TABLE 7 (Continued)

SIMPLE CORRELATIONS BETWEEN PARAMETER ESTIMATES AND MEASURES OF THE TEMPORARY RELATIVE VARIANCE OF PERMANENT AND TRANSITORY COMPONENTS OF THE PRICE

Wheat State	Corr($\Delta\hat{\beta}_3$, ρ_t)	Corr($\Delta\hat{\beta}_3$, $\Delta\gamma_t$)	Corr($\hat{\beta}_3$, ρ_t)	Corr($\hat{\beta}_3$, γ_t)
Iowa	-.212	-.244	-.317	-.365
California	-.691	-.650	.096	-.159
Kansas	.138	.053	-.195	-.173
Nebraska	-.202	-.284	-.447	-.526
Minnesota	-.363	-.394	.025	-.118
Illinois	-.046	-.019	-.431	-.354
Maryland	-.051	.020	.441	.519
Michigan	-.216	-.204	-.079	-.066
Missouri	.635	.556	.460	.435
Wisconsin	.158	.133	-.168	-.228
Indiana	-.061	-.157	-.340	-.311
Virginia	-.027	-.021	-.235	-.208
Pennsylvania	.354	.327	.027	-.022
New York	.106	.160	-.167	-.116
Ohio	-.175	-.206	-.163	-.171
North Dakota	-.511	-.470	-.037	-.065
South Dakota	-.007	-.002	.433	.446

Notes: (1) and (2) same definitions as for cotton states

(3) Sample period is 1867-1914, except California, 1869-1914; Minnesota, 1868-1914; and North and South Dakota, 1883-1914. Parameters estimated at 5-year intervals beginning in 1874 and ending in 1914, except North and South Dakota, which begin in 1889.

(4) Number of first differences correlated for each state = 8 (5 for North and South Dakota); number of undifferenced estimates correlated for each state = 9 (6 for North and South Dakota).

TABLE 8

PROBABILITY-VALUES OF SIGN FREQUENCIES OF CORRELATIONS BETWEEN PARAMETER ESTIMATES AND ESTIMATED VALUES OF TEMPORARY RELATIVE VARIANCE

Cotton States: $n = 10$

Pr(No. of +'s $\leq$ 1 or $\geq$ 9) = .021

Pr(No. of +'s $\leq$ 2 or $\geq$ 8) = .109

Wheat States: $n = 17$

Pr(No. of +'s $\leq$ 3 or $\geq$ 14) = .013

Pr(No. of +'s $\leq$ 4 or $\geq$ 13) = .049

Pr(No. of +'s $\leq$ 5 or $\geq$ 12) = .143

All States: $n = 27$

Pr(No. of +'s $\leq$ 5 or $\geq$ 22) = .001*

Pr(No. of +'s $\leq$ 6 or $\geq$ 21) = .003*

Note: *Normal approximation to the binomial.

TABLE 9

DURBIN-WATSON STATISTICS FOR TESTING AUTOCORRELATION OF THE OBSERVED RELATIVE PRICE

Cotton State	DW	Wheat State	DW
North Carolina	1.1903	Iowa	1.1976
South Carolina	2.1625	California	1.6789
Georgia	1.7048	Kansas	1.2818
Florida	1.6108	Nebraska	1.2568
Tennessee	1.1651	Minnesota	1.2869
Alabama	1.8208	Illinois	0.9693
Mississippi	2.0332	Maryland	0.7295
Arkansas	2.0000	Michigan	0.9679
Louisiana	1.8039	Missouri	1.2187
Texas	2.0914	Wisconsin	1.0056
		Indiana	0.8931
		Virginia	0.6348
		Pennsylvania	0.5609
		New York	0.5639
		Ohio	0.8628
		North Dakota	1.5590
		South Dakota	1.4876

Notes: (1) Sample period 1870-1914 for cotton states; 1867-1914 for wheat states, except California 1869-1914; Minnesota 1868-1914; and North and South Dakota, 1883-1914.

(2) Durbin-Watson statistic calculated for residuals of $P_t = \beta_o + e_t$ estimated by OLS.

(3) For test of autocorrelation at the 5% level of significance, the upper and lower bounds of the DW statistic are 1.57 and 1.48 for the cotton states, and 1.58 and 1.49 for the wheat states (except 1.50 and 1.37 for North Dakota and South Dakota). Source: [Johnston 1972, pp. 430-431]

TABLE 10

SHARES OF REGIONS IN WORLD PRODUCTION OF WHEAT AND COTTON, 1869-1914

Year	Cotton (1)	Cotton (2)	Wheat (3)	Wheat (4)
1859-60		77.9		
1869-70		56.4		
1880-81		72.5		
1885-89			21.6	33.0
1889-94			29.4	37.2
1890-91		70.3	20.1	29.3
1891-92		72.6	29.2	41.7
1892-93		64.5	24.7	36.1
1893-94	56.2	66.9	19.8	32.0
1894-95			21.0	33.2
1895-96			21.8	33.0
1896-97			20.6	31.2
1897-98			26.2	40.9
1898-99			24.8	38.8
1899-1900			24.1	36.3

TABLE 10 (Continued)

Year	Cotton (1)	Cotton (2)	Wheat (3)	Wheat (4)
1900-01			22.0	34.6
1901-02			25.9	40.2
1902-03			21.9	35.7
1903-04			19.7	33.7
1904-05			17.4	32.5
1905-06			20.8	35.8
1906-07			20.8	34.6
1907-08			19.3	34.3
1908-09			19.8	34.8
1909-10	59.2		18.5	35.1
1910-11	63.1		17.1	33.9
1911-12	71.7		16.9	31.1
1912-13	64.9		18.5	35.8
1913-14	63.8		18.1	36.2

TABLE 10 (Continued)

Key to the Columns of Table 10:

(1) U.S. cotton as percentage of total world crop
Sources: 1893: [United States Congress, Senate 1895, vol. I, pp. 501-506]
1909-1914: [United States Department of Agriculture 1937, p. 92]

(2) U.S. cotton as percentage of cotton crop of U.S. + India + Egype + Brazil
Source: [United States Congress, Senate 1895, vol. I, pp. 501-506]

(3) U.S. wheat as percentage of world wheat crop
Sources: 1885-1894: [Malenbaum 1953, pp. 238-239 (excludes China)]
1890-1914: [United States Department of Agriculture 1937, p. 18]

(4) U.S. wheat as percentage of wheat crop of U.S. + Europe excluding Russia
Sources: 1885-1894: [Malenbaum 1953, pp. 238-239]
1890-1914: [United States Department of Agriculture 1937, p. 18]

References

Bowman, John D. 1965. "An Economic Analysis of Midwestern Farm Land Values and Farm Land Income, 1860 to 1900." Yale Economic Essays 5, 2 (Fall 1965): 317-352.

Cooley, Thomas F. 1971. Estimation in the Presence of Sequential Parameter Variation, Unpublished Ph.D. Dissertation, University of Pennsylvania, 1971.

Cooley, Thomas F., and Prescott, Edward. 1973a. "Tests of An Adaptive Regression Model." Review of Economics and Statistics LV, 2 (May 1973): 248-256.

__________. 1973b. "An Adaptive Regression Model." International Economic Review 14, 2 (June 1973): 364-371.

__________. 1973c. "Varying Parameter Regression: A Theory and Some Applications." Annals of Economic and Social Measurement 2, 4 (October 1973): 463-473.

__________. 1974. "Estimation in the Presence of Stochastic Parameter Variation." Unpublished manuscript (February 1974).

David, Paul A. 1971. "Comment" in Frontiers of Quantitative Economics, ed. Intriligator, Michael D. (Amsterdam: North Holland Publishing Co., 1971): 459-467.

DeCanio, Stephen. 1973. "Cotton 'Overproduction' in Late Nineteenth-Century Southern Agriculture." Journal of Economic History XXXIII, 3 (September 1973): 608-633.

__________. 1974a. "Productivity and Income Distribution in the Post-Bellum South." Journal of Economic History XXXIV, 2 (June 1974): 422-446.

__________. 1974b. Agriculture in the Postbellum South: The Economics of Production and Supply. Cambridge, Mass.: M.I.T. Press, 1974 (forthcoming).

Fisher, Franklin M., and Temin, Peter. 1970. "Regional Specialization and the Supply of Wheat in the United States, 1867-1914." <u>Review of Economics and Statistics</u> 52, 2 (May 1970): 134-149.

__________. 1971. "Regional Specialization and the Supply of Wheat in the United States, 1867-1914: A Reply." <u>Review of Economics and Statistics</u> 53, 1 (February 1971): 102-103.

Gallman, Robert E., and Howle, Edward S. 1971. "Trends in the Structure of the American Economy Since 1840." <u>The Reinterpretation of American Economic History</u>, ed. Robert W. Fogel and Stanley L. Engerman. New York: Harper & Row, 1971.

Gray, Ralph, and Peterson, John M. 1974. <u>Economic Development of the United States</u>. Homewood, Illinois: Richard D. Irwin, Inc., 1974.

Griliches, Zvi. 1967. "Distributed Lags: A Survey." <u>Econometrica</u> 35, 1 (January 1967): 16-49.

Harvey, William H. 1895. <u>Coin's Financial School</u>, ed. Richard Hofstadter. Cambridge, Mass.: The Belknap Press of Harvard University Press, 1963.

Higgs, Robert. 1970. "Railroad Rates and the Populist Uprising." <u>Agricultural History</u> XLIV, 3 (July 1970): 291-297.

__________. 1971. "Regional Specialization and the Supply of Wheat in the United States, 1867-1914: A Comment." <u>Review of Economics and Statistics</u> 53, 1 (February 1971): 102-103.

Johnston, J. 1972. <u>Econometric Methods</u>, 2nd edition. New York: McGraw-Hill Book Company, 1972.

Lebergott, Stanley. 1966. "Labor Force and Employment, 1800-1960." National Bureau of Economic Research, Studies in Income and Wealth, Vol. 30: Output, Employment and Productivity in the United States After 1800. New York: Columbia University Press, 1966.

Lucas, R. 1973. "Econometric Policy Evaluation: A Critique." Carnegie-Mellon Working Paper, 1973.

Malenbaum, Wilfred. 1953. The World Wheat Economy. Cambridge, Mass.: Harvard University Press, 1953.

Mayhew, Anne. 1972. "A Reappraisal of the Causes of Farm Protest in the United States, 1870-1900." Journal of Economic History XXXII, 2 (June 1972): 464-475.

Muth, John F. 1960. "Optimal Properties of Exponentially Weighted Forecasts." Journal of the American Statistical Association 55, 290 (June 1960): 299-306.

Nerlove, Marc. 1958. The Dynamics of Supply: Estimation of Farmers' Response to Price. Baltimore: Johns Hopkins Press, 1958.

North, Douglass C. 1974. Growth and Welfare in the American Past, 2nd edition. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1974.

Nowshirvani, Vahid. 1971. "A Modified Adaptive Expectations Model." American Journal of Agricultural Economics 53, 1 (February 1971): 116-119.

Popper, Karl R. 1966. The Open Society and Its Enemies. 2 Vols., 5th edition (1st edition 1943). Princeton, N.J.: Princeton University Press, 1971.

Rosenberg, Barr. 1973. "The Analysis of a Cross Section of Time Series by Stochastically Convergent Parameter Regression." Annals of Economic and Social Measurement 2, 4 (October 1973): 399-428.

Sahi, R. K., and Craddock, W. J. 1974. "Estimation of Flexibility Cofficients for Recursive Programming Models--Alternative Approaches." _American Journal of Agricultural Economics_ 56, 2 (May 1974): 344-350.

United States Bureau of the Census. 1949. _Historical Statistics of the United States, 1789-1945_. Washington: Government Printing Office, 1949.

United States Congress, Senate. 1895. _Report of the Committee on Agriculture and Forestry on Condition of Cotton Growers in the United States, the Present Prices of Cotton, and the Remedy; and on Cotton Consumption and Production_. 53d Congress, 3d Session, Report 986, 2 Vols. Washington: Government Printing Office, 1895.

United States Department of Agriculture. 1937. _Agricultural Statistics 1937_. Washington: United States Government Printing Office, 1937.

Wright, Gavin. 1974? "Cotton Competition and the Post-Bellum Recovery of the American South." _Journal of Economic History_ (forthcoming).

Zellner, Arnold. 1971. _An Introduction to Bayesian Inference in Econometrics_. New York: John Wiley & Sons, Inc., 1971.