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In This Issue

In the Fall 1985 issue, this column discussed Lawrence J. Peter's tongue-in-cheek definition of an economist as "an expert who will know tomorrow why the things he predicted yesterday didn't happen today." Peter was needling the economics profession for its after-the-fact handling of economic problems. This column pointed out that, in spite of the apparent surface truth of his observation, economics is not a precise profession and its practitioners daily risk professional reputations by making economic analysis on less than complete information.

In this issue we have several examples of professional courage. In the research review section, Tweeten revisits a statement he made in this journal in July 1980: "I contend current land prices can be justified by prospective earnings." Time and economic events have not been kind to this statement. Land prices did continue to rise until 1982, but have since fallen 28 percent. In a reappraisal of his 1980 statement, Tweeten is in a sense carrying the ball for the agricultural economics profession because his assessment of the farmland market was not an uncommon view. So read "A Note on Explaining Farmland Price Changes in the Seventies and Eighties." Was our inability to foresee the significant drop in land prices due to faulty economic theory and analysis or due to events outside our control or ability to foresee?

In contrast to the economist with an established reputation exhibiting the courage to review a past statement that subsequent events did not support are economists Shoemaker and Somwaru, who are early in their careers. They exhibit the professional courage to present results that may differ from conventional wisdom about the cost and productivity structure of U.S. dairy farms. They apply total factor productivity, a somewhat more comprehensive technique than often used in past productivity measurements, to analyze a recently available data series, the Census of Agriculture Standard Industrial Classification (SIC) type of farm data. They examine this series for the implications of regional differences in productivity levels and for changes in dairy farm productivity. Their article deserves thoughtful reflection as this technique and this data source are hard to ignore. Total factor productivity based on a national income and product accounting-type framework imposes an accounting discipline on the productivity analyst that may require answering questions that never occur to users of other approaches. The Census type of farm data is also hard to ignore. These data are summaries of the census of the actual dairy farms that make up our national dairy sector. If results based on these data run counter to intuition or conventional wisdom, one has to wonder why.

Finally, Smallwood and Blaylock assume the risk of communicating a very econometrically oriented discussion of modeling issues concerning short-term forecasting to the readership. The topic is more technical than the usual AER article, and they undertake the task of writing at a level that will encourage wider readership while maintaining technical content and professional quality.

Gerald Schluter

Contents

Total Factor Productivity and Sources of Growth in the Dairy Sector

Robbin Shoemaker and Agapi Somwaru

Abstract

One would expect to find differences in total factor productivity (TFP) associated with factor allocation, given the technological change in the dairy sector over time and the regional disparity of regulations affecting production. The authors use a National Income and Product Accounting procedure to calculate total income and product, TFP, and sources of growth for seven dairy States in different regions. The average TFP growth for the seven States was 2.5 percent per year. Florida and California had higher TFP *growth* rates, but interspatial TFP estimates indicated Wisconsin and New York had greater relative TFP *levels* in both 1978 and 1982.

Keywords

National Income and Product Accounting, intertemporal and interspatial total factor productivity, rates of return, sources of growth

One would think the dairy industry is fairly diverse regionally. There has been considerable regulation of milk pricing and production within the dairy sector, but these regulations have differed markedly across regions, primarily because of Federal marketing orders, subsidized pricing, and different State-level effects of price-support programs. Such regional differentiation of regulations within an industry leads one to expect differences in factor returns, allocations, and productivity by region. Total factor productivity (TFP)—changes in output for a given level of total input—is usually associated with technological change or more efficient reallocation of a given level and quality of inputs. In this article, we examine TFP differences across regions within the dairy sector.

Productivity measures at the firm level are usually based on detailed enterprise data. These measures are often estimated as yield per acre or pounds of milk per cow. Insufficient data for performing the analysis on a milk-per-cow basis limited this analysis to the three-digit Standard Industrial Classification (SIC) of the dairy sector. Furthermore, since a productivity measure such as pounds of milk per cow can provide a biased measure of productivity, a TFP index measure of productivity growth is useful because it corresponds more closely to a production function; that is, the TFP index relates output to an implicit function of all inputs (*5*).[1] Although the index number approach is relatively simple to implement, it assumes uniform technical parameters across all regions, whereas those regional parameters can be estimated with an econometric approach.

We applied the analysis to seven regionally diverse dairy States: Pennsylvania, New York, Vermont, Wisconsin, Florida, California, and Texas. These States were selected as representative of diverse dairy-producing regions because their herd sizes and input costs differ considerably.

We provide some insight into the relative productivity of these different regions by using a National Income and Product Accounting (NIPA) procedure. These accounts provide a method consistent with the economic theory of production and income. We

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[1]Italicized numbers in parentheses refer to References at the end of this article.

use a procedure first proposed by Kendrick and Jones (*12*) in setting up the national agricultural income and product accounts. This method is used to derive gross national product at the national level where output (total product) is the final value of all goods and services at market prices. Income is the payment to all factors (that is, capital and labor). We chose this method because it enables us to account for all income and products in the dairy sector. The estimates of real factor payments and output allow us to calculate the difference between the growth in output and inputs, which is used to indicate productivity growth.

The NIPA method provides an accounting system with *all* inputs and outputs captured in a closed system; that is, all variables are defined such that total value of all factors is equal to the total value of output. Thus, we implicitly assume that dairy production is characterized by constant returns to scale, an assumption that may not apply to the dairy sector, but which cannot be tested in this type of analysis.[2] As a closed system, the procedure is complete in that it requires an accounting of all relevant variables. The requirement imposed by our analysis is no less a problem than it is for construction of the national accounts. However, for a particular sector, this type of accounting implies that the results regarding the sector's performance may be more suggestive than conclusive. Developing an income and product account of an economic sector is useful because it logically identifies key economic variables of that sector: gross product (value-added output), profit income (net farm income), property compensation, and rate of return to capital. By converting the value-added measure of output to a gross measure by including intermediate products and by estimating the service flows of capital, labor, and materials, one can estimate TFP. Using the estimates of the growth in factor inputs, outputs, and TFP, one can determine the sources of growth in output between the growth in factor inputs and technological change. We made regional comparisons for 2 census years, 1978 and 1982, and we calculated TFP levels and growth rates for this 5-year period.

In this article, we develop dairy-sector income and product accounts for the constant-dollar SIC, and we discuss regionally diverse incomes and returns. We derive aggregate productivity estimates. Finally, we perform a sources-of-growth analysis to quantify factors contributing to differences in the output growth across regions.

Income and Product Accounts

We first develop the income and product accounts for the SIC dairy farms. These accounts for the seven States are set up in both current and constant 1977 dollars for 1978 and 1982.

The Census of Agriculture classifies farms by two- and three-digit SIC codes at national and State levels. Farms where dairy products account for 50 percent or more of total farm sales are classified as three-digit SIC dairy farms. Income and product estimates reported here are based on data from the Census of Agriculture as used by Somwaru (*14*).

The derivation of dairy income and product follows the procedure used for the Gross Farm Product and Income account (*9, 12*) by the Bureau of Economic Analysis of the U.S. Department of Commerce. Total value of output is the sum of crop and livestock receipts (including net Commodity Credit Corporation (CCC) payments), Government payments, and income from custom work, rentals, and recreational services (tables 1 and 2). Including Government payments may be problematic because these payments may increase while actual production is constant, thus giving a policy-distorted increase in total output. When this potential distortion in total returns affects the allocation of inputs, including Government payments certainly is valid. The imputed value of home consumption of farm products and the change in crop and livestock inventories are included in other income.

One derives gross dairy product by subtracting the costs of intermediate products (feed, seed, energy, fertilizer, and so forth), custom work, rent, and repairs from total output. This figure yields the value-added measure of output for the dairy sector; that is, it contains the value of all dairy and nondairy products produced by the sector net of intermediate products that contribute to dairy produc-

[2]One makes several assumptions when using a NIPA framework. First, the longrun competitive price-taking behavior of producers is associated with profit maximization. Next, the SIC delineation of the dairy sector implies that firms are multiple-output producers. Furthermore, one assumes a constant-returns-to-scale multiple-output transformation function and that value-added output implies that production is separable from intermediate inputs.

Table 1—Gross dairy product and income, constant 1977 dollars, 1978

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				1,000 dollars			
Crop cash receipts:							
Grain	24,509	62	405	62,020	2,816	11,688	1,953
Cotton and cottonseed	0	0	0	0	14,548	0	407
Tobacco	5,300	0	239	5,657	0	0	0
Field seeds, hay, forage, and silage	15,215	876	200	23,898	4,956	9,995	679
Vegetables, sweet corn, and melons	1,673	116	468	8,430	1,738	2,645	82
Fruits, nuts, and berries	362	130	299	320	7,976	1,371	43
Nursery and greenhouse products	215	5	165	56	0	56	0
Other crops	662	12	211	684	1,070	343	729
Livestock cash receipts:							
Poultry and products	3,425	58	390	2,011	5	910	132
Dairy products	748,321	224,605	229,643	1,854,628	1,150,241	1,026,498	351,657
Cattle and calves	59,881	14,070	16,899	170,221	78,381	72,831	28,760
Hogs and pigs	5,893	70	183	36,856	247	789	504
Sheep, lambs, and wool	150	17	0	303	143	102	169
Other livestock	385	67	74	481	119	280	70
Government payments	2,262	261	45	4,571	2,160	1,536	2,541
Custom work	3,826	250	65	10,204	2,614	2,704	1,519
Rents	419	153	154	1,536	334	640	502
Recreational services	2,348	532	85	6,862	456	2,569	511
Other income:							
Home consumption	7,161	1,601	214	21,014	1,339	7,820	1,387
Change in inventories:							
Crops	15,750	1,047	558	35,274	7,893	10,322	1,608
Livestock	(16,511)	(4,777)	(4,965)	(41,941)	(24,633)	(22,104)	(7,686)
Total value of output	881,246	239,155	245,332	2,203,085	1,252,403	1,130,995	385,567
Intermediate expenses:							
– Intermediate products	277,562	93,598	124,674	565,393	555,006	402,995	179,970
– Custom work expense	7,820	882	726	20,343	11,975	7,042	2,728
– Rent expense	11,970	3,350	1,108	26,981	3,389	15,223	7,322
– Repairs	58,057	13,764	2,564	179,142	15,937	69,798	10,135
– Other expenses	23,884	6,941	6,999	56,613	30,963	31,368	10,831
= Gross dairy product	501,953	120,620	109,261	1,354,613	635,133	604,569	174,581
– Capital consumption	133,978	31,763	5,917	413,403	36,777	161,072	23,388
– Property taxes	18,767	3,449	2,097	40,628	8,592	14,361	4,608
= Income originating	349,208	85,408	101,247	900,582	589,764	429,136	146,585
– Labor compensation	47,052	16,185	24,043	93,692	84,817	71,564	22,257
= Property compensation	302,156	69,223	77,204	806,890	504,947	357,572	124,328
– Net interest	55,256	13,964	15,109	116,491	64,091	59,480	23,338
= Net farm income	246,900	55,259	62,095	690,399	440,856	298,092	100,990

Numbers in parentheses denote negative values.

Table 2—Gross dairy product and income, constant 1977 dollars, 1982

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				1,000 dollars			
Crop cash receipts:							
Grain	34,715	346	465	112,506	5,559	23,005	3,641
Cotton and cottonseed	0	0	0	0	27,629	0	0
Tobacco	5,632	0	0	5,589	0	0	0
Field seeds, hay, forage, and silage	5,982	1,724	470	10,604	8,744	5,927	1,488
Vegetables, sweet corn, and melons	2,156	105	0	9,540	2,102	3,039	202
Fruits, nuts, and berries	328	98	1,057	215	5,442	1,138	304
Nursery and greenhouse products	190	11	0	60	0	52	0
Other crops	1,233	12	352	1,303	1,150	624	1,135
Livestock cash receipts:							
Poultry and products	3,876	130	463	1,639	5	1,020	334
Dairy products	831,969	242,399	254,291	2,146,801	1,403,769	1,092,155	370,677
Cattle and calves	58,515	14,543	17,175	186,709	89,615	66,357	27,244
Hogs and pigs	5,396	60	181	31,190	679	595	735
Sheep, lambs, and wool	112	19	0	319	88	126	34
Other livestock	483	119	4	583	83	314	172
Government payments	2,192	325	135	5,385	1,479	2,138	577
Custom work	5,648	558	42	14,921	4,560	3,734	1,626
Rents	264	77	37	900	231	209	317
Recreational services	2,148	471	62	6,278	417	2,350	467
Other income:							
Home consumption	5,953	1,308	130	17,228	1,114	6,144	1,054
Change in inventories:							
Crops	(10,873)	(463)	(466)	(26,601)	(7,059)	(6,438)	(1,239)
Livestock	(8,023)	(2,257)	(2,391)	(20,964)	(13,131)	(10,189)	(3,516)
Total value of output	947,826	259,585	272,007	2,504,205	1,532,476	1,192,300	405,252
Intermediate expenses:							
– Intermediate products	245,700	83,865	108,296	652,172	581,628	370,994	158,451
– Custom work expense	1,563	210	128	4,099	3,557	1,218	430
– Rent expense	10,036	2,439	810	24,311	3,005	11,526	5,415
– Repairs	49,345	11,331	2,365	156,261	14,636	58,492	9,243
– Other expenses	42,499	9,957	9,681	95,927	50,136	45,535	15,205
= Gross dairy product	598,683	151,783	150,727	1,571,435	879,514	704,535	216,508
– Capital consumption	127,824	29,352	6,127	404,787	37,914	151,521	23,943
– Property taxes	18,515	3,409	2,102	44,792	12,526	13,759	5,289
= Income originating	452,344	119,022	142,498	1,121,856	829,074	539,255	187,276
– Labor compensation	48,754	19,232	26,764	113,397	99,622	86,214	22,107
= Property compensation	403,590	99,790	115,734	988,459	729,452	453,041	165,169
– Net interest	104,996	22,413	22,550	228,516	119,716	94,003	38,159
= Net farm income	298,594	77,377	93,184	759,943	609,736	359,038	127,010

Numbers in parentheses denote negative values.

tion. Subtracting capital consumption allowances and indirect business taxes (property taxes) from gross dairy product yields income originating in the dairy sector. Income originating in the sector is defined as the sum of all factor payments (that is, all payments to capital and labor); therefore, subtracting labor compensation yields property compensation or income earned by capital. Finally, property compensation less net interest (payments less receipts) yields sectoral net farm income or profit.

One derives constant dollar estimates of income and product by deflating separate components of the account by the respective prices received and paid by farmers using 1977 as the base year. For example, grain is deflated by the index of prices received for food grains. Cotton and cottonseed are deflated by the index of prices received for cotton and so on.[3] These deflators come from the *Agricultural Prices* annual summary (*18*). Because item-specific regional deflators are not available, the deflators used reflect national prices and are applied to all States.

Income and Returns

Using the gross dairy income and product account, we can derive some indicators for the sector's performance, including TFP growth and the capital-labor and capital-output ratios. The latter two ratios are of interest because they indicate relative factor intensity. We are interested primarily in the rate of return to capital. One can calculate this rate in each period by dividing the constant dollar value of property compensation (income from capital) by the constant dollar value of total capital stocks. This quotient yields capital income as a percentage of the value of capital stocks, that is, the amount of income flowing from capital stocks. The percentage is a real rate of return in the sense that it is derived as a ratio of constant-dollar-valued income and capital stocks.

This rate is used to calculate capital services. Because we do not have a direct measure for the rate at which capital is used, as we have for the hours of labor services, we must convert the stock of capital to a flow of capital services. Capital services are calculated as the product of the rate of return to capital and the weighted sum of capital stocks where the weights are the portions of each component of capital to the total.[4]

Capital stocks include land and structures, machinery and equipment, livestock inventories, and crop inventories. The current dollar value of land and structures and that of machinery and equipment valued at market prices are taken from the Agricultural Census. We derived constant dollar values of these capital stocks by deflating each component of capital by its respective price index (see the appendix for the list of deflators). Constant dollar livestock inventories are calculated from Census numbers of head times the price index for livestock. We derived crop inventories from State balance sheet data (*16, 17*) and prorated them to the SIC dairy sector using Census benchmarks (table 3). We measured producer durables (machinery and equipment) gross of depreciation because, given repairs and maintenance, the productive capacity of the equipment will endure (*11*).

In 1978, California received more than twice the rate of return (16.7 percent) as did the northern States. Florida and Texas also had rates greater than the northern States, receiving 11.8 percent and 9.2 percent, respectively. Pennsylvania, Vermont, Wisconsin and New York had similar rates. In 1982, both Florida and California had rates near 20 percent, suggesting a considerable growth in income and a potential underinvestment in capital. The return to capital increased in all northern States, but increased the least in Wisconsin.

These returns imply that operations in California and Florida earn a higher rate of return to more capital-intensive operations (in terms of the capital-output ratio) than do the smaller operations of the northern and Lake States. However, the reasons for these high returns in California and Florida differ. For example, Florida had high-valued returns because it received the benefit of the highest

[3]The specific items and their deflators appear in the appendix.

[4]One usually formulates the capital service price following Hall and Jorgenson (*8*):

$$p_t = q_t(r_t + d + T_t - g_t)$$

where q_t is the acquisition price, r_t is the rate of return, d is the depreciation rate, T_t is the tax rate applied to capital, and g_t is capital gains. We did not use this method for several reasons, chiefly because we lacked the data to support this method. Furthermore, we gained no additional information in our limited attempt to use this formula.

Table 3—Constant 1977 dollar capital stocks and rate of return to capital, 1978 and 1982

Year and item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				1,000 dollars			
1978:							
Land and structure	3,602,362	662,014	402,650	7,798,694	1,649,246	2,756,702	884,634
Machinery and equipment	668,287	158,435	29,514	2,062,073	183,446	803,434	116,661
Livestock inventories	719,618	209,149	216,893	1,824,302	1,077,285	965,958	335,177
Crop inventories	157,694	3,720	6,550	337,484	103,416	85,590	12,649
Total capital	5,147,961	1,033,318	655,607	12,022,553	3,013,393	4,611,684	1,349,121
				Percent			
Return to capital	5.87	6.70	11.78	6.71	16.76	7.75	9.22
				1,000 dollars			
1982:							
Land and structure	2,501,003	532,191	328,169	6,992,821	1,955,601	2,148,060	825,681
Machinery and equipment	492,184	145,474	30,368	2,006,194	187,908	750,964	118,666
Livestock inventories	941,982	273,006	274,470	2,551,538	1,347,751	1,233,106	435,793
Crop inventories	157,293	1,187	278	265,660	12,790	61,946	33,986
Total capital	4,092,462	951,858	633,285	11,816,213	3,504,050	4,194,076	1,414,126
				Percent			
Return to capital	9.86	10.48	18.28	8.37	20.82	10.80	11.68

average milk prices for the seven States because of local marketing order prices. In contrast, California received a far lower average price for milk, suggesting that marginal productivity and, therefore, the efficiency of its capital are considerably higher than in the northern and Lake States.[5]

Separating the influence of dairy-support programs from returns earned under a strictly market-oriented environment would be helpful in assessing differences in regional returns. Dairy programs simultaneously affect relative prices and production, and they partially explain the differential returns; however, we do not disentangle these effects here.

[5]One reviewer pointed out that the difference in nondairy outputs across States appears to make total outputs noncomparable. Although weighting the various outputs by their relative contribution to total revenue would allow for aggregation, we see, upon close inspection, that individual nondairy outputs constitute less than 1 percent of output; in fact, the total of all nondairy components of output represents only a little over 10 percent. This comparison demonstrates the advantage of using SIC classifications because the primary output is the one defined by the classification. To examine whether the interstate price differential has a significant effect on TFP, we looked at the average price received for milk in each State for 1978 and 1982. We compared each State's price with the seven-State average. We discovered Florida's price was approximately two standard deviations above the mean, whereas California's was one standard deviation below. All other States were very close to the mean. Florida was biased upward, but California was biased downward.

The variation among States in the average of the ratio of capital services to output for both years, which measures capital intensity, shows the differences in relative factor usage among regions. The ratio is larger in California (0.82), Florida (0.74), and Texas (0.77), relative to all States where values averaged 0.63. Although the ratio of capital to output is highest in the southern and western States, their rates of return to capital imply underinvestment in capital, which suggests these States should invest in more capital, making them considerably more capital-intensive relative to the other States.

Productivity Estimates

Productivity estimates are made from two perspectives: time (a comparison between 1978 and 1982) and region (a bilateral comparison of productivity between one arbitrarily chosen State, Pennsylvania, and the other States). Measuring the growth in TFP for different regions will enable us to compare relative efficiencies among regions. That is, after controlling for differences in input levels among regions, we can determine how much more output one region can produce than another for a given set of inputs.

Because this is an industry study, output is measured gross of intermediate products rather than value added. Christensen (*2*) points out that, although aggregate productivity studies use value added because intermediate products are canceled out across sectors (that is, one sector's output is another sector's input), intermediate products do not cancel at the sector or industry level.

We assume the dairy sector is characterized by constant returns to scale (CRS), which implies that the necessary condition for producer equilibrium is that the shares of intermediate inputs and value added to total gross product sum to unity (*10*). Assuming away increasing (decreasing) returns to scale may yield a positive (negative) bias in the TFP estimates (*4*). We maintain CRS because that assumption is implicit in the data construction and, unless we econometrically estimate a dairy production function, we do not know the degree of returns to scale.

The input categories consist of capital services (K), labor (L), and materials (M). One calculates capital services by weighting capital stocks by the rate of return to capital.[6] Labor is defined as the value of hired labor compensation plus self-employed and unpaid family labor valued at the hired wage rate. Material inputs include all intermediate purchased inputs and services such as feed, seed, energy, agricultural chemicals, and veterinary services. Assuming CRS and perfect competition in factor markets implies that we can define factor cost shares as input weights equivalent to output elasticities. With these assumptions, we can aggregate total input using a Tornqvist approximation to the Divisia index (*5*). Aggregating all factors with a Divisia index procedure permits us to estimate TFP growth that is not biased by the lack of factor substitution possibilities implied by average product productivity measures (for example, a Laspeyres index of TFP). The index is written as:

$$\ln(X_T/X_O) = 1/2 \sum_i (S_{iT} + S_{iO}) \ln(X_{iT}/X_{iO}) \qquad (1)$$

[6]It is interesting to note the possible effects of increases in capital consumption allowances (CCA) and indirect business taxes (IBT) on capital services and subsequently on TFP. Because one derives capital income by subtracting labor compensation, CCA, and IBT, an increase in CCA or IBT will reduce the rate of return to capital. That process will then decrease the value of capital services according to our method and thereby increase TFP.

where X is total input in period T and the base period O, and S is the cost share of input X_i. Total output, input, and average factor shares appear in table 4.

All factor shares tended to be comparable across most States. The share of labor was fairly constant at about 9-15 percent. Materials were most important in 1978 at 50 percent or more for all States and then declined to 40-45 percent in 1982. Capital varied within a range of 33-40 percent in 1978 and rose to 44 percent in 1982. Capital's share increased in the latter period, decreasing the shares of the other two inputs. This rise in capital's share was largely a function of the general increase in the calculated rate of return to capital.

The TFP index procedure also uses the Tornqvist index. This procedure allows us to define growth in TFP as growth in output minus the factor share-weighted growth in inputs. Because the growth rates are calculated as natural logarithms, by taking the exponential of the growth rates, we can convert them to index levels, which results in the base period being equal to 1. To compare the productivity level across States, we use a method of bilateral comparison (*3*). The productivity level of one State is selected as the base (that is, equal to 100), and each State is individually compared with it in both periods. Both intertemporal and interspatial indexes are produced by use of the Tornqvist index. The Tornqvist index for TFP growth is written as;

$$\ln(TFP_T/TFP_O) = \ln(Y_T/Y_O) - 1/2 \sum_i (S_{iT} + S_{iO}) \ln(X_{iT}/X_{iO}) \qquad (2)$$

where Y is output, and the other variables are as in equation 1. The time subscripts can be replaced with subscripts denoting regions. This substitution provides a measure of productivity differentials across regions. The intertemporal and interspatial levels of productivity appear in table 5. If 1978 = 100, the average annual TFP growth rate for the seven States was 2.5 percent. This growth rate is considerably less than the 11-percent annual growth in output per labor hour since 1979 reported by Fallert and others (*7*). Their study suggests the reasons for the rather large increase in productivity were the loss of some less efficient farms, substantial increases in capital, and improved breeding, feeding, and management. Our results (which are

Table 4—Constant 1977 dollar value of output, input, and factor shares, 1978 and 1982

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				1,000 dollars			
1978:							
Output	501,953	120,620	109,261	1,354,613	635,133	604,569	174,581
Capital	314,126	72,573	78,312	833,871	508,336	372,795	131,650
Total labor	106,134	29,017	27,031	258,675	103,275	132,745	36,977
Materials	359,503	114,303	134,237	801,148	601,906	504,161	200,936
Sum of share-weighted inputs	306,737	88,813	103,861	741,457	520,275	406,829	159,849
				Percent			
Capital share	40.3	33.6	32.7	44.0	41.9	36.9	35.6
Labor share	13.6	13.4	11.3	13.7	8.5	13.1	10.0
Materials share	46.1	52.9	56.0	42.3	49.6	49.9	54.4
				1,000 dollars			
1982:							
Output	598,683	151,783	150,727	1,571,435	879,514	704,535	216,508
Capital	413,626	102,229	116,544	1,012,770	732,457	464,567	170,584
Total labor	121,922	35,144	29,278	328,403	120,614	164,003	38,075
Materials	337,544	105,153	120,342	904,360	646,400	475,021	182,899
Sum of share-weighted inputs	343,477	93,776	108,662	869,022	646,144	424,400	163,451
				Percent			
Capital share	47.4	42.2	43.8	45.1	48.8	42.1	43.6
Labor share	14.0	14.5	11.0	14.6	8.0	14.9	9.7
Materials share	38.7	43.4	45.2	40.3	43.1	43.0	46.7

Table 5—Total factor productivity, intertemporal and interspatial comparisons, 1978 and 1982

State	Intertemporal		Interspatial	
	1978	1982	1978	1982
	Percent			
	------ 1978 = 100 ------		Pennsylvania = 100	
Pennsylvania	100.0	106.5	100.0	100.0
Vermont	100.0	112.0	86.8	91.3
Florida	100.0	124.1	70.9	82.6
Wisconsin	100.0	97.8	111.1	102.1
California	100.0	112.1	81.4	85.7
New York	100.0	106.6	93.0	93.1
Texas	100.0	117.0	73.4	80.7

consistent with those suggestions) illustrate that, when output is compared with the total measure of input, the productivity measure is often considerably less than the partial measure. Nonetheless, there are other significant influences (such as loss of farms and management) that are difficult, if not impossible, to measure and that are important to the productivity result.

Florida had the highest annual average rate of growth in productivity, 5.4 percent. Texas, California, and Vermont had annual growth rates of 3.9, 2.8, and 2.8 percent, respectively. New York, Pennsylvania, and Wisconsin had lower growth rates of 1.6, 1.58, and −0.55 percent per year, respectively. Except for Vermont, the traditional dairy States—especially Wisconsin—had TFP growth rates below the mean. Florida, Texas, and California had above-average TFP growth rates.

The higher TFP rates of the southern and western States may be a result of their relative capital intensity; that is, capital may contribute more to output than the other inputs do. If one region has more capital relative to labor or materials (for example, larger herds), this does not necessarily mean that other regions have different technologies. It does imply that they face different relative input price ratios and, therefore, have a different mix of inputs; that is, these regions are at different points along an isoquant. However, Florida and Texas have newer enterprises; therefore, they may have an advantage of operating with new capital equipment having technological improvements. The northern States generally have traditional dairy farms with older types of capital technology with fewer technological improvements than the southern and western States. These two regions may not share the same type of capital and, thus, may not be directly comparable.

Comparing bilateral productivity highlights spatial differences. If Pennsylvania's level of productivity is set to equal 100, Wisconsin was more efficient than Pennsylvania; however, New York and Vermont were less efficient than Pennsylvania in 1978, but increased somewhat in 1982. California, Florida, and Texas were less efficient than Pennsylvania in both 1978 and 1982. These comparisons are bilateral, not multilateral; therefore, we cannot compare TFP among States, but only individually with Pennsylvania. Nonetheless, productivity differs somewhat between the northern and southern regions. Finally, the important distinction between the intertemporal and interspatial productivity comparisons is interesting. Although the rate of growth in TFP over time is generally higher in the southern States, it does not mean that at a given time these States are the most efficient producers. However, according to TFP growth rates, they have certainly improved.

One advantage of having both intertemporal and interspatial TFP estimates is that the combination illustrates regional comparative advantage. For example, given their relative TFP levels in 1982, Wisconsin and Pennsylvania could probably survive an unexpected increase in production costs better than Florida or Texas could. The northern States appear to have this advantage because Wisconsin and Pennsylvania produce more output for a given level of input than the southern States. However, if we can extrapolate 1982 TFP growth rates into the future, the southern States will probably be more efficient and have a comparative advantage later. For example, let us compare Florida and Pennsylvania. In 1982, Florida had a TFP level of 82.5 and a growth rate of 5.4 percent, compared with Pennsylvania's TFP level of 100 and growth rate of 1.6 percent. Using a compound growth rate formula, we find Florida will exceed Pennsylvania's TFP level in just 3 years. Of course, this projection assumes current production practices remain the same across regions.

A policy change like the Dairy Herd Buy-Out provision of the 1985 farm act could significantly change regional productivity. This provision reduces milk production by 12 billion pounds from April 1986 to August 1987. To do so, the Government will buy out whole dairy herds and not permit other farmers to use the associated dairy facilities. Although using 1982 regional TFP estimates to examine events in 1986 may be inappropriate, participation rates in the buy-out program are highest in the regions where estimated TFP levels are lowest. This finding is not surprising since one would expect marginal producers to leave the sector first. Differing opportunity costs associated with staying in production also explain differential participation. For example, some of the reasons given for the exit of marginal producers are low returns, financial problems, and attractive alternatives. Lower participation rates in the northern States result from fewer alternatives for these producers or for their land and equipment. The higher TFP *growth* rates in the southern and western States suggest they had become more productive. If they are financially stressed now and see this program as an opportunity to liquidate, the buy-out program may encourage the potentially most productive producers to move out of the sector, which will probably affect the milk price structure. Therefore, although the program may have little impact on northern producers, the potentially more productive dairy farms in the South and West may produce less milk, altering regional productivity differentials.

Sources of Growth

After determining a measure of aggregate TFP, we investigated the extent to which growth in output is a result of either productivity gains or growth in various factor inputs. We can thus clarify the relationship between technological change and structure (where structure is defined as the relationship between, and the growth of, inputs).

Utilizing the relationship that growth in output should equal the weighted-average growth in inputs, we can determine the sources of growth in output (*13*). Assuming an aggregate production function for dairy, we can express the rate of change in output as:[7]

$$\hat{Y} = w_k \hat{K} + w_l \hat{L} + w_m \hat{M} + \hat{A} \quad (3)$$

[7]As indicated in footnote 2, we really assume a multiple-output production function. For simplicity in the growth-accounting procedure, we assume outputs to be aggregated as a single index. The derivative of the share-weighted growth in output follows Denny, Fuss, and Waverman (*4*) and Solow (*13*). We can express the production function as:

$$y = f(x_i, t) \quad (A.1)$$

where t represents time. Totally differentiating equation A.1 with respect to time and dividing by y yields:

$$(dy/dt)(1/y) = \sum_i (df/dx_i)(dx_i/dt)(1/y) + (df/dt)(1/y) \quad (A.2)$$

Define the last term on the RHS as a Hicks' neutral proportionate shift in the production function, and denote it as $\hat{A}$. Multiplying the second term by x_i/x_i produces the x_i output elasticities. Assuming competitive markets, the output elasticities will equal factor shares of output. Therefore we can express equation A.2 as:

$$\hat{Y} = \sum_i w_i \hat{X}_i + \hat{A} \quad (A.3)$$

where ∧ denotes proportionate rates of change and w_i are the factor share weights of total output. The share-weighted growth of an individual input indicates the contributions of that input to output growth. We can also express the growth rate of inputs and productivity as a percentage of the growth of output. This procedure suggests which portion of the growth in output can be attributed to specific inputs or to productivity. For example, the growth of output in New York was almost twice the growth in inputs, implying that input growth accounts for roughly half the growth in output. The residual, or $\hat{A}$ from equation 3, is the portion of output growth not explicitly explained by input growth; it is attributed to productivity growth.[8]

The contribution of total input growth to output varied considerably for all States (table 6). In California, input growth accounted for as much as 65 percent of output growth; in Texas and Florida, input growth acccounted for only 27 and 33 percent,

[8]The residual is an unknown. It could contain such elements as effects of changing input quality, changes in capacity utilization, economies of scale, or management and entrepreneurial capacity. Given the size of the residual and the number of possibilities that may explain it, it has also been called a "measure of our ignorance" (*1*).

Table 6—Sources of growth, 1978-82

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				Percent			
Average annual growth rates:							
Output	4.41	5.75	8.04	3.71	8.14	3.83	5.38
Total input	2.83	2.91	2.64	4.26	5.29	2.22	1.45
Capital	3.02	3.24	3.80	2.17	4.14	2.17	2.56
Labor	.48	.67	.22	.84	.32	.74	.07
Materials	−.67	−1.00	−1.38	1.25	.83	−.69	−1.19
Total factor productivity (TFP)	1.58	2.84	5.40	−.55	2.85	1.60	3.93
Growth in inputs and TFP:[1]							
Total input	64.13	50.64	32.82	114.78	65.01	58.09	26.92
Capital	68.44	56.48	47.25	58.34	50.91	56.82	47.66
Labor	10.85	11.64	2.76	22.73	3.95	19.35	1.34
Materials	−15.16	−17.48	−17.19	33.70	10.16	−18.09	−22.08
TFP	35.87	49.36	67.18	−14.78	34.99	41.91	73.08

[1]As a percentage of the growth of output.

respectively. The growth in inputs in Wisconsin was so great relative to output that inputs had negative growth in TFP. Capital was a major contributor to input growth in all States. The largest increases were in California and Florida, probably a result of large calculated returns to capital. To determine if these rates of return alone accounted for capital's significant role, we calculated capital services with both a lower rate of return and the same rate for all States. In both cases, the role of capital was significant.

The contribution of labor to output growth in the northern dairy States exceeded that in the southern and western States. Although operator labor may be undervalued when the hired wage rate is used, technology in the South and West is far more capital intensive than in the North. The relatively high capital growth rates in Florida and California are also consistent with the high relative rates of return to capital that attract capital investment. Furthermore, the northern and eastern States are characterized by smaller and more numerous farms with more operators and, hence, are more labor intensive relative to output.

The role of materials is problematic. The real quantity of material inputs may have declined in the 1978-82 period. However, it is more likely that the effective quantity or quality-adjusted quantity increased. This increase was probably due to the index number problem; that is, either inappropriate deflators were used for inputs (and outputs) or quantity weights in the indexes were not quality-adjusted and, therefore, do not reflect their true productive capacity. For example, greater use of improved feed additives and improved breeding practices and veterinary services would have increased the productive capacity of these purchased inputs. The role of materials appears most important in Wisconsin and less important in California. One possible explanation is that feed is generally purchased in California, whereas it is grown on farms in Wisconsin and other northern States, thereby requiring farmers to purchase seeds, fertilizers, and other material inputs.

TFP was the major source of output growth in all States except Wisconsin. Texas and Florida received the largest contributions from TFP because of declines in material inputs relative to a positive growth in output. One should remember that TFP is a residual measure; that is, the residual captures the productive qualities that do exist and are not accounted for by the input measurements. Accurate input measurement thus requires that all inputs be measured in efficiency units. Because of the new technologies, improved breeds and the use of feed additives, the contribution of both capital and the material input may be underestimated.

Conclusions

We have demonstrated a method to determine the differences in TFP within an industry and at the regional level. We developed constant dollar income and product accounts for the three-digit SIC dairy sector for Pennsylvania, Wisconsin, New York, Vermont, California, Florida, and Texas. We showed the importance and usefulness of income and product accounts as an economic tool by examining several variables: gross dairy product (valued-added output), profit income (net farm income), property compensation, and the rate of return to capital. The southern and western States had higher rates of return to capital than the northern States. The average TFP growth for the seven States from 1978 to 1982 was estimated at 2.5 percent per year, considerably lower than previous estimates of output per labor hour for the entire dairy sector. TFP estimates indicate that the southern States generally had higher TFP growth rates than the northern dairy States.

Bilateral interspatial TFP estimates were made for 1978 and 1982. Although the southern and western States had higher TFP growth rates over time, the northern States were generally more efficient in both periods. It is important to distinguish the two types of productivity. Capital was an important source of output growth in all regions, and materials were less important. The contribution of labor was more important in the more traditional regions and less important in the more capital-intensive regions. Productivity growth was significant in all regions.

These findings suggest two things. First, structure (in terms of relative factor intensity and growth) is important in explaining output growth and productivity differences across regions. Second, TFP growth and technological change are important contributors to regional output growth differentials. TFP is a residual based on measured items that can have measurement error; therefore, part of the residual is TFP, and part is measurement error. Nonetheless, the basic income accounting procedure is useful. When properly used, it can identify and examine the sources of growth and productivity of different regions.

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Appendix table—Deflator sources

Item	Source/price index	Deflators	
		1978	1982
		1977 = 100	
Crop cash receipts:			
Grain	Food grains	122	146
Cotton and cottonseed	Cotton	91	92
Tobacco	Tobacco	109	153
Field seeds, hay, forage, and silage	Feed grains and hay	101	120
Vegetables, sweet corn, and melons	Commercial vegetables	105	126
Fruits, nuts, and berries	Fruit	137	175
Nursery and greenhouse products	All crops	105	121
Other crops	do.	105	121
Livestock cash receipts:			
Poultry and products	Poultry and eggs	106	110
Dairy products	Dairy products	109	140
Cattle and calves	Meat animals	134	155
Hogs and pigs	do.	134	155
Sheep, lambs, and wool	do.	134	155
Other livestock	Livestock and products	124	145
Government payments	All farm products	115	133
Custom work	Farm services and cash rent	107	145
Rents	do.	107	145
Recreational services	Consumer price index, all items (*6*)	107	172
Other income:			
Home consumption	All farm products	115	133
Change in inventories:			
Crops	All crops	105	121
Livestock	Livestock and products	124	145
Intermediate products	Production items	108	155
Custom work expense	Farm services and cash rent	107	145
Rent expense	do.	107	145
Labor compensation	Wage rates	107	144
Repairs	Production items	108	155
Other expenses	do.	108	155
Capital consumption	Farm producer durable equipment (*19*)	108	148
Property taxes	Taxes	100	124
Net interest	Interest	117	241
Capital stocks:			
Land and structure	Real estate values (*15*)	109	157
Machinery and equipment	Farm producer durable equipment (*19*)	109	165
Livestock inventories	Livestock and products	124	145
Crop inventories	All crops	105	121

Source: All items from (*18*), except where noted.

Forecasting Performance of Models Using the Box-Cox Transformation

David M. Smallwood and James R. Blaylock

Abstract

The authors examine the small sample properties and forecasting performance of estimators in models using the Box-Cox transformation via a Monte Carlo experiment. They develop a simple estimator for the expected value of the untransformed dependent variable. They show that the sign and magnitude of the transformation parameter influence the precision of the estimators and the forecasting performance. These results support previous research. At different values of the transformation parameter, smaller variances of the parameter estimators do not necessarily imply improved goodness of fit for the model.

Keywords

Forecasting performance, transformations, Box-Cox, flexible functional forms

Economic theory usually provides few details as to the specific functional relationships among variables in econometric models. Therefore, the applied research economist is often forced to choose among many competing functional forms using noneconomic criteria. Flexible functional forms, because they minimize this subjective aspect of model construction, are becoming increasingly popular as a tool to discriminate among competing models' specifications. One frequent approach for adding flexibility to models is to incorporate the monotonic transformation introduced by Box and Cox (*3*).[1] Models incorporating the Box-Cox transformation allow researchers to discriminate statistically among many commonly used functional forms including the log, inverse, quadratic, and linear forms (*1, 4, 6, 8, 12, 14*). However, the Box-Cox transformation places additional burdens on the researcher in terms of the complexity of estimating and interpreting model parameters compared with ordinary-least-squares models. Furthermore, the small sample properties of the estimators and the forecast performance of models incorporating a transformed dependent variable are not well known (*11*).

Several papers have addressed estimation procedures and interpretation of parameters in Box-Cox models, but only Spitzer (so far as we know) has addressed the small sample properties and forecast performance. Estimating parameters in models employing the Box-Cox transformation involves maximizing a complex nonlinear likelihood function. Spitzer has outlined several procedures that can be used to accomplish this task (*12*). Procedures for interpreting parameters in Box-Cox models are discussed by Spitzer (*12*), Blaylock and Smallwood (*1, 2*), and others.

The small sample properties of the estimators are particularly important for the applied researcher. For example, how well do the estimators perform when one has only 30, or perhaps 60, observations? Can one use the standard t-test to test hypotheses about the model parameters? Although the maximum likelihood properties are well known, they apply only asymptotically, and the small sample properties are analytically intractable.

Spitzer has investigated the small sample properties of the Box-Cox estimators via Monte Carlo methods (*11*). However, as he notes, his results are tempered by the small number of replications (50) per model. Furthermore, he touches on forecast per-

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[1]Italicized numbers in parentheses refer to items in References at the end of this article.

formance only as a secondary issue.[2] Thus, several important questions, such as the calculation of the expected value of the untransformed dependent variable and out-of-sample forecast performance, are not addressed.

This article has two major objectives. Our first objective is to expand Spitzer's Monte Carlo study (*11*) by using twice the number of replications to provide more reliable information on the small sample properties of estimators in Box-Cox type models. The small sample properties of estimators have important implications for economists, and the properties of these estimators ultimately extend to the end use of the model. For example, consider the importance of a parameter's variance. Spitzer has suggested that, in highly nonlinear functional specifications such as the Box-Cox, the sign and magnitude of the transformation parameters may affect the estimation of the variances for all parameters in the model. If so, one must exercise extreme care in performing hypothesis tests, especially if the tests imply or embody policy or program implications.

Our second objective is to investigate the ability of transformed models to forecast the original (untransformed) variable and to forecast outside the sample used for estimation. Forecast performance is important in evaluating flexible functional forms because a common fear is that they fit an individual sample too well, including the random peculiarities. Limited numbers of observations in analyses of live data often prevent extensive testing outside the period of fit. Monte Carlo studies, in contrast, provide a unique opportunity for testing this aspect of model performance. The evaluation of forecasting performance in a scientifically controlled environment using simulated data provides the applied economist with valuable insights into the strengths and limitations of the Box-Cox technique.

To accomplish these objectives, we conducted a Monte Carlo experiment using the general framework set forth by Spitzer (*11*). The general model consisted of three variables and five parameters including a single Box-Cox parameter. The model was used to generate some 100 samples of observations which were used for estimation and forecast evaluation. This was done for five alternative Box-Cox parameter values and for two sample sizes. In contrast to Spitzer (*11*), each data sample contained 10 observations for use in forecast evaluation that were not used to estimate the model parameters.

We discuss the Box-Cox transformation and the method of estimation, and we outline model construction and data generation. We then discuss estimation and forecasting performance results and briefly summarize our research findings.

Box-Cox Transformations

The Box-Cox transformation for any positive variable W is defined as:

$$W(\lambda) = (W^{\lambda} - 1)/\lambda. \qquad \lambda \neq 0 \tag{1}$$
$$= \ln(W), \qquad \lambda = 0$$

where λ is a parameter to be estimated. The transformation is typically applied to models of the form;

$$Y_i(\lambda) = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda) + \epsilon_i, i = 1, 2, \ldots, N \tag{2}$$

The linear and logarithmic models are special cases of equation 2 when λ is equal to 1 and zero, respectively (*14*).

Assume that under the appropriate transformation, the ϵ_i's are independently and normally distributed with zero mean and constant variance, that is, $N(0, \sigma^2)$. The likelihood function can then be written as:

$$L(\beta, \sigma, \lambda) = (2\pi\sigma^2)^{-N/2} J \exp \left[- \sum_{i=1}^{N} \{Y_i(\lambda) - \beta_0 - \sum_{k=1}^{K} \beta_k X_{ik}(\lambda)\}^2 / 2\sigma^2 \right] \tag{3}$$

where J denotes the Jacobian for the transformation from $Y_i(\lambda)$ to the observed Y_i:

$$J = \prod_{i=1}^{N} \left| \partial Y(\lambda)/\partial Y \right| = \prod_{i=1}^{N} Y_i^{\lambda - 1} \tag{4}$$

[2]Spitzer's method (*11*) of deriving forecasts is shown in this article to be incorrect.

The log-likelihood function can be written as:

$$LL = -(N/2)\ln \tilde{\sigma}^2 + (\lambda - 1) \sum_{i=1}^{N} \ln(Y_i) \qquad (5)$$

where $\tilde{\sigma}^2 = \sum_{i=1}^{N} \tilde{\epsilon}_i^2/N$ is the estimated variance of ϵ_i.

We used the Fletcher-Powell algorithm with analytically computed first derivatives to maximize the log-likelihood function.[3] We used the fundamental statistical relationship that the asymptotic covariance matrix of a maximum likelihood estimator is equal to the inverse of the covariance matrix of the gradient of the likelihood function when estimating the asymptotic covariance matrix of the parameters (*10*).

Zarembka has shown that the distribution of the error term cannot be strictly normal in models where the dependent variable is Box-Cox transformed because a power transformation can be applied only to positive variables (*14*).

Specifically, if $\lambda > 0$, then $-1/\lambda < Y(\lambda) < \infty$; if $\lambda = 0$, then $-\infty < Y(\lambda) < \infty$; and if $\lambda < 0$, then $-\infty < Y(\lambda) < -1/\lambda$. Consequently, the magnitude and sign of λ affect the range of the dependent variable. However, Draper and Cox (*5*), Zarembka (*14*), and Spitzer (*12*) have shown empirically that so long as the distribution of the error term is reasonably symmetric and the probability of large negative values of the error term is low, normality may be a good approximation.

Model Construction and Data Generation

Following Spitzer (*11*), we specified the models as:

$$Y(\lambda) = 9.0 - 1.5X_1(\lambda) + 0.5X_2(\lambda) + \epsilon \qquad (6)$$

where $\lambda = -1.5, -1.0, -0.15, 1.0, 1.5$, respectively, for the five models. These values of λ were selected to represent a large range of possible transformation parameters because the size and sign of the parameter may be important in determining the shape and location of the sampling distribution of the coefficient estimates and may affect the forecasting ability of the models. In addition, the $X_i(\lambda)$'s were constructed such that:

$$\beta_1^2 \, var(X_1(\lambda)) = \beta_2^2 \, var(X_2(\lambda))$$

This condition was set so that each variable has equal importance in explaining the variance of $Y(\lambda)$.

The method used to generate values of $X_1(\lambda)$ and $X_2(\lambda)$ appears in the appendix. All models were estimated for 100 samples of sizes 30 and 60 ($N = 30, 60$). An additional 10 observations were also generated for each sample for use in evaluating the out-of-sample forecasting performance. The equation error term was generated from a population that was independently distributed as $N(0, \sigma^2)$, where $\sigma^2 = 0.4263$. The value of σ^2 was chosen to yield a residual variation equal to 5 percent of the total variation in $Y(\lambda)$.

Tukey (*13*) and Box and Cox (*3*) argue that the purpose of a transformation is to increase the degree of approximation to which three desirable properties for statistical analysis hold. In particular, they argue that transformations may lead to a more nearly linear model, may stabilize the error variance, and/or may lead to a model for which a normally distributed error term is acceptable. Of course, a transformation may increase the degree of approximation to two or more of these properties simultaneously. The true models are constructed such that all three properties hold simultaneously. The estimated models should, therefore, seek out the transformation parameter that stabilizes the error variance and normalizes the error distribution.

The calculation of unbiased predicted values in transformed models requires that special attention be given to the error term. Transformed dependent variables make predictions more difficult because one is interested in predicting the expected value of the original (untransformed) dependent variable rather than the transformed one. One derives the simplest predictor of Y_i, and probably the predictor most often used, by first noting that:

$$E\left[Y_i(\lambda)\right] = \beta_o + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda) \qquad (7)$$

[3]Spitzer used a modified Newton technique for estimation (*11*).

and then solving for Y_i:

$$Y_i = \left[1 + \lambda \left[\beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda)\right]\right]^{1/\lambda} \quad , \lambda \neq 0$$

$$= \exp\{\beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda)\} \qquad , \lambda \rightarrow 0 \qquad (8)$$

However, the expressions in equation (8) are equal to the expected value of Y_i only in the case of the linear model. For $\lambda \neq 1$, the expressions are biased estimators.[4] These formulas are biased because the expected value of a nonlinear function is not equal to the nonlinear inverse function of the expected value (7). In other words, the error term cannot be dropped from equation (7) before expectations are taken.

A simple approximation to the expected value of the original (untransformed) dependent variable can be derived as follows. First, define the model in terms of the transformed dependent variable as:

$$Z_i = (Y_i^{\lambda} - 1)/\lambda = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda) + \epsilon_i \qquad (9)$$

and note that the original dependent variable can be expressed as:

$$Y_i = F(Z_i) = (\lambda Z_i + 1)^{1/\lambda} \qquad (10)$$

where $F(Z_i)$ denotes the inverse of the Box-Cox transformation.

Expressing Y_i as a second-order Taylor expansion around the expected value of the transformed dependent variable yields:

$$\begin{aligned} Y_i \approx\ & F(\tilde{Z}_i) + (Z_i - \tilde{Z}_i)(\lambda \tilde{Z}_i + 1)^{(1-\lambda)/\lambda} \\ & + \tfrac{1}{2}(Z_i - \tilde{Z}_i)^2(1 - \lambda)(\lambda \tilde{Z}_i + 1)^{(1-\lambda)/\lambda} \end{aligned} \qquad (11)$$

where $\tilde{Z}_i = E(Z_i)$. One derives the expected value of the expression in equation (11):

$$E(Y_i) \approx F(\tilde{Z}_i) + \tfrac{1}{2}\sigma^2 (1 - \lambda)[F(\tilde{Z}_i)]^{1-2\lambda} \qquad (12)$$

by noting that the second term on the right-hand side (RHS) of equation 11 vanishes, that the expected value of $E(Z_t - \tilde{Z}_t)^2$ is the equation error variance, and that:

$$\begin{aligned} [(\lambda \tilde{Z}_i + 1)^{(1-2\lambda/\lambda)}] &= [(\lambda \tilde{Z}_i + 1)^{1/\lambda} \bullet (\lambda \tilde{Z}_i + 1)^{-2}] \\ &= [F(\tilde{Z}_i)]^{1-2\lambda} \end{aligned} \qquad (13)$$

The expression given in equation 12 differs from the simple formula of equation 8 by the second term on the RHS of equation 12. The sign of this term, which is uniquely determined by the value of λ, indicates the direction of bias involved by using equation 8 in lieu of the formula given in equation 12. A negative bias is generally present if $\lambda < 1$, and a positive bias is present if $\lambda > 1$.

We examine the small sample performance of the model parameters using a variety of performance statistics to measure bias and variation. For each parameter estimated in equation (6), let $\tilde{\theta}_i$ be the i-th sample value of the parameter, let $\sigma(\theta_i)$ be the asymptotic standard deviation of θ_i, and define the following:

Mean bias $= \sum \tilde{\theta}_i/N - \theta$,

Mean absolute bias $= \sum |\tilde{\theta}_i - \theta| /N$,

Root mean square error $= [\sum (\tilde{\theta}_i - \theta)^2/N]^{1/2}$, and

Mean asymptotic standard deviation $= \sum \sigma(\tilde{\theta}_i)/N$.

We use these statistics to evaluate the forecasting performance of the various models by assuming that $\tilde{\theta}$ represents the forecast value and θ represents the true value of the observation to be predicted.

Estimation and Forecast Performance

Table 1 shows mean bias (MB) and mean absolute bias (MAB) statistics for the coefficient estimates of the alternative simulations. The most striking result is perhaps the remarkable similarity between our results and those of Spitzer (*11*). Like Spitzer, we find that, except for β_0 in models with $\lambda > 0$, the MB's are relatively small and do not appear to indicate systematic under- or overestimation of para-

[4]Elasticity formulas frequently employed in studies using the transformation-of-variables technique are also in error because they are based on the same erroneous assumption about the expected value of the dependent variable.

Table 1—Mean bias (MB) and mean absolute bias (MAB) of parameter estimates

λ	N	$\tilde{\beta}_0$	$\tilde{\beta}_1$	$\tilde{\beta}_2$	$\tilde{\lambda}$	$\frac{MAB(\lambda)}{\lambda}$
	Sample size			*Estimates*		
MB:						
−1.5	30	−0.057	0.024	0.042	0.046	NA
	60	−.245	.012	.035	.044	NA
−1.0	30	−.085	.009	.040	.025	NA
	60	−.095	.016	.020	.017	NA
−0.15	30	−.021	−.014	.025	−001.	NA
	60	−.118	−.013	.016	−.000	NA
1.0	30	3.667	−.154	.003	−.017	NA
	60	2.026	−.117	−.005	.020	NA
1.5	30	4.394	−.156	.002	.027	NA
	60	2.302	−.116	−.006	.030	NA
MAB:						
−1.5	30	.952	.061	.092	.124	0.083
	60	.782	.045	.075	.102	.068
−1.0	30	.914	.064	.106	.098	.068
	60	.650	.042	.067	.065	.065
−0.15	30	1.538	.075	.137	.029	.193
	60	1.187	.046	.100	.020	.133
1.0	30	7.071	.521	.079	.233	.233
	60	4.203	.345	.045	.146	.146
1.5	30	7.884	.517	.076	.334	.223
	60	4.575	.342	.043	.210	.140

NA =Not applicable.

meters. However, the MAB's for β_0 and β_1 in models with positive λ's are several times larger than their counterparts in models with negative λ's. The MAB's for all model parameter estimates decline with increased sample size. Coupled with similar findings by Spitzer, this decline indicates the estimates are consistent. The MAB of λ as a percentage of λ generally increases as λ increases, indicating that the variance of λ increases as λ increases. Spitzer also noted this phenomenon. Therefore, the problem seems not to be one of a small number of sample replications.

The MB and MAB statistics show that: (1) parameter estimates are unbiased and consistent; (2) models with positive λ's perform less well than other models in terms of MB and MAB statistics; (3) the variance of λ seems to increase as λ increases; and (4) our results are similar to those of Spitzer, which is comforting in terms of the reliability of the test statistics and because we obtained our results using different estimation techniques.

Table 2 presents the root mean square error (RMSE) and mean asymptotic standard deviation (MASD) statistics for the parameter estimates. If parameter estimation bias is small, the MASD's should be good approximations to the RMSE's (that is, the ratio of the MASD and RMSE for a parameter should approach 1 as sample size increases). The MASD's and RMSE's for all models decline as sample size increases, and their ratio is virtually equal to 1 for N = 60 in all cases. This finding suggests that the estimated variances are consistent. However, the statistics for positive λ are many times larger than those for the models with nega-

Table 2—Root mean square error (RMSE) and mean absolute standard deviation (MASD) of parameter estimates

λ	N	$\tilde{\beta}_0$	$\tilde{\beta}_1$	$\tilde{\beta}_2$	$\tilde{\lambda}$
	Sample size		*Estimates*		
RMSE:					
−1.5	30	1.207	0.075	0.116	0.154
	60	.963	.055	.099	.130
−1.0	30	1.152	.080	.156	.129
	60	.810	.054	.088	.084
−0.15	30	1.978	.091	.177	.036
	60	1.531	.058	.132	.026
1.0	30	11.081	.693	.102	.301
	60	6.257	.467	.061	.191
1.5	30	12.805	.690	.098	.431
	60	6.952	.464	.059	.275
MASD:					
−1.5	30	1.640	.091	.171	.232
	60	1.037	.061	.102	.142
−1.0	30	1.397	.098	.182	.172
	60	.892	.061	.106	.104
−0.15	30	2.596	.100	.243	.049
	60	1.562	.061	.145	.029
1.0	30	13.378	.882	.119	.370
	60	6.387	.491	.066	.209
1.5	30	15.152	.870	.114	.530
	60	6.990	.485	.064	.300

tive λ, except for the statistics for β_2, which follow no obvious pattern. The results indicate that estimates from models with $\lambda < 0$ tend to be more precise.

One indicator of the concentration of the parameter estimates around the true parameter is the percentage of the estimates within ±20 percent of the true parameter (table 3). The results strongly indicate that models with a negative λ perform better. An examination of table 3 reveals that a larger percentage of the parameter estimates fall within the 20-percent range as λ decreases and as sample size increases. The exception is β_2, which shows no clear relationship with λ. However, as sample size increases, all parameters become more highly concentrated around the true parameter values. Thus, the parameter estimates obtained from larger samples and models with smaller λ are more precise than other models.

One must be cautious when using standard t-tests for hypothesis testing. To examine this issue further, we constructed two hypotheses. The first is a true hypothesis:

$$H_o : \beta_j = \beta_{jo},$$

where β_{jo} is the true value of β_j. Using a two-tailed test at the 0.05 significance level, we would expect to reject 5 percent of these hypotheses. Using the same procedures, we also tested the following false hypothesis:

$$H_o : \beta_j = 0$$

This test shows the power of the t-test (table 4).

The true hypothesis was rejected in 5 percent or less of the replications for models with a negative λ. The results were mixed for models with positive λ's,

Table 3—Percentage of estimates within 20 percent of true parameters

λ	N	$\tilde{\beta}_0$	$\tilde{\beta}_1$	$\tilde{\beta}_2$	$\tilde{\lambda}$
	Sample size		*Percent*		
−1.5	30	87	100	60	95
	60	95	100	74	97
−1.0	30	88	100	59	91
	60	98	100	79	96
−0.15	30	66	100	45	62
	60	77	100	65	73
1.0	30	22	37	70	54
	60	33	54	89	74
1.5	30	21	38	70	55
	60	32	56	89	75

Table 4—Rejections (R) and acceptances (A) of hypotheses[1]

λ	N	$\tilde{\beta}_0$		$\tilde{\beta}_1$		$\tilde{\beta}_2$		$\tilde{\lambda}$	
		R	A	R	A	R	A	R	A
	Sample size				*Numbers*				
−1.5	30	5	0	2	0	1	6	2	0
	60	5	0	5	0	3	0	5	0
−1.0	30	2	0	3	0	1	8	4	1
	60	5	0	4	0	2	0	2	0
−0.15	30	3	0	5	0	4	37	2	11
	60	5	0	4	0	5	0	4	0
1.0	30	9	100	6	54	1	1	3	24
	60	8	70	5	0	8	0	6	0
1.5	30	10	100	6	54	2	1	3	20
	60	8	81	5	0	9	0	6	0

[1]R denotes the number of samples out of 100 in which the true hypothesis $\beta_k = \beta_{k_0}$ is rejected at the 0.05 level. A denotes the number of samples out of 100 in which the false hypothesis $\beta_k = 0$ is accepted as true.

although they are unambiguously worse than the statistics from the models with negative λ's.

Models with $\lambda < 0$ generally performed better than those with positive λ. For example, the false hypothesis, $\beta_o = 0$, is never rejected for models with $\lambda = 1.0$, 1.5, and N = 30. In fact, even for the larger sample size (N = 60), a high percentage of the false hypotheses were accepted for the samples with $\lambda = 1.5$. However, the power of the test did tend to improve as sample size increased. The reason for the poor performance of the model with $\lambda > 0$ is, of course, the imprecision with which these model parameters are estimated. These test results are not encouraging for the application of t-tests to parameters estimated from Box-Cox models, especially for models with positive λ.

Table 5 reports test statistics for the equation error term. Contrary to Spitzer's assertion, our results

Table 5—Sample statistics for the error term, $\epsilon \sim N(0, 0.426)$

λ	N	MB of variance	MAB of variance	RMSE of variance	Percentage rejection of normality
	Sample size		*Estimates*		*Percent*
−1.5	30	−0.070	0.164	0.201	0
	60	−.058	.134	.164	3
−1.0	30	−.038	.170	.227	2
	60	−.028	.121	.144	0
−0.15	30	−.007	.138	.181	0
	60	−.013	.108	.133	0
1.0	30	1.413	1.653	4.394	35
	60	.474	.667	1.380	31
1.5	30	1.898	2.140	6.121	37
	60	.588	.787	1.541	34

Note: MB = mean bias, MAB = mean absolute bias, and RMSE = root mean square error.

clearly indicate that systematic bias occurs in the estimation of the error variance.[5] The models underestimate the true variance for λ less than zero, and they overestimate the variance for positive λ. This finding has serious implications for researchers because equation (12) expresses the expected value of the untransformed dependent variable as a function of the variance. Thus, forecasts made with equation (12) using an estimate of the variance will be biased, and the bias will depend on the size of the bias in the variance and the value of λ.

The MAB's and the RMSE's decline as sample size increases, indicating consistency. However, the test statistics for the models with a positive λ are many times larger than their counterparts derived from the models with a negative λ. In other words, the models with a positive λ once again performed far worse than their counterparts with a negative λ.

The error distribution cannot be strictly normal because of the limited range of the dependent variable. However, if the bounds implied on the error distribution occur in the extreme tails of the distribution as in the Monte Carlo experiment, departure from normality would not be expected to be significant. Table 5 shows the results of a test for normality of the estimated model error term using a two-tailed Kolmogorov-Smirnov goodness-of-fit at the 0.05 level. Regardless of sample size, normality was rejected in approximately one-third of the replications for models with positive λ. However, in the models with negative λ, normality was not rejected in the vast majority of cases.

Model performance is frequently evaluated in terms of its overall fit to the sample data. R^2, the coefficient of multiple determination, is probably the most often cited statistic for this purpose. When applying R^2 to models with a transformed dependent variable, one must be careful to compute it in terms of the original untransformed dependent variable because the untransformed dependent variable is the variable of interest and represents a standard for comparisons across models. Table 6 shows the average R^2's for the estimated models. The R^2's are higher for the extreme positive and negative values of λ than for $\lambda = -0.15$. When the R^2 criterion was used, models with $\lambda > 0$ performed the best of all models. R^2 decreased in larger size samples for $\lambda < 0$, but remained high and stable in models with positive λ. The drop in R^2 as sample size increases suggests that randomness in smaller samples may have more influence on the parameter estimates than in larger samples, resulting in a better fit to the particular sample, but not necessarily to the population of interest. This conjecture is consistent with the larger variances for the parameter estimates obtained in the smaller samples.

[5]Except for N = 30 with $\lambda = -1.5$, Spitzer's reported results (*11*) indicate the same type of bias as we find. We believe that Spitzer may have been too generous in stating that no error variance estimation bias appeared in his replications.

Models with a positive λ again appeared to perform below those with a negative λ in terms of the parameter estimates, but the reverse was true for the overall fit to the untransformed data. We found a potentially serious problem in the form of a systematic bias in the model error variance for models with positive and negative values of λ.

Table 6 shows MB's, MAB's, and RMSE's for the forecasts. MB's and MAB's are small in all models examined, which suggests that the simulated Box-Cox models forecast reasonably well for both positive and negative λ. It is surprising that the largest MB's are in the linear model, λ = 1.0. The extreme nonlinear cases, λ = ±1.5, have the smallest MB's and MAB's. This finding contrasts markedly with the performance of the parameter estimators examined earlier in which performance declined as λ increased from negative to positive values, but it is consistent with the performance measured by R^2.

Forecasts, in contrast to parameter estimates, improve little as sample size is increased from 30 to 60 observations. This finding indicates a biased estimator. Inspection of the MB's reveals a clear pattern of bias in the forecasts. Models with negative λ exhibit a positive bias, while those with positive λ exhibit a negative bias.

The source of the forecast bias is not clear. It may arise from the Taylor series approximation used to compute the forecasts. However, recall that the parameter estimator for λ was biased upwards for all models, except for λ near zero, and that the model variance had a positive bias in models with a positive λ and a negative bias in models with a negative λ. Thus, because of the role played by these parameters in the forecast equation and because the expected value formula is only an approximation, a combination of factors may contribute to the forecast bias.

The RMSE and percentage error of the forecasts reveal that forecast performance improves as λ moves away from zero in either direction. Models with positive λ's appear to perform better than models with negative λ's, especially when measured relative to the mean values. Note that the linear model, λ = 1.0, performs quite well in terms of the percentage error criterion, whereas in terms of the MB it ranks much lower in performance. This situation is partially due to the mean forecast value, but the RMSE decreases markedly as λ increases.

Conclusions

We have investigated the small sample properties of estimators in Box-Cox type models and the out-of-sample forecast performance. We expanded Spitzer's original study (*11*) to include twice the number of replications and several aspects of forecast performance. We have shown that using the inverse Box-Cox

Table 6—R^2 for the estimation sample and mean bias (MB), mean absolute bias (MAB), and root mean square error (RMSE) of forecasts

λ	N	R^2 [1]	MB	MAB	RMSE	Mean values: True	Mean values: Forecast	Error[2]
	Sample size				*Estimates*			*Percent*
−1.5	30	0.85	−0.005	0.034	0.144	0.263	0.258	2
	60	.78	.008	.039	.229	.269	.277	3
−1.0	30	.82	.013	−.062	.631	.202	.215	6
	60	.78	.052	−.163	2.198	.251	.303	17
−0.15	30	.65	.023	−.057	.585	.082	.106	23
	60	.35	.001	−.070	.628	.107	.108	< 1
1.0	30	.95	−.022	−.559	.708	24.887	24.865	< 1
	60	.95	−.051	−.550	.693	24.898	24.847	< 1
1.5	30	.95	−.006	−.168	.213	11.051	11.045	< 1
	60	.95	−.016	−.166	.209	11.054	11.039	< 1

[1] R^2 is measured in terms of the original untransformed dependent variable.
[2] Percentage error is calculated as |MB| /mean × 100%.

transform to forecast Y from Y(λ) leads to a biased estimator. We used a second-order Taylor series expansion to approximate the expected value of the original (untransformed) dependent variable. The size of the forecast bias depends on the size of the equation error variance and on the degree of nonlinearity in the model as measured by the departure of λ from 1.0.

The properties of the parameter estimators in this study are consistent with those found by Spitzer and support his pioneering research in this area. However, based on our larger number of replications, we were able to detect an emerging pattern of bias in the estimator of the equation error variance, which was neither obvious nor reported in Spitzer's study (*11*).

Parameter bias was not a significant problem in the models with $\lambda < 0$, but there was evidence of bias in models with $\lambda > 0$. It was fortunate that the MB in parameters showing the largest MB's dropped markedly when sample size was increased from 30 to 60 observations because one can have greater confidence in the parameter estimates as samples increase.

The RMSE's and the MASD's of the parameters indicated that parameter estimators in models with negative λ had tighter sampling distributions than those in models with positive λ. The results also showed that the distributions narrowed considerably as the sample size increased. The closeness between the RMSE's and the MASD's suggests that variance estimates for the parameters obtained from the inverse of the convariance matrix of the gradient of the likelihood function were good estimators. Spitzer found similar results for variance estimates obtained from the Hessian matrix using Newton's method.

In contrast to the parameter estimators, models with $\lambda > 0$ appeared to forecast remarkably well. The reason models with positive λ's yield poorer parameter estimates but better forecasts than models with negative λ's is unclear, but it seems to be related to the relative variances of the original and transformed dependent variable and to the distribution of the untransformed equation error. By construction, all models had the same variance for the transformed dependent variable. However, the untransformed variable had a larger variance as λ approached 1.0. Further research on this point may provide some useful guidelines for the applied researcher when applying the Box-Cox transformation to variables with particular distributions.

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Appendix: Data Generation and Estimation

Some 100 successive data samples were generated for each model and sample size specification in the Monte Carlo study by use of a procedure set forth by Spitzer (*11*). Each generated data sample was divided into two subsamples: one used for estimation and the other for forecast evaluation. Without loss of generality, the first N observations were placed in the estimation sample and the remaining K observations were placed in the forecast sample, where N = (30, 60) denotes the estimation sample size and K = 10 denotes the forecast sample size.

The transformed independent variables were obtained as follows: first, N + K pairs of uniform pseudorandom numbers (W_{1t}, W_{2t}) were generated by use of the Lehmer multiplicative congruential method from the LLRANDOM II computer package (*9*). This generator has the form:

$$U_{n+1} = A \cdot U_n \pmod{2^{31}-1}$$

where A = 397204092. When this value of A is used, the generator has very good statistical properties. A starting seed value for the process was specified as $U_0 = 4312657$.

Next, the N + K pairs were forced to orthogonality and standardized to zero mean and unit variance. The transformed independent variables $X_1(\lambda)$ and $X_2(\lambda)$ were obtained from the W_i as:

$$X_{1t}(\lambda) = 5 + (3)^{1/2}W_{1t},$$

$$X_{2t}(\lambda) = 45 + (0.4)(27)^{1/2}W_{1t}$$

$$+ [(0.84)(27)^{1/2}]W_{2t},\ t=1, 2, \ldots, N+K$$

For negative λ, each $X_{it}(\lambda)$ was multiplied by -1.0 to ensure that X_{it} was in the positive domain as required by the Box-Cox transformation. This specification implies a correlation between $X_1(\lambda)$ and $X_2(\lambda)$ of 0.4. The inverse Box-Cox transformation was applied to the $X_i(\lambda)$ to obtain X_1 and X_2.

We obtain the Y_t by untransforming the $Y_t(\lambda)$ computed from:

$$Y_t(\lambda) = 9.0 - 1.5\, X_{1t}(\lambda) + 0.5\, X_{2t}(\lambda) + \epsilon_t$$

where ϵ_t is an independently, identically distributed normal random error term generated with mean zero and variance 0.426. If $Y_t(\lambda)$ fell outside the feasible range such that the untransformed Y_t could not be computed, then another error term was generated to compute a replacement. This situation occurred only infrequently, suggesting that truncation of the error term (deviation from the assumption of normality) was not a significant problem for the specified models.

Marsaglia's "rectangular-wedge-tail" procedure as implemented in LLRANDOM-II was used to generate the pseudorandom normal error term. The error variance, σ^2, was chosen to make the residual variance approximately 5 percent of the total variance of $Y(\lambda)$.

Research Review

A Note on Explaining Farmland Price Changes in the Seventies and Eighties

Luther Tweeten

Farm real estate values from 1981 to 1985 fell by percentages unprecedented since the Great Depression (table 1). Nominal land values fell 47 percent in Iowa and an average of 17 percent in the contiguous 48 States. Adjusted for 25-percent inflation (as measured by the gross national product implicit deflator), real land values in the Corn Belt as of April 1, 1985, had fallen to less than half their real value as of February 1, 1981. The U.S. nominal capital loss was $154 billion from 1981 to 1985.

The popular press and some economists contended that plungers and speculators dominated the land market of the seventies, raising land prices to levels unjustified by agricultural earnings and ensuring collapse. The farmland market may indeed by characterized as "collapse" in many States. At issue is whether land prices fell in the eighties because farm real estate in the seventies was overpriced relative to the prospective earning capabilities of land in agriculture. Or did land prices collapse because of fundamental changes in underlying conditions that even prudent investors could not have foreseen and avoided? The basic issue is whether the land market is efficient, using available information to price land according to rational expectations of prospective future earnings of the land. I contend that the farm real estate market is reasonably efficient and that land was not overpriced in the seventies based on prudent expectations at the time.

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Table 1—Farm real estate value per acre and total value, selected years

State	Farm real estate value per acre				Total value of farmland and buildings		
	Feb. 1, 1981	April 15, 1985	Change, 1981-85	Change, 1973-81	Feb. 1, 1981	April 1, 1985	Change, 1981-85
	Dollars		*Percent*		*Million dollars*		
Michigan	1,289	1,052	−18	171	14,695	11,990	−2,705
Wisconsin	1,152	847	−26	220	21,427	15,254	−6,173
Minnesota	1,281	823	−36	359	38,942	25,032	−13,910
Ohio	1,831	1,126	−38	264	29,479	17,794	−11,685
Indiana	2,031	1,259	−38	293	34,121	20,651	−13,470
Illinois	2,188	1,314	−40	289	63,014	37,717	−25,297
Iowa	1,999	1,064	−47	317	67,366	35,754	−31,612
Missouri	990	659	−33	195	30,987	20,433	−10,554
North Dakota	436	360	−17	254	18,007	14,759	−3,248
South Dakota	329	250	−24	233	14,706	11,116	−3,590
Kentucky	1,033	906	−12	178	15,082	13,142	−1,940
Tennessee	1,070	982	−8	143	14,445	13,156	−1,289
Georgia	971	865	−11	124	14,080	11,676	−2,404
Alabama	910	769	−15	188	10,829	8,844	−1,985
Arkansas	1,056	849	−20	194	17,213	13,671	−3,542
Oklahoma	681	566	−17	169	23,154	18,684	−4,470
48 States	819	679	−17	198	843,657	689,807	−153,850

Source: (*5*). Italicized numbers in parentheses refer to items in the References at the end of this note.

Conceptual Framework

In a well-functioning land market, the land price would be expected to equal discounted future earnings from land. Land market participants offering less than this price would have land bid away from them by buyers content with a lower rate of return, and rational buyers would not pay more for land because their capital would earn more if invested elsewhere.

A simple formula for the current price of farmland is *(4)*[1]:

$$P_t = R_t/(b - i') \qquad (1)$$

or rearranging terms:

$$(R_t/P_t) = b - i' \qquad (2)$$

where P_t is land price per acre in year t, R_t is land earnings or rent in year t, b is the desired or equilibrium market real rate of return on investment in farmland, and i' is the expected real annual increase in land earnings. The latter assumes that land market participants view future real land earnings as a constant percentage trend that may be positive, zero, or negative. Evidence of speculation is present if the actual land price exceeds the present value of land, P_t, computed from equation (1) based on reasonable expectations for future earnings and the desired rate of return.

Explaining Land Prices at the End of the Seventies

As noted in equation 2, the ratio of land prices to land earnings is expected to equal $b - i'$, where b is the desired rate of return (which is influenced by the real farm mortgage interest rate and expected returns on alternative investment opportunities) and i' is the expected trend in real land earnings. Each parameter is influenced by past values.

Expectations for Real Earnings from Land

First, consider what would be a realistic expectation in 1980 for i', the future rate of increase in real earnings from land in agricultural uses alone. A start is to examine a realistic expectation of future aggregate supply-demand balance and real farm prices for the eighties. The U.S. population grew just over 1 percent annually in the seventies and could be expected to grow at least 0.9 percent annually in the eighties. Per-capita real disposable income grew 1.8 percent per year in the seventies and, as of 1980, could be expected to continue to grow at that rate. In real terms, U.S. farm exports grew 10 percent annually in the seventies, and it seemed realistic to expect real exports to increase 3 percent per year in the eighties. Farm exports were 30 percent of farm output in 1980. Given the above parameters and assuming a 0.1 domestic income elasticity of demand, the expected rate of increase in total demand for farm output was 1.66 percent annually.

One must compare this expected growth in demand with expected growth in supply due to productivity gains to determine expected trends in real commodity prices. Productivity measures vary widely from year to year (due to weather), making forecasts difficult. After growing at 2.4 percent per year in the fifties, multifactor productivity growth slowed to 1.2 percent per year in the sixties and 1.5 percent per year in the seventies. It was surely not imprudent for investors to anticipate that productivity growth would not exceed expected growth in demand of 1.66 percent annually in the eighties so that real farm prices and income would be maintained.

Table 2 shows real net rent (gross cash rent less property taxes adjusted by the GNP implicit deflator) trends for 16 States, States for which data are most reliable and coincidentally including States for which land prices fell the most in 1980-85.[2] Real land rents increased in all 16 States in the seventies and declined significantly in only one State, Michigan, in the sixties. If investors desired a real rate of return, b, of 4 percent on farmland from agricultural earnings alone in the eighties, then, if one applies equation 2, such a real return would be forthcoming even if real net returns fell in 10 States (as noted in the last column of

[1]Italicized numbers in parentheses refer to items in the References at the end of this note.

[2]Land cash rents are a contractual obligation that reflect expectations of earnings, but that would not be expected to reflect speculative expectations about land price. Although cash rents are not a perfect measure of land earnings, Pongtanakorn found they predict land price changes much more accurately than does net farm income. Land earnings were increasing in the seventies, and cash rents tended to lag trends in real land earnings. Hence, cash rents might have been expected to underestimate expected real land earnings in 1980.

Table 2—Actual real rate of increase in net cash land rent, 1960-69 and 1970-79, and expected future rate of increase based on 1980 conditions

State	Annual rate of increase, i′, in real net cash rent		
	Actual average		Expected if b = 0.04 or 4 percent
	1960-69	1970-79	1980[1]
	Percent		
Michigan	−1.83	4.32	1.23
Wisconsin	.26	2.18	.31
Minnesota	1.80	4.61	−.49
Ohio	1.72	6.94	.48
Indiana	1.85	6.20	−.49
Illinois	2.98	4.39	.25
Iowa	3.77	5.39	−.18
Missouri	3.61	4.95	−1.49
North Dakota	4.16	5.38	−1.53
South Dakota	2.67	1.73	−.90
Kentucky	.38	2.11	−.60
Tennessee	−.12	.69	−.46
Georgia	2.02	.09	.18
Alabama	1.45	.98	−.72
Arkansas	.26	2.72	−.91
Oklahoma	2.69	2.29	1.10

[1]Computed from formula $i' = b - (R_t/P_t)$, where b is the desired real rate of return on farmland investment, R_t is the current net land rent, and P_t is the current land price.

Source: Unpublished worksheets, Economic Research Service, U.S. Department of Agriculture. Net rent is gross cash rent less property taxes.

table 2). In States where real rents were expected to increase under these assumptions, the increases tended to be small relative to those in the seventies. These results suggest that investors were being cautious in 1980.

Expectations for the Discount Rate

Using econometric techniques and several alternative formulations including Almon-distributed lags to estimate equation 2, Pongtanakorn was unable to reject the hypothesis that land market participants view i′ as zero (*3*). Hence, it is useful to turn our attention to the second major parameter, b, which determines land value and the land rent-price ratio. The expected value of b, the real rate of return on farmland, may be influenced by the real farm mortgage interest rate and the expected return on alternative opportunities.

The real farm mortgage interest rate averaged 2-3 percent in the sixties, a rate characteristic of earlier decades as well (table 3). Real interest rates averaged near zero in the seventies and were negative in 1980. If i′ is zero and if land investors had used the real rate of interest in the seventies as their desired real rate of return on land investment, b, they would have paid a nearly infinite price for land in 1980.

Investors desired a real rate of return on land greater than real farm mortgage interest rates in the seventies. If i′ is zero, the ratio of net rent to land price indicates the real rate of return expected by investors in the land market. Table 3 shows that rate by actual ratios for the sixties, seventies, and 1980. The ratio in 1980 averaged 4.3 percent for the 16 States. Oil and natural gas earnings probably accounted for the low ratio in Oklahoma. The relatively low ratios (below 4.0) in Michigan, Wisconsin, Ohio, Illinois, and Georgia can be partly explained by urban influences that Pongtanakorn found to be statistically significant in reducing rent-land price ratios. When these States are omitted, the average rent-land price ratio, as a measure of expected real land returns, was 4.8 percent. Thus, if real interest rates had remained at historic levels of 2-3 percent and if real land earnings had remained constant in the early eighties, land investors would have realized real earnings approximately double real interest rates.

It is impossible to know the desired or equilibrium real return on farmland relative to the real rate of interest, but the return on farmland in 1980 was more than adequate to cover historic farm mortgage rates and far in excess of that rate in 1980. Furthermore, expected real rates of return on farmland in 1980 as measured by rent-value ratios were well in excess of rates of return on major alternative investments. Total rates of return on common stock and long-term bonds averaged negative in the seventies (*7*). Again, no evidence points to a land market in 1970-80 dominated by speculators and plungers who paid more for land than its present value based on reasonable expectations of future earnings in agriculture alone and expected future real interest rates.

Table 3—Ratio of net cash rent to farmland value and real farm mortgage interest rate, selected years

State	Real farm mortgage interest rate			Ratio of net cash rent to land value			
	Actual			Actual			Predicted
	1960-69	1970-79	1980	1960-69	1970-79	1980	1980
	Percent						
Michigan	2.42	−0.03	−1.0	4.77	3.60	2.77	2.80
Wisconsin	2.42	−.03	−1.0	6.48	4.99	3.69	3.92
Minnesota	2.42	−.03	−1.0	6.25	5.99	4.49	4.95
Ohio	2.67	.08	−1.1	5.60	4.18	3.52	3.82
Indiana	2.67	.08	−1.1	5.85	5.74	4.49	5.13
Illinois	2.67	.08	−1.1	4.61	4.56	3.75	4.02
Iowa	2.67	.08	−1.1	5.43	5.71	4.18	4.49
Missouri	2.67	.08	−1.1	6.15	5.88	5.49	5.56
North Dakota	2.59	−.06	−1.3	7.53	6.96	5.53	5.90
South Dakota	2.59	−.06	−1.3	6.25	5.90	4.90	5.36
Kentucky	3.01	.47	−.8	7.36	5.83	4.60	4.66
Tennessee	3.01	.47	−.8	8.74	5.56	4.46	4.41
Georgia	3.25	.65	−.6	9.29	4.93	3.82	3.81
Alabama	3.25	.65	−.6	8.94	5.68	4.72	4.76
Arkansas	3.18	.37	−1.0	7.52	5.65	4.91	4.11
Oklahoma	2.77	.08	−1.4	4.27	3.77	2.90	3.23

Source: Unpublished worksheets, Economic Research Service, U.S. Department of Agriculture. Predicted rent-value ratio from (*3*).

The Predicted Rent-Value Ratio

The ratio of net rent to land value decreased from the sixties to 1980. It is useful for us to pursue further the issue of whether land was overpriced in 1980 relative to earning capabilities after accounting for factors influencing land prices not explicitly dealt with in the foregoing analysis.

Pongtanakorn used regression analysis to explain the change in the ratio among 35 States from 1962 to 1982. The ratio was significantly influenced by population density (urbanization raised the value of farmland relative to rent), by the share of Federal Land Banks in real estate lending (interest rates were lower historically on such loans than on alternative sources of mortgages, hence raising land values relative to rent), by the real rate of interest, and by a time trend. The inflation rate and the past trend in real rents (a measure of i') did not significantly influence the rent-price ratio[3]. Inflation could have had an indirect impact on the time trend, which indicated an $18-per-year increase in land prices in the 35 States included in the model.

Inflation could have also influenced the real mortgage interest rate, which declined because inflation was unanticipated and added to land price. The inflation rate significantly lowered the rent-price ratio through interaction with the tax rate, an expected result because high inflation rates would be expected to raise the value of land relative to other investments. Capital gains were taxed at a lower rate than ordinary income. Therefore, income from land, which has had a large capital gain component, has been taxed at a lower rate than income from bonds and other investments with a lower capital gain component.

Predicted land rent-price ratios from Pongtanakorn exceeding actual values in 1980 could be interpreted as evidence of speculation in land markets. In the Corn Belt where land values have fallen most since 1980, predicted ratios exceeded actual ratios. The actual ratio exceeded the predicted normal ratio in Iowa by 7 percent, indicating that land values would

[3]See (*1*) for recent estimates regarding inflation.

need to fall 7 percent to restore the "normal" ratio if net rents remained constant. Differences in other States also were small and did not suggest that nominal land rent-price ratios were far out of line with the historic structure of land markets. The close fit of actual-to-predicted rent-price ratios again provides no evidence that speculation played a major role in the land market in the seventies.

Explaining Sources of Falling Land Prices in the Eighties

If speculation cannot be blamed for land market behavior in the seventies, it follows that bursting a speculative bubble cannot explain the sharp drop in land prices after 1980. What went wrong to so rudely contradict seemingly rational expectations for land prices in 1980? Again, land earnings and discount rates give clues. Gross farm income, net farm income, cash flow, and land rents held up well from 1980 through 1984 and hence cannot be blamed for falling land prices in that period (*2, 6*).

We must look to the discount rate to explain the large decrease in land prices. The real interest rate on Federal Land Bank mortgages went from negative in 1980 and 2.4 percent in 1981 to approximately 8-9 percent from 1982 through 1985. These latter rates were at least triple historic levels, excluding the seventies when rates were abnormally low. Potential land buyers who faced payments of such rates could hardly ignore them when judging how much to pay for land. It is apparent from equation 1 that the tripling real interest rates alone could sufficiently change discount rates to justify the fall in land values to half their 1980 level.

Falling land rents in 1985 further depressed farmland values. If the structure of land price determination has changed so that expectations of falling real land earnings enter the formula in equation 1, the expectation of a negative i' would likely depress land values further. Declining exports, excess capacity reflected in diverted acres and large commodity stocks, efforts to reduce budget deficits including farm program spending, and uncertainty over new farm commodity legislation provide little basis for optimism for real land earnings to increase in the near future. Thus, declining land earnings could continue to depress land values, even if real interest rates continued to fall.

Conclusions

The farmland market is reasonably efficient. It responds to available information, pricing farmland relative to its present value based on real interest rates and earnings from land in agricultural uses, the latter measured by cash rents in this study. In 1980, farmland was not overpriced relative to reasonable expectations of future earnings and real interest rates. Rent-value ratios in 1980 were at levels that could provide a real rate of return more than adequate to cover normal real interest costs of previous decades in the memory of investors, even if real land earnings failed to increase. Economists and noneconomists alike were optimistic about future land earnings in 1980. Of course, some plungers and speculators bid recklessly for land, but they did not dominate the land market. Other investors were conservative so that on average it is not possible to conclude that land prices were out of line with prospective future earnings from land in agricultural use alone.

Land values fell after 1980 primarily because of direct and indirect impacts of high real interest rates. The unanticipated rise in real interest rates to unprecedented levels is attributable to several sources, but a major source is large structural (or full employment) Federal deficits. The deficits influenced both the discount rate and rent in the formula for land value in equation 1. High real interest rates not only raised the discount rate; they also reduced rents by raising the value of the dollar which, in turn, reduced farm exports. The problem was compounded by commodity program support rates, holding prices at levels that encouraged continued output and discouraged exports. The resulting commodity surpluses brought program changes in 1985 that would initially depress farm prices and land earnings. Factors such as OPEC oil price increases and expansion in U.S. and world money supply and credit in the seventies to levels bringing unsustainable inflation and debt also contributed to high real interest rates and reduced farm exports in the eighties. Commodity programs did not offset the negative input of macroeconomic policies.

Farmers and other land investors did not anticipate and could not have been expected to anticipate the tripling of real interest rates from historic levels. Imprudent decisions regarding macroeconomic policy in the past decade rather than imprudent investors in land are mainly responsible for the financial stress in agriculture today.

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In Earlier Issues

Paarlberg states that "[People] see the windfall gains that accrued to landowners during the past forty-five years. They bid up the price of land to levels not justified by its present or prospective earnings " (p. 689). I contend current land prices can be justified by prospective earnings.

Luther Tweeten
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Rivers of Empire: Water, Aridity, and the Growth of the American West

Donald Worster. New York: Pantheon Books, 1985, 402 pp., $24.95.

Reviewed by Ralph E. Heimlich

Rivers of Empire is a history, but the kind economists should read more often. It intertwines the social organization consequent to a particular form of economic development engendered by a specific ecologic regime: the arid West. Worster's thesis, presented in contemplation of a sterile, concrete-lined ditch in Kern County, CA, so different from the pond that served as Thoreau's muse, is that the social order is conditioned by natural resource constraints. While the concept should be of particular interest to resource economists, Worster points out that economists were as apt to ignore the social consequences of water resource development in the West as the engineers who designed the dams and canals.

As Worster admits, his predecessor in the study of resource determinants of social organization was Karl August Wittfogel, who wrote in post-World War II Germany and fled from the Nazis to Seattle. Wittfogel was a historical materialist influenced by Marx and the sociology of Weber. Part of the Frankfurt school of radical social thought in the twenties, Wittfogel restored the neglected ecological factor in Marxist historical materialism, emphasizing the natural environment and technology as a means of production that shaped the social order as much as, if not more than, labor and the forms of property ownership. Given Worster's earlier work on the development of ecology as a discipline, Wittfogel's theory probably struck a sympathetic chord. Focusing on ancient Egyptian, Babylonian, Indian, and Chinese societies, Wittfogel postulated a synergism between the development of complex irrigation systems and the rise of centralized, despotic social organizations needed to control them.

Worster extends Wittfogel's taxonomy of hydraulic societies to encompass water resource development in the modern world. (Wittfogel, in a curious lapse, became an apologist for irrigation development in his adopted American West.) Wittfogel delineated a *local subsistence mode* of irrigation technology, which depends on traditional village organization to accommodate agricultural production to natural moisture cycles in arid environments, and an *agrarian state mode*, in which a centralized, autocratic social order and a complex irrigation system develop simultaneously. In the agrarian state mode, society becomes increasingly regimented as the naturally occurring water resource comes more and more under human control, and Wittfogel thought that this development was incompatible with a pre-existing democracy. Worster adds a *capitalist state mode* to Wittfogel's taxonomy in which power and wealth are concentrated and reinforced by the development of water resources necessary for intensive irrigated agriculture, even in nominally democratic societies.

Worster's capitalist state mode of hydraulic social development contrasts with other historical theories of societal development in the West. Beginning with Frederick Jackson Turner's theory of the frontier in American social development and continuing through the writing of Walter Prescott Webb, Bernard DeVoto, and the more recent proponents of the Sagebrush Rebellion, social historians have claimed that the harsh conditions of the American West called forth a rugged individualism and a democratic decentralized society long lost in the industrialized giantism of the eastern seaboard. Worster contends that the development of large-scale irrigated agriculture in the West, conditioned by scarce natural water, is more nearly akin to the rise of centralized capital in the East than to the mythic rugged, self-reliant Western pioneer spirit. Of interest to public servants are the roles of Federal capital and technical expertise in this development and the consequent power of the technical elite, including economists, to control the flow of water and wealth in the West.

The book then presents a four-part history of Western irrigation development. The chapter titled "Incipience" traces the first encounters of explorers and pioneers with the "Great American Desert" west of the Mississippi, particularly southern California. This section documents early visitors' reactions to the original landscape as the antithesis of arable land, let alone its future role as one of the world's garden spots. The efforts of early irrigation

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communities such as the Mormons in Utah, the Greeley experiment in Colorado, and the early small irrigators in Kern County are described. These localized cooperative ventures illuminated both the potential for irrigation to make the desert bloom and the limitations of local capital to support needed irrigation development.

"Floresence: The State and the Desert" describes the entry of more sophisticated hydraulic engineering schemes, building on the contemporaneous examples of British colonial projects in India and Australia. The cost of these larger works was too much for local capital and implied a planning horizon too long for existing national sources of private capital. The plateau at which irrigation development proponents found themselves by the 1890's could be surmounted only if Federal capital were made available to finance the vastly greater hydraulic potential that technical experts saw for the region. Congress acquiesced with the National Reclamation Act of 1902 which, in several manifestations over the succeeding 80 years, financed the major capital infrastructure of industrialized agriculture in the irrigated West.

"Florescence: The Grapes of Wealth" describes the third chapter in which Worster related the final conquest of natural water by the unique partnership of the technical and economic elite that came to rule not only the water but also the West. This pattern of technical dominance over nature and social dominance over other men became most highly developed in California. Worster describes the tension between the technical elite who controlled the water, mainly the Federal water management agencies, and the economic elite who controlled the land, organized and ran the giant fruit and vegetable farms, and reaped the wealth. This chapter covers the Depression era and the emergence of social critics such as John Steinbeck and Carey McWilliams, who provided an intellectual edge to early labor organization attempts among migrant fieldworkers. This period also saw the emergence of economic critics such as Marion Clawson and Walter Goldschmidt, who studied the California Central Valley project for the Bureau of Agricultural Economics, the predecessor agency of the Economic Research Service.

Finally, we arrive at the fourth chapter, "Empire," the modern hydraulic society in the postwar West. The section, "Leviathan Ailing," in this chapter is particularly interesting because it weaves together a series of seemingly disparate problems, such as salinity, sedimentation, pesticide contamination, falling ground-water levels, collapsing dams, and the "free rivers" movement, to question the continuing viability of a now mature hydraulic society. Worster concludes that the virtual freeze on new water resource development projects since the Carter administration may mean that sustaining the West's hydraulic empire is more difficult than its original construction.

Rivers of Empire has several lessons for economists, especially those who are part of the technical elite who justified and built the irrigation projects that made the West's hydraulic regime possible. First, economists and other technical experts failed to anticipate the size and dominance of industrialized irrigated agriculture because the costs of creating and sustaining such large and complex enterprises required a vastly different economic structure than the family farm of eastern, nonindustrial agriculture. The unique partnership between Federal water management agencies and the large landowners transcended the feasible limits of private agricultural firms, resulting in an agriculture whose scale and organization were completely unforeseen by agricultural economists. Second, economists have been too narrow in evaluating the success of irrigated agriculture, focusing on narrow measures of technical efficiency, such as the 160-acre limitation, and ignoring the wider institutional milieu that surrounds western irrigated agriculture and makes it work. Western industrial agriculture may offer important clues to economists concerning the eventual industrialization of the rest of U.S. agriculture.

One unsatisfactory aspect of the book is the scant attention Worster pays to reverse linkages in his materialist argument. Although most of the book argues that responding to and overcoming the water-poor environment of the West led to a particular social and economic structure, Worster only briefly touches on the impact of that structure on the West's environment. Only at the end does he hint that environmental determinism can be a two-way street with complex feedback loops further conditioning the economic and social systems that have evolved as responses to the original environment. Given Worster's earlier writing on the development of ecological thought, one could hope for more than a simple stimulus and response in his thesis regarding hydraulic societies and how they develop.

The book is impeccably written, as we should expect from a professor of history at Brandeis University, and it offers a fascinating and informative look at the agricultural development of one of the world's richest producing areas. It contains much that should literally broaden economists' minds.

In Earlier Issues

The sources of institutional and technical change are similar. Just as the supply curve for technical change shifts as a result of advances in knowledge in science and technology, the supply curve for institutional change shifts as a result of advances in knowledge in the social sciences and related professions (law, administration, social services, and planning).

Vernon W. Ruttan
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Agricultural Policies and World Markets

Alex F. McCalla and Timothy E. Josling. New York: MacMillan Publishing Company, 1985, 286 pp., $38.00.

Reviewed by H. Christine Bolling

The decade of the seventies was the era of U.S. agricultural trade. U.S. agricultural exports were the bright spot in total U.S. trade, bolstering the slipping total trade balance. While the seventies posed important policy questions—for example, the impacts of the devaluation of the dollar and high petroleum prices—the eighties have become a real challenge as we have seen agricultural markets shrink and prices plummet. Agricultural economists must now, more than ever, understand foreign markets to evaluate U.S. policy options.

McCalla and Josling provide the tools for the job; they have written a timeless book as well as a book for the times. They focus on the important policy choices facing agricultural policymakers around the world. They go beyond the neoclassical free trade case to the complexities of import levies, quotas, and other governmental policy instruments. They also present illustrations of the impacts of policy instruments in both the small-country and large-country cases, and macroeconomic linkages within and among countries. The graphics are especially helpful in explaining the effects of changes in exchange rates on wheat and cotton markets.

Two chapters deserve special mention. "Interdependence in Practice" provides an excellent description of how the analytical tools presented earlier relate to real world cases. The wheat market of the seventies is a well-chosen case study. Wheat is the most important agricultural commodity in terms of its value in international trade and is subject to more government intervention than nearly any other commodity. Consequently, it has probably been subjected to more study by agricultural economists than any other commodity. But McCalla and Josling do more than just repeat other people's work. Their analysis is a concise explanation of the factors that came together to cause the price explosion in the international wheat market in 1972-74, including the shortfall in the world wheat crop, the change in the Soviet grain importing policy, and the realignments in the international economy that were reflected in changes in exchange rates.

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Another section of this chapter deals with the Common Agricultural Policy (CAP) of the European Community (EC), a classic case of government intervention in agriculture. The analysis of EC agricultural policy, one of Josling's specialties, is similarly excellent. The subchapter called "The Cassava and Corn Gluten Caper" emphasizes how government intervention in one market can effectively alter world trade patterns of other commodities over time. The authors focus on why the EC was once a large importer of U.S. wheat and corn (commodities most affected by the CAP), but is no longer. Corn gluten meal and cassava chips were not even imported 20 years ago, but, because they were exempt from the exorbitant variable levies applied to grains, they have now become large livestock feed import items.

Chapter 8, "National Policy Choice in Practice," provides another excellent demonstration of the authors' skill in analyzing real world policy issues. Much of this chapter was from earlier work prepared for a University of California-Government of Egypt project funded by the U.S. Agency for International Development. The authors focus on tradeoffs among the Egyptian wheat, cotton, and beef programs, identifying the costs and benefits in terms of foreign exchange and domestic government expenditures, to determine how much of these basic products should be produced domestically and how much should be imported commercially. To develop these tradeoff functions, the authors change the relationships between the support price and the world price and are thereby able to trace out a tradeoff frontier. This thoughtful approach allows them to analyze the myriad cross-effects among commodity-specific programs. This section also shows how policy decisions in the farm sector affect the macroeconomy and vice versa.

Other case studies of general interest are the U.S. PIK (payment-in-kind) program and the international dairy market. By the end of their economic analysis, McCalla and Josling have brought us "both closer to the real world of choices and further away from neat simple policy analysis" (p. 163) very successfully. The latter chapters deal with international organizations and global policy goals, the role of stability, food aid, and other policy issues.

There are a few parts that I would have done differently. The authors do not mention explicitly all the main players in the international wheat and cotton markets. For example, China, Korea, Japan, Brazil, and sometimes India are important wheat importers, and Australia is one of the top four wheat exporters. Although their roles are less dramatic than those of the countries highlighted here, they are not mentioned. The same thing is true for the cotton market. The USSR is the second largest cotton exporter. China is the present destabilizer of the cotton market. Korea and Thailand are also some of the main players on the import side, but they are not mentioned. I would have opted for a graph of all the major traders, possibly extending the otherwise very informative graph on the impacts of an appreciation of the U.S. dollar on the wheat and cotton markets on page 89 into two graphs. In another vein, the mathematical economists among us may miss a mathematical presentation of the material (possibly as an appendix). The authors have demonstrated their skills in this area in other publications.

McCalla and Josling have given us a tool to analyze the continuing developments in international agricultural trade more intelligently. Their book is thoughtful and sophisticated. It is a pleasure to read a book of its caliber pertaining primarily to agricultural trade policy, while also incorporating the issues of the larger world.

In Earlier Issues

If confined to a single-product partial equilibrium framework, analysis of changes in commodity policies will yield erroneous estimates of the magnitude of their impacts when products are interrelated. It is also possible that using a single-product partial equilibrium model may result in errors in predicting the direction of changes in endogenous variables with respect to policy changes. The final result is an important empirical issue which can affect policy recommendation.

Philip L. Paarlberg and Robert L. Thompson
Vol. 32, No. 4, October 1980

The Organization and Performance of the U.S. Food System

Bruce W. Marion, NC 117 Committee, Lexington, MA: Lexington Books, 1986, 532 pp., $39.00.

Reviewed by Howard C. Madsen

This book summarizes the research of NC 117 (North Central Regional Research Project 117), which became an institutional entity in 1973. It was formed to describe, diagnose, and prescribe changes in the organization of food production and marketing in the United States.

This book does more than summarize research findings. Providing a wealth of information on several agricultural subsectors (food production, manufacturing, and distribution), the book is an excellent reference for economists, analysts, and researchers. If aimed at policymakers and managers, however, it falls short.

The book has five parts with different authors and coauthors for each part. To its credit, the book pulls together a considerable amount of research on the U.S. food system. It lays out issues relative to agricultural production, food system coordination, food manufacturing and distribution, the legal environment of the U.S. food system, and policy options. The authors list what they call six highly visible issues: (1) the farm financial crisis, (2) the ability of the United States to compete in world commodity markets, (3) the number and size of food company mergers, (4) the Government push for deregulation, (5) turmoil in the labor markets, and (6) the national debt.

The authors have attempted to identify the driving variables of the U.S. food system. What is not clear is how they rank those variables from the most to the least important. For example, the authors mention tax structure and policy as a major factor. But as to whether it's a first-ranked major factor or a 20th-ranked major factor, the authors are silent. Nor do they attempt to forecast where all these factors will lead us if they were to continue unabated. Had they done so, one might then be able to work backwards and identify the best candidates for change. This type of forecasting would make the research more useful for policymakers and managers.

The authors treat general economic factors more qualitatively than quantitatively. They barely mention the effect of environmental concerns on the U.S. food system. In the final chapter, the authors pose 10 policy issues for public action, such as goals of the farm program in the eighties, food quality issues, advertising, and conglomerates. These issues are the ones which the authors believe could be acted upon to improve food system performance. But it is not clear which ones should be acted upon first. For example, advertising is mentioned several times throughout the book. According to the authors, research results of NC 117 "indicate that tacit or explicit collusion and/or leading firm price leadership in industries with high entry barriers results in supracompetitive profits and prices in some food manufacturing industries" (p. 433). This issue is likely a controversial one, and I would like to see similar statements in the book developed further into actions. In brief, the book does not tell us what we should do next relative to the issues it raises. In fact, in trying to deal with the entire food marketing system, the book contains so much information that it is nearly impossible to digest everything in one reading. Sorting out the candidates for change involves further analysis of the research results and value judgments. This process calls for either a very long or a short review. I have chosen the latter.

Several megatrends are at work in the U.S. food system that provide a fertile ground for further research. The book is loaded with information, but further efforts analyzing what it all means would be helpful.

The reviewer is executive vice president of Agri-Commodities, Inc., a consulting and research firm in Andover, MA.

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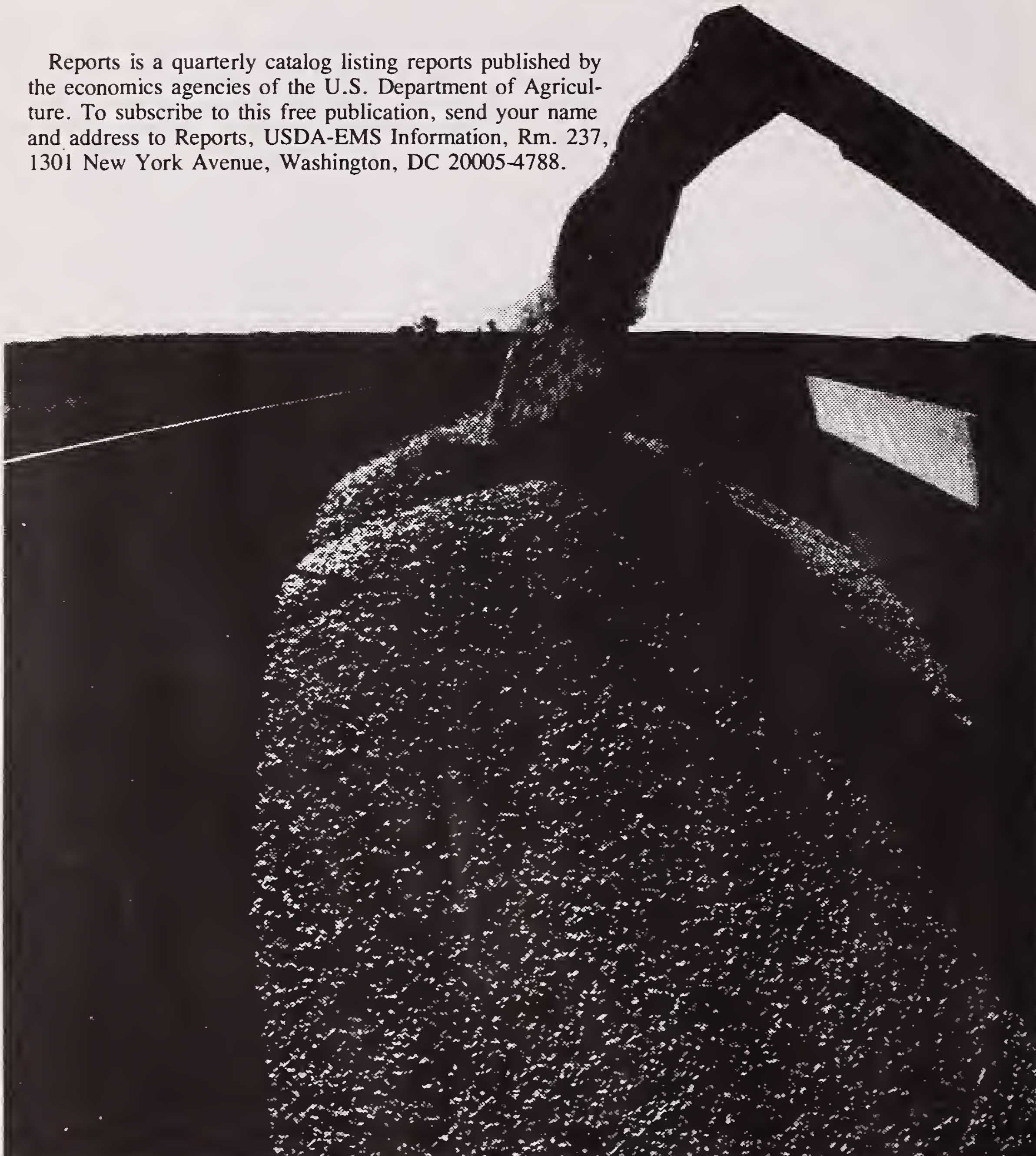

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