MEASURING LABOR PRODUCTIVITY IN PRODUCTION OF FOOD FOR PERSONAL CONSUMPTION

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Labor productivity is measured for each of 4 selected years for each of four components of personal consumption expenditures for food: food purchased for off-premises consumption, purchased meals and beverages, food furnished Government and commercial employees, and food produced and consumed on farms. The labor productivity estimates include both direct and supporting labor needs because, through input-output analysis, it was possible to identify supporting labor inputs regardless of their sectoral location in the economy.
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INTRODUCTION

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

The orientation of the study differs fundamentally from the norm. Most productivity studies proceed entirely along production-oriented lines. The analysts aggregate activities of specific producers because they produce similar goods and services. Such studies are useful, but they produce results which are difficult to interpret from the standpoint of how productivity contributes to societal goals. Economics is a study of the allocation of scarce resources to achieve competing ends. Production is not an end; consumption is. Thus, the productivity of an economy is best measured by the efficiency with which the economy provides consumption goods.

In our study, producers are considered together because their output is directly or indirectly necessary to produce goods which consumers use for similar purposes. Specifically, this is a study of the *food system* of the economy. We define food system as including exactly that portion of the activities of every industry involved in production and delivery of food for personal consumption. Following the productivity estimates, we discuss the contribution of selected industries to the system.

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OUTPUT OF THE FOOD SYSTEM

The process by which the United States 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 is indeed difficult, our measurement of final output is straightforward. We used personal consumption expenditures for food as reported in the national income and product accounts, given in current and constant dollars, and disaggregated into food purchased for off-premises consumption, purchased meals and beverages, food furnished Government and commercial employees, and food produced and consumed on farms.

Table 1 shows the components of real personal consumption expenditures (PCE) for food in 1958, 1963, 1967, and 1970. (The choice of years is explained later.) Total PCE for food has grown at a rate approximately twice that of population growth. From 1958 to 1970, total U.S. population grew at an annual rate of 1.3 percent (*4*), whereas real PCE for food rose 2.5 percent annually.[1] All components of real PCE for food grew at about the same rate except for food produced and consumed on farms. The latter component declined at an average annual rate of 6.5 percent, partially reflecting the decline in farm population.

LABOR INPUT IN THE FOOD SYSTEM

Now we turn to a consideration of the measurement of labor input. All labor used within the entire economy to produce and distribute food must be identified. A complete measure includes not just the labor used by farmers, food processors, and distributors. It also considers the labor used in making inputs the three groups use directly and the labor used in making the inputs to produce the direct inputs.[2] It will be argued below that

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

[2] As a further complication, consider the problem of imports. The United States imports food for personal consumption and imports inputs used in producing food. The assumption was made that the United States pays for these imports with exports. Thus the labor involved in producing those exports had to be measured.

Table 1.—Personal consumption expenditures for food in constant (1958) dollars, selected years, 1958-70

Food use	1958[a]	1963[b]	1967[c]	1970[d]
		Million dollars[e]		
Food purchased for off-premises consumption	58,404	64,541	74,585	80,297
Purchased meals and beverages	15,319	17,613	19,693	20,265
Food furnished Government and commercial employees	1,243	1,169	1,684	1,694
Food produced and consumed on farms	1,410	825	623	630
Food for personal consumption	76,376	84,148	96,685	102,846

[a]U.S. Dept. Commerce. "Personal Consumption Expenditures in the 1958 Input-Output Study," *Survey of Current Business.* October 1965. [b]U.S. Dept. Commerce. "Personal Consumption Expenditures in the 1963 Input-Output Study,"*Survey of Current Business*, January 1971. [c]U.S. Dept.Commerce, "Input-Output Structure of the U.S. Economy: 1967," *Survey of Current Business*, February 1974. [d]U.S. Dept. 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.*

the only way to measure labor input this exhaustively is through the use of national input-output tables (I/O)[3] (For the interested reader, an algebraic statement of our methodology appears in the appendix.) The information available in the national I/O tables can be used to relate PCE for food 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, and 1967.[4] For 1970 figures, the 1967 transactions matrix was used. The implications of re-use of the 1967 matrix are *not* intuitive and they are discussed after the algebraic model is developed in the appendix.

Total direct and indirect labor requirements appear in table 2. Direct labor requirement coefficients (the diagonal entries in the matrix L in the appendix) were computed as the number of civilian employees per unit of output.[5] Total labor required in the food system has remained relatively stable from 1958 to 1970. However, the labor force grew 1.66 percent annually, which implies that the share of the U.S. labor force needed to meet the food needs of the population is decreasing (*4*). Labor

[3] The idea of measuring productivity with the use of I/O is not new. One methodology has been examined theoretically by (*5*, pp. 79-108), and a review of the applications of I/O to productivity is contained in (*2*). Our specific methodology differs from all precursors.

[4] 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 in this article do not include the labor required in the capital goods industries (except labor necessary to produce spare parts for maintenance). A useful extension of the study would be to compute these additional labor requirements.

[5] The labor data are taken from worksheets on total civilian employment by industry, U.S. Dept. Labor, Bur. of Labor Statistics.

Table 2.—Total direct and indirect labor requirements to produce food for personal consumption, selected years, 1958-70

Labor use	1958	1963	1967	1970
		Thousands of persons engaged		
Food purchased for off-premises consumption	9,480	8,805	8,900	9,077
Purchased meals and beverages	2,536	2,717	2,778	2,815
Food furnished Government and commercial employees	202	176	203	174
Food produced and consumed on farms	264	145	85	73
Food for personal consumption	12,482	11,844	11,965	12,139

required to produce purchased meals and beverages has risen gradually and labor required for food produced and consumed on farms has declined markedly.

LABOR PRODUCTIVITY IN PRODUCING FOOD FOR PERSONAL CONSUMPTION

We measure labor productivity as the level of PCE divided by the number of people engaged in the food system (table 3). Note that labor productivity varies widely with the type of consumption and that this dispersion is increasing in magnitude. In 1958, highest value was $6,161 (for food for off-premises consumption) and its lowest, $5,341 (for food produced and consumed on farms); a range of 15 percent. By 1970, the range of this dispersion had grown to 35 percent: productivity was highest for food furnished Government and commercial employees, at $9,736, and lowest for purchased meals and beverages, at $7,199.

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 percent annually from 1958 to 1970. The growth rate was not constant, however; productivity grew rapidly during 1958-67 and slowed during 1967-70.[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 1960's has been noted before, and it 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 (because they are service-oriented), which is seen to be true. Also, the growth during 1958-70 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 change means, in essence, that labor productivity is

[6] As noted above, the 1970 productivity estimate was made using the 1967 direct requirements matrix. It is unlikely that all slowdown in productivity during 1967-70 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 *a priori* reason to suppose that re-use of the 1967 direct requirements matrix understates growth in productivity. As noted in the appendix, it might easily be overstated. It will be possible to check whether the slowdown was real when the 1972 national I/O study becomes available.

Table 3.—Output per person engaged in production of food for personal consumption, selected years, 1958-70

Type of food use	1958	1963	1967	1970
	1958 dollars			
Food purchased for off-premises consumption	6,161	7,330	8,380	8,846
Purchased meals and beverages	6,041	6,483	7,089	7,199
Food furnished Government and commercial employees	6,153	6,642	8,296	9,736
Food produced and consumed on farms	5,341	5,690	7,329	8,630
Food for personal consumption	6,119	7,105	8,081	8,472

Table 4.—Labor productivity, average annual growth rates

Food use	1958-1963	1963-1967	1967-1970	1958-1970
	Percent			
Food purchased for off-premises consumption	3.54	3.40	1.81	3.06
Purchased meals and beverages	1.42	2.26	.51	1.47
Food furnished Government and commercial employees	1.54	5.71	5.48	3.90
Food produced and consumed on farms	1.27	6.54	5.60	4.08
Food for personal consumption	3.03	3.27	1.59	2.75

growing faster for farming (and its input industries) than for marketing and transportation (and their input industries.)[7]

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

AN ECONOMY-WIDE PROCESS

In this section, we make our concept of the food system more concrete and support our assertion that only by using I/O can productivity be correctly measured. The process by which the United States 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 presents gross output required from each of the 28 industries for the economy to produce food for personal consumption. Table 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 appearing in table 5. Table 7 contains the income generated (or value added) in each of the selected industries.

[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.

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

Table 5.—Gross output needed from selected industries to produce food for personal consumption, selected years, 1958-70

Producing industry	1958	1963	1967	1970
	Million 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	11,133
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 food for personal consumption selected years, 1958-70

Producing industry[a]	1958	1963	1967	1970
	Million dollars			
1.	2,019	1,652	1,390	1,176
2.	1,756	1,493	1,301	1,299
3.	23,	23,	26	26
4.	136	140	134	180
7.	29	17	14	17
8.	40	32	27	25
12.	97	98	103	81
14.	1,656	1,580	1,591	1,624
24.	73	90	88	90
25.	54	61	73	76
26.	128	133	133	140
27.	70	66	82	78
31.	26	20	17	17
35.	45	45	50	55
39.	51	44	45	46
44.	10	9	10	9
59.	20	14	15	17
65.	667	525	502	490
66.	76	59	64	64
68.	59	51	50	48
69.	4,069	4,323	4,721	4,905
70.	173	160	151	169
71.	52	48	50	54
72	67	78	89	98
73.	226	312	376	452
75.	42	36	43	45
77.	46	42	43	48
80	0	0	0	0
Other industries	772	693	777	810
Total	12,482	11,844	11,965	12,139

[a]For complete stub, refer to table 5.

Table 7.—Income generated in selected industries to produce food for personal consumption, selected years, 1958-70

Producing industry[a]	1958	1963	1967	1970[b]
	Million dollars			
1.	7,359	5,250	6,472	
2.	6,774	8,496	8,551	
3.	227	247	361	
4.	429	341	785	
7.	211	171	175	
8.	764	717	782	
12.	1,165	963	1,209	
14.	15,066	17,406	20,924	
24.	672	1,011	1,177	
25.	450	610	755	
26.	795	1,030	1,298	
27.	807	1,083	1,447	
31.	420	548	656	
35.	389	452	603	
39.	492	512	672	
44.	79	79	108	
59.	229	218	252	
65.	5,085	4,708	5,478	
66.	779	923	1,211	
68.	941	1,144	1,358	
69.	20,727	26,662	34,564	
70.	1,228	1,222	1,481	
71.	3,157	3,789	5,146	
72.	212	295	392	
73.	2,051	2,772	4,263	
75.	422	497	655	
77.	188	210	263	
80.	0	0	0	
Other industries	5,461	6,346	8,331	
Total	76,579	87,702	109,369	

[a]For complete stub, refer to table 5. [b]A conceptually consistent estimate of income generated cannot be computed for 1970.

Thus, each entry in table 7 is the output shown in table 5 minus purchases of intermediate products.[9]

These three tables present some interesting numbers. Note that the farming industries' participation in the food system is dwarfed by that of the other industries. For example, in 1967, production of food for personal consumption generated $253 billion of total business activity but only $42 billion (17 percent) represents output from the agricultural industries (I/O industries 1 and 2). Similarly, the agricultural industries retain only 14 percent of the income generated. One implication of these results is that the price which consumers pay for food is relatively insensitive to factor compensation (returns to labor and capital) 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 had fallen to 1.18 million workers. The proportion of total labor requirements from all industries accounted for by the

[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 article. 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 alone would have little significance.

[10]From 1972 to 1973, factor compensation in farming rose 60 percent while the implicit price deflator for PCE for food rose 13 percent, a ratio consistent with our results (*3*).

two agricultural industries fell from 30.3 percent in 1958 to 20.4 percent in 1970.

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

Conversely, wholesale and retail trade has the highest labor requirements (40 percent of the total in 1967) and the highest proportion of value added (32 percent). But the proportion of total business activity is much smaller (19 percent).

Both the trade and service industries are expanding in importance within the food system. Wholesale and retail trade increased its share of total gross output from 15.6 percent in 1958 to 19.0 percent in 1970, and its share of labor requirements from 32.6 percent to 40.4 percent. Business services (I/O 73) increased its share of gross output required to produce food for PCE from 1.1 percent to 3.3 percent from 1958 to 1970.

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

I/O data must be used to measure labor input exhaustively because 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 accounted for less than four-fifths of total labor input. Exhaustively measuring labor input requires the identification of the sector location of all economic activity supporting the production of food, which necessitates 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 *nxl* vector of outputs, and Y is an *nxl* vector of final demands.

For the study, A was taken from the 82-industry national I/O model, as noted. 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. Labor requirements could be easily computed by multiplying each industry's output requirements by its labor coefficient (labor per unit of output).[11] The problem with this approach is that it 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, their cost must be accounted for.

Imports must be considered in two contexts with respect to the way in which the U.S. economy 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 processes. As pointed out earlier, we assume that the United States pays for its imports of goods by exporting goods.[12] Thus, when output requirements are computed for the production of food for personal consumption, they must be adjusted upward to include output which was used in the production of those exports which were necessary to pay for imports. An algebraic statement of our methodology follows.

Equation (1) must be altered to make exports endogenous. As a first step, include exports in equation (1) which results in

$$X = A\,X + Y + E\,e \qquad (2)$$

where E is an *nxl* vector giving the average share of each industry in $1 of exports and *e* is an *lxl* matrix of exports. Industry 80 in the 82-industry matrix is an aggregate import industry. If M denotes an *lxn* vector containing the 80th row of $(I - A)^{-1}$, 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

$$e = \frac{1}{1 - M\,E}\,M\,Y \qquad (4)$$

Substituting equation (4) into equation (2) and solving for X results in

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

Equation (5) may be simplified by noting that

$$\left(I + E\ \frac{1}{1 - M\,E}\ M\right) = (I - EM)^{-1} \qquad (6)$$

[11] For an illustration of this approach, see (*1*).

[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 United States 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.

and, substituting equation (6)[13] into (5) and simplifying

$$X = (I - A - \widetilde{E})^{-1} Y \quad (7)$$

where $\widetilde{E}$ 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:

$$\frac{u\, Y\, P^{-1}}{u\, L(I - A - \widetilde{E})^{-1}\, Y} \quad (8)$$

where u is a row vector of units and 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 *nxl* vector showing each industry's direct share of a dollar expenditure for food for personal consumption. By substitution and simplification, labor productivity is:

$$\frac{1}{P\, u\, L(I - A - \widetilde{E})^{-1}\, K} \quad (9)$$

These steps indicate clearly that labor productivity depends computationally on the composition of final demand (K), the labor coefficients (L), the direct requirements coefficients ($\underset{\sim}{A}$), the composition of foreign demand for U.S. exports ($\widetilde{E}$), and the price index (P).

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[13] Equation (6) may be proven by noting that, by a power expansion and simplification:

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

As stated earlier, we re-used the 1967 A matrix for the 1970 computations though adjusting it to reflect changes in relative prices between 1970 and 1967. For 1970, the matrices 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 was 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, thus increasing some elements of A but decreasing an element of L. Therefore, the bias could be either way. Intuitively, it seems that the procedure is justified if $L(I - A - \widetilde{E})^{-1}\, \widetilde{K}$ has approximately the same Frobenius eigenvalue with the 1967 A as with the 1970 A, but that assertion has not been proven. ($\widetilde{K}$ is a diagonal matrix containing the elements of K.)

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