Productivity Growth and Input Mix Changes in Food Processing

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To examine productivity growth in New Jersey's food-processing sector, this study conducts a joint analysis of total and partial factor productivity indexes. Results indicate growing material intensity, declining labor and capital intensities, and relatively slow material productivity growth. However, due to the high cost share of material inputs, material productivity growth contributed more to total factor productivity growth than did growth in the productivity of any other input. In fact, almost half of the growth in overall productivity is attributed to material productivity growth. Results also suggest that the 1973 decline in total factor productivity was characterized by greater decline in material productivity than in the productivities of labor and capital.

Changes in labor and total factor productivity have been the focus of several studies on the U.S. food-processing sector. Results of these studies generally indicate that while labor and total factor productivity increased over time, both declined in 1973 and in the period immediately following. The temporary declines in these productivity indexes have been attributed to the supply shock resulting from the 1973 energy crisis (Lee; Jorgenson, Gollop, and Fraumeni; Heien). A major limitation of these studies, however, is that they ignored (1) the behavior of productivity indexes for nonlabor inputs and (2) the effects of energy prices on such productivity indexes.

In most manufacturing industries, labor intensity is high. In conducting productivity analysis in these industries, it makes sense to focus on labor productivity. In food processing, however, material inputs account for over 60% of production cost (Adelaja 1992). It does not make intuitive sense for productivity studies to focus on labor productivity because material productivity growth is probably more relevant than labor productivity growth, and gains in material efficiency are likely to have greater effect on total factor productivity growth than do gains in labor efficiency.

Knowledge of the behavior of productivity indexes for nonlabor inputs and of the contributions of these indexes to total factor productivity growth is useful to economists in understanding the nature and sources of productivity growth in food processing. Information on the impact of energy price shocks on productivity indexes for nonlabor inputs could also contribute to knowledge about the role of energy inputs in the food-processing sector. Agricultural economists should particularly be interested in productivity indexes for material inputs because 70% of materials used in U.S. food processing are farm products (Adelaja 1992). That is, material productivity indexes should reflect the dynamics of the efficiency of use of farm products in food processing. For example, the contributions of efficiency gains in material use to total factor productivity gains should be of interest to agricultural economists.

Using the state of New Jersey as a case study, this paper estimates and analyzes changes in total factor productivity as well as productivity indexes for four classes of food-processing inputs: production labor, nonproduction labor, capital, and materials. For each year in the 1964–84 period, these productivity indexes are derived for the aggregate food-processing sector (SIC 20) and for each subsector (three-digit SIC categories).[1] To facilitate decomposition of growth in total factor productivity indexes into growth in partial factor productiv-

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[1] Growth in New Jersey's food-processing sector has been slower than in the U.S. New Jersey's shares of U.S. food-processing employment, value of shipments, and value-added fell from 4.2%, 4.0%, and 4.5% in the early 1970s to 3.8%, 2.9%, and 3.7%, respectively, by 1984. New Jersey's share of U.S. population remained constant at 3.4% during this period (*Annual Survey of Manufacturers*, U.S. Department of Commerce).

ity indexes, the theoretical relationship between the two is derived. This decomposition allows one to observe the extent to which efficiency gains in the use of a specific input contribute to total factor productivity growth. By further focusing on productivity changes in the 1972–73 period, the immediate impacts of the energy crisis are further examined. Results illuminate the structure of productivity growth and some of the implications of such growth.

The plan for the rest of this paper is as follows. The theoretical relationships between total and partial factor productivity indexes are derived in the following section. The empirical model used in productivity analysis and decomposition appears next followed by a discussion of the data and the empirical results. The final section presents concluding remarks.

Total and Partial Factor Productivity Indexes

Denote the total factor productivity index for the tth period as TFP_t and the partial factor productivity index for the ith input in the tth period as PFP_{i_t}. TFP_t indexes reflect overall efficiency gains (in the utilization of all inputs). On the other hand, PFP_{i_t} indexes reflect not only efficiency gains in the utilization of specific inputs, but also changes in input mix due to technological biases and input substitution.[2] Because TFP_t and PFP_{i_t} are related under certain conditions, one can decompose changes in overall efficiency into changes in efficiencies of each input. This decomposition procedure is outlined in the rest of this section.

Assume the existence of a production function relating inputs to output (Q). Further assume competitive input markets (CP) and constant returns to scale (CRS). Following the convention in the *Annual Survey of Manufacturers* (ASM) and *Census of Manufacturers* (CM), also assume four categories of inputs: (1) production labor (L), nonproduction labor (R), material inputs (M), and capital (K).[3] Denote the quantities used of these inputs in time period t by X_{L_t}, X_{R_t}, X_{M_t}, and X_{K_t} so that X_t is a vector of input quantities (X_{i_t}) in period t. For the tth period, denote the price of the ith input as P_{i_t} (e.g., price of material inputs is P_{M_t}) and output price as P_{Q_t}. The production function can be specified implicitly as

$$(1)\qquad Q_t = F_t(X_t, T_t).$$

In (1), T_t is the value of a trend variable in the tth period. It is therefore a proxy for technology. Following Evenson, Landau, and Ballou, obtain

$$(2)\qquad \frac{\partial Q_t}{\partial T_t} \cdot dT_t = \sum_{i=1}^{n} F_{i_t} \cdot \frac{\partial X_{i_t}}{\partial T_t} \cdot dT_t + F_{T_t} \cdot dT_t,$$

where $F_{i_t} = \partial Q_t/\partial X_{i_t}$ equals the marginal product of the ith input in the tth period. Profit maximization implies that $F_{i_t} = P_{i_t}/P_{Q_t}$. Hence,

$$(3)\qquad \frac{\partial Q_t}{\partial T_t} \cdot dT_t = \sum_{i=1}^{n} \frac{P_{i_t}}{P_{Q_t}} \cdot \frac{\partial X_{i_t}}{\partial T_t} \cdot dT_t + F_{T_t} \cdot dT_t,$$

and

$$(4)\qquad \frac{\partial \ln Q_t}{\partial T_t} \cdot dT_t = \sum_{i=1}^{n} S_{i_t} \cdot \frac{\partial \ln X_{i_t}}{\partial t} dT_t + \frac{F_{T_t}}{Q_t} \cdot dT_t.$$

S_{i_t} is cost share of the ith input in the tth period. Under CRS, $P_{Q_t}Q_t = \Sigma_{i=1}^{n} P_{i_t}X_{i_t}$, and $\Sigma_{i=1}^{n} S_{i_t} = 1$.

TFP growth rate ($\widehat{TFP}_t$) is

$$(5)\qquad \widehat{TFP}_t = \frac{F_{T_t}}{Q_t} \cdot dT_t = \frac{\partial \ln Q_t}{\partial T_t} \cdot dT_t - \sum_{i=1}^{n} S_{i_t} \frac{\partial \ln X_{i_t}}{\partial T_t} \cdot dT_t = \hat{Q}_t - \sum_{i=1}^{n} S_{i_t}\hat{X}_{i_t}.$$

Productivity growth rate of the ith input ($\widehat{PFP}_{i_t}$) is

$$(6)\qquad \widehat{PFP}_{i_t} = \frac{\partial \ln(Q_t/X_{i_t})}{\partial T_t} \cdot dT_t = \frac{\partial \ln Q_t}{\partial T_t} \cdot dT_t - \frac{\partial \ln X_{i_t}}{\partial T_t} \cdot dT_t = \hat{Q}_t - \hat{X}_{i_t}.$$

The simple unweighted average of the PFP_{i_t} growth rates ($\widehat{APFP}_t$) is

[2] TFP_t is the ratio of output (Q_t) to the quantity of aggregate input in the tth year. It shows changes in aggregate input when output is held constant. PFP_{i_t} is the ratio of output (Q_t) to the quantity of the ith input (X_{i_t}) in the tth year. It shows changes in the input's quantity when output is held constant.

[3] Materials include inputs that are completely exhausted in production. Nonproduction labor includes management and service-type workers.

$$(7)\quad \widehat{APFP}_t = \frac{1}{n}\sum_{i=1}^{n}\widehat{PFP}_{i_t} = \frac{1}{n}\sum_{i=1}^{n}(\hat{Q}_t - \hat{X}_{i_t}) = \hat{Q}_t - \frac{1}{n}\sum_{i=1}^{n}\hat{X}_{i_t}.$$

From (5) and (7), note that

$$(8)\quad \hat{Q}_t = \frac{1}{n}\left[\sum_{i=1}^{n}\widehat{PFP}_{i_t} + \sum_{i=1}^{n}\hat{X}_{i_t}\right] = \widehat{TFP}_t + \sum_{i=1}^{n}S_i\hat{X}_i = \widehat{APFP}_t + \frac{1}{n}\sum_{i=1}^{n}\hat{X}_i.$$

According to (8), $\widehat{APFP}_t$ is output growth rate minus simple average growth rate of inputs, while $\widehat{TFP}_t$ is output growth rate minus weighted average growth rate of inputs. Derive the following from (8):

$$(9)\quad \widehat{TFP}_t = \hat{Q}_t\sum_{i=1}^{n}S_{i_t} - \sum_{i=1}^{n}S_{i_t}\hat{X}_{i_t} = \sum_{i=1}^{n}S_{i_t}(\hat{Q}_t - \hat{X}_{i_t}) = \sum_{i=1}^{n}S_{i_t}(\widehat{PFP}_{i_t});$$

$$(10)\quad \widehat{APFP}_t = \hat{Q}_t - \frac{1}{n}\sum_{i=1}^{n}\hat{X}_i = \frac{1}{n}\sum_{i=1}^{n}(\hat{Q}_t - \hat{X}_{i_t}) = \frac{1}{n}\sum_{i=1}^{n}\widehat{PFP}_{i_t}.$$

Hence, $\widehat{TFP}_t$ is the weighted average of $\widehat{PFP}_{i_t}$ values, while $\widehat{APFP}_t$ is the simple average. The difference between $\widehat{APFP}_t$ and $\widehat{TFP}_t$ is defined as follows:

$$(11)\quad BIAS_t = \widehat{APFP}_t - \widehat{TFP}_t = \sum_{i=1}^{n}S_{i_t}\hat{X}_{i_t} - \frac{1}{n}\sum_{i=1}^{n}\hat{X}_{i_t}.$$

The contribution of growth in the productivity of the ith input to total factor productivity growth is obtained from (9) as $S_i\widehat{PFP}_{i_t}$. The proportion of total factor productivity growth that is due to growth in productivity of the ith input (C_i) is therefore obtained as

$$(12)\quad C_i = \frac{S_i\widehat{PFP}_{i_t}}{\widehat{TFP}_t}$$

Note that $\Sigma_{i=1}^{n} C_i = 1$ under CRS. If $(\widehat{Q/X_M}) > (\widehat{Q/X_K})$, then $\hat{X}_K > \hat{X}_M$ and $\widehat{X_K/X_M} > 0$. Hence, changes in input ratios are reflected by differences in partial factor productivity growth rates. Partial factor productivity indexes can be used to characterize changes in input intensity via intensity measures (IV), defined as follows:

$$(13)\quad IV_{i_t} = \left(\frac{1}{n}\sum_{i=1}^{n}\widehat{PFP}_{i_t} - \widehat{PFP}_{i_t}\right)\Bigg/\left(\left|\frac{1}{n}\sum_{i=1}^{n}\widehat{PFP}_{i_t}\right|\right).$$

In (13), IV_{i_t} is the change in the intensity of input i in time period t and $|U|$ is the absolute value of U. If $IV_{i_t} > 0$ ($IV_{i_t} < 0$), production becomes more (less) input i intensive over time. Note that $\Sigma_{i=1}^{n} IV_{i_t} = 0$.

Empirical Model

The analysis in the previous section is in continuous time. However, it is difficult to calculate productivity indexes from continuous time-series data since both S_i and X_i change between periods. To solve this problem, Jorgenson, Gollop, and Fraumeni recommend discrete approximation via the logarithmic indexing method (LIM). LIM is consistent with the translog production-function specification of the implicit production function in equation (1).

Following Jorgenson, Gollop, and Fraumeni, define $\widehat{TFP}_t$ as the average growth rate of TFP between two discrete points in time, say time period (t) and ($t - 1$). That is, $\widehat{TFP}_t$ is approximated by $TFP^*_t = ½[TFP_t + TFP_{t-1}]$. Further define $S^*_{i_t}$ as the average factor shares of the ith input between two discrete points in time. That is, $S^*_{i_t} = ½[S_{i_t} + S_{i_{t-1}}]$. Considering that TFP^*_t is also the difference between successive logarithms of output minus the weighted average of the difference between successive logarithms of inputs with the weights being the $S_{i_t}^*$s (Christensen, Cummings, and Jorgensen), it can be obtained as

$$(14)\quad TFP_t^* = \ln Q_t - \ln Q_{t-1} - \sum_{i=1}^{n} S_{i_t}^* [\ln X_{i_t} - \ln X_{i_{t-1}}] = Q_t^* - \sum_{i=1}^{n} S_{i_t}^* X_{i_t}^*,$$

where $Q_t^* = \ln Q_t - \ln Q_{t-1}$ and $X_{i_t}^* = \ln X_{i_t} - \ln X_{i_{t-1}}$. Note also that

$$(15)\qquad Q_t^* = TFP_t^* + \sum_{i=1}^{n} S_{i_t}^* X_{i_t}^*.$$

Equations (14) and (15) show the traditional *TFP* decomposition relationship.

CRS and CP are imposed on the translog production function via the constraint that $\Sigma_{i=1}^n S_i = 1$. This constraint allows one to define *TFP* growth rate as the weighed average of partial factor productivity growth rates (see equation 9). These assumptions are not required to use LIM. However, they are required to use the *TFP* decomposition relationship in equation (9) since the relationship is based on the premise of CRS and CP. CRS and CP imply that the constraint $\Sigma_{i=1}^n S_i = 1$ must be imposed in using the LIM procedure. This is equivalent to the constraint that $\Sigma_{i=1}^n S_{i_t}^* = 1$. Imposition of the constraint is further discussed in the data section.

$\widehat{PFP}_{i_t}$ is approximated by $PFP_{i_t}^* = [\ln Q_t - \ln Q_{t-1}] - [\ln X_{i_t} - \ln X_{i_{t-1}}] = Q_t^* - X_{i_t}^*$. Hence from (15),

$$(16)\quad PFP_{n_t}^* = Q_t^* - X_{n_t}^* = TFP_t^* + \sum_{i=1}^{n-1} S_{i_t}^* X_{i_t}^* + S_{n_t}^* X_{n_t}^* - X_{n_t}^*.$$

Under CRS, $S_{n_t}^*(X_{n_t}^*) - X_{n_t}^* = X_{n_t}^*(1 - S_{n_t}^*) = -\Sigma_{i=1}^{n-1} S_{i_t}^* X_{n_t}^*$. Hence,

$$(17)\qquad PFP_{n_t}^* = TFP_t^* + \sum_{i=1}^{n-1} S_{i_t}^*[X_{i_t}^* - X_{n_t}^*]$$

and

$$(18)\qquad TFP_t^* = PFP_{n_t}^* - \sum_{i=1}^{n-1} S_{i_t}^*[X_{i_t}^* - X_{n_t}^*].$$

Using (14) and (17), TFP_t^* and $PFP_{i_t}^*$ can be calculated from time-series data on real quantities of outputs and inputs, and cost shares of inputs. Indexes of TFP_t and PFP_{i_t} can be further constructed. The relationships in (5) through (13) also apply to the *TFP* and *PFP* indexes obtained via discrete approximations if CRS and CP are imposed in using the LIM.

Data and Calculations

CM and ASM publish annual New Jersey data on value of shipments (*VS*), expenditures on materials (*ME*), hours of production labor employment (*LH*), wages paid to production labor (*LE*), wages paid to all labor (*LRE*), number of workers (*LRN*), and number of production workers (*LN*) for the food-processing sector (SIC 20) and each three-digit SIC category except for fats and oils (SIC 207). The data is consistently available for the years 1964 through 1984.

The quantity index for the production labor input (X_L) is obtained as the index of *LH*. Total number of nonproduction workers (*RN*) is calculated as *LRN* − *LN*. The index of the nonproduction labor input (X_R) is obtained as the imputed hours of employment of nonproduction workers (*RH*), which is obtained by assuming that each nonproduction worker works 40 hours per week and 52 weeks per year. X_M is obtained by dividing *ME* by the producer price indexes for materials and components obtained from producer price indexes (U.S. Department of Labor, Bureau of Labor Statistics). This data source also provides data on producer price indexes for all food products (SIC 20) and for each three-digit SIC category of food products. These are used as deflators for *VS* to obtain implicit output quantity indexes (Q_t). The annual cost of capital and the index of capital input in real terms (X_K) are obtained from Adelaja (1988, 1992). The base year for all indexes is 1964 (1964 = 100).

Wages paid to nonproduction workers (*RE*) are calculated as *LRE* − *LE*. Total cost of production (*TC*) is calculated as *KE* + *RE* + *ME* + *LE*. Input shares (S_i) are calculated as *KE, RE, ME,* or *LE* divided by *TC* so that $\Sigma_{i=1}^n S_i = 1$, as required

Table 1. Estimated Productivity Indexes for New Jersey's Aggregate Food-Processing Sector (SIC 20), 1964–84

Year	Total Factor Productivity	Production Labor Productivity	Nonproduction Labor Productivity	Material Input Productivity	Capital Input Productivity
1964	100	100	100	100	100
1965	98	96	105	98	106
1966	96	92	102	95	109
1967	102	102	111	100	118
1968	102	103	112	101	119
1969	102	102	107	100	122
1970	101	108	120	97	134
1971	102	110	121	98	137
1972	102	112	127	97	140
1973	87	101	117	81	128
1974	93	104	119	87	136
1975	99	113	126	93	150
1976	108	131	140	101	160
1977	105	137	151	96	172
1978	107	137	150	97	174
1979	111	135	153	102	177
1980	117	135	156	109	180
1981	124	140	161	117	187
1982	125	144	160	117	190
1983	126	144	160	118	183
1984	128	144	158	121	182
Percent Growth:					
1964–84	28	44	58	21	82
1972–73	−15	−10	−8	−16	−9

under the CRS and CP assumptions.[4] Values of (PFP_i^*) are used to obtain indexes of partial factor productivity (PFP_i), while those of TFP^* are used to obtain indexes of TFP. Validity of the translog production-function specification is assumed.

Empirical Results

TFP_t and PFP_{i_t} indexes derived for the aggregate sector appear in Table 1.[5] Percentage growths of these indexes for the 1964–84 and 1972–73 periods are also reported in Table 1. For the same periods, percentage growths in TFP_t and PFP_{i_t} for the subsectors appear in Table 2. Intensity values (IV) for the sector and subsectors appear in Table 3.

The Aggregate Sector, 1964–84

Table 1 indicates that all indicators of food-processing efficiency (all productivity measures) in New Jersey experienced secular growth during the 1964–84 period. The 28% growth in TFP in the aggregate sector is tantamount to a 21% material productivity growth, 44% production labor productivity growth, 58% nonproduction labor productivity growth, and 82% capital productivity growth. Obviously, labor productivity growth alone does not provide a full picture of productivity growth in food processing. These results indicate that economists need to examine other partial productivity indexes to fully understand productivity growth.

Material productivity growth was relatively slow during the 1964–84 period (21%, compared to 44%, 58%, and 82% for other inputs). This suggests greater constraints in increasing the productivity of materials vis-à-vis other inputs. This phenomenon can be attributed to the strong complementarity between material inputs and output,

[4] Constraints implied by CRS and CP impose strong restrictions on the characterization of food-processing technology, but they allow definition of input shares as output elasticity and definition of TFP growth rate as the weighted-average growth rates of PFP_i. Evidence of market power and price-setting behavior in food processing appears in Azzam and Pagoulatos, Schroeter, Schroeter and Azzam, and Connor, Rogers, Marion, and Mueller. Pratten, amongst others, also provides evidence of non-constant returns to scale in food processing. These suggest that TFP_t and PFP_{i_t} measures derived in this analysis may be biased. For example, TFP_t would be biased downwards if production is characterized by increasing returns to scale and upwards if characterized by decreasing returns to scale.

[5] Productivity indexes generated from implicit quantity indexes are sensitive to price variation and the choice of price deflator.

Table 2. Estimated Percentage Growth in Total and Partial Factor Productivity Indexes for the Subsectors

SIC Code[a]	Total Factor Productivity	Production Labor Productivity	Nonproduction Labor Productivity	Material Input Productivity	Capital Input Productivity
1964–84					
201	10	−21	−13	17	11
202	24	79	118	8	74
203	30	8	23	24	63
204	3	−16	81	2	82
205	45	56	89	34	90
206	34	96	111	16	142
208	24	89	98	−4	130
209	22	5	1	21	77
1972–73					
201	−14	−6	−9	−15	−8
202	−9	−6	−18	−8	−15
203	−9	−5	−17	−9	−16
204	−21	19	−23	−21	−14
205	−14	−11	−11	−16	−14
206	−26	−12	−14	−32	−4
208	−18	−13	−1	−25	−11
209	−19	−21	−1	−20	−1

[a]The SIC categories are as follows: 201, meat products; 202, dairy products; 203, preserved fruit and vegetable products; 204, grain mill products; 205, bakery products; 206, sugar and confectionery products; 208, beverage products; and 209, miscellaneous products.

and limited short-run substitution of other inputs for materials (Adelaja 1992). Food processors seem to face less constraints in increasing labor and capital productivity.

Table 3. Estimated Input Intensity Values

SIC Code[a]	Intensity Measures IV_L	IV_R	IV_M	IV_K
1964–84				
20	0.14	−0.14	0.59	−0.61
201	9.50	5.50	−9.50	−9.50
202	−0.131	−0.69	0.89	−0.06
203	0.73	0.23	0.20	−1.10
204	1.43	−1.19	0.95	−1.22
205	0.16	−0.33	0.49	−0.34
206	−0.05	−0.22	0.82	−0.56
208	−0.14	−0.26	1.05	−0.67
209	0.81	0.96	0.19	−1.96
1972–73				
20	−0.09	−0.27	0.45	−0.18
201	−0.40	−0.10	0.50	−0.20
202	−0.50	0.50	−0.33	0.25
203	−0.58	0.42	−0.25	0.33
204	0.00	0.21	0.11	−0.26
205	0.38	−2.38	1.00	0.75
206	−0.25	−0.13	1.00	−0.75
208	0.00	−0.92	0.92	−0.15
209	0.91	−0.91	0.82	−0.91

[a]The SIC categories are as follows: 20, total for all food products; 201, meat products; 202, dairy products; 203, preserved fruit and vegetable products; 204, grain mill products; 205, bakery products; 206, sugar and confectionery products; 208, beverage products; and 209, miscellaneous products.

In spite of limited material productivity growth, material productivity's contribution to total factor productivity growth should not be downplayed because of materials' high cost share. Material productivity's true contribution to total factor productivity growth is the product of the average material factor share (.60) and total material productivity growth (21%), divided by total factor productivity growth (28%). Hence, material productivity growth alone contributed 45% of the 28% growth in total factor productivity (12.6% *TFP* growth). This significant contribution to total factor productivity growth accrues from waste reduction, recycling, production of by-products, etc. (Adelaja 1992).

Capital productivity growth was rapid during the 1964–84 period. Hence, capital intensity declined. Material intensity increased, however, suggesting that materials were substituted for capital (see Table 3). Production labor intensity increased while nonproduction labor intensity decreased (see Table 3). Hence, nonproduction labor productivity growth outpaced growth in production labor productivity. The apparent substitution of production for nonproduction labor is consistent with Oi's argument that less capital-intensive technologies require less management and nonproduction workers, and more production workers. Apparently, as production became less capital-intensive, the relative demand of New Jersey food processors for nonproduction labor, much of which is management labor, declined. Overall, the changes in input mix in the sector were toward less nonproduction labor and capital intensities, but greater production labor and material intensities.

The declining New Jersey shares of U.S. food-processing activities have been attributed to changing transportation economics, increasing costs of acquiring raw material locally (due to declining local supply of farm products), stringent waste-disposal regulation, and high fixed costs of production (e.g., higher real estate costs) in New Jersey (Lopez and Henderson). Adelaja (1988) argued that slower *TFP* growth in New Jersey food processing, relative to the rest of the U.S., also made New Jersey a less attractive location. Results of this study provide additional information on New Jersey's food-processing industry. Specifically, the results explain the input mix changes and productivity growth that accompanied the decline of New Jersey's share of food-processing activities in the U.S.

The Subsectors, 1964–84

Note that material productivity increased in all subsectors except the beverage group, which is highly material-intensive. The trend in beverage production in New Jersey has been from full processing to the mere dilution of concentrates shipped in from other states (Adelaja 1988). Hence, the significant increase in material intensity and the decline in material productivity in beverage production is not surprising.

Consistent with aggregate-sector findings, material productivity growth was outpaced by growth in other inputs' productivities in four of the eight subsectors (dairy, bakery, sugar and confectionery, and beverage). Material intensity increased in these same subsectors. Material intensity also increased in the preserved fruit and vegetables, grain mill, and miscellaneous-products subsectors. Consequently, the only exception to increased material intensity is meat processing, where material productivity growth outpaced growth in productivities of other inputs. The relatively rapid growth in material productivity in the meat subsector may reflect greater incentives to implement material and waste-reducing technologies due to the heavy regulation of material waste from meat processing.

Consistent with the pattern for the aggregate sector, capital intensity declined in all subsectors, but capital productivity increased. Growth in nonproduction workers' productivity exceeded that of production workers' productivity in most subsectors. The *IV* values further suggest that production labor was generally substituted for nonproduction labor. This is consistent with the finding for the aggregate sector. Contrary to the trend for the aggregate sector and most subsectors, production labor productivity actually declined in the meat (SIC 201) and grain mill (SIC 204) subsectors. The *IV* values indicate that in both subsectors substitution of production labor for nonproduction labor was significant.

The relative growth rates of *TFP* are worth noting. For example, *TFP* growth was most rapid in the bakery subsector (45% gain). Bakery was followed by sugar and confectionery (34% gain), preserved fruit and vegetables (30% gain), dairy and beverage (24% gain), and miscellaneous products (22% gain). Grain mill products experienced the least gain in total factor productivity (3% gain). *TFP* gain in meat production was also limited (10%).

The Energy Crisis

Given some of the recent events in the Middle East, there is growing concern among economists that drastic shocks in energy prices, similar to what happened in 1973, might again occur. Changes in intensity values and productivity indexes in 1973 should generally reflect potential impacts of future energy price hikes on productivity and the structure of production. In the aggregate sector and all subsectors, total factor productivity declined drastically in 1973. Similarly, all partial factor productivity indexes declined in 1973, except in the case of production labor productivity, which declined in grain mill production. It appears, therefore, that because they result in greater declines in output than in inputs, energy price shocks are usually productivity-dampening in the short run. The exception in the case of grain mill production is difficult to explain.

In the aggregate sector, material productivity fell more than did productivities of other inputs in 1973. Hence, material intensity increased, while the intensities of other inputs declined. Producers therefore seem less capable of reducing material consumption (compared with other inputs) when energy price shocks occur. This is an indication of the strong complementarity between materials and output. Apparently, recessions resulting from energy price shocks would result in greater labor and capital unemployment than in material unemployment. This implies that farmers are not as likely to get hurt as would suppliers of other resources to the food-processing sector when energy prices surge.

In the aggregate sector, the energy crisis resulted in greater unemployment of nonproduction than production workers. This is not surprising considering that the former are more highly paid and that the energy crisis also reduced capital intensity. Greater unemployment of nonproduction than production workers is likely to accompany future increases in energy prices.

TFP declined by 15% in 1973. Also, the 1973 decline in material productivity exceeded those of other inputs. Following the weighting procedure in (12), material inputs' true contribution to the 1973 decline in *TFP* is estimated to be 64%. The implication is that material productivity changes are very important, especially during periods of energy price shocks.

Now, examine the impacts of the energy crisis on total and partial factor productivities in the subsectors. In the meat, bakery, sugar and confectionery, beverage, and miscellaneous-product groups, the impacts were similar to the aggregate case in that material productivity declined more than the productivities of other inputs. Also, consistent with the aggregate sector case, the instantaneous effect of the energy price shock involved increased material intensity and material-capital substitution in most subsectors.

In the cases of dairy, preserved fruit and vegetables, and grain mill products, greater decline in nonproduction labor productivity than in the productivities of materials, capital, and production labor resulted from the energy crisis. Hence, management workers in these subsectors seem to enjoy an unemployment buffer when energy prices rise. Note also from the intensity values in Table 3 that the energy price shock involved greater unemployment of production than nonproduction labor in meat, dairy, preserved fruit and vegetables, and sugar and confectionery processing, while it resulted in greater unemployment of nonproduction than production labor in the rest of the subsectors.

Conclusion

This paper combines total and partial factor productivity indexes in an innovative way to analyze productivity growth and input mix changes in New Jersey's food-processing industry. While it may have some limitations, the approach allows better accounting of contributions of specific inputs to total factor productivity growth. Results for the entire 1964–84 period suggest a 28% overall productivity growth and slower material productivity growth than labor and capital productivity growth. However, given the high cost share of material inputs, gains in the efficiency of use of materials explain almost half of the growth in total factor productivity. An implication of this is that material productivity growth, which is typically ignored in productivity studies, is an important component of productivity growth in food processing.

Capital productivity grew rapidly in the sector. Simultaneously, the relative demand for nonproduction labor, vis-à-vis production labor, declined due to the complementarity between the former and capital-intensive technologies. Information obtained on input intensities in the sector are useful in analyzing the trends in input mix and in correlating these with the pattern of productivity growth. Such analysis is hardly ever conducted in conjunction with productivity analysis.

An objective of this study was to examine the immediate impact of the 1973 energy crisis. Results indicate that productivities of all inputs (as well as total factor productivity) tend to fall in the short run when energy price shocks occur. The decline in material productivity exceeds the declines in the productivities of other inputs, while the reduction in material use is less than reductions in other inputs. Hence, farmers supplying food processors are better protected than other resource suppliers when energy price shocks occur. The 1973 energy crisis also resulted in greater unemployment of nonproduction than production labor, suggesting that the former is more vulnerable in times of energy price increases.

References

Adelaja, A.O. *The Agriculture and Food Complex of New Jersey.* New Jersey Agricultural Experiment Station Publication no. SR-02521-1-88. June 1988.

Adelaja, A.O. "Material Productivity in Food Manufacturing." *American Journal of Agricultural Economics* 74, no. 1(1992):177–85.

Azzam, A.M., and E. Pagoulatos. "Testing Oligopolistic and Oligopsonistic Behavior: An Application to the U.S. Meat-Packing Industry." *Journal of Agricultural Economics* 41(1990):260–70.

Christensen, L.R., D. Cummings, and D.W. Jorgenson. "Economic Growth, 1947–1973: An International Comparison." In *New Developments in Productivity Measurement and Analysis*, edited by J.W. Kendrick and B.N. Vaccara. Chicago: National Bureau of Economic Research, 1980.

Connor, J.M., R.T. Rogers, B.W. Marion, and W.F. Mueller. *The Food Manufacturing Industries: Structure, Strategies, Performance and Policies.* Lexington, MA: Lexington Books, 1988.

Evenson, R.E., D. Landau, and D. Ballou. "Agricultural Productivity Measures for U.S. States, 1950–82." In *Evaluating Agricultural Research and Productivity.* Miscellaneous Publications no. 52-1987. Minnesota Agricultural Experiment Station, University of Minnesota, 1987.

Heien, D.M. "Productivity in U.S. Food Processing and Distribution." *American Journal of Agricultural Economics* 65(1983):297–302.

Jorgenson, D.W., F. Gollop, and B. Fraumeni. *Productivity and U.S. Economic Growth.* Cambridge: Harvard University Press, 1987.

Lee, D.R. "Labor Market Dynamics in the Food Sector." *American Journal of Agricultural Economics* 70(1988): 90–102.

Lopez, R.A., and N.R. Henderson. "The Determinants of Location Choices for Food Processing Plants." *Agribusiness* 5(1989):619–32.

Oi, W.Y. "Slack Capacity: Productive or Wasteful?" *American Economic Review* 21(1981):64–69.

Pratten, C. "A Survey of Economies of Scale." In *Research on the "Cost of Non-Europe," Basic Findings.* Luxembourg: Office for Official Publications of the European Communities, 1988.

Schroeter, J.R. "Estimating the Degree of Market Power in the Beef Packing Industry." *Review of Economics and Statistics* 70(1988):158–62.

Schroeter, J.R., and A. Azzam. "Measuring Market Power in Multi-Product Oligopolies: The U.S. Meat Industry." *Applied Economics* 22(1990):1365–76.

U.S. Department of Commerce. Bureau of the Census. *Annual Survey of Manufacturers.* Various years.

______. *Census of Manufacturers.* Various years.

U.S. Department of Labor. Bureau of Labor Statistics. *Producer Price Indexes.* Various years.