Valuation of Intangible Capital in Agriculture

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Abstract

This study examines the valuation of research as intangible capital in agriculture using Tobin's q theory. The market value of public research capital is estimated to be 8.6 times higher than conventional assets. Private research capital is valued 5.2 times higher than conventional assets. The estimated valuation multiplier for all farm assets dropped 1/3 over the last decade. In recent years the valuation multiplier has dropped below a dollar, which indicates the market is undervaluing farm assets.

Key Words: farm assets, flexible intercept model, principal components, research evaluation, ridge regression, Tobin's q theory

Agricultural economists have for a long time been interested in the valuation of farm assets, especially land. Considerable effort has been focused on analyzing the impact of commodity prices and government programs on land values (Alston; Burt; Harris). Valuation of government quotas has also been addressed (Vantreese, Reed, and Skees). However, market valuation of intangible assets such as the stock of research capital has not been addressed in agriculture.

In determining the valuation of intangible assets in agriculture, it is important to distinguish the impacts of research on society in general and on agriculture in particular. The empirical studies which have measured the impacts of agricultural research typically measure the rates of return from the perspective of overall society. Huffman and Evenson recently cited 40 different estimates from the literature, which averaged 51 percent rate of return to society. In comparison, the rate of return on tangible assets in agriculture, including current income and real capital gains, averaged 4.9 percent for the period 1950-91 (*USDA, Economic Indicators of the Farm Sector*). Thus the social rate of return

on public research as an intangible asset was 10 times the rate of return on tangible assets.

Many of the benefits of public agricultural research accrue to consumers because of the inelastic demand for agricultural products in the short-run. The high benefit-cost ratios to society as reported in the literature do not necessarily imply high benefit-cost ratios to farmers. The returns from public research to farmers would be expected to be lower than the returns to society. Some economists argue that farmers need commodity price support programs to compensate them for possible welfare losses resulting from agricultural research. Valuation of intangible public research capital takes into account the direct benefits of research to farmers and the indirect benefits of price support programs which help ameliorate the impacts of productivity increases with an inelastic demand.

Valuation of intangible private research capital must distinguish the benefits to private agribusiness firms and to farmers. Some of the benefits from private research are captured by the firms conducting the research. Patents and other

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forms of protection for intellectual property rights increase appropriability and curtail the spillover of benefits to other firms. If the agribusiness firms captured all the benefits of private research there would be no incentive for adoption. Empirical evidence indicates that some of the benefits of private agricultural research accrue to consumers and farmers. Huffman and Evenson measured public returns from private research in agriculture. They estimated a rate of return of 46.3 percent on private research and reported four previous estimates ranging from 25.5 percent to 90 percent. The average of these 5 estimates was 63 percent.

For the nonagricultural sector, valuation of intangible capital can be examined through the appreciation in the stock market's valuation of firms. Since agricultural firms are not traded on the stock market, USDA estimates are generally used to measure changes in asset values in agriculture. Valuation of intangible capital in agriculture can be measured by quantifying the impact of research on changes in asset values. With land being the major asset in agriculture, the benefits of research would be expected to be capitalized into land values. However, other asset values may also be influenced by research.

Valuation of intangible assets can be determined using Tobin's *q* theory. This theory allows for deviations between the market value and the book value of assets. Such deviations could be attributed to unmeasured sources of rent which drive a wedge between the market value and the book value of assets (*Hall*). With Tobin's *q*, the unmeasured sources of rent can be explained in terms of intangible assets.

Griliches considered a sample of 457 large firms over the period 1968-74. His results indicated that the long-run effect of a dollar of research and development (*R&D*) added about $2 to the market value of the firm. Cockburn and Griliches examined 722 manufacturing firms with 1980 data and reported estimated shadow prices of research capital ranging from 0.34 to 1.44. The impacts of research were higher than these prices in some cases, because interaction terms with research capital were also included in the models. Hall analyzed 2,480 manufacturing firms from 1973 to 1991. He reported a shadow price of research

capital stock of 0.48, which is relative to 1 for tangible capital. These shadow prices for research capital are quite different from the results to be expected in the current study. These studies considered the effect of private research by a firm on the valuation of that firm. The present study examines the effects of public research on the valuation of the agricultural sector. It also examines the public effects (those not captured by private non-farm firms) of private research on the valuation of the agricultural sector.

The objective of this paper is to examine market valuations of public and private research capital for U.S. agriculture. A model of firm valuation based on Tobin's *q* theory is developed and applied to the U.S. agricultural sector. Particular attention is focused on the valuation multiplier, which is the market value relative to the replacement cost of total assets. It shows the market value of each dollar of assets. Although the valuation multiplier is not observed directly, it is estimated for each year.

Theoretical Framework

Following Hayashi and Wildasin, the theoretical framework is based on the maximization of an individual firm's discounted flow of net income. The firm receives income from the sale of output and has expenses for variable inputs, investment, and adjustment costs. In this discussion, time subscripts are suppressed where ever possible. Production is assumed to be generated according to a production technology *F* which is a linear homogeneous function over capital *(K)* and the vector of variable inputs *(L)*. Adjustment costs are assumed to take the form of lost output and/or waste of investment goods *(Wildasin)*. Hence two adjustment cost functions are considered. First, the loss in output resulting from investment *(I)* is assumed to be a linear homogeneous function *G(I,K)*. Secondly, the loss in investment goods resulting from investment is assumed to be a linear homogeneous function *H(I,K)*. Net income (π) is given by

$$\pi(t) = p_o[F(K,L) - G(I,K)] - wL - p_I[I + H(I,K)], \quad (1)$$

where p_o is the price of output, w is the vector of variable input prices, and p_I is the price of investment goods.

The discounted value of net income, is given by

$$V(0) = \int_0^\infty \pi(t)\tau(t)dt, \tag{2}$$

where $\tau(t) = exp(-\int_0^t \rho(s)ds)$, and ρ is the discount rate.

Maximization of the objective function is subject to a capital constraint. The net change in capital stock $(\dot{K})$ is composed of investment in capital and depreciation of existing capital goods.

$$\dot{K} = I - \gamma K, \tag{3}$$

where γ is the depreciation rate. Substituting *(1)* into *(2)* and using an auxiliary variable λ for the constraint yields

$$V(0) = \int_0^\infty (\{p_0[F(K, L) - G(I,K)] - wL - p_I[I$$

$$+ H(I,K)]\}\tau + \lambda[\dot{K} - (I - \gamma K)])dt. \tag{4}$$

First order conditions for maximization for all time periods are

$$p_0F_L - w = 0; \tag{5a}$$

$$\lambda - [p_0G_I + p_I(1 + H_I)]\tau = 0; \tag{5b}$$

$$-\dot{\lambda} = [p_0(F_K - G_K) - p_IH_K]\tau - \lambda\gamma; \text{ and} \tag{5c}$$

$$lim \ \lambda(t)K(t) = 0,$$
$$t\rightarrow\infty \tag{5d}$$

where subscripts on *F, G,* and *H* denote partial derivatives.

Previous literature has emphasized equation *(5b)* in empirically estimating an investment equation. This equation involves an unobservable variable λ, but Hayashi proved that with homogeneity of *F* and *G* and the application of Euler's theorem:

$$V(0) = \lambda(0)K(0). \tag{6}$$

Defining Tobin's *q* as *V/K* gives an observable measure of λ. Alternatively, Griliches empirically estimated a relationship that is a direct extension of *(6)*, although his work preceded Hayashi's derivation. Griliches used two forms of capital -- conventional inputs and the firm's intangible stock of knowledge, which was estimated as a distributed lag measure of past research and development *(R&D)*. Following the notation used by Cochburn and Griliches

$$V = b[A + \Sigma\delta_iK_i], \tag{7}$$

where *V* is the market value of the firm, *b* is the average multiplier of market value relative to the replacement cost of total assets, *A* is tangible capital, *K* is intangible capital, and δ is the relative shadow price for intangible capital. The estimation equation is derived by adding a multiplicative error term, dividing through by *A* and taking logarithms of both sides of equation *(7)*. When $\Sigma K_i/A$ is relatively small, $log(1+\Sigma K_i/A)$ can be approximated by $\Sigma K_i/A$. The estimation equation used by Cockburn and Griliches is given by

$$log(q) = log(b) + \Sigma\delta_iK_i/A + e, \tag{8}$$

where q = V/A, K_i is an intangible asset, and *e* is the error term.

Flexible Intercept Model

Previous studies of valuation models, including Griliches and Hall, have dealt with both time-series and cross-sectional data. Hence it was possible in these earlier studies to use year-specific dummies. While only time-series data are used in the present study, variable intercepts will be accounted for with a flexible intercept regression model, which is a special case of a time-varying parameter model. A flexible intercept is particularity important in the current study, because the intercept of equation (8) reflects the valuation multiplier, which may have changed over time.

A time-varying parameter model can be formulated as follows:

$$y_t = x_t \, 'B_t + \varepsilon_t, \quad t = 1, 2, \ldots T \tag{9}$$

where y_t is the tth observation of the dependent variable, x_t is a K component vector of explanatory variables, B_t is a K component vector of parameters subject to sequential variation, and ε_t is the prediction error. Kalaba and Tesfatsion proposed that the parameters in the model change only a small amount from period to period with the following pattern of variation:

$$B_t = B_{t-1} + v_t \tag{10}$$

where v_t is the dynamic error.

In a traditional constant parameters model the parameters would be estimated by minimizing

$$W = \sum_{t=1}^{T} \varepsilon_t^2 \tag{11}$$

where W is the sum of the squared residual prediction errors. In Kalaba and Tesfatsion's general model, which is called flexible least squares, the parameters are estimated by taking both prediction and dynamic errors into account. Again the sum of the squared errors are minimized, normalizing on the sum of the squared prediction errors by giving these errors a weight of one and giving the sum of the squared dynamic errors an arbitrary weight of μ. The flexible least squares estimator minimizes

$$W(\mu) = \mu \sum_{t=2}^{T} v_t \, ' \, v_t + \sum_{t=1}^{T} \varepsilon_t^2 \tag{12}$$

where $W(\mu)$ is the μ-weighted sum of squared residual prediction and dynamic errors, and $v_2 = B_t - B_{t-1}$. Recall that v_t is a K component vector and ε_t is a scalar.

Large values of μ will penalize dynamic errors heavily, causing the dynamic errors to diminish. If there are no dynamic errors, the model becomes an ordinary least squares model. Alternatively, small values of μ penalize prediction errors heavily, causing prediction errors to diminish. As μ approaches zero, the model approaches a random coefficient model.

Estimation Procedure

Using matrix notation, the flexible intercept model can be estimated as follows:

$$B = A^{-1}X \, 'y \tag{13}$$

where B is the coefficient vector with the first T coefficients being year-specific intercepts $B = (B_1 \ldots B_T, \, B_{T+1}, \ldots B_{T+K}) \, '$, and y is the $(T x 1)$ vector of endogenous variables. The A and X matrices are defined below.

$$A = \begin{bmatrix} \mu+1 & -\mu & 0 & 0 & \cdots & 0 & X_{11} & \cdots & X_{K1} \\ -\mu & 2\mu+1 & -\mu & 0 & \cdots & 0 & X_{12} & \cdots & X_{K2} \\ 0 & -\mu & 2\mu+1 & -\mu & 0 & \vdots & \vdots & & \vdots \\ \vdots & \ddots & \ddots & \ddots & \ddots & \vdots & & & \\ \vdots & \cdots & 0 & -\mu & 2\mu+1 & -\mu & & & \\ 0 & \cdots & & 0 & -\mu & \mu+1 & X_{1T} & \cdots & X_{KT} \\ X_{11} & X_{12} & \cdots & & & X_{1T} & X_1'X_{1*} & \cdots & X_1'X_{K*} \\ \vdots & \vdots & & & & \vdots & \vdots & \ddots & \vdots \\ X_{K1} & X_{K2} & \cdots & & & X_{KT} & X_K'X_{1*} & \cdots & X_K'X_{K*} \end{bmatrix} \tag{14}$$

Where X_{t*} is a vector of exogenous variables $(X_{t1}, X_{t2}, \ldots, X_{tT}) \, '$.

$$X = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 & X_{11} & \cdots & X_{K1} \\ 0 & 1 & 0 & \cdots & 0 & X_{12} & & X_{K2} \\ 0 & 0 & 1 & & \vdots & \vdots & & \vdots \\ \vdots & & \ddots & & & & \ddots & \\ & & & 0 & 1 & 0 & & \\ & & & 0 & 0 & 1 & X_{1T} & \cdots & X_{KT} \end{bmatrix} \qquad (15)$$

Let the variance from the model be given by σ^2. The covariance of the flexible intercept model with independently and identically distributed ε_t is as follows:

$$cov(B) = \sigma^2 A^{-1} X'XA. \qquad (16)$$

Since σ^2 is unknown, its estimate is used in equation *(16)*.

Multicolinearity was a problem with the data, so a ridge regression model with flexible intercepts was used. The ridge regression estimator is

$$b_r = [A + rD]^{-1}X'y, \qquad (17)$$

where D is a diagonal matrix containing the diagonal elements of A and r is an arbitrary scalar. The variable r was incremented from .01 to 1.0 by .01 with the appropriate r chosen on the basis of the b_r coefficients being stable. When the absolute value of changes in all coefficients averaged less than one percent, that was the value of r chosen.

For comparison purposes, several regression models will be used, including least squares, principal components, and ridge regression with constant intercepts. The latter two approaches are used to deal with multicolinearity problems which are evident in the data. These procedures are widely reported in econometric texts, including Greene. However, these models with constant intercepts do not report how the valuation multiplier changes over time.

Data

The period of analysis covers 1950 through 1991. Data for the farm variables were mainly from *Economic Indicators of the Farm Sector (USDAc)*. The sum of total liabilities and proprietors' equity for the farm sector, excluding households, was used to reflect total value of farm assets.

Data for public and private research expenditures and a price index for research expenditures were from Huffman and Evenson. Their time series covered 1888 to 1990, but only 1915-90 was used in the present study. Private research was reported only as decade averages prior to 1956. Interpolation between decade averages was used for annual estimates prior to 1956. Following Cockburn and Griliches and Hall, research capital was calculated as a stock variable from previous research expenditures under the assumption of a 15 percent depreciation rate. Expenditures were deflated using the Huffman and Evenson research price index to calculate the stock variable. Then the stock variable was reflated to current dollars. Separate capital variables were calculated for public research and private research.

Two cash flow variables -- government payments and value of agricultural exports -- were included in the analysis. The government payments variable was from *Economic Indicators of the Farm Sector* (USDAc) and the value of agricultural exports variable was from *Agricultural Statistics (USDAb)*. In both cases, lagged variables were used in the analysis.

The tangible capital stock included gross capital expenditures in farm structures and land improvement, motor vehicles, and machinery. Data for these variables were from *Economic Indicators of the Farm Sector (USDAc)*. The 1945 level of assets in real estate, motor vehicles, and machinery was taken as the base level of capital. Annual additions to the base were derived from investments. Annual reductions in capital were based on depreciation and loss of farmland. Depreciation rates were calculated as the ratio of depreciation expenditures to the beginning values of assets in each year for each category. Data used to calculate depreciation rates were from *Economic Indicators of*

the Farm Sector (USDAc). Depreciation rates were 0.22 for automobiles, 0.21 for trucks, 0.12 for tractors, 0.14 for machinery and 0.03 for buildings. The capital stocks were constructed with deflated variables. After depreciation was accounted for, the variables were reflated to current dollars. Indexes of prices paid by farmers for automobiles, tractors, machinery and buildings and fences were obtained from *Agricultural Prices (USDAa)*. Livestock and crop inventories, which were obtained from *Economic Indicators of the Farm Sector (USDAc)*, were also included in the measure of tangible capital. The tangible capital variable is the sum of capital in automobiles, trucks, tractors, machinery, buildings, land, livestock, and crops.

Results

Regression models of equation *(8)* were estimated to explain q, which is the ratio of market value to book value, for U.S. agricultural assets. The explanatory variables include capital stock variables for public research and private research. Two cash flow variables -- government payments and agricultural exports -- were also included in the regression models. All four explanatory variables were divided by book value of assets.

Four alternatives estimation procedures were used. These procedures were least squares with a correction for autocorrelation *(AR1)*, principal components regression *(PCR)*, and two ridge regression models. One of the ridge regression models had a constant intercept and the other had flexible intercepts which varied from year to year.

Regression results are reported in table 1. The *AR1* model explains 91 percent of the variation in the model, but the standard errors are quite high, which is indicative of a multicolinearity problem. In fact, none of the explanatory variables are statistically significant in the AR1 model. Since these coefficients are not measured with adequate precision, two traditional models to address multicolinearity problems are estimated. The results from PCR and ridge regression with constant intercepts are similar, and all the coefficients are statistically significant at the 0.01 level. From these two models, the shadow prices for a dollar of public research capital are $7.20 and $7.79. The shadow

prices for a dollar of private research capital are $3.63 and $5.42.

The coefficients for the ridge regression model with flexible intercepts are similar in magnitude to the results for PCR and ridge regression with constant intercepts. All the coefficients in the ridge regression with flexible intercepts are statistically significant at the 0.01 level. Its shadow prices are $8.59 for public research capital and $5.22 for private research capital. These shadow prices are relative to tangible assets. Hence each dollar of public research capital is valued 8.59 times as much as a dollar of tangible capital. Likewise, each dollar of private research capital is valued 5.22 times as much as a dollar of tangible capital.

Conglomerate results from all four models are reported in table 2. For each model, 99% confidence intervals were calculated for the coefficients of the explanatory variables. The overlapping portions of these confidence intervals are reported in table 2. The shadow price for public research capital could fall within the range from $7.69 to $8.07 and be within the confidence intervals of all four models. For private research capital, there was no value that would fall within the confidence intervals of all four models. Table 2 also reports 99 percent confidence intervals for the ridge regression model with flexible intercepts. Its coefficient for public research capital could range from $7.69 to $9.48 as a 99 percent confidence interval. Likewise, its coefficient for private research capital could range from $4.63 to $5.81.

The exponential of each intercept in the ridge regression with flexible intercepts is the market valuation multiplier of agricultural assets. These multipliers for the period 1950-91 are shown in figure 1. In one sense the multiplier might be thought of as rather stable over the period 1950-80, followed by a dramatic reduction from 1980-91. An alternative interpretation might be that the multiplier began to decline after 1960. However, the prosperity experienced by agriculture in the 1970s caused a departure from the long-term decline in the valuation multiplier. After the 1980 peak, the multiplier reverted back to its long-term downward trend.

Table 1. Selected Regression Models of Tobin's q for U.S. Agriculture, 1950-91.

	Means	Autoregression (AR1)	Principal Components Regression	Ridge Regression	
				Constant Intercept	Flexible Intercept
Intercept		1.022* (0.123)a	0.203* (0.037)	0.406* (0.028)	
Public Research/Assets	.026	9.439 (14.262)	7.790* (1.416)	7.196* (0.339)	8.587* (0.348)
Private Research/Assets	.036	-7.911 (8.245)	5.422* (0 986)	3.626* (0 307)	5.219* (0.230)
Government Payments/Assets	.022	1.030 (0.902)	7.119* (1.294)	2.839* (1.035)	5 469* (0.594)
Value of Exports/Assets	.529	0.185 (0.114)	0.349* (0.063)	0.258* (0.036)	0.349* (0.021)
Autocorrelation Coefficient		0.855* (0.068)			

ªVariables in parentheses are standard errors.
* Statistically significant at 0.01 level.

Table 2. Confidence Intervals (99%) for Shadow Prices of Intangible Capital

Variables	Conglomerate Results of 4 Models			Ridge Regression with Flexible Intercept		
	Mean Price	Highest Lower Limit	Lowest Upper Limit	Price	Lower Limit	Upper Limit
Public Research	8.253	7.693	8 067	8.587	7.693	9 481
Private Research	1.589	4.627	4.415	5.219	4.628	5.810
Government Payments	4.114	3.942	3.348	5.469	3.942	6.996
Exports	0.285	0.295	0.351	0.349	0.295	0.403

The valuation multiplier had historically been above 1, which indicates that the market has valued agricultural assets above their replacement costs. However, the multiplier dropped from 1.22 in 1980 to .84 in 1991, which represents a 1/3 drop in just one decade. In 1987 for the first time the valuation multiplier dropped below 1. The market now values agricultural assets at less than their replacement costs.

Conclusions

Both public and private research capital have been highly valued in U.S. agriculture. Using four different approaches, each dollar of public research capital had an average value that was 8.25 times as much as a dollar of tangible capital or conventional assets such as real estate, vehicles,

machinery, and livestock. Since the rate of return on conventional assets averaged 4.9 percent over the 1950-91 period, the valuation price indicates the rate of return on research capital would be 40.4 percent *(= 8.25 x 4.9 percent)*. A rate of return on research of 40.4 percent would be comparable to earlier estimates, and it would indicate public research continues to offer a high rate of return.

The valuation multiplier, which shows how the market values farm assets, was high from 1950-80. However, it dropped by 1/3 between 1980 and 1991. For 1991, the valuation multiplier was .84, indicating each dollar of farm assets was valued by the market at only 84¢. Undervaluation is not a long-term equilibrium situation. Adjustments in investments in the agricultural sector can be expected to drive the valuation multiplier back up

Figure 1. Valuation Multiplier
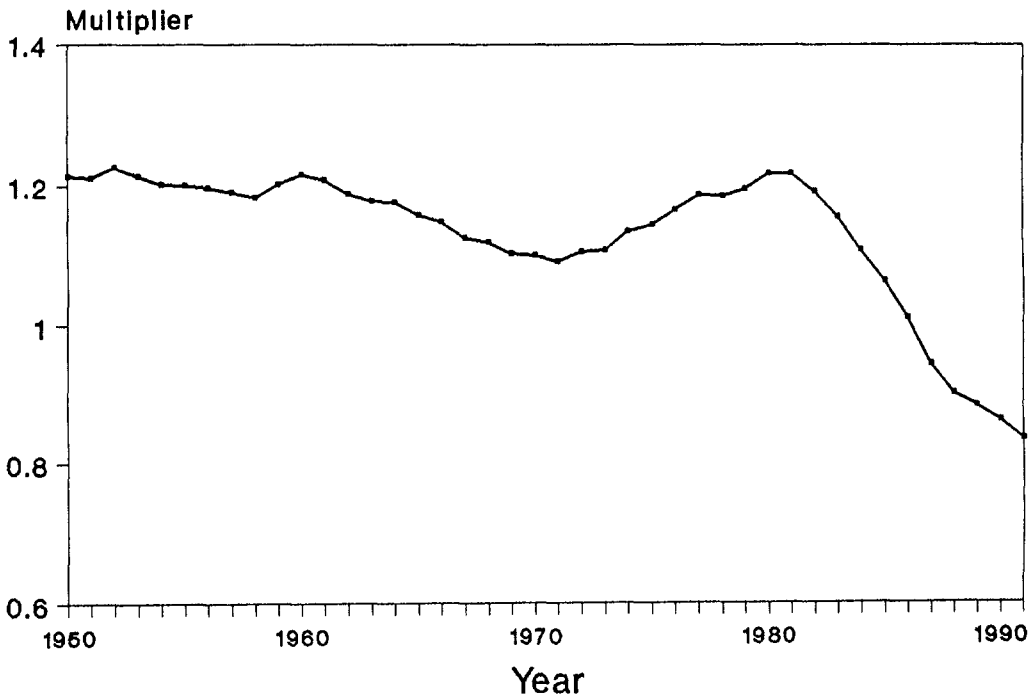
towards 1. Two types of adjustments in investment might occur in the near future. First, farmers may continue to disinvest until the market adjusts.

Alternatively, the market may realize farm assets are undervalued and bid up prices of farm assets. The type of adjustment undertaken will be dependent on other macroeconomic forces.

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