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MEASURING PRODUCTIVITY CHANGES IN

U.S. FOOD MANUFACTURING, 1959-1982

by

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MEASURING PRODUCTIVITY CHANGES IN U.S. FOOD MANUFACTURING: 1959-82

Many factors, including sharp increases in real energy prices, changes in labor force composition and slower rates of growth in research and development expenditures, have been cited in accounting for the slowdown of labor productivity growth in the U.S. economy in the late 1960's and 1970's (Kendrick; Baily; etc.). The importance of understanding both the determinants of this productivity decline and its implications for sectoral and overall macroeconomic performance has led to extensive analysis of productivity trends in many U.S. industries in recent years.

The agricultural and food sector is no exception. In recent years, Brown, Ball, and Capalbo, et. al., have all examined total factor productivity changes in U.S. production agriculture over the post-World War II era. Research on productivity beyond the farm gate has been considerably more limited, however. Gisser and Kelton both examined the relationships between market structure variables and productivity changes in U.S. food manufacturing, but their studies yielded inconsistent results. Grieg analyzed productivity changes in food processing and distribution but did not take advantage of the availability of improved methodological techniques for total factor productivity measurement which yield empirical results consistent with production theory. Most recently, Heien estimated a Tornqvist productivity index for the <u>total</u> food processing and distribution industry for the period 1950-77. While this index is theoretically superior to those estimated by Grieg, two major inputs, capital equipment and capital structures, were excluded from the analysis. In addition, by aggregating food manufacturing and distribution sectors, these results obscure the differential productivity trends which have characterized these industries in recent years.

This paper estimates superlative (Tornqvist) output, input, and total factor productivity indexes for the U.S. food manufacturing industry for the period 1959-82. The analysis makes three contributions to research on food system productivity. First, the results are developed specifically for the food processing industry. Both trends in the underlying data and prior research on the food industry suggest that fundamentally different factors have accounted for productivity changes in food manufacturing and food distribution in recent years. Second, the analysis gives particular attention to the development of a superlative index for capital inputs, which have either been excluded or not consistently included in prior food manufacturing productivity studies. Finally, the indexes are developed for a period through 1982. This is important because recent discussion has centered on the likelihood of a revival of U.S. productivity growth in the 1980's (Clark; Baily and Chakrabarti). Yet little evidence is thus far available regarding the extent to which the growth in food industry productivity has changed following the late 1970's.

Total Factor Productivity Indexes

An increasingly common approach to productivity measurement, due primarily to its desirable theoretical properties, has been the development of "Tornqvist" indexes of output, input and total factor productivity. The commonly used fixed-weight Laspeyres index is exact for Leontief and linear production processes and thus implies perfect substitutability among inputs. This assumption in food manufacturing would appear to be inappropriate, however, given the results of Lutton, who found "substantial variation in substitute and complement relationships across [food processing] industries" (p. 85). In view of this, an alternative index aggregator which does not impose such restrictive assumptions on the production process and which possesses other desirable properties is the Divisia index (Jorgenson and Griliches). The Divisia index is a continuous index, however, and must be approximated in empirical use by a discrete form.

The Tornqvist (1936) index is such a discrete approximation. The Tornqvist input quantity index (Q) takes the form:

$$\ln (Q_t/Q_{t-1}) = 1/2 \sum_{i=1}^{m} (r_{it} + r_{it-1}) \ln (X_{it}/X_{it-1}) \quad (1)$$

where r_{it} is the share of total factor payments attributable to the i^{th} input, X_{it}. Among other attributes, the Tornqvist index is exact for the linear homogeneous translog aggregator function (Diewert), which has been shown to provide a second order local approximation to any arbitrary linear homogeneous function (Christensen, Jorgensen, and Lau).

With regard to output aggregation, Diewert has shown that the Tornqvist index will yield a consistent aggregation of outputs if the production function is separable in outputs and inputs and if the translog function is used as the aggregator. The output index takes the form:

$$\ln (Y_t/Y_{t-1}) = 1/2 \sum_{j=1}^{n} (s_{jt} + s_{jt-1}) \ln (q_{jt}/q_{jt-1}) \quad (2)$$

where s_{jt} is the revenue share of the j^{th} output, q_{jt}.

Christensen and Jorgensen, and later, Caves, Christensen, and Diewert have also shown that, under the above assumptions, the (Tornqvist) translog bilateral total factor productivity index can be written as:

$$\ln (TFP_t/TFP_{t-1}) = 1/2 \sum_{j=1}^{n} (s_{jt} + s_{jt-1}) \ln (q_{jt}/q_{jt-1}) \qquad (3)$$

$$- 1/2 \sum_{i=1}^{m} (r_{it} + r_{it-1}) \ln (X_{it}/X_{it-1})$$

Given their desirable theoretical properties and relative ease in computation, Tornqvist approximations to Divisia input, output and productivity indexes have been used frequently by researchers in recent years to study changes in total factor productivity, following their initial use by Christensen and Jorgensen.

Variable Construction and Data

This section describes the data construction used in the calculation of Tornqvist output, input, and productivity indexes for U.S. food manufacturing. All data were developed for Bureau of Labor Statistics Standard Industrial Classification (SIC) category 20, "food and kindred product manufacturing." The index values reported here begin in 1959, the year following a major reorganization of SIC classifications, and continue through 1982, the year of the most recent Census of Manufactures.

In constructing the output index, time series are required on revenue shares and real output levels for each of the major subsectors in food manufacturing. These data were constructed at the "four-digit" SIC level for the major industries within each of the nine major food manufacturing industries: meat products; dairy products; preserved fruits and vegetables; grain mill products; bakery products; sugar and confectionery products; fats and oils; beverage products; and miscellaneous food products. Revenue shares were estimated from value of shipments data reported in the Census of Manufactures (CM) and the Annual Survey of Manufacturers (ASM) over the 1958-82 period. These data were adjusted for changes in value of inventories of finished products so that output would be measured in terms of actual production rather than shipments. The total value of production and the sectoral shares (s_{jt}) were then obtained from these adjusted shipments data.

In measuring real output levels, adjusted gross output was calculated through the deflation of value of output by an appropriate deflator, as opposed to the measurement of real value-added through the "double deflation" of both value of sales and materials costs. The latter procedure requires strong partial separability of capital and labor from other inputs. Based on tests of the separability hypothesis and their rejection for U.S. manufacturing by Norsworthy and Malmquist, this analysis follows the first approach and deflates the value of output (adjusted for inventory changes) by the Producer Price Index for the appropriate food manufacturing industry (1972=100). This yields real output values at SIC four-digit levels (q_{it}), which are then used in the construction of output indexes for SIC three-digit industries and the overall sector.

Input data were constructed for the following inputs: labor (production and non-production workers); capital services (equipment and structures); energy; and non-energy materials. Data on value of input shares (r_{it}) and real input levels (X_{it}) were required for each of the six inputs. Tornqvist quantity indexes of labor and capital inputs were constructed separately prior to estimation of the final input and productivity indexes.

For the labor inputs, total annual hours of production worker employment and associated wage costs are available in CM and ASM. Annual hours of non-production workers are not directly available but were estimated following the procedure used by Hulten and Schwab, by subtracting production worker employment from total employment to get annual non-production worker employment, then multiplying the results by 2,080 (assuming a standard 40-hour work week throughout the year). Wages of non-production workers were calculated by subtraction of production worker wages from total wages paid. Data on non-wage payments to labor (fringe benefits, etc.) are not available from the standard sources prior to 1967, and thus these payments are not included in the share estimation. The resulting labor share and quantity (hours) data were used to construct a Tornqvist index of labor input in which each category's labor input was weighted by its respective share of total payments to labor over the period 1959-1982.

Construction of the capital input data (shares and quantities) was considerably more complicated. While time series on new capital investment in capital equipment and structures are readily available from CM and ASM, it is the value of services from the total capital stock that is the theoretically correct capital input. The approach used here in the valuation of capital services prices and quantities is based on Griliches and Jorgenson's durable goods model (as summarized in Brown, p. 39-45), which has been extensively used in factor productivity analysis.

Assume that the flow of capital services (for equipment (e) and structures (s)) is proportional to capital stock:

$$V_{i,t} = P_{i,t} K_{i,t-1} \tag{4}$$

The value of capital services in period t ($V_{i,t}$) is therefore the product of the price of capital ($P_{i,t}$) times the capital stock existing at the end of the previous period. $P_{i,t}$ can be calculated, following Brown, as

$$P_{i,t} = n_{i,t-1} r_t - (n_{i,t} - n_{i,t-1}) + n_{i,t-1} \delta_i + n_{i,t-1} \theta_{i,t} \tag{5}$$

where: $n_{i,t}$ is the price of new capital investment in good i in year t; r_t is the rate of return on capital; δ_i is the rate of depreciation of existing capital; and $\theta_{i,t}$ is the effective tax rate.

In calculating the prices of capital equipment and services, data on each of these four components is required. The price of new capital investment was derived implicitly from the current and constant dollar series on gross fixed nonresidential capital investment in U.S. manufacturing in BEA (1982) and recent year estimates derived from CM and ASM. As a proxy for the rate of return on capital (r_t), Moody's Corporate Industrial Bond Rate was used. The rate of depreciation (δ_t) was assumed constant, following Hulten and Wykoff, at their estimated rates for U.S. manufacturing: 3.61% annually for structures and 14.64% for equipment. The annual effective tax rate (θ_t) was estimated from pre- and post-tax corporate profits data for food manufacturing reported in the National Income and Product Accounts and Survey of Current Business. Due to a lack of data on capital gains in food manufacturing, this component ($n_{i,t}$ - $n_{i,t-1}$) was not included in the capital price estimates (see also Denny et al., and Capalbo et al.).

The second component of capital services value, the capital stock of good i in year t, $K_{i,t}$, is given, by definition, as the previous year's capital stock minus depreciation plus new investment:

$$K_{i,t} = K_{i,t-1} - \delta_i K_{i,t-1} + I_{i,t} \tag{6}$$

Equation (6) again assumes a constant rate of depreciation. It also requires, under the perpetual inventory method, a benchmark estimate of capital stock. An estimate of net capital stock for all U.S. manufacturing is available in BEA (1982). Capital stock (for each of equipment and structures) was allocated to food manufacturing under the assumption that the existing capital stock in manufacturing is proportional to new capital investment. In the benchmark year used here, 1958, the food industry accounted for 10.6% of new capital investment (and employment) in U.S. manufacturing. Thus this allocation factor was used.

With these benchmark values for capital equipment and structures stocks, knowledge of the depreciation rate and new capital investment (from BEA) enables calculation of an annual series on estimated capital stocks. These stocks estimates, multiplied by the estimated prices of capital (equipment and structures) in equation (5), yield the capital service values used in the calculation of the input and productivity indexes.

Finally, cost shares and input levels were calculated for energy and non-energy materials. Annual energy (fuel and power) costs for food manufacturing are available in CM and ASM. These data were used to calculate cost shares and then deflated by the PPI for fuel and power to estimate real energy inputs. Materials costs are also available from CM and ASM annually. These data were first adjusted to exclude energy costs, and then adjusted for materials inventory changes prior to calculating input cost shares. Real materials inputs were then calculated by dividing the adjusted series by an input price deflator estimated as an index of prices for materials inputs in food manufacturing, consisting of producer prices for raw agricultural products, intermediate inputs, containers and supplies.

Results and Implications

Estimated output revenue shares for the nine three-digit SIC industry classifications in food manufacturing are given in table 1 for the period

1959-82. Revenue shares have remained generally quite stable over this period. The most notable changes have been slight increases in the shares of the preserved fruit and vegetable, sugar and confectionery, and beverage industries, and small decreases in the shares of the meats, dairy products and bakery industries.

Table 2 reports the input cost shares for the six input categories: labor (production and non-production workers); capital (equipment and structures); energy and materials. Input cost shares are also relatively stable over the 1959-82 period. The most important trend evident in table 2 is the increase in capital's share of total factor costs, offsetting a decline in labor's share. The share accounted for by non-energy materials is large, ranging between 68 and 74 percent, but quite stable over time. Interestingly, despite the large increases in energy prices over the past decade or so and the concomitant attention this input has received, energy's share of total input costs in food manufacturing is very low (1-2 percent) and has risen only very modestly in recent years.

Quantity indexes of input usage are reported in table 3. The large decrease in labor input (-17% between 1959-82) and even larger proportionate increase in capital inputs (nearly 87%) are largely responsible for the abovementioned shifts in factor shares. The trend of capital substitution for labor inputs in U.S. food manufacturing is clear. At the same time, energy and, in particular, materials inputs have increased significantly since 1959. The trend in energy inputs (as for materials) is not monotonic; presumably as a result of high relative prices for energy inputs following 1973, energy inputs have declined significantly from their highest level reached in 1972. Overall, both the Tornqvist indexes for total food manufacturing input and output show gradual increases over most of the 1959-82 period. These increases are not uniform, however, with both input and output declining on four occasions during this period, mostly during the mid- to late 1970's. While total input usage has stabilized in recent years, food manufacturing output has (with the exception of 1979) been steadily increasing since 1975.

The overall Tornqvist index of total factor productivity (table 3) represents the difference between the annual rates of change in output and input (with a base of 1972=100). Several important results are evident from this index. To begin, total factor productivity has risen rather slowly in U.S. food manufacturing over the 1959-82 period, exhibiting an average growth rate of only just over 0.3% annually. This is a significantly lower rate of growth than U.S. manufacturing overall, which has been generally estimated to have exhibited annual productivity growth of between 1% and 2% in the past two to three decades (Kendrick; Hulten and Schwab; etc.). These results also show a more modest rate of productivity growth in food manufacturing than reported by Grieg and are closer to the estimates of Heien, though the current results also account for capital inputs.

Closer inspection of the results reveals three fairly distinct periods of productivity change in the 1959-82 period. An early period, 1959 through 1970, was characterized by stagnant productivity growth with increases in output coinciding with increases in input use. Between 1970 and 1975, productivity change was more highly variable and generally decreasing, as input use (with the exception of 1973) grew more rapidly than output. Fluctuations in both input and output quantities were presumably due largely to the rapid increases in farm and food prices which characterized the early to mid-1970's. After 1975, however, with the exception of 1977, growth in total factor productivity resumed and at a stronger rate than any prior period. Between 1975 and 1982, productivity growth in U.S. food manufacturing averaged around 1.4% annually. It is important to note, however, that the calculation of average annual productivity growth rates is often highly sensitive to the periods over which they are calculated.

In terms of policy implications, recent economic developments suggest that the modest revival of productivity growth may be continuing. High production and stocks levels for both petroleum-based fuels and farm commodities have led to lower real prices for these inputs. In recent years, less stringent enforcement of environmental, safety, and other regulations may have decreased compliance costs for manufacturing firms, although this is just a hypothesis. Regarding labor, although the data are limited to date, continuing capital-labor substitution, an older and more experienced labor force, substantial labor concessions to management, and other factors (Filer) have likely all had an impact in raising labor productivity. One major remaining question concerns capital. Until very recently, high real interest rates have continued to limit capital investment in new plant and equipment in U.S. manufacturing, despite strong economic growth in the last several years. Macroeconomic and tax policies designed to reduce real interest rates and increase capital investment would appear to be a necessary step in ensuring continued growth in food manufacturing productivity.

Table 1: Revenue Shares for U.S. Food Manufacturing Industries, 1959-82

Year	Revenue Shares for SIC Industries*								
	201	202	203	204	205	206	207	208	209
1982	0.242	0.139	0.107	0.108	0.064	0.056	0.060	0.138	0.086
1981	0.241	0.136	0.102	0.117	0.062	0.060	0.066	0.134	0.083
1980	0.245	0.132	0.103	0.114	0.061	0.063	0.071	0.128	0.083
1979	0.261	0.128	0.106	0.109	0.061	0.053	0.075	0.124	0.083
1978	0.257	0.129	0.106	0.108	0.060	0.053	0.075	0.124	0.088
1977	0.240	0.135	0.107	0.116	0.063	0.056	0.074	0.121	0.089
1976	0.253	0.137	0.099	0.117	0.068	0.057	0.071	0.116	0.082
1975	0.255	0.132	0.099	0.120	0.068	0.066	0.073	0.118	0.069
1974	0.244	0.128	0.098	0.124	0.064	0.077	0.086	0.111	0.067
1973	0.280	0.133	0.096	0.119	0.063	0.053	0.077	0.108	0.071
1972	0.274	0.141	0.099	0.106	0.069	0.057	0.061	0.120	0.073
1971	0.251	0.143	0.102	0.108	0.071	0.061	0.062	0.129	0.074
1970	0.258	0.140	0.098	0.111	0.072	0.061	0.060	0.126	0.074
1969	0.265	0.145	0.099	0.111	0.074	0.060	0.054	0.119	0.073
1968	0.256	0.150	0.104	0.112	0.076	0.061	0.054	0.115	0.072
1967	0.256	0.153	0.097	0.118	0.077	0.060	0.060	0.108	0.071
1966	0.254	0.153	0.098	0.116	0.079	0.057	0.066	0.105	0.072
1965	0.253	0.156	0.097	0.114	0.080	0.058	0.063	0.104	0.074
1964	0.245	0.164	0.097	0.116	0.081	0.060	0.060	0.104	0.073
1963	0.244	0.162	0.094	0.119	0.082	0.064	0.059	0.100	0.075
1962	0.248	0.172	0.091	0.117	0.083	0.058	0.063	0.097	0.071
1961	0.247	0.178	0.093	0.116	0.084	0.057	0.058	0.095	0.071
1960	0.253	0.178	0.091	0.114	0.086	0.058	0.052	0.094	0.074
1959	0.256	0.177	0.084	0.115	0.086	0.058	0.057	0.095	0.072

*SIC Industry Classifications:

20 : Food and kindred products
201: Meat products
202: Dairy products
203: Preserved fruits and vegetables
204: Grain mill products
205: Bakery products
206: Sugar and confectionery products
207: Fats and oils
208: Beverage products
209: Miscellaneous food products

Table 2: Input Cost Shares in U.S. Food Manufacturing, 1959-82

Year	Labor		Capital		Materials*	Energy
	Production	Non-Production	Equipment	Structures		
1982	0.059	0.035	0.102	0.111	0.675	0.018
1981	0.058	0.033	0.096	0.107	0.690	0.016
1980	0.058	0.034	0.097	0.107	0.689	0.015
1979	0.060	0.034	0.089	0.096	0.708	0.014
1978	0.061	0.035	0.085	0.092	0.713	0.014
1977	0.062	0.036	0.086	0.094	0.709	0.013
1976	0.057	0.035	0.086	0.103	0.705	0.013
1975	0.059	0.036	0.072	0.093	0.729	0.011
1974	0.058	0.036	0.071	0.090	0.736	0.009
1973	0.064	0.039	0.075	0.092	0.721	0.008
1972	0.071	0.043	0.084	0.101	0.692	0.010
1971	0.074	0.047	0.087	0.102	0.681	0.010
1970	0.074	0.048	0.089	0.099	0.681	0.009
1969	0.074	0.048	0.090	0.095	0.685	0.009
1968	0.075	0.048	0.088	0.091	0.689	0.009
1967	0.076	0.050	0.081	0.075	0.708	0.009
1966	0.075	0.051	0.072	0.073	0.720	0.009
1965	0.077	0.053	0.078	0.071	0.712	0.009
1964	0.079	0.054	0.080	0.070	0.708	0.009
1963	0.080	0.054	0.081	0.067	0.709	0.010
1962	0.079	0.055	0.084	0.069	0.705	0.009
1961	0.078	0.054	0.089	0.073	0.696	0.009
1960	0.081	0.056	0.094	0.075	0.685	0.009
1959	0.079	0.054	0.093	0.076	0.688	0.009

*Excludes energy inputs.

Table 3: Input, Output, and Total Factor Productivity Indexes in U.S. Food Manufacturing, 1959-82

Year	Input Quantity Indexes				Total Input Index	Total Output Index	Total Factor Productivity Index
	Labor	Capital	Materials*	Energy			
				(1972 = 100)			
1982	92.70	130.03	108.60	78.89	109.9	115.9	105.1
1981	95.20	126.90	109.13	68.84	109.8	114.7	104.2
1980	96.75	124.50	107.93	73.51	108.8	111.2	102.0
1979	97.67	121.22	109.14	85.29	109.4	111.0	101.2
1978	97.00	118.33	112.56	96.76	111.5	111.8	100.0
1977	95.59	114.62	111.81	91.43	110.1	108.5	98.3
1976	96.03	111.30	102.99	88.47	103.5	106.3	102.7
1975	96.17	108.22	103.63	81.96	103.4	98.7	95.4
1974	96.75	105.43	101.81	75.68	101.6	100.5	99.0
1973	99.38	102.17	96.41	88.34	97.6	96.4	98.8
1972	100.00	100.00	100.00	100.00	100.0	100.0	100.0
1971	100.75	97.46	93.87	92.15	95.4	95.5	100.1
1970	103.84	94.75	92.03	91.92	94.0	92.5	98.5
1969	105.76	91.76	90.94	88.02	92.8	91.7	98.7
1968	104.65	89.23	88.98	80.16	90.8	90.5	99.6
1967	106.18	87.06	88.01	80.80	89.9	88.3	98.1
1966	106.96	80.93	82.95	73.53	85.4	83.2	97.4
1965	106.89	77.60	80.71	72.17	83.2	81.8	98.2
1964	108.31	75.13	80.03	71.16	82.5	81.9	99.3
1963	106.68	72.96	75.26	70.69	78.5	78.5	100.0
1962	109.88	71.52	74.61	66.67	78.1	77.4	99.1
1961	110.73	69.91	72.53	66.56	76.4	75.3	98.6
1960	111.69	69.71	68.64	64.62	73.6	74.2	100.9
1959	111.48	69.56	69.00	63.51	73.8	72.1	97.7

*Excludes energy inputs.

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