# Agricultural and Rural Finance Markets in Transition

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# The Effect of Diversification on Agricultural Returns and Volatility: An Informational Approach

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This study examines the effect of agricultural diversification on the average rate of return on agricultural assets and the volatility of those returns using a informational measure of diversification. Starting with the seminal work by Markowitz, financial economics has used mean-variance formulations to estimate the effect of diversification on the performance of economic decisions. In the mean-variance formulation the selection of a portfolio of stocks have determine the maximum return obtainable for a given level of variance. Under standard assumptions, increased expected returns are only obtainable at the cost of increased risk (i.e., increased variance). In this formulation the risk-reducing effect of portfolio selection is indirect. This analysis takes an alternative approach. We follow Moss (2007) by using an informational measure of specialization.

**Measuring Diversification/Specialization**

This study uses a variant of the entropy measure used by developed by Moss (2007). Moss defines specialization based on previous work by Hackbart and Anderson (1975). They measure the diversification of the economy using entropy $J$

$$J = -\sum_{i=1}^{N} s_i \ln\left(s_i\right) \qquad (1)$$

where $s_i$ is the share of economic activity generated in sector $i$. If the economy is perfectly diversified then $s_i = 1/N$, $J \rightarrow \ln\left(N\right)$. Moss 2007 builds on previous work by Theil and Moss (1999) who examine the inequality of consumption across goods. Specifically, Theil and Moss define $J_k$ as the inequality in the consumption of good $k$ across consumers as

$$J_k = -\ln\left(N\right) - \frac{1}{N}\sum_{c=1}^{N} \ln\left(\frac{B_{ck}}{B_{.k}}\right) \qquad (2)$$

where $B_{ck}$ is the expenditure share for consumer $c$ on good $k$ and $B_{.k}$ is the consumption of good $k$ across all consumers (i.e., $B_{.k} = \sum_{c=1}^{N} B_{ck}$). Unlike Theil and Moss, Moss defines the overall inequality across all goods as

$$J = -\ln\left(N\right) - \frac{1}{N}\sum_{c=1}^{N} \ln\left(B_{c.}\right) \quad (3)$$

where $B_{c.} = \sum_{k=1}^{K} B_{ck}$ is the total expenditure for each consumer $c$. The inequality in Equation 3 is then the expenditure inequality across all individuals. Given these definitions, he concludes that

$$J = \overline{J} - \overline{I} \qquad (4)$$

where $\overline{J} = \sum_{k=1}^{K} B_{.k} J_k$ is the average inequality of consumption across all commodities and $\overline{I} = 1/N \sum_{c=1}^{N} I_c$ with $I_c$ is defined as

$$I_c = \sum_{k=1}^{K} B_{.k} \ln\left( \frac{B_{.k}}{B_{ck} / B_{c.}} \right) \qquad (5)$$

where $I_c$ measures the dispersion of shares for state $c$ from the average portfolio.

To investigate the effect of specialization on economic growth and volatility, we then regress the average rate of return on agricultural assets and the volatility of the rate of return on agricultural assets on for each of the 48 contiguous states

$$\begin{aligned} \bar{r}_c &= \alpha_0 + \alpha_1 \tilde{I}_c + \varepsilon_c \\ \sigma_c^2 &= \beta_0 + \beta_1 \tilde{I}_c + \nu_c \end{aligned} \qquad (6)$$

where $\bar{r}_c$ is the average and $\sigma_c^2$ is the variance of the rate of returns for state $c$ and $\tilde{I}_c$ is the geometric average dispersion coefficient for each state (defined by Equation 4). Following traditional economic assumptions, we assume that $\alpha_1 > 0$ or that the return on agricultural assets is an increasing function of agricultural specialization and that this increased return due to specialization implies higher risk ($\beta_1 > 0$).

Given the panel structure of the dataset, we use generalized least squares applied to panel data as described by Hsiao (1986). Specifically, we let $X_i$ be the data matrix for each state over time, the first column of this matrix is the observed cash flow for each year divided by one plus the corresponding interest rate (i.e., for that year/state combination), the second column is the land value for the preceding times the interest rate divided by one plus the interest rate, and the final column is the land value in the preceding year times the inflation rate value of farmland in the preceding year. The dependent variable matrix, $Y_i$, is the change in farmland values between year $t+1$ and year $t$. The generalized least squares results are then given by

$$\hat{\beta}_{GLS} = \left[ \frac{1}{T} \sum_{i=1}^{M} X_i' Q X_i + \psi \sum_{i=1}^{M} (\bar{x}_i - \bar{x})(\bar{x}_i - \bar{x})' \right]^{-1} \left[ \frac{1}{T} \sum_{i=1}^{M} X_i' Q Y_i + \psi \sum_{i=1}^{M} (\bar{x}_i - \bar{x})(\bar{y}_i - \bar{y})' \right] \qquad (7)$$

where $Q = I_T - \frac{1}{T} e e'$ and $e$ is a conformable vector of ones (this is the sweep matrix), $\psi$ is a relative weighting of the variance components ($\psi = \sigma_u^2 / (\sigma_u^2 + T\sigma_\alpha^2)$), $\bar{x}_i$ denotes the average value of $x$ for a given individual $i$ over time, and $\bar{x}$ is the average value of $x$ across all individuals and time periods. This specification allows for the decomposition of the overall estimator into two components: the within estimator and the between estimator. The within estimator ($\beta_{cv}$) is the average regression coefficient across all individuals

$$\hat{\beta}_{cv} = \left[ \sum_{i=1}^{M} X_i' Q X_i \right]^{-1} \left[ \sum_{i=1}^{M} X_i' Q Y_i \right] \qquad (8)$$

and the between estimator is the regression relationship defined between the average observations for each individual

$$\hat{\beta}_b = \left[ \sum_{i=1}^{M} \left( \bar{x}_i - \bar{x} \right) \left( \bar{x}_i - \bar{x} \right)' \right]^{-1} \left[ \sum_{i=1}^{M} \left( \bar{x}_i - \bar{x} \right) \left( \bar{y}_i - \bar{y} \right)' \right] \qquad (9)$$

Given this estimator, we can then define the average intercept value across all individuals ($\hat{\mu}$) as

$$\hat{\mu} = \bar{y} - \hat{\beta}_{GLS} \bar{x} . \qquad (10)$$

To complete this formulation, we estimate $\sigma_u^2$ using the estimated variance from the uncorrected (i.e., homoskedastic) estimates of $\hat{\beta}_{cv}$ and $\sigma_\alpha^2$ using a similar regression based on the sample means.

**References**


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Table 1. Entropy Across Revenue Sources

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field Crops | 0.7383 | 0.7953 | 0.8176 | 0.8299 | 0.8025 | 0.7729 | 0.7894 | 0.7719 | 0.7834 | 0.8344 | 0.8516 | 0.8438 | 0.8289 | 0.8979 |
| Fruits and Vegetables | 2.7996 | 2.7419 | 2.7884 | 2.8702 | 2.8881 | 2.8593 | 2.8248 | 2.8790 | 2.8470 | 2.9193 | 2.8608 | 2.8907 | 2.9470 | 2.9099 |
| Cattle | 1.0419 | 1.0898 | 1.1684 | 1.1662 | 1.1364 | 1.1580 | 1.1437 | 1.1261 | 1.1429 | 1.1714 | 1.2319 | 1.1979 | 1.1580 | 1.1725 |
| Hogs | 1.7988 | 1.8443 | 1.9171 | 1.9162 | 1.9457 | 1.9568 | 1.9869 | 2.0398 | 2.1098 | 2.1097 | 2.1458 | 2.2136 | 2.2410 | 2.3120 |
| Dairy | 0.7866 | 0.7981 | 0.8239 | 0.8417 | 0.8512 | 0.8749 | 0.8703 | 0.8855 | 0.9237 | 0.9328 | 0.9798 | 1.0099 | 1.0296 | 1.0327 |
| | | | | | | | | | | | | | | |
| $J$ | 0.6731 | 0.6913 | 0.7145 | 0.7088 | 0.7100 | 0.6885 | 0.7068 | 0.7023 | 0.7115 | 0.7462 | 0.7581 | 0.7530 | 0.7651 | 0.7892 |
| $\bar{J}$ | 1.1402 | 1.1421 | 1.1942 | 1.2009 | 1.2238 | 1.2126 | 1.2348 | 1.2619 | 1.2643 | 1.3023 | 1.3020 | 1.3175 | 1.3399 | 1.3429 |
| $\bar{I}$ | 0.4671 | 0.4508 | 0.4798 | 0.4921 | 0.5138 | 0.5240 | 0.5279 | 0.5596 | 0.5528 | 0.5561 | 0.5438 | 0.5644 | 0.5749 | 0.5537 |

Table 2. Effect of Specialization on Rate of Return and Volatility

| Variable | Rate of Return | Variance of Rate of Return |
|---|---|---|
| Constant | 0.1125*** | 0.0088*** |
| | (0.0070)[a] | (0.0003) |
| Specialization | -0.0305** | -0.0008 |
| | (0.0134) | (0.0006) |
| $R^2$ - Within | 0.0119 | 0.0044 |
| $R^2$ - Between | 0.0026 | 0.0005 |
| $R^2$ - Overall | 0.0013 | 0.0004 |
| Fixed Effect Test | 31.99 | 456.14 |

[a]Numbers in parenthesis denotes standard errors.
***Denotes statistical significance at the 0.01 level of confidence.
**Denotes statistical significance at the 0.05 level of confidence.

Appendix A. State Level Specialization Indices

| State | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alabama | 0.0864 | 0.1291 | 0.1095 | 0.1593 | 0.1547 | 0.2199 | 0.2178 | 0.2118 | 0.1949 | 0.1838 | 0.2379 | 0.2913 | 0.2600 | 0.1930 |
| Arizona | 0.1756 | 0.1384 | 0.2379 | 0.1791 | 0.1539 | 0.2098 | 0.2034 | 0.1946 | 0.3182 | 0.3797 | 0.2120 | 0.2628 | 0.2312 | 0.2424 |
| Arkansas | 0.3508 | 0.3355 | 0.3346 | 0.4188 | 0.3965 | 0.4165 | 0.3935 | 0.3919 | 0.3802 | 0.4397 | 0.4992 | 0.5820 | 0.5135 | 0.5209 |
| California | 0.6340 | 0.6341 | 0.7015 | 0.7327 | 0.7733 | 0.7661 | 0.7430 | 0.8191 | 0.8113 | 0.7993 | 0.8193 | 0.8169 | 0.8585 | 0.9102 |
| Colorado | 0.2767 | 0.2778 | 0.2829 | 0.3041 | 0.2683 | 0.2582 | 0.3304 | 0.3146 | 0.2892 | 0.3820 | 0.3659 | 0.4015 | 0.3339 | 0.3361 |
| Connecticut | 0.3348 | 0.3490 | 0.3478 | 0.3302 | 0.4060 | 0.3891 | 0.4366 | 0.4010 | 0.4048 | 0.3490 | 0.3589 | 0.4379 | 0.3927 | 0.3982 |
| Delaware | 0.2181 | 0.3583 | 0.3574 | 0.2831 | 0.2455 | 0.2527 | 0.2334 | 0.3642 | 0.3591 | 0.2984 | 0.4518 | 0.3233 | 0.3188 | 0.3222 |
| Florida | 0.6897 | 0.6704 | 0.6857 | 0.7635 | 0.7260 | 0.7267 | 0.6972 | 0.7751 | 0.7164 | 0.6915 | 0.6823 | 0.7407 | 0.7537 | 0.7814 |
| Georgia | 0.0566 | 0.0788 | 0.0630 | 0.0711 | 0.0507 | 0.0765 | 0.0693 | 0.0929 | 0.0708 | 0.0609 | 0.0913 | 0.0628 | 0.1027 | 0.1107 |
| Idaho | 0.2396 | 0.2040 | 0.2809 | 0.2494 | 0.2890 | 0.2696 | 0.3544 | 0.3673 | 0.4063 | 0.3371 | 0.3252 | 0.4744 | 0.4853 | 0.4279 |
| Illinois | 0.4959 | 0.4339 | 0.4476 | 0.4326 | 0.5115 | 0.5541 | 0.5775 | 0.5499 | 0.5616 | 0.6002 | 0.5864 | 0.6548 | 0.5784 | 0.6375 |
| Indiana | 0.4336 | 0.3587 | 0.3778 | 0.3798 | 0.3892 | 0.4278 | 0.4346 | 0.4490 | 0.4472 | 0.4347 | 0.4632 | 0.4546 | 0.4802 | 0.4785 |
| Iowa | 0.7211 | 0.6422 | 0.6965 | 0.6330 | 0.7483 | 0.7482 | 0.7733 | 0.8181 | 0.7780 | 0.9947 | 0.8688 | 0.9055 | 1.0143 | 0.8932 |
| Kansas | 0.8811 | 0.7390 | 0.8626 | 0.9547 | 0.8095 | 1.1343 | 0.8863 | 1.1413 | 0.9962 | 0.9708 | 0.9260 | 0.8497 | 0.9047 | 0.9258 |
| Kentucky | 0.3685 | 0.4020 | 0.4120 | 0.4541 | 0.5956 | 0.5542 | 0.5964 | 0.6724 | 0.5516 | 0.6418 | 0.5539 | 0.5242 | 0.6199 | 0.5517 |
| Louisiana | 0.3970 | 0.3814 | 0.4175 | 0.4899 | 0.5280 | 0.4214 | 0.5036 | 0.5596 | 0.6293 | 0.6763 | 0.5889 | 0.6263 | 0.7537 | 0.5894 |
| Maine | 0.3513 | 0.2697 | 0.3062 | 0.3373 | 0.3401 | 0.2772 | 0.3208 | 0.3692 | 0.3741 | 0.3077 | 0.3339 | 0.3858 | 0.4050 | 0.3552 |
| Maryland | 0.1275 | 0.1621 | 0.1355 | 0.1907 | 0.1508 | 0.1620 | 0.1841 | 0.2405 | 0.2335 | 0.1880 | 0.1853 | 0.2095 | 0.1991 | 0.2029 |
| Massachusetts | 0.7222 | 0.7801 | 0.7943 | 0.9009 | 0.8713 | 0.5637 | 0.5311 | 0.4942 | 0.5026 | 0.4906 | 0.5724 | 0.5829 | 0.4861 | 0.5226 |
| Michigan | 0.1290 | 0.0927 | 0.1006 | 0.0878 | 0.1184 | 0.1357 | 0.1407 | 0.1410 | 0.1585 | 0.1681 | 0.1960 | 0.1663 | 0.1744 | 0.1626 |
| Minnesota | 0.2579 | 0.2119 | 0.2389 | 0.1921 | 0.2227 | 0.2522 | 0.2833 | 0.2971 | 0.2906 | 0.3341 | 0.3011 | 0.3111 | 0.3353 | 0.3674 |
| Mississippi | 0.4119 | 0.4546 | 0.4733 | 0.5374 | 0.5419 | 0.6089 | 0.4906 | 0.5223 | 0.4712 | 0.5411 | 0.5618 | 0.6347 | 0.5892 | 0.4031 |
| Missouri | 0.2961 | 0.2828 | 0.2975 | 0.3297 | 0.3286 | 0.3362 | 0.3418 | 0.3890 | 0.3593 | 0.3758 | 0.3415 | 0.3793 | 0.3433 | 0.3454 |
| Montana | 0.9641 | 0.7125 | 0.7708 | 0.7449 | 0.8538 | 0.7680 | 0.8854 | 0.8374 | 0.7767 | 0.6905 | 0.6703 | 0.6854 | 0.7317 | 0.8581 |
| Nebraska | 1.7546 | 1.6603 | 1.7761 | 1.7118 | 1.8698 | 1.9748 | 2.0877 | 2.0647 | 2.0053 | 2.1544 | 1.9966 | 1.9903 | 2.1323 | 2.0394 |
| Nevada | 0.1948 | 0.2124 | 0.1890 | 0.1674 | 0.2009 | 0.2320 | 0.2277 | 0.2081 | 0.3103 | 0.2040 | 0.2234 | 0.2585 | 0.2536 | 0.2339 |
| New Hampshire | 0.4389 | 0.4601 | 0.5504 | 0.6146 | 0.5971 | 0.5810 | 0.4840 | 0.4521 | 0.5321 | 0.4406 | 0.4690 | 0.5227 | 0.4645 | 0.4199 |
| New Jersey | 0.6422 | 0.7435 | 0.6890 | 0.7052 | 0.7602 | 0.7699 | 0.7207 | 0.9381 | 0.9286 | 0.9373 | 0.8164 | 0.7972 | 0.8926 | 0.8818 |
| New Mexico | 0.3706 | 0.3926 | 0.3659 | 0.5620 | 0.5666 | 0.5563 | 0.4706 | 0.6074 | 0.6320 | 0.5850 | 0.6452 | 0.7066 | 0.6959 | 0.7462 |
| New York | 0.5426 | 0.5417 | 0.5972 | 0.6987 | 0.6579 | 0.6787 | 0.6856 | 0.6799 | 0.6767 | 0.6768 | 0.6583 | 0.7440 | 0.7046 | 0.6552 |

Appendix A. State Level Specialization Indices (Continued)

| State | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Carolina | 0.4115 | 0.3736 | 0.4446 | 0.4609 | 0.5107 | 0.4886 | 0.4282 | 0.4865 | 0.4965 | 0.4576 | 0.4848 | 0.5540 | 0.5754 | 0.5080 |
| North Dakota | 1.6506 | 1.5479 | 1.6885 | 1.6492 | 1.7479 | 1.8854 | 1.8906 | 1.9593 | 1.8952 | 2.0682 | 1.9598 | 1.8862 | 2.0764 | 1.9808 |
| Ohio | 0.2030 | 0.1944 | 0.2144 | 0.1367 | 0.2273 | 0.2029 | 0.2186 | 0.2321 | 0.1805 | 0.1585 | 0.2281 | 0.2277 | 0.1905 | 0.1783 |
| Oklahoma | 0.4998 | 0.4496 | 0.3882 | 0.4909 | 0.4567 | 0.5446 | 0.4510 | 0.6484 | 0.5132 | 0.6014 | 0.5875 | 0.4142 | 0.5150 | 0.6041 |
| Oregon | 0.1381 | 0.1411 | 0.1317 | 0.1758 | 0.1804 | 0.1488 | 0.1452 | 0.1812 | 0.1766 | 0.1488 | 0.1607 | 0.1998 | 0.2136 | 0.1985 |
| Pennsylvania | 0.2347 | 0.2479 | 0.2673 | 0.2546 | 0.2487 | 0.2853 | 0.3065 | 0.2734 | 0.2867 | 0.2745 | 0.2403 | 0.2467 | 0.2622 | 0.2191 |
| Rhode Island | 0.2996 | 0.2899 | 0.3050 | 0.2210 | 0.2634 | 0.2872 | 0.2749 | 0.2359 | 0.1977 | 0.2162 | 0.2265 | 0.2629 | 0.1499 | 0.1611 |
| South Carolina | 0.0405 | 0.0686 | 0.0849 | 0.1309 | 0.0998 | 0.0750 | 0.0569 | 0.0676 | 0.0573 | 0.0166 | 0.0701 | 0.0699 | 0.0620 | 0.0469 |
| South Dakota | 1.4556 | 1.3782 | 1.4923 | 1.4378 | 1.5967 | 1.6520 | 1.7647 | 1.7758 | 1.7073 | 1.8542 | 1.7163 | 1.6870 | 1.8272 | 1.7422 |
| Tennessee | 0.1371 | 0.1151 | 0.1474 | 0.1241 | 0.1471 | 0.1308 | 0.1625 | 0.1426 | 0.2390 | 0.1428 | 0.1386 | 0.1788 | 0.1601 | 0.1356 |
| Texas | 0.2762 | 0.2747 | 0.3012 | 0.3055 | 0.3181 | 0.3109 | 0.2966 | 0.3407 | 0.3450 | 0.2993 | 0.3380 | 0.3478 | 0.3045 | 0.3312 |
| Utah | 0.2489 | 0.2494 | 0.3015 | 0.2392 | 0.2170 | 0.1893 | 0.2572 | 0.1912 | 0.2395 | 0.3364 | 0.2570 | 0.2526 | 0.2617 | 0.2536 |
| Vermont | 0.9108 | 0.9757 | 1.0762 | 1.1323 | 1.0272 | 1.0516 | 1.0333 | 1.0699 | 1.0779 | 0.9451 | 0.9918 | 1.1448 | 1.1149 | 1.0166 |
| Virginia | 0.0366 | 0.0233 | 0.0264 | 0.0489 | 0.0411 | 0.0335 | 0.0443 | 0.0682 | 0.0505 | 0.0450 | 0.0331 | 0.0256 | 0.0384 | 0.0235 |
| Washington | 0.3016 | 0.2956 | 0.3150 | 0.2846 | 0.3338 | 0.2766 | 0.2977 | 0.3121 | 0.3611 | 0.3316 | 0.3876 | 0.3746 | 0.4018 | 0.4164 |
| West Virginia | 0.1126 | 0.0789 | 0.0740 | 0.0751 | 0.1284 | 0.1230 | 0.1426 | 0.2255 | 0.2218 | 0.1807 | 0.1587 | 0.1797 | 0.2439 | 0.2591 |
| Wisconsin | 0.3774 | 0.3191 | 0.3321 | 0.3598 | 0.3177 | 0.3929 | 0.3961 | 0.3906 | 0.4093 | 0.3473 | 0.3537 | 0.4225 | 0.3863 | 0.3267 |
| Wyoming | 1.6645 | 1.6228 | 1.6417 | 1.5379 | 1.7430 | 1.8917 | 1.9556 | 1.9884 | 1.9722 | 2.1107 | 1.8722 | 1.9937 | 1.9882 | 1.8834 |