Decomposing Agricultural Profitability Using DuPont Expansion and Theil's Information Approach

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Introduction

This study extends to the analysis of Mishra et al. (2009) by analyzing the informational content of the DuPont expansion in explaining the rate of return on agricultural equity. The significance of the factors analyzed in the DuPont analysis (i.e., the gross margin on agricultural sales, the asset turnover ratio, and the leverage of the farm firm) are important in the debate on the ongoing support of the farm sector. Historically the continued justification of agricultural policy in the United States has been attributed to a vast array of factors (Schmitz et al. 2009). However, of these hypothesized factors, the persistently low return on agricultural assets and other factors of production such as farm labor has been one of the more universally accepted. Given this linkage between factor returns and agricultural policy, this study attempts to determine which financial factor may be responsible for these low returns.

The DuPont System

The DuPont expansion is an artifact of the conglomeration movement of corporate entities. Originally, the DuPont Corporation used the DuPont expansion to analyze the performance of its ventures. Most of the agricultural adaptations of the DuPont system have been to emphasize the financial and business components of risk. Collins (1985) used a general form of the DuPont expansion to develop a model of optimal debt which emphasizes the choice of equity.

This study follows the more general development of the DuPont expansion used by Mishra et al. 2009. This formulation starts with the general decomposition of the rate of return to equity into the rate of return on assets and the leverage ratio

$$\frac{R}{E} = \left(\frac{R}{A}\right)\left(\frac{A}{E}\right) \tag{1}$$

where R is defined as gross receipts minus the cost of production, E is the level of equity, and A is the total value of agricultural assets. Expanding on this analysis, the returns are then decomposed into gross sales S less the cost of production C. The gross margin on sales then becomes $S-C$. The DuPont expansion can then be expressed as

$$\frac{R}{E} = \left[\frac{S-C}{S}\right]\left[\frac{S}{A}\right]\left[\frac{A}{E}\right] \tag{2}$$

where the term in the first bracket on the right-hand side of Equation 2 is the gross margin on sales, the term in the second bracket is the asset-turnover ratio, and the third bracket contains the leverage ratio. Taking the natural logarithm of Equation 2 then yields

$$\ln\left(\frac{R}{E}\right) = \ln\left(\frac{S-C}{S}\right) + \ln\left(\frac{S}{A}\right) + \ln\left(\frac{A}{E}\right) \tag{3}$$

Using this formulation as a starting point, the effect of each factor on the rate of return on equity can be estimated using the regression

$$\ln\left(\frac{R}{E}\right) = \alpha_0 + \alpha_1 \ln\left(\frac{S-C}{S}\right) + \alpha_2 \ln\left(\frac{S}{A}\right) + \alpha_3 \ln\left(\frac{A}{E}\right) + \varepsilon \tag{4}$$

where the αs are estimated parameters and ε is a residual.

Empirical Model: Bits of Information in a Panel

To determine the relative importance of each component of the DuPont expansion, this study proposes a panel formulation of the bits of information model proposed by Theil (1987) and estimated by Moss (1997) for the agricultural sector. Specifically, Theil presents a formulation to decompose the multiple correlation coefficient from a simple regression into the amount of information contributed by each regressor. Specifically, Theil develops the relationship between the multiple correlation coefficient for the regression and the individual correlation coefficients and partial correlation coefficients

$$\left(1-R^2\right)=\left(1-r_{01}^2\right)\left(1-r_{02\bullet 1}^2\right)\cdots\left(1-r_{0p\bullet 12\cdots(p-1)}^2\right) \tag{5}$$

where R^2 is the multiple correlation coefficient from regression and each $r_{0p\bullet 12\cdots(p-1)}^2$ is the partial correlation between independent variable p and the dependent variable conditional on the covariance between independent variables $1,2,\cdots(p-1)$. From Equation 5, $p=3$ or

$$\left(1-R^2\right)=\left(1-r_{01}^2\right)\left(1-r_{02\bullet 1}^2\right)\left(1-r_{03\bullet 12}^2\right). \tag{6}$$

Theil's index measure is the $\log_2$ of Equation 6 yielding

$$-\log_2\left(1-R^2\right)=-\log_2\left(1-r_{01}^2\right)-\log_2\left(1-r_{02\bullet 1}^2\right)-\log_2\left(1-r_{03\bullet 12}^2\right). \tag{7}$$

Theil's measure allows for the decomposition of explanatory properties of each independent variable in that the measure increases arithmetically as the correlation between the independent variable and the dependent variable increases. In addition, Theil recognizes that the order each variable added makes a difference. Thus, $-\log_2\left(1-r_{01}^2\right)\geq-\log_2\left(1-r_{01\bullet 2}^2\right)$ if independent variables 1 (i.e., logarithmic changes in the returns to farmland) and 2 (i.e., logarithmic changes in the interest rates) are correlated and both individually explain changes in farmland values. Hence, Theil proposes averaging the logarithmic measure across all possible orderings.

This study expands the informational applications of Theil and Moss by considering the implications of panel data for the information measure. Refining the specification of the regression model in Equation 4, we specify the regression equation as

$$\ln\left(\frac{R}{E}\right)_{it} = \alpha_0^* + \alpha_1 \ln\left(\frac{S-C}{S}\right)_{it} + \alpha_2 \ln\left(\frac{S}{A}\right)_{it} + \alpha_3 \ln\left(\frac{A}{E}\right)_{it} + \varepsilon \tag{8}$$

where i denotes an individual region, t denotes a year, and α_0^* denotes constants that are possible different between regions (i.e., the fixed effect model). Specifically, using the panel specification from Hsiao (1986) we derive the fixed estimator from covariance matrices for each state. At the region-level, we use a covariance matrix including the dependent variable and three independent variables specified as

$$W_{XX,i} = \sum_{t=1}^{T}\left[\begin{pmatrix} y_{it}-\bar{y}_i \\ x_{1it}-\bar{x}_{1i} \\ x_{2it}-\bar{x}_{2i} \\ x_{3it}-\bar{x}_{3i} \end{pmatrix}\begin{pmatrix} y_{it}-\bar{y} & x_{1it}-\bar{x}_{1i} & x_{2it}-\bar{x}_{2i} & x_{3it}-\bar{x}_{3i} \end{pmatrix}\right] \tag{9}$$

where $\bar{y}_i$ is the average level of the dependent variable for each region across years and $\bar{x}_{1i}$ is the average for the first independent variable for each state across years. These individual variance matrices can then be used to define the fixed effects estimator. Defining W_{XX} as the state adjusted covariance matrix

$$W_{XX} = \sum_{i=1}^{n} W_{xx,i} \ . \tag{10}$$

Noting that the first column of W_{XX} matrix ($W_{XX(2:k,1)}$) contains Hsiao's $\tilde{W}_{XY}$ vector and the lower $k \times k$ partition of the W_{XX} matrix ($W_{XX(2:k,2:k)}$) contains Hsiao's $\tilde{W}_{XX}$ matrix, we can define the fixed effects estimator (β_{cv}) as

$$\beta_{cv} = W_{XX(2:k,2:k)}^{-1} W_{XX(2:k,1)} = \tilde{W}_{XX}^{-1}\tilde{W}_{XY} \ . \tag{11}$$

However, the covariance information in W_{XX} can also be used to compute the relative amount of information from each explanatory variable in the panel specification.

To further develop this decomposition, we will rely on the projected variance matrix assuming normality (Anderson 1984). First, we note that the covariance between the dependent and first independent variable as $\sigma_{01} = W_{XX(2:1)}$. The partial autocorrelation coefficient (r_{01}) in Equation 5 is then defined as

$$r_{01} = \frac{\sigma_{01}}{\sqrt{\sigma_{00}\sigma_{11}}} = \frac{W_{XX(2:1)}}{\sqrt{W_{XX(1:1)}W_{XX(2:2)}}} \tag{12}$$

where σ_{00} is the variance of the dependent variable (which is equal to $W_{XX(1:1)}$ in Equation 9) and σ_{11} is the variance of the first independent variable (which is equal to $W_{XX(2:2)}$ in Equation 9). Next, we derive the partial correlation between the dependent variable and the second independent variable given that their mutual correlation with the first independent variable has been removed. The first step is to compute the conditional covariance matrix between the dependent variable and the first independent variable as

$$\begin{bmatrix} \sigma_{00\bullet 1} & \sigma_{02\bullet 1} \\ \sigma_{02\bullet 1} & \sigma_{22\bullet 1} \end{bmatrix} = \begin{bmatrix} W_{XX(1,1)} & W_{XX(1,3)} \\ W_{XX(3,1)} & W_{XX(3:3)} \end{bmatrix} - \begin{bmatrix} W_{XX(1,2)} \\ W_{XX(3,2)} \end{bmatrix} W_{XX(2,2)}^{-1} \begin{bmatrix} W_{XX(1,2)} & W_{XX(3,2)} \end{bmatrix} \tag{13}$$

The partial correlation can then defined as

$$r_{02\bullet 1} = \frac{\sigma_{02\bullet 1}}{\sqrt{\sigma_{00\bullet 1}\sigma_{22\bullet 1}}}. \tag{14}$$

Expanding this approach to $r_{03\bullet 12}$ simply involves extending the projected variance matrix in Equation 14 to

$$\begin{bmatrix} \sigma_{00\bullet 12} & \sigma_{03\bullet 12} \\ \sigma_{03\bullet 12} & \sigma_{33\bullet 12} \end{bmatrix} = \begin{bmatrix} W_{XX(1,1)} & W_{XX(1,4)} \\ W_{XX(4,1)} & W_{XX(4,4)} \end{bmatrix} - \begin{bmatrix} W_{XX(1,2)} & W_{XX(1,3)} \\ W_{XX(4,2)} & W_{XX(4,3)} \end{bmatrix} \begin{bmatrix} W_{XX(2,2)} & W_{XX(2,3)} \\ W_{XX(3,2)} & W_{XX(3,3)} \end{bmatrix}^{-1} \begin{bmatrix} W_{XX(1,2)} & W_{XX(4,2)} \\ W_{XX(1,3)} & W_{XX(4,3)} \end{bmatrix} \tag{15}$$

Data and Empirical Results

This study follows the approach Mishra et al. (2009) using the state-level USDA sector accounts for 1960 through 2004. Income is defined as cash sales net of cash expenses, capital consumption, and interest. Hence, income represents returns to operator's labor, management, and farm assets. Like Mishra et al. we do not consider capital gains, focusing instead on operating returns. This focus requires a certain amount of aggregation because not all states yield positive returns throughout the sample periods. Specifically, the returns to operator's labor, management, and farm assets were negative throughout the Cornbelt in 1984 during the height of the last farm crisis. Further, there are persistently negative cash returns for West Virginia and Wyoming in the dataset. Negative values are particularly problematic given the logarithmic specification in Equation 8. Further, cleaning the specification by dropping the offending points from the estimation would bias the estimation. In this paper, we convert all dollar figures (returns, expenses, sales or income, agricultural assets, and equity) to real dollars using the implicit GDP deflator and we averaged all the ratio variables over 1960-69, 1970-79, 1980-89, 1990-99, and 2000-2004. Table 1 reported a statistical summary of the variables used in the analysis .

Table 2 presents both fixed effect model and the pooled national regression. Consistent with our expectations, the rate of return on agricultural equity is an increasing function of the all three explanatory variables were positive and statistically significant in both model specifications. because the reponse variable and the explanatory variables are in log terms, the parameter estimates of the explanatory can be interpreted as elasticity estimates. The estimates of the fixed effect model show that a 1% increase in the asset-turnover ratio will lead to 1.1 percent increase in the rate of return to equity, holding other variables in the model constant. Similarly, a

1% increase in the profit margin ratio and the leverage ratio will lead to about 0.9% and 1.7% increases in the rate of return on equity after holding all other parameters constant. With respect to the pooled model, the elasticity estimates show that, holding other parameters unchanged, a 1% increases in the asset to turnover ratio will lead to about 1% increase in the rate of return on equity. Similary a 1% increase in the profit margin or the leverage ratio will lead to approximately 0.9% increases in the rate of return on equity. Table 3 presents the bits of information (i.e., demonstrated in Equation 7) for each possible ordering of the DuPont regression under the fixed effect specification while Table 4 presents the bits of information for the pooled estimate. Averaging each table gives the respective bits of information from each regression presented in the first portion of Table 2. These results follow the general regression results in that most of the information in each regression is contained in the asset-turnover ratio and the profit margin. These variables contain roughly the same information with slightly more information being contained in the asset-turnover ratio in the fixed effect model, However, the resuls of the pooled model show that the profit margin is more informative than all other variables. It contains approximately 55% of the bits of information on the rate of return to equity. Both the fixed effect model and the pooled regression model show that the leverage ratio is the least informative variable in the model, it contains about 7 to 8% of the bits of information on the variable rate of return to equity.

Conclusions

As discussed by Schmitz et al. 2009, agricultural policy in the United States has been justified by a variety of reasons, but the most persistent reason has been to address the persistently low return of factors of production in the farm sector. While several studies have questioned whether the return on agricultural inputs is low, this study examines the characteristics of the farm sector that may contribute to these low factor returns using the DuPont formulation from financial analysis. In addition, the study proposes a refinement on previous estimation by extending the information content of regression to a fixed effect formulation.

The results of this study indicate that most of the variation in the rate of return on agricultural equity can be attributed to variations in the asset-turnover ratio and profit margin at the both regional and nationa levels. The fixed effect estimation reveals that the asset- turnover ratio is slightly more important that the profit margin variable with regard to the information on the rate of return to equity. More specifically, the asser-turnover ratio contains about 49% of the bits of information of the model while the profit margin contains only about 44% of bits of information of the mode.The pooled model estimation reveal a powerful effect of the profit margin variable.this variable contains about 55% of all the bits of information of the model. The amount of statistical information contained in the leverage ratio stays the same across the two model specification. From an economic perspective, these results are consistent with many farm policy questions. The farm sector is very different from other industries in that the sector is typified by a preponderance of specialized assets. Anecdotally, farmers in many areas of the United States have significant investments in machinery that are used for relatively short time periods. Corn producers may use expensive tractors for planting briefly in the spring and combines for three weeks in the fall. For most of the year these assets may set in a barn. Thus, the asset turnover ratio tends to be low for these specialized assets. Alternatively, in some areas of the country double cropping increases the use period for this equipment. Hence, differences in asset-turnover ratio may in fact provide justification for differential treatment of the farm sector. However, this justification has to be considered with the knowledge that the asset portfolio in agricultural has become increasingly dominated by farmland values.

The amount of information in the profit margin may be attributed to difference between commodity versus specialized agriculture. Specifically, following standard economic precepts the more competitive the industry the lower the pure rents to production. In the limit, in a perfectly competitive enterprise the profit is completely distributed across the factors of production. Hence, if we accept the hypothesis that the more commodity oriented production regions can be described by more competitive markets, these areas would have lower profit margins. However, areas with more specialized production such as fresh fruits and vegetables in California and Florida may be less commodity oriented, leading to higher profit margins. Undoubtedly, the commodity orientation of agriculture in the United States may be a justification for agricultural policy.

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Table 1: Mean Summary of the Variables used in the analysis [a]

Region	ROR	TRNOVR	PRFMG	ASTEQU
Northeast	0.065	0.254	0.214	1.172
	(0.031)	(0.087)	(0.070)	(0.061)
Lake States	0.063	0.217	0.229	1.247
	(0.022)	(0.019)	(0.076)	(0.046)
Corn Belt	0.056	0.177	0.254	1.197
	(0.015)	(0.023)	(0.057)	(0.048)
Northern Plains	0.072	0.206	0.280	1.233
	(0.016)	(0.036)	(0.077)	(0.042)
Appalachia	0.063	0.185	0.250	1.168
	(0.051)	(0.072)	(0.116)	(0.042)
Southeast	0.082	0.234	0.287	1.202
	(0.023)	(0.034)	(0.070)	(0.057)
Delta States	0.076	0.221	0.275	1.228
	(0.023)	(0.053)	(0.070)	(0.055)
Southern Plains	0.042	0.157	0.222	1.186
	(0.010)	(0.021)	(0.051)	(0.040)
Mountain	0.040	0.156	0.198	1.199
	(0.019)	(0.046)	(0.072)	(0.060)
Pacific	0.077	0.226	0.271	1.236
	(0.021)	(0.048)	(0.042)	(0.040)
AK and HI	0.038	0.143	0.215	1.075
	(0.031)	(0.089)	(0.073)	(0.023)

[a] standard deviations reported within parenthesis

Table 2. Bits of Information and the Parameter estimates of the Fixed Effect and Pooled Regression Models[b]

	Bits of Information			Regression Results			
	Ln(TRNOVR)	Ln(PRFMG)	Ln(ASTEQU)	Constant	Ln(TRNOVR)	Ln(PRFMG)	Ln(ASTEQU)
Fixed Effect Model	2.180	1.983	0.310		1.106***	0.925***	1.674**
					(0.073)	(0.070)	(0.518)
Pooled Model	1.847	2.755	0.374	0.102	1.000***	0.880***	0.879**
				(0.108)	(0.054)	(0.050)	(0.255)

*, **, and *** denotes that the parameter is significance at 10, 5 and 1% level of significance

[b] The standard errors reported in parenthesis

Table 3. Bits of Information for Different Orderings for the Regional Fixed Effect Model

ln(TRNOVR)	ln(PRFMG)	ln(ASTEQU)
1.25	2.78	0.44
1.25	2.81	0.41
2.84	1.19	0.44
3.14	1.19	0.14
1.46	2.81	0.21
3.14	1.13	0.21

Table 4. Bits of Information for Different Orderings for the Pooled Model

Ln(TRNOVR)	Ln(PRFMG)	Ln(ASTEQU)
1.85	2.76	0.37
1.85	3.11	0.02
3.45	1.15	0.37
3.24	1.15	0.58
1.74	3.11	0.12
3.24	1.62	0.12