Biased Biased Technological Progress in the U.S. Farm Sector: A Structural Perspective

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The U.S. farm sector has seen considerable structural change in both farm size and number of farms over the last half century. The number of farms has steadily declined from 5.4 million in 1950 to 2.1 million in 1996, while the value of products (measured in 1992 dollars) has increased from $54.8 billion to $191.7 billion during the same period (Harrington *et al.*, 1998). The trend towards fewer, but larger farms accelerated during the 1950's and 1960's, but has slowed somewhat since the 1970's. The latest census data show that the long-term trend of declining farm numbers, slightly declining land in farms, and increasing average farm size continued throughout the 1980’s and 1990’s (1997 Census of Agriculture, U.S. Department of Agriculture). Thus, farms have become fewer and larger and the movement toward greater production concentration has been a persistent feature of production agriculture. The exhaustive list of factors affecting the U.S. farm structural change includes technological change, economies of size, farm policy and programs, tax laws, and credit and income programs (Cochrane, 1993; Ramussen and Stanton, 1993; Sumner: 1990, Tweeten, 1993). Major contributions to this literature include Gardner and Pope (1978) for technological change, Lu (1985), and Kislev and Peterson (1982) for bias toward machinery in technological change, Hallam (1993), Miller (1979), and Miller *et al.* (1981) for economies of scale, and Leathers (1992) for government farm programs.

Ever since the days of Thomas Jefferson, the expressed intent of the nation's agricultural policy has been to support family farms, particularly small land-owning farms (Madden and Tischbein, 1979). While a primary stated purpose of government commodity programs has been to support small family farms, researchers often have reached conflicting conclusions as to the efficacy of policies for this purpose. Some economists claim that government programs reduce farm numbers (Cochrane, 1993; D'Souza and Ikerd, 1996; Leathers, 1992; Quance and Tweeten, 1972), but others contend that farm programs preserve farms (Gardner, 1978; Richardson, Smith and Knutson, 1988; Stanton, 1978), or farm programs have no impact on farm size and numbers at all (Kislev and Peterson, 1982; Spitze, *et al.*, 1980). Most would agree that price support programs would help to keep marginal farmers in business. If there are payment limitations, then programs tend to favor smaller farmers. However, if benefits are proportional to output, then support programs are skewed toward larger farms and can encourage farm consolidation and enlargement. Preliminary evidence by Leathers (1992) suggests that farm programs, such as price supports and the CRP, reduce the number of farms. Lowenberg-DeBoer and Boehlje (1986) also found that government programs, which lower financing costs of credit, lead to farm operations becoming larger. Harrington and Reinsel (1995) summarize some of the apparently conflicting findings of this literature.

Public agricultural research is another program which has often been criticized on the grounds that benefits from publicly-funded research is skewed toward the larger producers (Gebremedhin and Christy, 1996). The assumption is that, agricultural research and cooperative extension service programs have provided the basis for highly innovative agriculture, which is geared to capital-intensive, large-scale farm, and not to low-income farmers. To mitigate any negative impacts on small farms, it may be necessary to make new technologies more readily accessible to small- and moderate-size farms as well as to provide them training in the use of these technologies (Lu, 1985).

The objective of this study is to empirically evaluate the structural changes in the U.S. farm sector. While most previous studies provided various descriptive reasoning why the production concentration of the U.S. farm sector is increasing at the expense of the declining number of *rural residential farms*, we attempt to test quantitatively and verify the factors behind this concentration.

Farm Size Distribution and Economies of Size

Economists often evaluate the structural changes of an industry by estimating economies of size for that industry (MacDonald and Ollinger, 2000; Paul, 1999) or the size distribution of that industry (Chan, 1981; Garcia, Offutt, and Sonka, 1987). While economists are interested in economies of size as they affect efficiency and sustainability of family farms, much research in agricultural economics has focused on farm size as an independent issue to the normative desirability of sustaining the family farm (Hallam, 1993). Our intention is to introduce an alternative approach that can be used simultaneously to evaluate economies of size and the size distribution of the U.S. farm sector without estimating an aggregate sector cost function.

Assume that the cost of producing output y_{i+1} equals the cost of producing y_i in N_i separate but identical operations such that:

(1) $c_{i+1} (y_{i+1}(x_1, x_2, .., x_n)) = N_i(y_i(x_1, x_2, .., x_n))c_i(y_i(x_1, x_2, .., x_n))$ for $i = 1, 2, . . . , m$-1,

where $c_{i+1} (y_{i+1})$ is the cost function associated with the output level y_{i+1}, N_i is the number of farms in the *i*th size class, x_k is the *k*th input, and $c_i(y_i)$ is a cost function associated with the output level y_i.

Differentiating both sides of equa tion (1) with respect to input price p_k associated with x_k and applying Shephard's lemma, result in the following:

(2) $[?\ln N_i(y_i) / ?\ln p_k] = [p_k x_k(y_{i+1}) / c_{i+1}(y_{i+1})] – [p_k x_k(y_i) / c_i(y_i)]$ for $i = 1, 2, . . . , m$-1.

The left-hand side from the equality in equation (2) represents the kth input price elasticity for the number of the ith size farm. First and second terms of the right-hand side from the equality represent the kth input cost shares of the $(i+1)$th size farm and the ith size farm, respectively. Equation (2) indicates that the input price elasticity for the number of farms in each size class can be used to determine whether the changes in U.S. farm structure are the kth factor saving or the kth factor using technical changes. If the right-hand side is positive (negative), the ith size farm is considered to have kth-input saving (using) technical change.

Summing both sides of the equality in equation (2) and assuming the input price elasticities of output are the same across the size of farms, equation (2) can be rewritten as:

$$\textbf{(3)} \qquad \sum_{k=1}^{n} [?\ln N_i(y_i) / ?\ln p_k] = [\eta(y_i) - \eta(y_{i+1})] \left| \sum_{k=1}^{n} [\partial \ln (y_i) / ?\ln p_k] \right|,$$

where $\eta(y_i)$ is the elasticity of total costs associated with the production of y_i from the ith size farm. In a conventional point estimate of economies of size obtained from a cost function, the farm reveals economies of size if $\eta(y_i) < 1$, so that larger-sized operations are more cost-effective, and diseconomies of size if $\eta(y_i) > 1$, so that many smaller-size farm operations are more cost effective. In equation (3), a farm reveals economies of size if $\eta(y_i) < \eta(y_{i+1})$ so that $\sum_{k=1}^{n} [?\ln N_i(y_i) / ?\ln p_k] < 0$ and larger-size farm operation is more cost effective. It is clear from equation (3) that an econometric model for the number of farms in each size class which is regressed on input prices can be used to evaluate the structural changes in the U.S. farm sector.

To define the functional form of $N_i(y_i)$ function, divide both sides of the equality in equation (3) with p_k and then integrating both sides of equation (3) results in the followings:

$$\textbf{(4)} \qquad \ln N_i(y_i) = ?[h(y_{i+1})(¶\ln(y_{i+1})/?p_k) - h(y_i)(¶\ln(y_i)/?p_k)]\, dp_k, \quad \text{or equivalently,}$$

(5) $N_i(y_i) = \exp\{?[\eta(y_{i+1})(\partial \ln(y_{i+1})/?p_k) - \eta(y_i)(\partial \ln(y_i)/? p_k)] \, dp_k\}$,

which has an exponential form. Since the number of farms for each size class is *count variable*, use of the ordinary regression model would result in inefficient, inconsistent, and biased estimators. Therefore, a decomposed Negative Binomial Regression Model (NBRM) for the U.S. farm structure, which acknowledges the diverse effects of economic factors by size class, is represented in the following section.

A Decomposed Negative Binomial Regression Model

To better understand the causes of the decline in the number of farms, it is necessary to classify farms by size. The farm typology groups constructed by the Economic Research Service of the U.S. Department of Agriculture (ERS/USDA) classify all farms with annual gross sales less than \$250,000 as small farms. For the purposes of this study these small farms are further grouped into two size groups we call *rural residential farms* and *small family farms*. *Rural residential farms* represent farms with annual sales less than \$100,000 (a combination of ERS' limited-resource, retirement, residential/lifestyle, and farming occupation/lower sales farms). *Small family farms* in this paper represent small farms with annual sales between \$100,000 and \$250,000 where the operator identified farming as his or her primary occupation. All other farms with annual sales greater than \$250,000 are classified as *large farms*. Under these size classifications, the reduction in the number of U.S. farms in the past came primarily from the declining number of *rural residential farms*, which have steadily declined from more than 3.8 million in 1960 to 1.7 million in 1996. The number of *small family farms* and *large farms* have steadily increased with minor fluctuations over the same period from 95,000 to 212,000 and from 24,000 to 141,000, respectively. It should also be noted that small family farms defined in most previous studies represent *rural residential farms* in our classification of farm sizes.

Approximately half of the total value of U.S. agricultural output comes from crop production and half from animal products, with minor fluctuations. Farming and ranching require labor and capital, and may be influenced by government farm programs and publicly financed agricultural research. In this analysis the short-term bond interest rate and the prices paid index for farm machinery are included to represent financial capital and machinery capital, respectively.

We adopt the following specification of the decomposed NBRM of structural changes in the U.S. farm sector, consistent with the cost minimization:

(6)
$$E[N_{j,t}] = exp\{ \sum_{i=1}^{3} a_i D_i(w / P_y)_t + \sum_{i=1}^{3} b_i D_i (r/P_y)_t + \sum_{i=1}^{3} g_i D_i((K - \bar{K})/P_y)_t + \sum_{i=1}^{3} d_i D_i((R - \bar{R})/P_{y\,t})] + \sum_{i=1}^{3} q_i D_i((G - \bar{G})/P_y)_t] + \sum_{i=1}^{2} l_i D_{i,t} + e_{j,t}\} \quad (j = 1, 2, 3)$$

where, the subscripts $i = j = 1$ are for *rural residential farms*, $i = j = 2$ for *small family farms*, and $i = j = 3$ for *large farms*, N_j = the number of farms which are in farm size category j, w = the index of hourly wage of farm workers (1992=100), r = the index of average interest rates of 3 year and 10 year yields (1992=100), K = the index of machinery prices paid by farmers (1992=100), $\bar{K}$ = average index of machinery price, P_y = the index of output prices received by farmers (1992=100), R = agricultural research expenditures, $\bar{R}$ = average annual expenditures for agricultural research, and G = government payments, $\bar{G}$ = average annual government payments, D_i = a dummy variable associated with the ith farm size class such that $D_i = 1$ if $i = j$, and $D_i = 0$ for otherwise.

The wage rate, interest rate, and machinery price elasticities for the number of farms in each size class are estimated from equation (6) and results are represented in equations (7) through (9), respectively.

(7) $?_i(w) = [?E(N_i)/?w][w/E(N_i)] = a_i(w/P_y)$ $i = 1, 2, 3.$

(8) $?_i(r) = [?E(N_i)/?r][r/E(N_i)] = ß_i\ (r/P_y)$ $i = 1, 2, 3.$

(9) $?_i(K) = [?E(N_i)/?K][K/E(N_i)] = g_i\ (K/P_y)$ $i = 1, 2, 3.$

In general, smaller farming operations are more labor-intensive and larger farming operations are more capital-intensive. As the wage rate rises, farms of all size achieve economic efficiency by replacing labor with machinery. Therefore, from equation (6), the sign of a_i is expected to be negative for *rural residential farms* and positive for *large farms*. The sign of the parameters $ß_i$ ($i = 1, 2, 3$) and γ_i ($i = 1, 2, 3$) associated with the rate of interest and the price index of machinery, respectively, depends on whether labor is a substitute or a complement with each of financial capital and machinery capital, and whether financial capital and machinery capital are complementary or substitutes. For instance, when financial capital is a substitute for labor, the sign of the parameter $ß_i$ is expected to be negative for *rural residential farms*, but positive for *large farms*.

Since the green revolution, the rate of investment in publicly financed agricultural research has steadily grown. The rapid innovation in mechanical technologies earlier last century resulted in rapid structural change because they were capital embodied, indivisible technologies, and hence exhibited a strong size bias, and the chemical and biological technologies were less size biased, yet still created incentives for structural changes (Batte and Johnson, 1993). Since the adoption rate of new technologies varies across different size of farms, the sign of the parameter d_i, is expected to be positive for *large farms*, but negative for *rural residential farms*.

The sign of the parameter q_1, which is associated with the normalized government expenditures for farm programs, represents how government programs affect farms. For *rural* *residential farms*, when the estimate is negative, government farm programs would have negative effect on growth as Cochrane (1993), and Quance and Tweeten (1972) have noted. If the parameter estimate is positive, government farm programs would help small family farms to stay in farm production as Gardner, Richardson, Smith and Knutson (1988), and Stanton (1978) have claimed. However, if the parameter estimate is statistically insignificant or is statistically significant but it is small enough so that [?E(N_i)/?G] from equation (6) is negligible, then government farm programs would have no impact on farm size and number as Spitze *et al.* (1980) noted.

While the input price elasticity for the number of farms in each size class reveals whether there are economies of size and whether the technical change is labor-intensive or capital intensive, it does not reveal the magnitude of bias of technical changes, as presented in the following section.

Biased Technical Change in the U.S. Farm Sector

The relative share of labor in the U.S. agricultural sector is V-shaped with only minor fluctuations during the period between 1960 and 1996. To evaluate how labor and capital have been employed in the U.S. farm sector, we modified Hick's approach, bias of technical change (Lianos, 1971) as defined as follows:

(10) $\mathbf{B}_{i,\,i+1} = \{[?(MP_C / MP_L)_i / ?\, i] \,/\, (MP_C / MP_L)_i\}$ for $i = 1, 2$

where the subscript C and L represent financial capital and labor, respectively, and the subscript i represents the size of farm. Bias of technical progress $B_{i,\,i+1} > 0$ indicates that as the farm size increases from the ith size class to the (i+1)th size class, technical progress increases the marginal product of financial capital relative to that of labor. Similarly $B_{i,\,i+1} < 0$ indicates that as the size of farm increases from the ith size class to the (i+1)th size class, technical progress increases the marginal product of labor relative to the marginal product of financial capital.

To estimate the marginal rate of technical substitution of labor for financial, $MRTS_{\text{of } L \text{ for } C}$, the output price elasticity for the number of farms in each size class, measured at a mean value for each variable, is represented by:

(11) $?_i(P_y)_m = - [a_i(w/P_y) + ß_i(r/P_y)]$ for $i = 1, 2, 3$

where the subscript m indicates that the output price elasticity for the number of farms is measured at a mean value for each variable. The result in equation (11) indicates that the output price elasticity for the number of farms measured at mean values equals the negative sum of the elasticities of labor and financial capital for the number of farms in each size class, as presented in equations (7) and (8).

Since each of inputs is used up to a point where the value of marginal product equals the unit price of that input, equation (11) can be rewritten as follows:

(12) $?_i(P_y)_m = - [a_i \, MP_L(i) + ß_i \, MP_C(i)]$ for $i = 1, 2, 3.$

where MP_L and MP_C represent the marginal product of labor and the marginal product of financial capital, respectively. The marginal rate of technical substitution (MRTS) of labor for financial capital for the ith size farms, $(MP_C / MP_L)_i$, derived from equation (12), is given by:

(13) $[MP_C / MP_L]_i = - a_i / [?_i(P_y)_m + ß_i]$ for $i = 1, 2, 3.$

Equation (13) is used to estimate bias in technical change presented in equation (10).

Empirical Results

Farm size as defined by value of products sold is a useful measure for a given year. However, the effects of price changes blur the boundaries between size classification over time so that a time series analysis of structural change requires consistent boundaries in the definition of farm size. Therefore, data on the number of farms in each size class are obtained from Teigen (1996), who estimated the annual number of farms with constant volume of output in 1992 dollars by using a Trapezoidal density function.

Data on publicly financed agricultural research expenditures obtained from Huffman and Evenson (1993) are the sum of the expenditures (in million dollars) on Experiment Station Research, Cooperative Agricultural Extension. Government program payments include deficiency payments, disaster payments, and conservation reserve payments. Time-series data on total government payments from various volumes of USDA's *Agricultural Statistics* are reported as an item under cash receipts of U.S. gross farm income. Since our study is regarded as an aggregate analysis, the index of prices received by farmers (also from *Agricultural Statistics*) is used for output price. Prices received represent sales from producers to first buyers and are averaged over all grades, qualities, and commodities including all crops, dairy products, and livestock and livestock products. Hourly nominal farm wage rates without room and board are obtained from *Agricultural Statistics*. The rate of interest, which is an average of 3 year and 10 year bond yields, is obtained from various issues of the *Economic Report of the President*. Both wage rates and interest rates are also indexed to 1992 as a base year.

The decomposed NBRM in equation (6) is estimated with a maximum likelihood method by using Eviews software. Parameter estimates are presented in Table 1. Except for the farm program expenditure variable for *rural residential farms*, all estimators are statistically significant. The sign of parameter estimators a_i (i = 1, 2) associated with the normalized wage variables, (w/P_y), for *rural residential farms* and *small family farms*, are negative, while the sign of parameter estimator, a_3, for *large farms* is positive. These results may indicate that as the wage rate rises farm operators achieve economic efficiency by switching from a labor-intensive operation to capital-intensive operation. Since small farm operators are considered to be more labor-intensive and large farm operations to be more capital-intensive, the number of small-size farms would decline and the number of large-size farms would increase as small operators mechanize and become larger.

Parameter estimator γ_1 associated with the normalized machinery prices, $(K - \overline{K}) / P_y$, for *rural residential farms* is positive, while parameter estimators γ_i ($i = 2, 3$) for *small family farms* and *large farms*, respectively, are negative. These results may indicate that as the machinery price rises, farm operators achieve economic efficiency by switching from a machinery capital-intensive operation to a labor-intensive operation. Therefore, the number of large size farms would decline, while those for small-size farms would increase.

Parameter estimators associated with the normalized rates of interest for *rural residential farms* and *small family farms* are negative, while that for *large farms* is positive. It appears that the financial capital is a substitute for labor, but it is complementary with machinery capital. The rate of interest normalized with output price index has declined by 49 percent during the periods between 1960 and 1996, which encouraged all farm operators to make more capital investment. The normalized hired farm labor wage and machinery prices increased steadily by 126 percent and 84 percent, respectively, during the same period

The parameter estimate associated with the normalized government expenditures for farm program variable is statistically insignificant for *rural residential farms* and is positive for *small family farms*, but it is negative for *large farms.* A possible explanation for this is the distribution of farms and ranches that make up our three size groups. Over 80 percent of all U.S. farming operations fall into the *rural residential* category. Over half of these farms report negative farm income and rely mostly on off-farm earnings for household income. While government payments contribute a substantial share of these farms' total farm income, the total is insignificant. On the other hand, many *large farms* are classified that way because they produce high-value agricultural products that are not eligible for government payments. Government payments are primarily paid for field crops and most of the farms in the smallest and many of the farms in the largest size groups do not grow program crops.

The parameter estimate associated with publicly financed agricultural research expenditure is negative for *rural residential farms* and is positive for *small family farms* and *large farms*. The estimate for *large farms* is more than twice that for *small family farms*. These results indicate that the number of both *small family farms* and *large farms* increase as a result of the publicly financed agricultural research, with greater increase by *large farms*. An increase in yield resulting from the agricultural research would translate into reducing their average production costs. *Large farms* would benefit from the publicly financed agricultural research more than *small family farms*, largely due to economies of size.

The estimated elasticities of input prices for the number of farms in each size class are presented in Table 2. The elasticities of the normalized wage variable for the number of *rural residential farms* and for *small family farms* are negative, while that is positive for *large farms*. These results imply from equation (2) that *rural residential farm* and *small family farms* use labor-intensive technology, while *large farms* use labor saving technologies.

Rural residential farms are considered in general to have capital-saving operations, while *large farms* have capital-intensive operations. However, the estimated elasticity of the normalized interest rate is negative for *rural residential farms* and *small family farms*, but it is positive for *large farms*. It appears that relatively low rates of interest during the 1960-96 period encouraged farmers to make more investment. The estimated elasticity of machinery capital for the number of farms is positive for *rural residential farms* and is negative for *small family farms* and *large farms*. These results imply from equation (2) that *rural residential farms* have capital-saving technology while *small family farms* and *large farms* have capital-using technology.

The aggregate input price elasticity for the number of farms in each size, estimated with equation (3) and presented in Table 2, is negative for *rural residential farms* and *small family farms*, with the latter is greater. These results imply that there are economies of size in *rural residential farms* and *small family farms*. However, equation (3) is defined only for $i = 1, 2, . . , m-1$, where m is the total number of size classes, it is indeterminate for *large farms*.

The MRTS of labor for financial capital for each size of farms are presented in Table 3. Results show that the marginal products of financial capital are less than the marginal products of labor for *rural residential farms* and *small family farms*, but the marginal products of capital are greater than the marginal products of labor for *large farms*. The MRTS of labor for capital increases as the size class increases. The MRTS of labor for capital is 0.85 for *rural residential farms*, 0.95 for *small family farms*, and 1.22 for *large farms*.

Bias of technical change between *rural residential farms* and *small family farms* is $B_{1,2} = 0.1167 > 0$, while it is $B_{2,3} = 0.2872 > 0$ between *small family farms* and *large farms*. These results may imply that technological progress increased the marginal product of capital relative to that of labor. Given a factor price ratio, this would give an incentive for farmers to substitute capital for labor to increase the capital-labor ratio. These results are somewhat consistent with earlier findings that the elasticity of substitution is greater than unity and U.S. agriculture is characterized by capital-using technological progress (Kaneda; Lianos).

The implications of these results are significant for policy makers. The number of farms has steadily declined but the size of farms has steadily increased. The *rural residential farms* are often not operated at a profit and are seen by the operators as ways of life, owned property with extra resources being used for agriculture but with the main source of household income coming for off-farm employment. The increasing marginal products of capital relative to that of labor, along with the declining interest rate normalized with output price and increasing publicly financed agricultural research, all have contributed to the steadily increasing farm size with those farm operators who truly try to make farming a business trading labor for capital.

Conclusions

Using a decomposed Negative Binomial Regression Model (NBRM) of the U.S. farm sector under cost minimization we have quantitatively evaluated, rather than simply describing and explaining, why the number of *rural residential farms* has been declining, while the production concentration has been increasing in the U.S. farm sector. We have shown two types of structural changes: single input related technological change and total input related (induced) technological change. If the input price elasticity of an input for the number of farms in each size class is negative (positive), farms in that size class are considered to have an input using (saving) technology of that input. If the sum of all input elasticities for the number of farms in each size class is negative, farms in that size class have economies of size.

The decomposed NBRM is used to estimate the marginal rate of technical substitution of labor for capital. We also presented a modified Hick's bias of technological changes. If the marginal rate of technical substitution of labor for capital increases (decreases) as the size of farm increases, technical progress increases (decreases) the marginal product of capital relative to that of labor.

The estimated parameters of a decomposed NBRM show that the increasing normalized wage rate has significantly affected the structure of the U.S. agriculture by the increasing concentration of agricultural production at the farm level. While the declining normalized financial capital cost with output price contributed to the increasing concentration level of agricultural production, the increasing machinery price had opposite effects on the production concentration level. These results are consistent with financial capital being a complement to machinery capital, but a substitute for labor.

Even though the government farm programs are considered to provide some benefits to most farms, the estimates are inconclusive. Furthermore, publicly funded agricultural research has provided the basis for highly innovative agriculture, which is geared to capital-intensive, large-scale farming so that *large farms* have benefited from technological progress reducing their average production costs more than *small family farms.*

Other important findings include the following: First, the estimates obtained show that there are economies of size in the U.S. farm sector so that the *rural residential farm* operators and *small family farm* operators can achieve economic efficiency by increasing their size of farm operation. Second, the marginal product of labor is greater than the marginal product of capital for *rural residential farms* and *small family farms*, and declining as farm size increases, but the marginal product of capital is greater than the marginal product of labor for *large farms*. Third, the marginal rate of technical substitution of labor for capital increases as the size of farm increases. Fourth, according to Hick's definition of neutrality of technological changes, the U.S. farm sector increased the marginal product of capital to that of labor. Given historic factor price ratios, this gave an incentive for farmers to substitute capital for labor to increase the capital-labor ratio.

Table 1. Parameter estimates for a decomposed Negative Binomial regression model of the U.S. farm structural changes[1].

Parameter	Coefficient	z-Statistics
Normalized wage of labor: (w / P_y)		
a_1	- 0.0504	- 27.5683
a_2	- 0.2743	- 15.2831
a_3	4.2869	38.7236
Normalized rent for capital: (r / P_y)		
$ß_1$	- 0.0535	- 13.7032
$ß_2$	- 0.2086	- 7.8324
$ß_3$	0.8060	13.3710
Normalied mchinery price: $(K - \overline{K}) / P_y$		
$?_1$	0.0702	9.9394
$?_2$	- 0.0542	- 7.4148
$?_3$	- 2.3018	- 10.2467
Normalized research expenditure: $(R - \overline{R}) / P_y$		
d_1	- 0.0402	- 16.9913
d_2	0.0485	12.7664
d_3	0.0968	11.6442
Normalized farm program expenditures: $(G - \overline{G}) / P_y$		
$?_1$	- 0.0001	- 0.4576*
$?_2$	0.0014	2.6639
$?_3$	- 0.0057	- 9.5509
Dummy variable:		
$?_1$	7.8736	83.7603
$?_2$	5.1899	21.5636

[1] Subscripts 1, 2, and 3 represent *rural residential farms*, *small family farms*, and *large farms*, respectively.

* Statistically insignificant at 95 percent confidence level.

Table 2. The estimated elasticities of wage rate and interest rate for the number of farms in each size class, measured at mean values.

Farm-size class	$?_i(w)$	$?_i(r)$	$?_i(\mathrm{K})$	$\sum_{k=1}^{n} [?\ln N_i(y_i)/?\ln p_k] = \eta(y_i) \left\lvert \sum_{k=1}^{n} [\partial \ln(y_i)/?\ln p_k] \right\rvert - \eta(y_{i+1}) \left\lvert \sum_{k=1}^{n} [\partial \ln(y_{i+1})/?\ln p_k] \right\rvert$
Rural residential farms	- 0.0373	- 0.0754	0.0519	- 0.0608
Small family farms	- 0.2030	- 0.2941	- 0.0401	- 0.5372
Large farms	3.1723	1.1363	- 1.7033	

Table 3. Estimated marginal rate of technical substitution of labor for capital of the U.S. farm sector.

Farm size class	MP_C / MP_L	$B_{i,\ i+1}$
Rural residential Farms	0.8514	0.1167
Small family farms	0.9508	0.2872
Large farms	1.2239	

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