A TEST OF ASSET FIXITY IN SOUTHEASTERN U.S. AGRICULTURE

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Abstract

A test for static equilibrium developed by Schankerman and Nadiri is used to evaluate the hypothesis that land and capital in aggregate southeastern U.S. agriculture behave as fixed inputs. Empirical results reject the hypothesis that these two inputs are at their long-run equilibrium levels implied by observed prices. Thus, some degree of asset fixity may be concluded.

Key words: asset fixity, specification tests, static duality.

Examination of the literature on asset fixity over the past 30 years reveals several different explanations for the existence of fixed assets in agriculture. The oldest and perhaps best known explanation for asset fixity is based on arguments related to the divergence of salvage values and acquisition costs (Edwards, 1959; Johnson, 1960, 1982). This explanation has been criticized by Johnson and Pasour (1981) as erroneously treating opportunity costs. Although this criticism has been extensively debated (Johnson, 1982; Johnson and Pasour, 1982), asset fixity based on this notion has yet to be tested empirically.

The absence of empirical tests of fixed asset theory as espoused by Edwards and Johnson is not surprising. This theory is based at the firm level and as noted by Edwards (1985) "... aggregation problems and data limitations make fixed asset analysis difficult at the aggregate level despite its complete simplicity at the farm level" (p. 136). In addition, the theory does not yield hypotheses that are readily testable with the types of aggregate data usually available for empirical analysis (Chambers and Vasavada, 1985).

As such, empirical investigations of asset fixity have produced alternative definitions of asset fixity that have yielded empirically testable hypotheses at the aggregate level of analysis. Chambers and Vasavada (1983) defined asset fixity in technological terms, hypothesizing that the *ex ante* cost function allowed input substitution, but the *ex post* cost function was characterized by fixed proportions. Under this definition, inputs are not fixed because decision makers do not choose to alter their input combinations, but rather because they are unable to substitute inputs.

Chambers and Vasavada (1983) analyzed four aggregate inputs (labor, materials, land, and capital) using a putty-clay model of technology developed by Fuss. While land was held fixed by assumption, their empirical results found no evidence to suggest any fixity in the remaining three inputs.

A second cause of asset fixity is found in the literature on dynamic duality. Within this framework fixity, or more properly quasi-fixity, results from the existence of either internal or external adjustment costs. Asset fixity is implicitly defined in terms of the rate of adjustment of inputs to the long-run equilibrium level implied by current prices. If the hypothesis of instantaneous adjustment to equilibrium in each period is rejected, then some degree of fixity can be concluded.

Taylor and Monson examined aggregate southeastern U.S. agriculture and considered four input categories: labor, materials, land, and capital. Labor and materials were maintained to be variable inputs, with land and capital being treated as potentially fixed. It was found that the hypothesis of instantaneous adjustment of land and capital to long run equilibrium could be rejected and hence some degree of fixity for aggregate land and capital inputs could be concluded.

In contrast with the study by Taylor and Monson, the study of aggregate U.S. agriculture conducted by Vasavada and Chambers considered all input aggregates (labor, materials, land, and capital) as potentially fixed. The results of their analysis found evidence to support the existence of some degree of fixity for labor, land, and capital, but no evidence of fixity for the materials input.

The purpose of this paper is to investigate asset fixity in southeastern U.S. agriculture using a test recently proposed by Schankerman and Nadiri.

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Within the framework of static duality, asset fixity is evaluated by using a short-run variable cost function and evaluating the hypothesis that over the period of analysis, the shadow values in each period of those inputs hypothesized to be fixed are equal to their market (or rental) prices. Rejection of this hypothesis suggests that those inputs under investigation do not adjust to long-run cost minimizing levels in each period and hence exhibit some degree of fixity.

The plan of the paper is as follows. First, the static model used to develop a testable definition of asset fixity is outlined. Second, the Schankerman and Nadiri test is presented. Third, the empirical model and results are presented. Finally, a summary and concluding comments are given.

THEORETICAL CONSIDERATIONS

Temporary equilibrium models (Berndt and Fuss) have existed for some time under the guise of restricted or short-run dual functions. These models lend themselves to the Marshallian notion of the long run wherein all inputs are considered as variable and adjusted to equilibrium levels in each period and the short run wherein some inputs are at least quasi-fixed, in that they do not completely adjust to long-run equilibrium levels implied by current prices in each period.

Assume that a firm uses some set of inputs $\tilde{x} = (x_1,...x_n)$, with corresponding input price vector $\tilde{p} = (p_1,...,p_n)$, to produce some output, y, according to the transformation function $F(y,\tilde{x}) = 0$. If F satisfies certain regularity conditions and optimizing behavior is characterized by cost minimization, then the dual cost function, $c(y,\tilde{p})$, will also satisfy certain regularity conditions and provide a complete characterization of technology and producer behavior (Diewert, 1982).

The cost function, $c(y,\tilde{p})$, however, is implicitly a long-run construct because all inputs are assumed to be variable and to adjust in each period to levels that minimize total cost. If some inputs are not adjusted to minimize total cost in each period, they are in essence fixed or, in more recent terminology, quasi-fixed as regards static cost minimizing behavior. In such circumstances, $c(y,\tilde{p})$ is not an appropriate representation of short-term producer behavior.

A valid representation of producer behavior within the context of static cost minimization can, however, be obtained by explicitly recognizing that certain inputs are not necessarily adjusted to cost minimizing levels in each period and by utilizing a variable cost function. To expand on this point, assume that the input vector $\tilde{x}$ is partitioned into two mutually exclusive and exhaustive subsets such that $\tilde{x} = (x,z)$, where $x = (x_1,....,x_k)$ and $z = (x_{k+1},....,x_n)$, and similarly partition the input price vector such that $\tilde{p} = (p,u)$, where $p = (p_1,....,p_k)$ and $u = (p_{k+1},....,p_n)$. If only those inputs in the partition x adjust so as to minimize variable costs $(p \cdot x)$ in each period given y and z, a short-run cost function, c(y,p,z), may be defined. Those inputs in the partition, z, are taken as fixed in the decision problem of minimizing variable cost and hence are not necessarily at levels that minimize total cost given observed prices.[1]

The relationship between the long-run cost function $c(y,\tilde{p})$ and the short-run cost function c(y,p,z) provides the link that allows an empirical test of asset fixity to be developed. Assuming the firm to be in short-run equilibrium so that variable costs are minimized conditional on z and y, total cost in any given period may be expressed as

(1) $TC = p \cdot x(y,p,z) + u \cdot z = c(y,p,z) + u \cdot z.$

This equation highlights the fact that the short-run cost function is a more general representation of producer behavior than that given by $c(y,\tilde{p})$ because in (1) the producer is only assumed to be minimizing variable costs over the subset of inputs, x, rather than minimizing total costs with respect to all inputs (i.e., x and z).

The long-run total cost function is obtained by minimizing (1) with respect to the fixed inputs z. This yields the first order conditions

(2) $c_z(y,p,z) = -u,$

where c_z is the gradient vector of the cost function taken with respect to fixed inputs. Denoting the optimal value of the fixed inputs as $z^* = z(y,p,u)$ and substituting into equation (1) yields the long-run cost function.

(3) $c(y,p,u) = c(y,p,z(y,p,u)) + u \cdot z(y,p,u).$

The key relationship in developing a test of input fixity is given in equation (2). The left-hand side of (2) gives the marginal change in minimum variable cost realized by a change in z. In other words, this expression yields the shadow value of the observed levels of z, or the implicit set of prices u^* that would yield the observed levels of z as those that minimize total cost. If inputs in the partition z do minimize

[1] It is important to emphasize that inputs in the partition x are assumed to be chosen to minimize variable cost in each period conditional on observed levels of z and y. Although inputs in the partition z may be optimal in the sense that they are at levels that would minimize total cost in each period or following an optimal adjustment path, derivation of the static restricted cost function takes observed levels of inputs in the partition as given.

total cost (i.e., $z = z^*$), the shadow value of these inputs (u^*) and observed market prices (u) will be equal. However, if inputs in the partition z do not minimize total cost, then u^* and u will differ. Thus, a test of asset fixity can be obtained by statistically testing the equality of market prices for inputs in the partition z to the shadow values implied by observed levels of z obtained from the short-run cost function. Rejection of the hypothesis that these two prices are equal would imply the existence of some degree of fixity.

THE SCHANKERMAN NADIRI TEST

The literature offers three alternatives for testing the hypothesis of input fixity within a static equilibrium framework. The Schankerman and Nadiri (SN) test is equivalent to a Hausman specification test and considers all observations in the sample simultaneously. The test developed by Kulatilaka is a generalization of a t-test and permits testing at every observation in the sample as well as the entire sample as a whole. Conrad and Unger proposed a standard likelihood ratio test of static equilibrium. The SN test is somewhat more general than the other tests in that it permits a broader class of alternative hypotheses and hence is used in this analysis.[2]

The SN test is developed by specifying a parametric form of the short-run cost function, the corresponding variable input demand equations obtained by application of Shephard's lemma, and the shadow value equations defined in equation (2). This system of equations may be expressed as

(4a) $c = c(y,p,z,B_0) + e_1$,

(4b) $x = c_p(y,p,z,B_1) + e_2$,

(4c) $-u = c_z(y,p,z,B_2) + e_3$,

where c_p denotes the gradient vector of the restricted cost function in (4a) taken with respect to the variable input price vector p; c_z denotes the gradient vector for the fixed inputs, z; B_i, $i = 0,1,2$ denote the coefficient vectors for (4a) - (4c); and e_i, $i = 1,2,3$ are disturbance terms.

The test for fixity may be expressed in parametric terms by recognizing that since (4b) and (4c) are explicitly derived from (4a), under the null hypothesis of long-run equilibrium for all inputs (both x and z) the parameter vectors B_1 and B_2 are contained in B_0. If (4b) is taken as a maintained hypothesis, so that only B_1 is assumed to be contained in B_0, the null hypothesis of input fixity of z may be stated in parametric terms as $B_2 \subset B_0$.

To test this hypothesis, Schankerman and Nadiri suggest a version of the Hausman specification test. This is accomplished by comparing a restricted estimate of B_0, based on the system (4a) - (4c) wherein the null hypothesis is imposed, to an unrestricted estimate of B_0 obtained by using only (4a) and (4b).

Let $\hat{B}_0$ and $\hat{V}$ denote the restricted parameter estimates and estimate of the covariance matrix obtained from (4a) - (4c). Denote the estimated parameters and covariance matrix obtained from estimation of the unrestricted model, (4a) - (4b), by $\tilde{B}_0$ and $\tilde{V}$, respectively. Schankerman and Nadiri show that the test statistic,

$$(5)\quad M = T(\tilde{B}_0 - \hat{B}_0)' V^{-1} (\tilde{B}_0 - \hat{B}_0)$$

where $V = (\tilde{V} - \hat{V})$, has an asymptotic X^2 distribution with degrees of freedom (q) equal to the number of restrictions contained in the null hypothesis $B_2 \subset B_0$.

EMPIRICAL MODEL AND RESULTS

Implementation of the SN test for asset fixity requires specification of a short-run cost function. Several functional forms for the restricted cost function, including the generalized Leontief, normalized quadratic, and translog, were considered. Although all of these functional forms may be considered flexible in the sense of providing a second order Taylor series approximation to the "true" underlying cost function at the point of approximation, how well each satisfies the theoretical regularity conditions over the entire sample can only be evaluated empirically. It was found that the homothetic[3] form of translog restricted cost function was the only specification to satisfy globally concavity in input prices.[4]

[2] The test proposed by Kulatilaka is not meaningful when the variable cost function fails to satisfy monotonicity in fixed inputs. As this was the case in the model estimated, the test proposed by Kulatilaka was deemed inappropriate. The likelihood ratio test proposed by Conrad and Unger can only evaluate nested hypotheses, which necessarily limits the form of alternative hypotheses evaluated.

[3] The hypothesis of homotheticity was tested and could not be rejected at the five percent significance level. Thus the assumption of homotheticity was maintained throughout the analysis. It is worth noting that the nonhomothetic translog specification failed to satisfy concavity at all data observations, whereas the homothetic specification was concave in variable input prices at all observations.

[4] It is interesting to note for all of the specifications considered, application of the SN test resulted in a rejection of the null hypothesis. Thus, it appears the inferences obtained in the analysis are not sensitive to the choice of functional form for the restricted cost function.

Table 1. Parameter Estimates For The Restricted And Unrestricted Models

	Restricted Model		Unrestricted Model	
Parameter	Estimate	Standard Error	Estimate	Standard Error
a_o	69.495	35.831	541.88	86.301
a_1	0.1958	0.1793	-0.1537	0.1305
a_{11}	-0.0036	0.0084	0.0142	0.0073
b_a	0.2834	0.4158	-121.08	23.573
b_k	-0.6075	0.4438	-28.893	7.169
b_{aa}	-0.0372	0.0470	17.957	3.9182
b_{kk}	0.0963	0.0534	4.6105	1.1839
b_{ak}	-0.0509	0.0278	0.3732	1.1081
c_{la}	-0.0265	0.0177	-0.0098	0.0239
c_{lk}	-0.0384	0.1624	0.0853	0.0152
d_y	-15.665	9.5435	-14.421	7.5086
d_{yy}	2.0627	1.2792	2.0263	1.0120
d_t	12.682	15.565	-147.90	40.174
d_{tt}	1.8117	3.4374	79.129	16.312
d_{lt}	-0.1655	0.0190	-0.2416	0.0630
d_{at}	0.2535	0.0323	32.658	7.4652
d_{kt}	-0.1994	0.0525	-6.5352	3.0622
d_{yt}	-1.6137	2.0902	-4.1356	1.7576

Following Taylor and Monson, aggregate output (y) for southeastern U.S. agriculture is expressed in terms of four input categories: labor, materials, land, and capital. Under the null hypothesis that land and capital are fixed inputs, the short-run cost function may be expressed as:

$$\text{(6a)}\quad \begin{aligned} \ln C = {} & a_0 + \sum_i a_i \ln P_i + \frac{1}{2}\sum_i\sum_j a_{ij}\ln P_i \ln P_j \\ & + \sum_r b_r \ln Z_r + \frac{1}{2}\sum_r\sum_s b_{rs}\ln Z_r \ln Z_s \\ & + \sum_i\sum_r c_{ir}\ln P_i \ln Z_r + d_y \ln Y + \frac{1}{2} d_{yy}(\ln Y)^2 \\ & + d_t T + \frac{1}{2} d_{tt}T^2 + \sum_i d_{it}\ln P_{it} T + \sum_r d_{rt}\ln Z_r T \\ & + d_{yt} YT + e_0, \end{aligned}$$

where P_i, i = 1, m denote the respective prices of labor and materials; Z_r, r = a, k represent land and capital, respectively; Y denotes output; T is a time trend included as a proxy measure for technology; and e_0 is a disturbance term. The parameter restrictions for homogeneity of degree 0, $\sum_i a_i = 0$, $\sum_i a_{ij} = 0$, j = 1, m, $\sum_i c_{ir} = 0$, r = a, k, $\sum_i d_{it} = 0$, and symmetry, $a_{ij} = a_{ji}$ and $b_{rs} = b_{sr}$, are imposed a priori.

Differentiating (6a) with respect to P_1, Z_a, and Z_k and imposing parameter restrictions yields the system of equations:

$$\text{(6b)}\quad S_1 = a_1 + a_{11}\ln\left(\frac{P_1}{P_m}\right) + c_{1a}\ln Z_a + c_{1k}\ln Z_k + d_{1t}T + e_1,$$

$$\text{(6c)}\quad \begin{aligned} -S_a &= b_a + b_{aa}\ln Z_a + b_{ak}\ln Z_k + c_{1a}\ln\left(\frac{P_1}{P_m}\right) + d_{at}T + e_2, \\ -S_k &= b_k + b_{ak}\ln Z_a + b_{kk}\ln Z_k + c_{1k}\ln\left(\frac{P_1}{P_m}\right) + d_{kt}T + e_3, \end{aligned}$$

where S_1 denotes the labor's share in total variable cost, S_a and S_k denote the ratio of expenditures on land and capital to variable cost, respectively, and e_i, i = 1,2,3 are disturbance terms appended to reflect errors in optimizing behavior. Note that equations (6a) and (6b) are the empirical analogues of equations (4a) and (4b). Similarly, (6c) is the empirical representation of equation (4c). Because the variable cost share equations for labor and materials must sum to one, the share equation for materials is not required in (6b).

Data used for estimation covered the 1951 to 1980 period. Implicit price indexes and expenditure data for the labor, material, and capital aggregates and aggregate output were obtained from Monson. The price indexes were obtained by using Fisher's weak factor reversal test[5] in combination with regional quantity indexes. Labor input was measured by the index of total hours of farmwork. The materials index represents an aggregate of seed, feed, fertilizer, agricultural chemicals, and other inputs while capital is represented by the index of farm machinery. Price and expenditure data for the land aggregate were the same as used by Shumway and Fawson and were obtained from the authors.

The SN test requires estimation of the unrestricted model represented by equations (6a) and (6b) and the restricted model composed of equations (6a), (6b), and (6c). The unrestricted model was estimated using an iterated generalized least squares estimator (IGLS). Given the assumption that the disturbance vectors follow a multivariate normal distribution, this estimator is equivalent to the maximum likelihood estimator (Judge *et al.*) and the parameter estimates are invariate to the equation deleted. The restricted model was estimated using I3SLS, because under the null hypothesis land and capital are correlated with the disturbance terms.

The parameter estimates and standard errors for both the restricted (6a) - (6c) and unrestricted (6a) - (6b) models are presented in Table 1. Eleven of the

[5] See Diewert (1976) for a discussion of Fisher's weak factor reversal test.

Table 2. Estimated R2 Values For The Restricted And Unrestricted Models

Equation	Restricted Model R^2	Unrestricted Model R^2
Variable Cost	0.998	0.989
Labor Share	0.911	0.830
Land Share	-	0.960
Capital Share	-	0.370

eighteen estimated parameters for the unrestricted model exceed two times their respective asymptotic standard errors. As demonstrated in Table 2, with the exception of the capital share equation, all of the estimated equations exhibit good fits as measured by R^2.

In terms of theoretical regularity conditions, parameter estimates for both models satisfy monotonicity and concavity in input prices at all data points. However, whereas the parameters estimated for the restricted model satisfy monotonicity and convexity in fixed inputs at all data points, the parameter estimates obtained for the unrestricted model do not.[6]

Application of the SN test yielded a calculated value for the test statistic [equation (5)] of 44.85 with nine degrees of freedom. This value is larger than the critical value of the 16.9190, and the null hypothesis that observed market prices for land and capital inputs in southeastern U.S. agriculture are equal to their respective shadow values is rejected. Hence, some degree of asset fixity may be concluded.[7]

As pointed out by one of the reviewers, the fact that land and capital are exogenous to the decision problem does not imply that they are exogenous in an econometric sense. Hence it is possible that land and capital are correlated with the disturbance term. To account for this possibility, both the restricted and unrestricted models were estimated using instrumental variables. Although the results of these estimations are not reported, the estimated value of the SN test statistic was 35.73. Thus, using instrumental variables to estimate both the restricted and unrestricted model still leads to a rejection of the null hypothesis.

Given the rejection of the null hypothesis, it is interesting to note the difference in the parameter estimates of the restricted and unrestricted models. The magnitude of these differences make clear that inferences based on the assumption that all inputs adjust to minimize total cost in each period will provide very different and, based on the results of the SN test, erroneous inferences concerning aggregate producer behavior. One must be content to analyze only short-run aggregate behavior using the variable cost function or to specify some type of dynamic model that explains the adjustment process of those inputs exhibiting sluggish adjustment.

SUMMARY AND CONCLUSIONS

The early writings on asset fixity generally attributed asset fixity to the divergence between acquisition costs and salvage values. The models based on this notion were rooted at the firm level and not amenable to aggregate analysis or empirical verification. Thus, alternative definitions of asset fixity that are testable with aggregate data have arisen. Chambers and Vasavada (1983) defined asset fixity in technological terms by evaluating the hypothesis that aggregate agriculture is characterized by a putty-clay technology. Taylor and Monson and Vasavada and Chambers implicitly tested for asset fixity using dynamic duality and testing for instantaneous input adjustment.

In this paper, a third method by which asset fixity can be tested was applied. Using a static equilibrium model and a test suggested by Schankerman and Nadiri, asset fixity in southeastern U.S. agriculture was evaluated by testing the hypothesis of the equality of shadow values and market (rental) prices for certain inputs. The hypothesis of equality between the estimated shadow values and market prices for land and capital inputs was rejected, suggesting these inputs exhibit some degree of fixity. This finding is generally consistent with those of Taylor and Monson and Vasavada and Chambers.

The consistency of these findings is especially important because the test of asset fixity used in this analysis is somewhat more general than those based on dynamic duality. Within the context of dynamic duality, fixity is tested by evaluating the hypothesis

[6] The failure of the cost function estimated using only equations (6a) and (6b) to satisfy monotonicity and convexity in fixed inputs is not surprising. In a recent comparison of econometric models analyzing productivity and aggregate technology, Capalbo found that all of the short-run models considered (i.e., those containing fixed inputs) failed to satisfy these two properties.

[7] The likelihood ratio test for equality of market prices and shadow values suggested by Conrad and Unger yielded a likelihood ratio statistic of 59.56 with nine degrees of freedom. Thus the hypothesis of equality of observed prices and shadow values for land and capital is rejected by this test as well.

of instantaneous adjustment. This hypothesis, however, is conditioned by the form of the adjustment process assumed, which in empirical applications of dynamic duality is necessarily quite restrictive. Within the static equilibrium framework, the cause of asset fixity does not matter since it is not necessary to specify any type of adjustment process.

It should be noted, however, that the SN test is conditioned by the choice of which inputs are maintained to variable. While one can easily hypothesize all inputs to be quasi-fixed in the context of a dynamic dual model, it is not clear how this would be accomplished using a static equilibrium model. Theoretically, it would seem that one could use the SN test in conjunction with a distance (price minimal cost) function (Shephard). This function is the mathematical dual of the cost function and can be shown to satisfy an "inverse Shephard's lemma." However, it is not clear how one could obtain reliable parameter estimates of the distance function under the assumption that all inputs are quasi-fixed.

Finally, much of the discussion concerning asset fixity has been within the context of explaining the existence of the overproduction trap and rationalizing low returns to resources in agriculture. Indeed, the results of this analysis provide evidence in support of the existence of some fixity. However, testing for asset fixity in the manner presented here has some current methodological implications as well.

The use of static duality in specifying and estimating systems of demand (and supply) equations has become a common practice in empirical analysis. However, the proper use of static duality requires those inputs considered as choice variables to respond in each period in the optimal fashion implied by the behavioral rule assumed. If inputs do not adjust to their optimal levels in each period when observed prices change, then falsely assuming they do can yield misleading inferences.

The test for fixity presented in this paper permits a simple and straightforward means of testing for the appropriateness of long-run and short-run static dual model specifications. If one assumes that all inputs adjust to their cost minimizing levels given observed prices in every period, a Marshallian long-run model is implicitly assumed. If, however, all inputs do not fully adjust in every period due to unobserved adjustment costs or other factors, inferences from a long-run static model will be erroneous. Valid inferences can only be obtained for a portion of the technology by using a short-run dual specification or by explicitly modeling the adjustment processes for those inputs that are not fully adjusting to market prices in each period.

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