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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

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

where s_i is the share of economic activity generated in sector i . If the economy is perfectly diversified then $s_i = 1/N$, $J \rightarrow \ln N$. 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

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

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

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

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

$$J = \bar{J} - \bar{I} \quad (4)$$

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

$$I_c = \sum_{k=1}^K B_{ck} \ln \left(\frac{B_k}{\overline{B}_{ck}} \right) \quad (5)$$

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

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

where \bar{r}_c is the average and σ_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

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

where $Q = I_T - \frac{1}{T} ee'$ and e is a conformable vector of ones (this is the sweep matrix), ψ 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 ($\hat{\beta}_{cv}$) is the average regression coefficient across all individuals

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

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

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

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

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

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

References

- Hackbart M.H. and D.A. Anderson. (1975) "On Measuring Economic Diversification." *Land Economics* 51(4), 374–78.
- Moss, C.B. "Impact of Diversification on Expected Growth and Volatility: An Inequality Component Approach." Mimeographed paper, Food and Resource Economics Department, University of Florida, May 2007.
- Theil, H. and C.B. Moss. "The Measurement of Inequality by Components of Total Expenditure." *Empirical Economics* 24(3): 559–61.

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*** (0.0070) ^a	0.0088*** (0.0003)
Specialization	-0.0305** (0.0134)	-0.0008 (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

^aNumbers 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