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Growth and Competitiveness of Food Processing: Linkages from Primary Agriculture

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Abstract

High-value agricultural products such as processed foods are becoming increasingly important in U.S. production and trade. Efficiency gains in primary agriculture are transferred to the processed-food sector in the form of cheaper inputs. In turn, efficiency gains in processed-food sectors are transferred, in part, back to primary agriculture by increasing the derived demand and, thus, mitigating commodity price declines. Efficiency gains are relatively more important in primary agriculture than in food processing. Policies that encourage productivity growth and lower production costs will tend to increase the competitiveness of both sectors. Since almost all of the productivity growth in primary agriculture and food processing are passed along in lower prices, consumers are the ultimate beneficiaries.

Keywords: Processed-food products, growth, technological externalities, U.S. agricultural competitiveness

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Summary

High-value agricultural products such as processed food are becoming increasingly important for domestic uses and international trade. The overall share of high-value products in U.S. agricultural exports rose from approximately 30 percent in 1980 to 56 percent in 1993. The importance of high-value products partly reflects a changing pattern of demand, but also a change in the pattern of comparative advantage toward higher value products. This does not imply that the basic comparative advantage of primary agriculture is diminished, but rather that the comparative advantage of primary agriculture could be transferred to the processing sector through increased availability of raw inputs at declining real prices.

Over the period 1959-91, the average annual growth of primary agricultural output (2.16 percent) was dominated by two major effects: the large positive growth in total factor productivity (2.31 percent per year), and the countervailing decline in real prices of agricultural output (-1.19 percent per year). This combination suggests that the majority of efficiency gains in primary agriculture are passed on to intermediate and final consumers.

In contrast, the major factor contributing to growth in food-processing Gross Domestic Product (GDP) (1.04 percent per year) during 1959-91 was the growth of material inputs (1.46 percent per year), which include primary agricultural output. Average annual total factor productivity (TFP) growth in the food-processing sector is a relatively low 0.41 percent. The real price of the food-processing sector has also been declining at an annual rate of -0.83 percent. U.S. efficiency gains in primary agriculture combined with other supply factors around the world have tended to shift supply more than demand, resulting in a decline in the prices of agricultural output. Thus, TFP growth in primary agriculture translates into input level effects for the food-processing sector. External sources of efficiency gains such as investments in public agricultural research and development (R&D) and public infrastructure are more readily available in primary agriculture than in food processing, explaining the large difference in TFP rates between the sectors. While these investments have served to sustain a growth rate of real agricultural GDP at 0.97 percent annually, they have also contributed to the competitiveness of the food-processing sector. Hence, policies that stimulate productivity growth and lower production costs will tend to increase the competitiveness of both sectors. The ultimate gains are to consumers in the form of lower food prices.

Growth and Competitiveness of Food Processing: Linkages from Primary Agriculture

Munisamy Gopinath, Terry Roe, and Mathew Shane[1]

Introduction

Processed food is a growing share of foreign trade.[2] High-value exports, including processed foods, accounted for 56 percent of total U.S. agricultural exports in 1993, compared with an average of less that 35 percent prior to 1980. The sector's real Gross Domestic Product (GDP) grew by an average 1.04 percent per year over the period 1959-91, while primary agriculture averaged 0.97 percent annually during the same period. This performance reflects efficiency gains at both the primary agriculture and food-processing levels. Annual growth in agricultural output averaged a robust 2.16 percent over the period 1959-91. Its slow growth in real GDP was largely explained by the decline in its output prices at an average rate of 1.19 percent per year, which was offset by its relatively high rate of growth of total factor productivity (TFP) at 2.31 percent (Gopinath and Roe, 1995). The rising importance of the food-processing sector is, in part, due to transfer of the efficiency gains in primary agriculture that are transferred to the processing sector through increased availability of primary inputs at declining real prices. The growth of TFP in food processing is transferred, in part, back to the primary sector by increasing its demand and thus mitigating the price decline that would otherwise occur. These linkages facilitate growth in both sectors by increasing their capacity to compete for economywide resources.

The nature and magnitude of these linkages are an important public policy issue since many of the sources of growth in TFP are outside the sector, such as public investments in research and development (R&D). Moreover, growth in TFP may yield larger benefits to other sectors than to the sector within which growth originates. Understanding the extent to which other sectors benefit is important to determining the social profitability of the various sources of economic growth that are external to a sector. The means of internalizing the technological externalities, the nature of which is discussed in the "new" growth theory (Lucas, 1993; Romer, 1990; and Stokey, 1988), include public investments in R&D, public infrastructure, patent protection, and learning-by-doing.

This paper assesses the sources of growth in the U.S. food-processing sector's real GDP and contrasts them with the results obtained for primary agriculture. Sources of growth in GDP are attributed to changes in relative output prices and input levels, and to growth in TFP. The first

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[2]Processed-food sectors include 49 four-digit industries under food and kindred products (SIC code 20), and 4 four-digit industries under tobacco products (SIC code 21), respectively (see Appendix I).

two effects are referred to as level effects, the latter as a rate effect. Level effects link the sector to prices in other sectors of the economy and to the competition among sectors for economy-wide resources. The contribution from TFP to growth is particularly important since this dynamic (rate) effect determines the sector's longrun rate of growth and, its capacity to compete for economywide resources (i.e., its competitiveness). In addition, it raises questions as to how these efficiency gains are shared with the rest of the economy.

The analysis draws upon the envelope properties of the "sectoral GDP function" and the quadratic approximation lemma of Diewert (1976). The application of this lemma to the sectoral GDP function permits the derivation of indices of real prices, output, input, and TFP effects on growth. Data from the National Bureau of Economic Research (NBER) productivity database by Bartelsman and Gray (1994) for the period 1959-91 are used for this purpose. As TFP is measured as a residual, it includes substantial noise from unanticipated changes in exogenous variables, like the oil price shocks of the 1970's and weather. Consequently, the Hodrick-Prescott (1980) filter is used to capture the underlying growth component in the series.

Results indicate that annual growth in the food-processing sector's GDP was negatively affected by a decline in its index of real output prices, but growth in material and other inputs has tended to more than offset the price decline. The material input category includes primary agricultural output as the single largest input subcategory, which accounted for 26 percent (U.S. Input Output Tables, ERS, U.S. Department of Agriculture) of total input costs. The contribution from TFP to the sector's GDP growth is low relative to primary agriculture, suggesting fewer technological externalities because the returns to inventing a new product such as a cake mix or a cereal are captured by the increased level of resources devoted to this activity by the respective food-processing firms. For primary agriculture, public R&D expenditures do not appear among the resources allocated within the sector. Firm-specific investments are not a technological externality *per se*, while the public R&D addresses an externality whose effect on growth is captured by our estimates of TFP. Since the output of primary agriculture appears in the material input category of the food-processing sector, TFP effects in primary agriculture translate into level effects in food processing. Thus, policies that tend to distort markets by, for example, raising the price of primary agricultural outputs, will adversely affect the competitiveness of the food-processing sector (for a definition of competitiveness see Appendix II). Policies that induce productivity growth by lowering production costs in either sector will tend to increase the competitiveness of both sectors.

The conceptual and empirical framework is outlined in the next section, following which are results, conclusions, and policy suggestions. The data are described in Appendix I.

The Model

Consider the case of an economy with three outputs (vectors) y_j, j = primary agriculture (A), food processing (F), and non-agriculture (N), and four categories of inputs (v_A, v_F, v_N, v_E), where the input vector v_j, j = A, F, N is specific to sector j and v_E is a vector of economywide factors, such as labor and material inputs. Following Woodland (1982), define the economywide GDP function as:

$$G(p_A, p_F, p_N, \bar{v}_A, \bar{v}_F, \bar{v}_N, \bar{v}_E ; \gamma) \equiv \max_X \{ \sum_{j=A,F,N} p_j Y_j(v_j, v_E^j; \gamma_j) \}$$

$$X = \{ (v_A, v_F, v_N, v_E^A, v_E^F, v_E^N) : v_A \le \bar{v}_A, v_F \le \bar{v}_F, v_N \le \bar{v}_N, v_E^A + v_E^F + v_E^N \le \bar{v}_E \}, \tag{1}$$

and $Y_j(v_j, v_E^j; \gamma_j)$ for j=A,N,S is a constant returns to scale or vintage production function (Diewert, 1980). The Lagrangian multipliers of this (constrained) maximization problem (λ_A, λ_F, λ_N, λ_E) are the shadow prices for the three sector-specific inputs and one economywide factor. The feasible set X is bounded by the endowments of the private sector. The variable γ_j in Y_j is an externality in the sense that it is not a choice variable of the individual firm. It broadly represents the level of efficiency or in other words, technology. The sources of efficiency gains or technological progress include learning-by-doing, and public investments in infrastructure, and research and development. Since most of these sources of efficiency gains are external to and not necessarily made within a sector, they are referred to as externalities.

The envelope properties of G (see Woodland, 1982) imply the supply function y_j (for j = A, F, N) and the factor rental rate or inverse demand function λ_j (for j = A, F, N, E):

$$\frac{\partial G}{\partial p_j} = y_j(p_A, p_F, p_N, \bar{v}_A, \bar{v}_F, \bar{v}_N, \bar{v}_E; \gamma_j);$$

$$\frac{\partial G}{\partial v_j} = \lambda_j(p_A, p_F, p_N, \bar{v}_A, \bar{v}_F, \bar{v}_N, \bar{v}_E; \gamma_j). \tag{2}$$

Given the solutions (v_E^{j*}, v_A, v_F, v_N) to the problem in equation 1, redefine it as:

$$\max_X \sum_{j=A,F,N} p_j Y_j(v_j, v_E^j; \gamma_j)$$

$$X = \{ v_A \le \bar{v}_A, v_F \le \bar{v}_F, v_N \le \bar{v}_N, v_E^j \le v_E^{j*} \text{ for all } j \}. \tag{3}$$

Proposition 1[3]

The solution to the problem in equation 3 is given by:

$$G(p_A, p_F, p_N, \bar{v}_A, \bar{v}_F, \bar{v}_N, \bar{v}_E; \gamma) \equiv \sum_{j=A,F,N} g_j (p_j, v_E^{j*}, \bar{v}_j; \gamma_j). \tag{4}$$

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[3] See Appendix II of Gopinath and Roe (1995) for proof.

The function g_j is referred to as the sectoral GDP function, and under certain regularity conditions, completely characterizes the underlying technology set (following Diewert, 1974). This product function is homogeneous of degree one in each of p_j, and (v_E^{j*}, v_j^*) and has the same envelope properties as the economywide GDP function. The function g_j and its specific (translog) functional form are the basis for the non-parametric analysis (see Kohli, 1993 for the terminology) of contributions to growth in sectoral GDP.

The food-processing sector is given by g_F[4] (for notational convenience g, hereafter) with four outputs, one sector-specific input, and three economywide input (see Appendix I for description of data). For given real prices[5] and the levels of the sector-specific and economywide inputs used in this sector, define the period t theoretical productivity index (following Diewert and Morrison, 1986 who provide indices for an economywide GDP function) as:

$$R^t(p, v_E^F, \bar{v}_F) \equiv \frac{g(p, v_E^F, \bar{v}_F ; \gamma_F^t)}{g(p, v_E^F, \bar{v}_F ; \gamma_F^{t-1})}. \tag{5}$$

The index R^t represents the percentage increase in sectoral GDP (valued at reference prices) that can be produced by the period t technology relative to the period t-1 technology. Two special cases of R^t are:

$$R_L^t \equiv \frac{g(p^{t-1}, v_E^{F,t-1}, \bar{v}_F^{t-1} ; \gamma^t)}{g(p^{t-1}, v_E^{F,t-1}, \bar{v}_F^{t-1} ; \gamma^{t-1})}; \quad R_P^t \equiv \frac{g(p^t, v_E^{F,t}, \bar{v}_F^t ; \gamma^t)}{g(p^t, v_E^{F,t}, \bar{v}_F^t ; \gamma^{t-1})}. \tag{6}$$

The index R_L^t is a Laspeyres-type index which uses period t-1 output prices and primary input quantities as references, while R_P^t is a Paasche-type productivity index based on period t prices and quantities. Since the two indices in equation 6 are not observable, a geometric mean of the two can be obtained using a translog functional form for the sectoral GDP function. For an explicit specification refer to Appendix III of Gopinath and Roe (1995).
It follows that,

$$g(p^t, v_E^t, v_F^t; \gamma^t) \equiv \lambda_E^t v_E^t + \sum_l w_l^t v_l^t \equiv \sum_k p_k^t y_k^t, \tag{7}$$

where, v_E is the vector of economywide factors used in this sector and **w** is the vector of sector-specific factor returns. Then,

[4] A similar treatment of the primary agricultural sector can be found in Gopinath and Roe (1995).

[5] We derive the real prices by deflating the sectoral price indices by a GDP deflator, in principle, discounting them for average price increases in the economy. Figure 1 depicts the changes in U.S. real price indices for four major sectors.

$$(R_L^t R_P^t)^{\frac{1}{2}} = \frac{a}{b*c*e}, \tag{8}$$

where,

$$a = \frac{p^t y^t}{p^{t-1} y^{t-1}}, \tag{9}$$

$$\ln b = \frac{1}{2} \sum_{k=1}^{K} \left(\frac{p_k^t y_k^t}{p^t y^t} + \frac{p_k^{t-1} y_k^{t-1}}{p^{t-1} y^{t-1}}\right) \left(\frac{\ln p_k^t}{\ln p_k^{t-1}}\right), \tag{10}$$

$$\ln c = \frac{1}{2} \sum_{l=1}^{L} \left(\frac{w_l^t v_l^t}{p^t y^t} + \frac{w_l^{t-1} v_l^{t-1}}{p^{t-1} y^{t-1}}\right) \left(\frac{\ln v_l^t}{\ln v_l^{t-1}}\right), \tag{11}$$

and

$$\ln e = \frac{1}{2} \left(\frac{\lambda_E^t v_E^t}{p^t y^t} + \frac{\lambda_E^{t-1} v_E^{t-1}}{p^{t-1} y^{t-1}}\right) \left(\frac{\ln v_E^t}{\ln v_E^{t-1}}\right). \tag{12}$$

Note that the right-hand side of equation 8 can be evaluated using aggregate price and quantity data. In equation 8, **a** is growth in real value of output (GDP), **b** is a translog output price index, so **(a/b)** is an implicit output quantity index, while **c** and **e** are primary and economywide input quantity indexes. Individual real price and input contributions to growth in real food-processing GDP can be obtained by disaggregating the indexes in equations 10 and 11 (Diewert and Morrison, 1986). The output (real) price effect for each good k is given by ln b_k while, for each input l, input level effect is given by ln c_l. For instance, b_k is interpreted as the change in real GDP (between periods t and t-1) attributable to change in real price of kth good from p_k^{t-1} to p_k^t holding other prices (including the economywide input prices) and all inputs constant. Equations 9, 10, 11, and 12 comprise the key components of the non-parametric analysis.

The index in equation 8 is akin to Solow's residual, TFP, and referred to as a rate effect since, in the context of competitive markets and constant returns to scale technologies, it encompasses sources of technological change that are not necessarily among the choice set of producers. Examples include spill-in effects from new ideas, learning-by-doing, and expansion of knowledge leading to increased efficiency that, while requiring resources to produce, are typically not taken into account when individual producers make production choices. These types of effects are common to the endogenous growth literature where markets fail to internalize technological externalities. Note also that the efficiency gains in other sectors of the economy enter the jth sector's procurement vector v_E. However, empirically TFP also includes unanticipated changes in exogenous variables such as weather and other shocks to the economy. Our primary interest is to capture the underlying growth component of this TFP series that is devoid of these low-frequency fluctuations. So, we employed the Hodrick-Prescott (1980) filter to smooth the series. The method involves choosing smoothed values $\{s_t\}^T_{t=1}$ for the series $\{x_t\}^T_{t=1}$, which solve the following problem:

$$\min_{\{s_t\}} \left(\frac{1}{T}\right) \sum_{t=1}^{T} (x_t - s_t)^2 + \left(\frac{\delta}{T}\right) \sum_{t=2}^{T-1} [(s_{t+1} - s_t) - (s_t - s_{t-1})]^2, \tag{13}$$

where $\delta > 0$ is penalty on variation, where variation is measured by the average squared second difference. A larger value of δ implies that the resulting series $\{s_t\}$ is smoother. Following Hansen (1985), we chose $\delta = 1600$; varying δ, the penalty on variation, between 1200 and 4800, however, did not change the general trend of the series.

Results

Estimates of the contributions to the food-processing sector's real value of output (GDP) due to changes in real prices, input levels, and TFP are presented in tables 1 to 3 (equations 9, 10, 11, and 12). We draw on the work of Gopinath and Roe (1995, 1996) to compare the level and rate effects on growth in this sector's GDP with that of primary agriculture and the aggregate U.S. economy (app. tables 1 and 2). Tables 4 through 7 present the estimates for the four subsectors of food processing: crops, grains, dairy, and meat.

Aggregate Food Processing

Table 1 provides estimates of the average annual rates of growth of the food-processing sector's GDP and its decomposition into the effects of TFP, input levels, and changes in real prices (level effects) for the period 1959-91. During this period, the rate of growth in food-processing GDP averaged 1.04 percent annually. The major contributor to this rate of growth is the rise in the levels of input (equation 11). The rise in input levels caused, all else being constant, the GDP of food processing to rise by an average of 1.46 percent per year. TFP accounted for 0.41 percent of the average growth rate (equation 8). Of course, all else is not constant. The real price index of food processing declined at an annual rate of 0.83 percent (equation 10), which partially offset the positive effects from inputs and TFP. Nevertheless, this negative effect stands in contrast to the positive effect of the rise in the price index of the services sector on growth of the U.S. economy (app. table 2). The rate effect (TFP) on growth in food processing is relatively small. Figure 2 shows the trend in TFP growth smoothed by the Hodrick-Prescott filter. The growth rate of TFP has declined from about 0.8 percent in 1959 to 0.3 percent in 1991, resulting in an average rate of 0.41 percent annually over the period. Relatively low growth rates in TFP should not necessarily be alarming, since it is likely that sources of technological externalities may be small.[6]

In contrast, growth in primary agriculture is largely due to TFP, while aggregate input growth has been stagnant. Moreover, the real price decline in the agricultural sector exceeded that of the food-processing sector by a factor of about one and a half. As mentioned earlier, growth in real agricultural GDP averaged 0.97 percent with TFP growth at 2.31 percent and real prices declining at -1.19 percent per year over the period 1959-91 (see app. table 1). The ERS official estimate of TFP growth in primary agriculture is 2.08 percent (Ball et al., 1995) for the same period. The difference between the two estimates, although small, is largely due to our accounting for the terms of trade effects (real prices) on agricultural real GDP growth. App. table 2 includes comparable estimates for the aggregate U.S. economy. U.S. real GDP grew at an annual average rate of 2.92 percent, for the period 1958-92. While price effects on growth are negative for primary agriculture and food processing, terms of trade effects on growth for the entire economy tend to be positive. These domestic terms of trade effects are largely due to the rise in the price index of the services sector of the U.S. economy relative to the agricultural and manufacturing (including food-processing) sectors.

For the economy, the level effects of resources on growth are important. Capital and labor inputs account for 81 percent of the growth (40 and 41 percent, respectively) in the U.S. economy, while the contribution from TFP growth averaged 16 percent (i.e., an economywide TFP growth rate of 0.47 percent per year). Thus, the growth rate of TFP in primary agriculture is large in contrast to that of food processing in particular, and to the more aggregated sectors of manufacturing and services, more generally. This result suggests that agriculture is likely to be more responsive to technological externalities than many other sectors of the U.S. economy.

Consider next a more detailed decomposition of the level effects on growth. Table 2 presents a decomposition of the price effects on growth for the four categories: crops, grains, dairy, and meat. All four subsectors experienced a decline in their respective real prices. The effect on growth in food-processing GDP from price declines is largest for the processed products associated with the meat sector (0.36 percent) followed by the prices of crops (0.21 percent), grains (0.14 percent), and dairy (0.13 percent), although year-to-year variations are fairly large as suggested by standard deviations.[7] The largest variability appears in the processed-crops and -meat sectors. These results suggest that the declines in these real prices amount to gains to consumers as the output of these sectors flow to consumers at lower real prices.

As noted, the largest contributor to growth in food-processing output is the level effects from inputs. Table 3 provides estimates of the contribution from individual inputs: labor, capital,

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[6]Note that efficiency gains due to investments of the firms that are captured by the industry are not included in TFP.

[7]Tables 4 through 7 provide estimates of the components of growth of each of these sectors.

energy, and materials.[8] Two-thirds of the level effects originate from growth in the material inputs, including the output of primary agriculture. Growth in capital accounts for the remainder. The contribution of labor is negative (-0.06 percent), suggesting that this resource is departing the sector. The contribution from energy is positive but small (0.02 percent). While the contributions from materials and capital are relatively large, they exhibit a declining trend over the period 1959-91 (5-year averages).

This result needs to be interpreted in light of the declining prices of the food-processing sector's outputs, its relatively low TFP, and, while relatively high, a nevertheless stagnant growth in primary agriculture's TFP. In this context, these results suggest that the food-processing sector is employing a declining share of the economy's resources and, thus, that the sector's domestic competitiveness is declining in the sense that its relative ability to bid resources away from the rest of the economy appears to be falling. If, for example, agriculture and/or food processing had a higher rate of growth in their respective TFP, then food processing should have been able to maintain its growth in labor, material, and capital inputs unless, in a large country context, the resulting increase in food supply would have resulted in an even faster decline in output prices. As we discuss in the next section, not all of the food-processing subsectors are losing resources. Closer inspection suggests that the sector is in the process of specialization and division of labor wherein some subsectors decline, effectively transferring some resources to subsectors that are growing.

The social welfare implications of this evolution depend on whether policy, at home or abroad, distorts markets and whether markets reward factors of production for their full contribution to productivity. The new growth literature suggests that nonrival and nonexcludable nature of knowledge embodied in technology cause markets to fail in this regard.

On average, the decline in the real prices of primary agricultural products has benefited the processing sector in the form of cheaper inputs. To illustrate, recall that the share of primary agricultural output in food-processing output is 26 percent. A price decline of 1.19 percent in the primary sector translates into a 0.31-percent (0.26*1.19) decline in the procurement costs to the food-processing sector. If the food-processing sector's price has declined at the rate of 0.31 percent, then all the gains from the decline in the price of primary agricultural output are passed on to consumers. However, the decline in the real prices of food-processing sector averaged 0.83 percent. This suggests that the additional price decline in the food-processing sector (0.83 - 0.31 = 0.52 percent) has come from efficiency gains within the sector. Since the TFP growth within the food-processing sector has been only 0.41 percent per year, the ultimate gains from efficiency growth in the primary and food-processing sectors are to consumers (through retail and wholesale trade, and hotels and restaurants).

[8] See Appendix I for the details on data. Material inputs, among others, include primary agricultural products but exclude energy.

The efficiency gains in primary agriculture in the United States as well as its major competitors lead to supply shifts that cause a global decline in the prices of agricultural output, given a relatively lower growth rate in demand. It is in this way that the rate effects of primary agriculture translate into level effects for the food-processing sector. Investments in public agricultural R&D and public infrastructure have been found to be robustly associated with TFP growth in agriculture (Gopinath and Roe, 1995). While these investments have served to sustain a growth rate in real agricultural GDP of about 0.97 percent, they have contributed to the competitiveness of the food-processing sector through lower primary agricultural product prices.[9]

Subsector Results

While all the four of the subsectors (processed-crops, grains, dairy, and meat) experienced positive real rates of growth in their respective GDP, the processed-crops and -grains subsectors have benefited from larger input level effects on growth than have processed-dairy and -meat. It can be said that the processed-grains and -crops subsectors have, on average, been relatively more competitive than the processed-dairy and -meat. Clearly, the reasons for this competitiveness are not solely due to efficiency growth within these processed subsectors *per se*, but also to the efficiency gains experienced in the production of crops and grains (see Gopinath and Roe, 1995 for further discussion of a disaggregated primary agriculture).

Processed-Crops Sector

The growth accounting results for the processed-crop products, which account for 45 percent of food-processing sector GDP, are presented in table 4. Among the four sectors considered, the processed-crops sector experienced the largest growth in its GDP, at 1.69 percent, on average, over the period 1959-91. The level effects from all inputs account for almost nine-tenths of the growth in the real value of output in this sector (1.56 percent). Of the input level effects, the largest are from material inputs, followed by capital. The level effect from energy is positive and that from labor is negative; both, however, are relatively small. While price effects contributed negatively to growth in its value added (-0.43 percent), they are nevertheless smaller than are the price effects in the other sectors. The growth effect of TFP averaged 0.56 percent per year, which exceeds the averages of the other subsectors. The filtered TFP growth series (using Hodrick-Prescott filter) in figure 3 suggests an overall declining trend over the sample period with moderate increases in the later periods of the sample. Overall, this subsector appears the most competitive, on average, in its competition for resources relative to the other subsectors.

Processed-Grains Sector

This subsector's share of food-processing GDP averaged 18 percent. On average, over the period 1959-91, the annual rate of growth in this subsector's GDP is 0.81 percent. The effects of

[9] To the extent that the fall in primary agriculture's output prices is in response to efficiency gains, technological change has been almost immiserizing.

declining real prices are 0.80 percent, which is similar to the price effects on the aggregate food-processing sector. As above, the level effects from inputs contributed the most to growth in this subsector's GDP. Material inputs and capital contributed almost equally (0.71 and 0.62 percent, respectively) to this subsector's GDP growth. The contribution from energy is again small and positive, while that of labor is relatively large and negative (-0.14 percent). TFP growth accounted for about 50 percent of its GDP growth. The filtered TFP growth series (fig. 3) shows increasing TFP growth rates until the late 1970's and falling thereafter. Thus, on average, the effects of this subsector's TFP, in conjunction with the efficiency gains in primary agriculture, appear to have caused unit processing costs to fall sufficiently to offset the real decline in output price. This offsetting effect induced the sector to increase its derived demand for material inputs. In a large country context, this increase in demand likely mitigated the decline in the real price of grain at the farm level. Through the decline in the real price of processed grain, the efficiency gains of both the primary and the processing subsector were passed to wholesale and retail markets. In spite of the adverse terms of trade effects, this subsector appears relatively competitive in attracting resources, although the results suggest a possible substitution of capital for labor over the period.

Processed-Dairy Sector

The processed-dairy sector experienced the lowest rate of growth in its GDP, compared with the other subsectors. It accounts for 13 percent of food-processing sector's GDP. This is largely due to negative real prices effects which, if all else were constant, would have caused this subsector's value added to fall at an average rate of 1.00 percent per year. This negative effect almost totally offset the positive effects on growth in GDP attributable to inputs and TFP. As with the processed-grains sector, growth in material inputs and capital contributed the most to growth in GDP. While energy inputs had relatively small effects on GDP, labor input's contribution to growth in the dairy sector GDP is large and negative (-0.23 percent). This result implies that labor has departed the subsector as it became more capital intensive. The contribution of TFP is the smallest of all subsectors, although the standard deviation is large in all cases. Still, the dairy sector's filtered TFP growth series in figure 3 suggests an increasing trend since 1970.

Processed-Meat Sector

The processed-meat sector has grown at an annual average rate of 0.65 percent over the period 1959-91. Of the four sectors, the processed-meat sector experienced the largest negative effect on growth in its value added from a decline in real prices. All else constant, the decline in real prices would have decreased the growth in value added by -1.42 percent per year. The level effects from inputs on the growth of its GDP fortunately is also the largest of the subsectors. With a relatively lower contribution from TFP growth (0.28 percent), the level effects of inputs are largely offset by the decline in real prices. In addition, the real prices of the processed-meat sector exhibits high variability (standard deviation of 7.26 percent). The growth component of TFP, as measured by the Hodrick-Prescott filter, suggests a declining TFP over the entire sample period in figure 3.

Conclusions

The major factor contributing to growth in food-processing GDP (1.04 percent annually) during 1959-91 is the level effects from inputs. Material inputs including primary agricultural products, account for almost all growth in food-processing GDP. However, the contribution from other inputs to growth in the sector's real GDP are offset by the 0.83-percent decline in real price for the sector's output. Total factor productivity growth in food processing is relatively low at 0.41 percent. This compares with a TFP growth rate of 0.47 percent for the economy and 2.31 percent per year for primary agriculture. The filtered TFP growth suggests declining trends in its contribution to growth in the food-processing GDP over the period 1959-91.

Decomposing growth in the food sector, in an economywide context, provides insights into the nature and magnitude of its linkages to the primary agricultural sector. The domestic terms of trade effects among the various sectors in an economy suggest that the food-processing sector benefited from the decline of 1.19 percent in the real output prices of primary agriculture. This decline is mostly an outcome of efficiency gains, TFP effects, in the United States and its major competitors in the presence of a relatively lower growth rate in food demand. Due to the decline in primary output prices, the processed-food sector was able to increase its employment of material inputs even though it experienced a price decline for processed food. It is in this way that rate effects in primary agriculture are transferred into level effects in food processing. Since the output of agriculture accounts for about 26 percent of the material inputs in food processing, the decline of 0.83 percent in the price of processed food implies that more than the entire price decline experienced by primary agriculture has been, on average over the period, passed on to wholesale and retail markets. In other words, efficiency gains from both the primary agriculture and processed-food sectors translate into lower real prices for consumers.

Thus, policies that tend to distort markets by, for example, raising the price of primary agricultural outputs, will adversely affect the competitiveness of the food-processing sector. Policies and programs that tend to induce productivity growth, such as public agricultural R&D that lowers production costs, in either sector will tend to increase the competitiveness of both sectors. The rate effects (TFP) in primary agriculture are the major source of growth in its GDP. TFP growth is found to be robustly associated with public investments in sector-specific research and development and infrastructure (see for example, Gopinath and Roe, 1995). These investments, while maintaining the viability of the farm sector, contribute significantly to the competitiveness of the food-processing sector, with ultimate gains to consumers in the form of lower real food prices. Other sectors of the economy receive indirect benefits from the savings in food expenditures that can be allocated to purchases of nonfood goods and services.

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Tables

Table 1--Components of U.S. food-processing GDP growth

Year	GDP growth	Real price effect	Input contribution	TFP growth
			Percent	
1959-91	1.04	-0.83	1.46	0.41
Std. Devn.	3.14	3.27	1.78	1.05
1959-63	0.95	-1.79	1.84	1.00
1964-68	1.61	-1.03	2.34	0.34
1969-73	3.52	1.54	1.46	0.52
1974-78	1.84	-0.51	2.64	-0.29
1979-83	-1.46	-2.27	-0.09	0.90
1984-88	0.78	-1.15	1.14	0.79
1989-91	-0.64	-0.94	0.59	-0.29

Table 2--Real price effects on U.S. food-processing GDP growth

Year	Crops price	Grains price	Dairy price	Meat price	Aggregate price
			Percent		
1959-91	-0.21	-0.14	-0.13	-0.36	-0.83
Std. Devn.	1.60	0.89	0.34	1.86	3.27
1959-63	-0.56	-0.13	-0.05	-0.98	-1.79
1964-68	-0.39	-0.19	-0.03	-0.42	-1.03
1969-73	1.02	0.32	0.19	0.01	1.54
1974-78	-0.30	-0.04	-0.01	-0.15	-0.51
1979-83	-0.91	-0.63	-0.34	-0.39	-2.27
1984-88	-0.15	-0.22	-0.27	-0.51	-1.15
1989-91	-0.35	-0.37	-0.15	-0.07	-0.94

Table 3--Input contributions to U.S. food-processing GDP growth

Year	Labor	Capital	Energy	Materials	Aggregate input
			Percent		
1959-91	-0.06	0.49	0.02	1.01	1.46
Std. Devn.	0.14	0.17	0.03	1.64	1.78
1959-63	-0.11	0.53	0.02	1.40	1.84
1964-68	-0.02	0.68	0.05	1.63	2.34
1969-73	-0.11	0.58	0.01	0.98	1.46
1974-78	-0.03	0.56	0.02	2.09	2.64
1979-83	-0.12	0.42	-0.00	-0.35	-0.09
1984-88	0.01	0.30	0.02	0.79	1.14
1989-91	-0.01	0.26	-0.02	0.36	0.59

Table 4--Components of U.S. processed-crops sector GDP growth

Year	GDP growth	Real price effect	Input contribution	TFP growth
		Percent		
1959-91	1.69	-0.43	1.56	0.56
Std. Devn.	3.74	3.59	2.30	1.59
1959-63	2.17	-0.99	1.52	1.64
1964-68	1.98	-1.42	3.01	0.39
1969-73	3.34	0.38	2.35	0.61
1974-78	3.68	1.25	2.91	-0.48
1979-83	-1.06	-1.19	-0.54	0.77
1984-88	1.25	-0.46	0.95	0.76
1989-91	-0.38	-0.67	0.15	0.14

Table 5--Components of U.S. processed-grains sector GDP growth

Year	GDP growth	Real price effect	Input contribution	TFP growth
		Percent		
1959-91	0.81	-0.80	1.21	0.40
Std. Devn.	4.35	5.18	1.47	1.97
1959-63	1.06	-0.89	1.77	0.18
1964-68	0.49	-1.42	1.81	0.10
1969-73	3.06	1.98	0.25	0.83
1974-78	0.46	-1.20	1.54	0.12
1979-83	-0.42	-1.95	0.03	1.50
1984-88	0.66	-0.85	1.12	0.39
1989-91	0.05	-1.62	2.61	-0.94

Table 6--Components of U.S. processed-dairy sector GDP growth

Year	GDP growth	Real price effect	Input contribution	TFP growth
		Percent		
1959-91	0.16	-1.00	0.95	0.22
Std. Devn.	2.78	2.64	2.63	2.33
1959-63	0.31	-0.35	3.01	-2.35
1964-68	0.18	0.10	1.00	-0.92
1969-73	1.09	-0.84	1.00	0.93
1974-78	1.23	-0.59	1.22	0.60
1979-83	-0.04	-1.54	0.43	1.07
1984-88	-0.44	-3.01	0.57	2.00
1989-91	-2.01	-0.63	-1.60	0.22

Table 7--Components of U.S. processed-meat sector GDP growth

Year	GDP growth	Real price effect	Input contribution	TFP growth
		Percent		
1959-91	0.65	-1.42	1.81	0.28
Std. Devn.	5.32	7.56	3.59	2.14
1959-63	-0.72	-4.69	2.19	1.76
1964-68	2.74	-0.21	2.42	0.53
1969-73	5.69	5.42	0.95	-0.68
1974-78	0.22	-2.30	3.62	-1.10
1979-83	-3.69	-5.15	0.41	1.05
1984-88	0.61	-1.71	1.70	0.60
1988-91	-0.91	-1.21	1.13	-0.83

Figures

Figure 1. Agriculture and food processing show large price declines

U.S. Real Price Indices

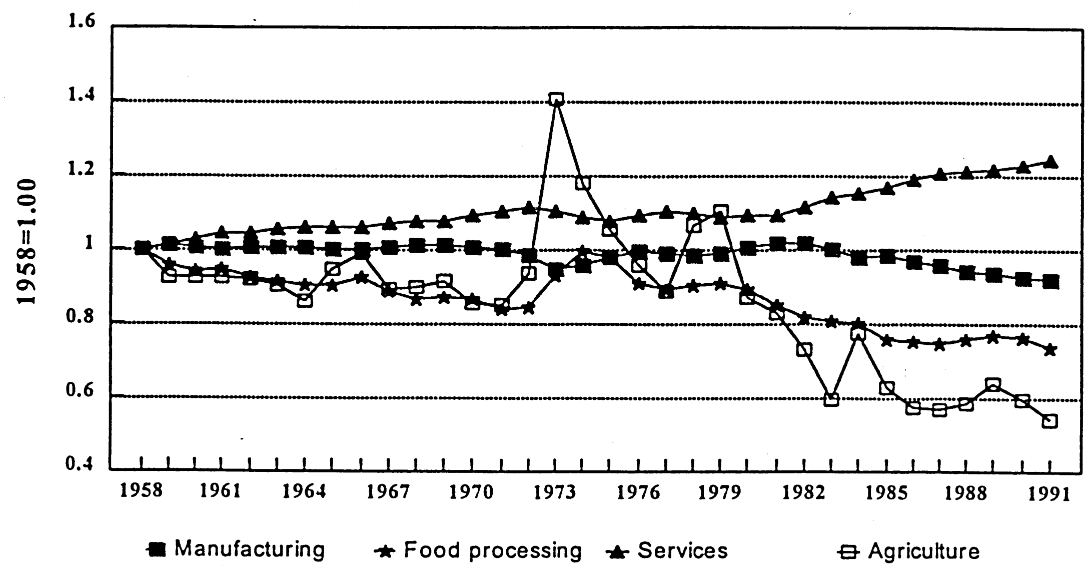


Figure 2. Food-processing TFP growth shows a downward trend

Filtered TFP Growth

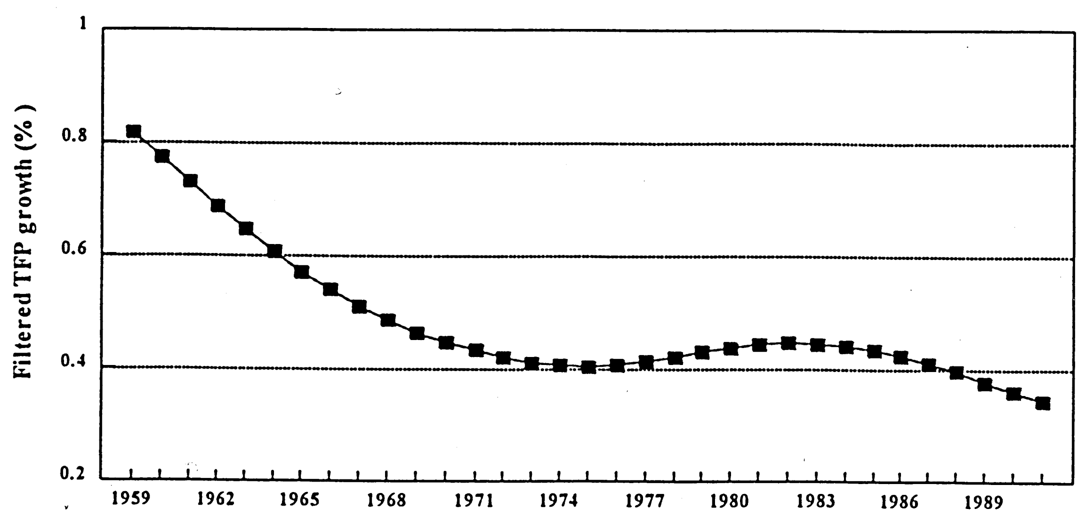
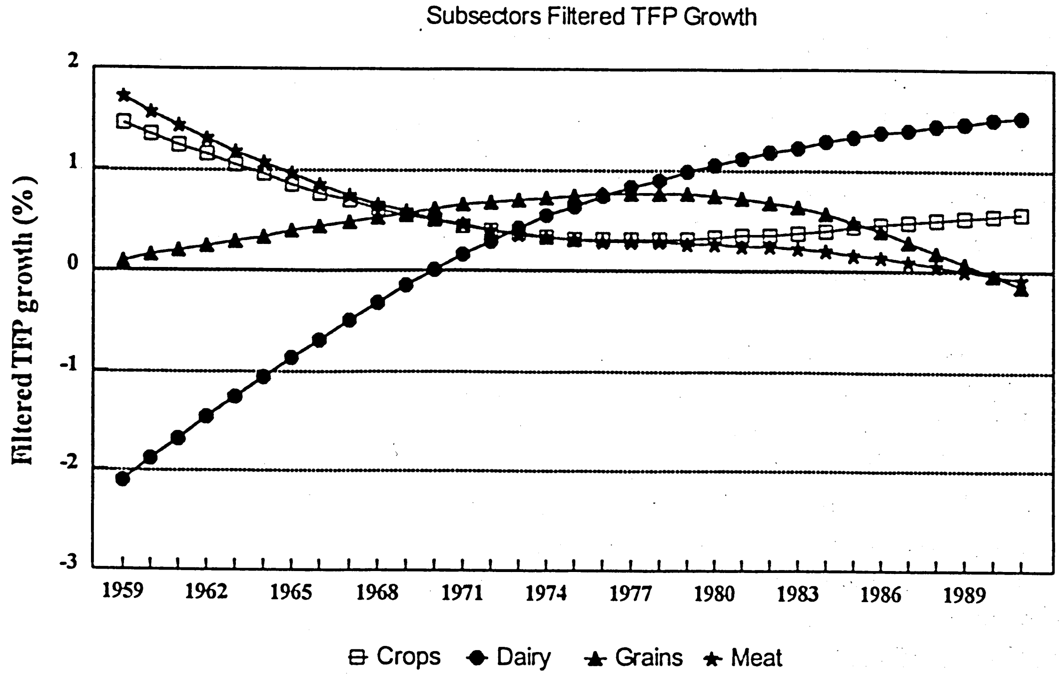


Figure 3. Most subsectors show a declining trend in TFP growth



Appendix I

Data

The data series were taken from the National Bureau of Economic Research (NBER) Manufacturing Productivity Database developed by Bartelsman and Gray (1994). These data are not in published form, but available electronically through the Internet (anonymous ftp NBER, nber.harvard.edu, pub/productivity sub-directory). Annual data series were available for 450 manufacturing industries based on 1987 SIC codes for the period 1958-91. The original sources of the data are Annual Survey of Manufactures and Census of Manufactures, Bureau of Economic Analysis, U.S. Department of Commerce.

The food and kindred products industry (two-digit SIC code 20) consisting of 49 four-digit industries was aggregated into four major categories: processed meat, dairy, grains, and other crops. In addition, tobacco (SIC code 21) was included in the other crops category. See the Annual Survey of Manufactures and Census of Manufactures for more detailed definitions of each industry. Value of industry shipments, available in current and constant prices for four-digit SIC codes, was aggregated back to the four sectors. The output price index is then the ratio of current and constant price value of shipments. Labor was represented by employment in thousands of people and the compensation was available in millions of current dollars. Capital stock was in millions of 1987 dollars. The perpetual inventory method was employed in deriving the stock of capital. Material inputs include primary agricultural products but exclude energy. The payments to both material inputs and energy were also available in current and constant prices.

We derive the real prices by deflating the four output price indices by a GDP deflator, in principle, discounting them for average price increases in the economy. The GDP deflator was obtained from the National Income and Product Accounts of the United States, 1929-1995, Bureau of Economic Analysis, U.S. Department of Commerce (electronic form).

Industry Codes

Industry	SIC code	Industry	SIC code
Meat packing	2011	Candy & confecty.	2064
Sausages & other meats	2013	Choclate. & cocoa prods.	2066
Poultry	2015	Chewing gum	2067
Creamery, butter	2021	Sltd. & rstd. nuts & seeds	2068
Cheese, natural & process.	2022	Cottonseed oils	2074
Dry, cond. & evop. dairy	2023	Soybean oils	2075
Ice cream & frz. desserts	2024	Vegetable oils	2076
Fluid milk	2026	Anim. & marine fats & oil	2077
Canned specialites	2032	Other edible oils & fats	2079
Canned fruits & veg.	2033	Malt beverages	2082
Dehydrated fr. & veg	2034	Malt	2083
Pickles, sauces & dressng.	2035	Wines, brandy & br. sprt.	2084
Frozen fr. & veg.	2037	Distilled & blndd. liquor	2085
Other frozen specialities	2038	Bottled & cnd. sft. drinks	2086
Flour & grain mill prods.	2041	Flavoring extracts & oth.	2087
Cereal brkfast. foods	2043	Cnd. & cured fish & sfds.	2091
Rice milling	2044	Fresh/frozen prep. fish	2092
Prepared flours & doughs	2045	Roasted coffee	2095
Wet corn milling	2046	Pot. chips & oth. snacks	2096
Dog and cat food	2047	Manufactured ice	2097
Prepared feeds	2048	Macaroni & spaghetti	2098
Bread, cake & related	2051	Oth. food preparations	2099
Cookies & crackers	2052	Cigarettes	2111
Frozen bakery	2053	Cigars	2121
Raw cane sugar	2061	Chewing & smkg. tobac.	2131
Cane sugar refining	2062	Tobac. stemmg. & dryg.	2141
Beet sugar	2063		

Appendix Tables

Appendix table 1--Components of U.S. agricultural GDP growth

Year	GDP growth	Real price effect	Input contribution	TFP growth
		Percent		
1959-91	0.97	-1.19	-0.15	2.31
1959-63	0.14	-2.40	0.00	2.67
1964-68	0.39	-1.95	-0.69	3.22
1969-73	8.97	5.71	-0.19	3.38
1974-78	-2.73	-4.18	1.99	0.14
1979-83	-4.56	-2.86	-1.45	0.09
1984-88	0.78	-2.17	-1.21	4.69
1989-91	5.65	0.03	0.94	5.03

Appendix table 2--Components of U.S. real GDP growth

Year	GDP growth	Agri. price	Mft. price	Serv. price	Labor	Capital	TFP growth
				Percent			
1958-92	2.92	-0.03	-0.23	0.35	1.18	1.18	0.47
Percent contribution	100	(-1)	(-8)	(12)	(41)	(40)	(16)
1958-62	3.00	0.00	-0.34	0.58	0.49	0.97	1.26
1963-67	4.77	-0.01	-0.09	0.22	2.02	1.64	0.92
1968-72	2.98	0.02	-0.31	0.39	0.88	1.45	0.53
1973-77	2.64	-0.02	0.17	-0.11	1.36	1.22	-0.01
1978-82	1.28	-0.06	0.05	0.14	0.98	1.28	-1.10
1983-87	3.85	-0.08	-0.64	0.75	1.74	1.00	1.03
1988-92	1.91	-0.04	-0.48	0.49	0.62	0.70	0.60

Appendix Tables

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1959-91	0.97	-1.19	-0.15	2.31
1959-63	0.14	-2.40	0.00	2.67
1964-68	0.39	-1.95	-0.69	3.22
1969-73	8.97	5.71	-0.19	3.38
1974-78	-2.73	-4.18	1.99	0.14
1979-83	-4.56	[illegible]	[illegible]	[illegible]
1984-88	0.78	[illegible]	[illegible]	[illegible]
1989-91	5.65	0.03	0.94	5.03

Appendix table 2--Components of U.S. real GDP growth

Year	GDP growth	Agri. price	Mft. price	Serv. price	Labor	Capital	TFP growth
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1958-62	3.00	0.00	-0.34	0.58	0.49	0.97	1.26
1963-67	4.77	-0.01	-0.09	0.22	2.02	1.64	0.92
1968-72	2.98	0.02	-0.31	0.39	0.88	1.45	0.53
1973-77	2.64	-0.02	0.17	-0.11	1.36	1.22	-0.01
1978-82	1.28	-0.06	0.05	0.14	0.98	1.28	-1.10
1983-87	3.85	-0.08	-0.64	0.75	1.74	1.00	1.03
1988-92	1.91	-0.04	-0.48	0.49	0.62	0.70	0.60