Labor productivity

Measuring Labor Productivity: An Economy-wide Study of the Production of Food for Personal Consumption

By
Eric C. Howe, Gerald E. Schluter,
and Charles R. Handy*

I. Introduction.

The principal purpose of this paper is to report a new measure of labor productivity for the U.S. production of food for personal consumption. We measure productivity for the aggregate, as well as four components.

The orientation of this study is fundamentally different from the norm. Most productivity studies proceed entirely along production oriented lines. Aggregates are formed based on production oriented similarities. Such studies are useful-but sometimes produce results which are difficult to interpret. After all, economics is a study of the allocation of scarce resources to achieve competing ends. Production is not an end; consumption is. Thus the ultimate test of the productivity of an economy is the efficiency with which it provides consumption goods for itself. In this study, producers are "considered together" because their output is directly or indirectly necessary to produce goods which have consumption oriented similarities. Specifically, this is a study of the "food system" of the economy, where the food system is defined to include that portion of the activities of every industry that is necessary in the process whose end product is the delivery of food for personal consumption. Following our productivit estimates, we discuss the contribution of selected industries to th system.

* We would like to acknowledge and thank Bessie Yeh and Gene Le their contributions to this study.

Paper presented at AEA annual meeting Penn State University, Aug. 15-18, 1

II. Output of the Food System.

The process by which the U.S. provides food for itself is obviously quite complex. Consequently, it may be suspected that any attempt to measure output, labor input, and hence labor productivity for the food system would be rather complicated. Whereas measurement of labor input, and hence labor productivity for the food system would be rather complicated. Whereas measurement of labor input is indeed difficult, our measurement of final output is straightforward. The final output of the food system was measured by personal consumption expenditures for food as reported in the national income and product accounts. It is given there in current and constant dollars, and disaggregated into i) food purchased for off-premises consumption, ii) purchased meals and beverages, iii) food furnished government and commercial employees, and iv) food produced and consumed on farms.

Table 1 shows the components of real personal consumption expenditures (P.C.E.) for food for the years 1958, 1963, 1967, and 1970. (The choice of years is explained in the following section.) Total P.C.E. for food has grown at a rate approximately twice the rate of population growth. From 1958 to 1970, total U.S. population grew at an annual rate of 1.3% 1/ whereas real P.C.E. for food grew at a rate of 2.5%. All components of real P.C.E. for food grew at about the same rate except food produced and consumed on farms which declined at an average annual rate of 6.5%, partially reflecting the decline in farm population.

1/ U.S. Dept. of Commerce, Statistical Abstract of the United States.

Table 1.--Personal Consumption Expenditures for Food in Constant (1958) Dollars

	1958 a/	1963 b/	1967 c/	1970 d/ e/
	Millions of 1958 Dollars			
1. Food Purchased for Off-Premises Consumption	58,404	64,541	74,585	80,297
2. Purchased Meals and Beverages	15,319	17,613	19,693	20,265
3. Food Furnished Government and Commercial Employees	1,243	1,169	1,684	1,694
4. Food Produced and Consumed on Farms	1,410	825	623	630
5. Food for Personal Consumption	76,376	84,148	96,685	102,846

a/ U.S. Dept. of Commerce, "Personal Consumption Expenditures in the 1958 Input-Output Study," Survey of Current Business, Oct., 1965.

b/ U.S. Dept. of Commerce, "Personal Consumption Expenditures in the 1963 Input-Output Study," Survey of Current Business, Jan., 1971.

c/ U.S. Dept. of Commerce, "Input-Output Structure of the U.S. Economy: 1967," Survey of Current Business, Feb., 1974.

d/ U.S. Dept. of Commerce, "U.S. National Income and Product Accounts," Survey of Current Business, July, 1972.

e/ The deflator for each component is the U.S. Department of Commerce implicit price deflator for that component as published in Table 8.6 of the annual "National Income Issue" of the Survey of Current Business.

III. Labor Input in the Food System.

To measure labor input, we must "track down" all the labor used within the entire economy to produce and distribute food. Not just the labor used by farmers, by food processors, and by distributors; but also the labor used in making the inputs that they use directly, and the labor used in making the inputs for producing the direct inputs, etc. It will be argued below that the only way to measure labor input this exhaustively is through the use of national input-output tables. For the interested reader, an algebraic statement of our methodology is included as an appendix. Suffice it to say that the information available in the national I/O tables was used to relate P.C.E. for food (discussed above) to the labor needed in all parts of the economy to produce this food. We computed labor productivity for the recent years for which national I/O tables are available: 1958, 1963, 1967. 3/ Labor productivity was computed for 1970 by using the 1967 transactions matrix. The implications of the re-use of the 1967 matrix are not intuitive and can be discussed only after the algebraic model is developed in the appendix.

2/ The idea of measuring productivity with the use of I/O is not new. One methodology has been examined theoretically by Rymes ("The Measurement of Capital Total Factor Productivity," Review of Income and Wealth, 1972, pp. 79-108) and a review of the applications of I/O to productivity is contained in a paper by Howe and Handy ("Inventory and Critique of Productivity Estimates in the Food Fiber Sector," American Journal of Agricultural Economics, Dec. 1975). Our specific methodology differs from all precursors.

3/ The 82-industry current transactions tables were used in each year. Since the current transactions tables do not include capital flows, the labor requirements shown below do not include the labor required in the capital goods industries (except for labor necessary to produce spare parts for maintenance). A useful extension of this study would be to compute these additional labor requirements.

The total direct and indirect labor requirements are shown in Table 2. Since our direct labor requirements coefficients (the diagonal entries in the matrix L in the appendix) were computed as the number of civilian employees per unit of output, the units in Table 2 are thousands of civilian employees engaged. 4/ The total labor required in the food system has remained stable from 1958 to 1970. However, the labor force grew 1.66 % annually 5/, which implies that a decreasing share of the U.S. labor force is needed to provide the food needs of the population. Labor required to produce purchased meals and beverages has increased gradually and labor required for food produced and consumed on farms has declined markedly.

IV. Labor Productivity in Producing Food for Personal Consumption.

We measure labor productivity as the level of personal consumption expenditures per person engaged in the food system. This measure is shown in Table 3. Note that labor productivity varies widely with the type of consumption and that this dispersion is increasing in magnitude. The highest value of productivity in 1958 was $6,161 (for food for off-premises consumption) and the lowest was $5,341 (for food produced and consumed on farms); a difference of 15%. By 1970 the dispersion has grown to 35 %: productivity was highest for food furnished government and commercial employees, at $9,736, and lowest for purchased meals and beverages, at $7,199.

4/ The labor data is taken from Bureau of Labor Statistics worksheets on total civilian employment by industry.
5/ U.S. Dept. of Commerce, Statistical Abstract of the United States.

Table 2.---Total Direct and Indirect Labor Requirements to Produce Food For Personal Consumption.

	1958	1963	1967	1970
	Thousands of Persons Engaged			
1. Food Purchased for Off-Premises Consumption	9,480	8,805	8,900	9,077
2. Purchased Meals and Beverages	2,536	2,717	2,778	2,815
3. Food Furnished Government and Commercial Employees	202	176	203	174
4. Food Produced and Consumed on Farms	264	145	85	73
5. Food for personal consumption	12,482	11,844	11,965	12,139

Table 3.--Output per Person Engaged in the Production of Food for Personal Consumption

	1958	1963	1967	1970
	1958 Dollars			
1. Food Purchased for Off-Premises Consumption	6,161	7,330	8,380	8,846
2. Purchased Meal and Beverages	6,041	6,483	7,089	7,199
3. Food Furnished Government and Commercial Employees	6,153	6,642	8,296	9,736
4. Food Produced and Consumed on Farms	5,341	5,690	7,329	8,630
5. Food for Personal Consumption	6,119	7,105	8,081	8,472

This growing dispersion reflects differing rates of productivity growth, which is evident from examining Table 4. Growth in labor productivity for the production of food for personal consumption averaged 2.75% annually, 1958-1970. The growth rate was not constant, however. Productivity grew rapidly during 1958-1967 and slowed during 1967-1970. 6/ The results shown in Table 4 verify conventional wisdom in several respects. The general slowdown in the rate of productivity advance during the late sixties has been noted before and is reflected in the aggregate shown in the bottom line of Table 4. Conventional wisdom further suggests that productivity advance would be lowest for purchased meals and beverages (due to its service-oriented nature) which is seen to be true. Also, the 1958-1970 growth in productivity is higher for food produced and consumed on farms than for food purchased for off-premises consumption. Because the former category consists of foods which require little transportation or marketing service, this means, in essence, that labor productivity is growing faster for farming (and its input industries) than for marketing and transportation (and their input industries.) 7/

6/ As noted above, the 1970 productivity estimate was made using the 1967 direct requirements matrix. It is unlikely that all of the slow-down in productivity during the period 1967-1970 resulted from this re-use of the 1967 table - though some of it may have. Due to the way in which technological change impacts on an I/O matrix, there is no apriori reason to suppose that re-use of the 1967 direct requirements matrix understates growth in productivity; as remarked in the appendix, it might easily be overstated. It will be possible to check whether the slow-down was real when the 1972 national I/O study becomes available.

7/ A word of caution is in order here. The I/O methodology assumes that the slaughtering of livestock consumed on farms is done in I/O industry 14 (food-processing). Thus some of the productivity advance shown for food produced and consumed on farms may be attributable to I/O 14.

Table 4.--Growth in Labor Productivity, Average Annual Growth Rates.

	1958 -1963	1963 -1967	1967 -1970	1958 -1970
	Percent			
1. Food Purchased for Off-Premises Consumption	3.54	3.40	1.81	3.06
2. Purchased Meals and Beverages	1.42	2.26	.51	1.47
3. Food Furnished Government and Commercial Employees	1.54	5.71	5.48	3.90
4. Food Produced and Consumed on Farms	1.27	6.54	5.60	4.08
5. Food for Personal Consumption	3.03	3.27	1.59	2.75

While a number of provocative fluctuations in the rate of productivity advance can be seen by examining the three subperiods shown in Table 4, relating these changes to specific technological innovations and to shifting input mixes, is beyond the scope of this study.

V. The Food System.

In this section we make our conception of the food system more concrete and support our assertion that only by using I/O may productivity be correctly measured for the food system. The process by which the U.S. produces food for personal consumption is quite complex, as will now be established by showing the levels at which 28 selected industries participate in the food system. 8/ We show participation in three ways. Table 5 shows the gross output required from each of the 28 industries for the economy to produce food for personal consumption. Tables 6 and 7 can both be related to Table 5. Table 6 shows the labor needed in each of the 28 industries to produce the output shown in Table 5. Table 7 shows the income generated (or value added) in each of the selected industries. Thus, each entry in Table 7 is the output shown in Table 5 minus purchases of intermediate products. 9/

8/ Generally we selected the 28 industries whose participation was largest. However, some smaller industries were included when they seemed of particular interest.

9/ More productivity measures would result from deflating each entry in Table 7 and dividing by the corresponding entry in Table 6. This was not done for lack of appropriate price deflators. In addition, the measure would factor to a ratio of the direct employment requirements per dollar of real income retained, ignoring indirect employment requirements, and thus not conforming to the approach to productivity taken in this paper. Using these additional productivity numbers, we might seemingly measure the contribution of each industry to the overall increase in productivity shown above, but the theoretical basis for such an analysis would have to be developed. At best, the numbers would have little significance by themselves.

Tables 5, 6, and 7 present some interesting numbers. For one thing, the farming industries' participation in the food system is dwarfed by the other industries. For example, in 1967 the production of food for personal consumption generated $253 billion of total business activity but only $42 billion (17%) is output from the agricultural industries (I/O industries 1 and 2). Similarly the agricultural industries retain only 14% of the income generated. One implication of these results is that the price which consumers pay for food is relatively insensitive to factor conpensation in agriculture. 10/ The livestock and livestock products industry required 2.02 million workers to produce food for personal consumption in 1958. By 1970 its labor requirements fell to 1.18 million workers. The proportion of total labor requirements from all industries accounted for by the two agricultural industries fell from 30.3% in 1958 to 20.4% in 1970.

While food processing (I/O 14) contributed 31% of total business activity required to produce food for personal consumption in 1967, its proportion of total value added (19%) and total labor requirements (13%) was much smaller.

Conversely, wholesale and retail trade has the highest labor requirements (40% of the total in 1967) and accounts for the highest proportion of value added (32%), but accounts for a much smaller proportion of total business activity (19%).

Both the trade and service industries are expanding in importance within the food system. Wholesale and retail trade increased both its share of total gross output from 15.6% in 1958 to 19.0% in 1970 and its share of labor requirements from 32.6% to 40.4%. Business services

10/ From 1972 to 1973 factor compensation in farming rose by 60% while the implicit price deflator for PCE for food rose by 13% (Survey of Current Business, July, 1974), a ratio consistent with our results.

Table 5.--Gross output needed from selected industries to produce food for personal consumption.

	Producing Industry	1958	1963	1967	1970
		Million of dollars			
1.	Livestock and livestock products	21,465	20,931	24,522	30,249
2.	Other agricultural products	13,406	15,620	17,490	19,968
3.	Forestry and fishery products	581	723	858	1,027
4.	Agricultural, forestry and fishery services	961	1,037	1,376	1,829
7.	Coal mining	362	292	299	501
8.	Crude petroleum and natural gas	1,243	1,269	1,365	1,526
12.	Maintenance and repair construction	1,902	1,713	2,061	2,665
14.	Food and Kindred products	59,036	64,981	78,011	94,005
24.	Paper and allied products, except containers	1,933	2,756	3,181	3,712
25.	Paperboard containers and boxes	1,203	1,534	2,054	2,391
26.	Printing and publishing	1,684	2,127	2,611	3,110
27.	Chemicals and selected chemical products	2,091	2,657	3,928	4,194
31.	Petroleum refining and related industries	2,096	2,348	2,569	2,761
35.	Glass and glass products	701	825	1,087	1,399
39.	Metal containers	1,466	1,499	1,926	2,338
44.	Farm machinery and equipment	220	240	310	346
59.	Motor vehicles and equipment	789	735	823	1,019
65.	Transportation and warehousing	8,422	7,734	9,336	11,156
66.	Communications; except radio and TV broadcasting	915	1,089	1,460	1,646
68.	Electric, gas, water and sanitary services	1,927	2,445	2,862	3,278
69.	Wholesale and retail trade	28,609	36,358	47,745	57,821
70.	Finance and insurance	2,192	2,220	2,628	3,545
71.	Real estate and rental	4,363	5,161	6,933	8,405
72.	Hotels; personal and repair service, excluding auto	348	462	657	808
73.	Business services	4,471	5,673	8,276	10,181
75.	Automobile repair and services	877	840	1,193	1,504
77.	Medical, educational services, and nonprofit organizations	276	300	376	509
80.	Gross imports of goods and services	5,048	5,245	6,243	7,457
	Other industries	14,455	15,876	21,290	25,555
	Total	183,042	204,690	253,470	304,882

Table 6.--Direct and indirect labor requirements in selected industries to produce for personal consumption

	Producing Industry	1958	1963	1967	1970
		Thousand of Persons Engaged			
1.	Livestock and livestock products	2,019	1,652	1,390	1,176
2.	Other agricultural products	1,756	1,493	1,301	1,299
3.	Forestry and fishery products	23	23	26	26
4.	Agricultural, forestry and fishery services	136	140	134	180
7.	Coal mining	29	17	14	17
8.	Crude petroleum and natural gas	40	32	27	25
12.	Maintenance and repair construction	97	98	103	81
14.	Food and Kindred products	1,656	1,580	1,591	1,624
24.	Paper and allied products, except containers	73	90	88	90
25.	Paperboard containers and boxes	54	61	73	76
26.	Printing and publishing	128	133	133	140
27.	Chemicals and selected chemical products	70	66	82	78
31.	Petroleum refining and related industries	26	20	17	17
35.	Glass and glass products	45	45	50	55
39.	Metal containers	51	44	45	46
44.	Farm machinery and equipment	10	9	10	9
59.	Motor vehicles and equipment	20	14	15	17
65.	Transportation and warehousing	667	525	502	490
66.	Communications; except radio and TV broadcasting	76	59	64	64
68.	Electric, gas, water and sanitary services	59	51	50	48
69.	Wholesale and retail trade	4,069	4,323	4,721	4,905
70.	Finance and insurance	173	160	151	169
71.	Real estate and rental	52	48	50	54
72.	Hotels; personal and repair service, excluding auto	67	78	89	98
73.	Business services	226	312	376	452
75.	Automobile repair and services	42	36	43	45
77.	Medical, educational services. and non-profit organizations	46	42	43	48
80.	Gross imports of goods and services	0	0	0	0
	Other industries	772	693	777	810
	Total	12,482	11,844	11,965	12,139

Table 7.--Income generated in selected industries to produce food for personal consumption

Producing Industry	1958	1963	1967	1970 a/
	Millions of dollars			
1. Livestock and livestock products	7,359	5,250	6,472	
2. Other agricultural products	6,774	8,496	8,551	
3. Forestry and fishery products	227	247	361	
4. Agricultural, forestry and fishery services	429	341	785	
7. Coal mining	211	171	175	
8. Crude petroleum and natural gas	764	717	782	
12. Maintenance and repair construction	1,165	963	1,209	
14. Food and Kindred products	15,066	17,406	20,924	
24. Paper and allied products, except containers	672	1,011	1,177	
25. Paperboard containers and boxes	450	610	755	
26. Printing and publishing	795	1,030	1,298	
27. Chemicals and selected chemical products	807	1,083	1,447	
31. Petroleum refining and related industries	420	548	656	
35. Glass and glass products	389	452	603	
39. Metal containers	492	512	672	
44. Farm machinery and equipment	79	79	108	
59. Motor vehicles and equipment	229	218	252	
65. Transportation and warehousing	5,085	4,708	5,478	
66. Communications; except radio and TV broadcasting	779	923	1,211	
68. Electric, gas, water and sanitary services	941	1,144	1,358	
69. Wholesale and retail trade	20,727	26,662	34,564	
70. Finance and insurance	1,228	1,222	1,481	
71. Real estate and rental	3,157	3,789	5,146	
72. Hotels; personal and repair service, excluding auto	212	295	392	
73. Business services	2,051	2,772	4,263	
75. Automobile repair and services	422	497	655	
77. Medical, educational services, and non-profit organizations	188	210	263	
80. Gross imports of goods and services	0	0	0	
Other industries	5,461	6,346	8,331	
Total	76,579	87,702	109,369	

a/ A conceptually consistent estimate of income generated cannot be computed for 1970

(I/O 73) increased its share of gross output required to produce food for PCE from 1.1% to 3.3%.

It is commonly realized that expenditures for chemicals (I/O 27) has been increasing due to increased expenditures for fertilizers, pesticides, and food additives. Indeed, the nominal dollar output of I/O 27 (necessary for the production of food for personal consumption) has been growing at an average annual rate of 5.9%. Yet even this rapid increase has only raised I/O 27's share of total business activity from a 1958 value of 1.14% to a 1970 value of 1.37%.

We asserted above that the only way to measure labor input exhaustively is through the use of I/O. This is true because the production of food for domestic personal consumption is an economy-wide process. Farming, food processing, transportation, wholesaling, and retailing certainly predominate, yet (in 1970) they account for less than four-fifths of total labor input. The exhaustive measurement of labor input requires the identification of the sectoral location of all economic activity supporting the production of food, which requires the use of I/O.

APPENDIX

The fundamental identity for input-output analysis is:

$$X = A X + Y \qquad 1.$$

where A is an nxn matrix of direct requirement coefficients, X is an nx1 vector of outputs, and Y is an nx1 vector of final demands.

For this study, A was taken from the 82-industry national I/O model, as noted above. By taking Y, then, as the vector of final demands for food for personal consumption (available in the sources listed in the footnotes to Table 1,) equation 1 could be used to compute output requirements, X, for the production of food for personal consumption. Then labor requirements could be easily computed by multiplying each industry's output requirements by its labor coefficient (labor per unit of output). 11/ This approach, however, treats imports as though they were free! It ascribes to domestic labor some part of the productivity of foreign workers. Since imported goods are not free, something must be done to account for their cost.

Imports must be considered in two contexts with respect to the way in which our society provides food for its own personal consumption. Some food is directly imported. In addition to the (relatively small) direct imports of food, almost every industry in the economy (at the 82-industry level of aggregation) uses some imports directly in its production processess. As pointed out above, we assume that the U.S. pays for its imports of goods by exporting goods. 12/ Thus when we compute

---

11/ For an illustration of this approach, see Hazen Gale's article "Industry Output, Labor Input, Value Added, and Productivity," Ag. Econ. Research, Oct., 1968.

12/ This is a perfectly reasonable assumption in the long run. It does however, ignore the fact that the U.S. annual balance of trade could be negative. In that case the U.S. would be paying for imports with I.O.U.'s. Since the balance of trade was positive in 1958, 1963, 1967, and 1970 the assumption is justified.

output requirements for the production of food for personal consumption, we need to adjust it upward to include that output which was used in the production of those exports which were necessary to pay for imports. We now turn to an algebraic statement of our methodology.

Equation 1 must be altered to make exports endogenous. As a first step, include exports in equation 1, resulting in

$$X = A X + Y + E e \qquad 2.$$

where E is an nx1 vector giving the average share of each industry in one dollar of exports and e is a 1x1 matrix of exports. Industry 80 in the 82-industry matrix is an aggregate import industry. If we let M denote a 1xn vector containing the 80th row of the $(I - A)^{-1}$ then total import requirements will be M(Y + E e). Imposition of the constraint that imports are paid for with exports results in the condition:

$$e = M(Y + E e) \qquad 3.$$

which implies

$$e = \frac{1}{1 - M E} MY \qquad 4.$$

Substituting equation 4 into equation 2 and solving for X results in:

$$X = (I - A)^{-1} (I + E \frac{1}{1 - M E} M)Y \qquad 5.$$

Equation 5 may be simplified by noting that 13/

$$(I + E \frac{1}{1 - M E} M) = (I - E M)^{-1} \qquad 6.$$

13/ Equation 6 may be proven by noting that, by a power expansion and simplification:

$$(I - E M^{-1} = I + E M + (E M)^2 + (E M)^3 + \ldots$$
$$= I + E(1 + M E + (M E)^2 + (M E)^3 + \ldots)M$$
$$= I + E \frac{1}{1 = M E} M$$

and, substituting equation 6 into 5 and simplifying

$$X = (I - A - \tilde{E})^{-1} Y \qquad 7.$$

where E is an nxn matrix which has the E vector in its import column and zeroes elsewhere.

Let L and V denote two nxn diagonal matrices of labor coefficients and value added coefficients, respectively. Then labor requirements are given by the expression L X and income generated by the expression V X.

Our measure of output per person engaged is:

$$\frac{u Y P^{-1}}{u L(I - A - \tilde{E})^{-1} Y} \qquad 8.$$

where u is a row vector of units per P^{-1} is the reciprocal of the implicit price index for PCE for food. Equation 8 may be altered to a more useful form. Let $f = u Y$ be the total nominal dollar PCE for food and let $K = Y \frac{1}{f}$

be an nx1 vector showing each industry's direct share of a dollar expenditure for food for personal consumption. By substitution and simplification, labor productivity is:

$$\frac{1}{P u L(I - A - \tilde{E})^{-1} K} \qquad 9.$$

This indicates clearly that labor productivity depends computationally on the composition of final demand (K), the labor coefficients (L), the direct requirements coefficients (A), the composition of foreign demand for our exports ($\tilde{E}$), and the price index (P).

As was commented, we re-used the 1967 A matrix for the 1970 computations though we adjusted it to reflect changes in relative prices between 1970 and 1967. For 1970 the matrics L, P, and E were computed as for other years. The composition of final demand was kept constant within each of the four components of PCE for food, but K varied due to the change in the relative weight of each component. It will be possible to check whether this procedure was justified when the 1972 national I/O study is published.

It might seem that this procedure for 1970 must necessarily understate productivity growth. That is not true. An industry may save on labor by the use of more purchased inputs; this increasing some elements of A but decreasing an element of L. Thus, the bias could be either way. Intuitively it seems that the procedure is justified if $L(I - A - \tilde{E})^{-1}\tilde{K}$ has approximately the same Frobenius eigenvalue with the 1967 A as with the 1970 A, but that has not been proven. ($\tilde{K}$ is a diagonal matrix containing the elements of K.)