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Total Factor Productivity Growth
in U.S. Food Processing

by Azzeddine M. Azzam, Elena Lopez,
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Preface

This article examines the role of imperfect competition in determining total factor productivity growth (TFPG) by bringing together a New Empirical Industrial Organization (NEIO) model and the TFPG model of Nadiri and Mamuneas (1998). Applying the integrated model to 1973-92 data from 29 food processing industries revealed that changes in markups, economies of scale, and demand growth contributed positively to TFPG while the disembodied technical change was a negative contributor. Furthermore, the TFPG estimates are starkly different from the conventional (Solow's residual) TFPG measures, underscoring the need to account for imperfect competition, returns to scale, and demand in analyses of this type.

Key Words: productivity growth, imperfect competition, scale economies, food processing.

1. Introduction

Much of the recent research on total factor productivity growth (TFPG) has focused on extending the measures and decomposition of productivity growth beyond the traditional Solow's (1957) residual by relaxing some of its most restrictive assumptions such as perfect competition and constant returns to scale. Plenty of progress has been made by extending Solow's residual to incorporate parametric measures of cost functions or production functions (e.g., Denny, Fuss, and Waverman, 1981, among others) and to account for markup behavior (e.g., Morrison, 1992) or demand factors (Nadiri and Schankerman, 1981).

On the other hand, parallel progress has been made by the New Empirical Industrial Organization (NEIO) literature in modeling markup behavior, or more precisely, imperfect competition, while integrating cost and demand structures (e.g., Bresnahan, 1989). The purpose of this article is to integrate these two frameworks by bringing together the TPFG decomposition method proposed by Nadiri and Mamumeas (1998) with the NEIO model of Lopez, Azzam, and Lirón-España (2001) in order to measure and decompose the sources of total factory productivity growth and include markup behavior, economies of scale, and demand structures.[1] The integrated model is applied to data from the U.S. food processing sector.

From the food processing perspective, the role of TFPG in competitiveness acquires particular significance given the globalization of food markets and cut in federal programs. Although food industry competitiveness in the sense of lower production costs has long been a high priority research area, much of the recent research focus has been on the sector's degree of competition. TFPG, on the other hand, captures competitiveness and depends on how the industry's productive inputs are being employed. Ultimately, this dimension of efficiency depends not only on the degree of competition but also on demand dynamics, economies of scale, and technical change.[2]

The few studies on TFPG in U.S. food processing (e.g., Heien, 1983; Lee, Maier, and Lynch, 1987) use the conventional method of growth accounting, defined as the rate of growth of aggregate output minus the rate of growth of aggregate inputs. This method assumes constant returns to scale and perfect competition. When these assumptions are grossly violated, as they are in many food processing industries (Azzam and Schroeter, 1995; Bhuyan and Lopez, 1997), then TFPG may be grossly biased (Denny, Fuss, and Waverman, 1981).[3] From the standpoint of industrial policy, an understanding of the magnitude of TFPG and its sources is crucial for improving competitiveness, just as an understanding of the degree of market power is crucial for improving competition.

The next section points out some linkages between imperfect competition and productivity growth. The third section provides the framework for decomposing TFPG in the presence of imperfect competition. The fourth section presents and discusses the empirical results, while the final section provides some concluding remarks.

2. Competition and Productivity Growth

Empirical work on the linkage between competition and productivity growth has yielded mixed results. For example, Nickell's (1996) survey found that the relation between competition and corporate performance is inconclusive. For the telephone and airline industries, which followed a natural experiment of deregulation in the 1980s, empirical evidence indicates a positive relationship between competitive pressure and technical efficiency under nearly constant returns to scale (e.g., Gort and Sung, 1999; Semenick-Alam, Ross and Sickles,

[1] Morrison (1992) presents an integrated framework to measure productivity growth accounting for markups, economies of scale, and subequilibria. This analysis differs from the work of Morrison's (1992) in two fundamental respects. First, conceptually, the TFPG decomposition presented in this article is based on Nadiri and Mamumeas (1998), which is an extension of Nadiri and Schankerman's (1981) work. Morrison's approach integrates the scale effects reconized by Ohta (1975) with the effects of markups on the Solow's residual emphasized by Hall (1988). Second, empirically, the model parameters are estimated using an NEIO model rather than a predominantly production theory-based model.

[2] Strong TFPG in food processing not only benefits farmers through an upward shift in the derived demand of their output but also benefits processors through improved competitiveness in food exports (Gopinath, Roe, and Shane, 1996) and the general economy through an improved balance of trade.

[3] When the assumptions of constant returns to scale and perfect competition are violated, the conventional TFPG measure includes not only the effect of technical change (which shifts the production function) but also the effects of non-constant returns to scale and market imperfections. In addition, even if economies of scale exist, their exploitation will depend on demand growth since they can be exercised in expanding markets but they would be inhibited in declining markets. Under the assumptions of constant returns to scale and competition, productivity growth is often identified with technical change (Gort and Sung, 1999).

2001). These natural experiments compare regulated with unregulated markets across space or time. However, productivity growth embodies other factors as well as technical change that may make firms and industries more or less productive in the context of competitive pressure.

Gort and Sung (1999) point out four ways in which competition can affect productivity growth. First is the level and composition of output. For example, an increase in demand may not directly induce shifts in the cost function, but it often leads to increases in productivity through better utilization of existing capacity and technology. In this regard, Lopez, Azzam, and Lirón-España (2001) show that industrial concentration may both increase market power while at the same time allow for a better use of economies of scale. A related point is made by Morrison (1992) in that demand growth, economies of scale and markups are important in determining productive efficiency.

A second point raised by Gort and Sung (1999) is the price and quality of inputs. For example, lower capital prices tend to lead to an improvement in the vintage of capital goods, leading to faster demand growth and, hence, to a positive effect of competition on the quality of capital inputs. The third point is rivalry's impact on accumulation of firm-specific organizational capital. The fourth factor is the Schumpeterian hypothesis by which less competitive firms may have a greater incentive to innovate, leading to dynamic or long-term efficiency at the expense of short-term, static allocative efficiency.

In this article, we do not address the issue of the quality of inputs or quality changes in the output of the producing firms. Rather, we focus more intensively on the issues of changes in markups, economies of scale, demand structure, factor prices, and disembodied technical change. As shown below, these components are interactive and can be decomposed or sorted out from output growth.

3. TFPG Decomposition with Imperfect Competition

The decomposition of the TFPG requires seven parameters: changes in markups, the price elasticity of demand, the income elasticity of demand, the rate of demand growth, economies of size, changes in economies of size, and the rate of technical change. The starting point of the decomposition, as shown by Nadiri and Schankerman (1981), is the "quasi-Divisia" index of TFPG:

$$TFPG = \dot{Q} - \sum s_i \dot{X}_i , \qquad (1)$$

where

$$\dot{Q} = (\partial Q / \partial t)(1/Q) ,$$

and

$$\dot{X}_i = (\partial X_i / \partial t)(1/X_t) ,$$

are, respectively, the rates of output and input growth, t denotes time, and s_i is the share of the ith input in total revenue ($s_i = W_i X_i / PQ,$ where W_i and P denote input and output prices, respectively).

For our particular application, we assume that the food industry employs three factors:

X_1 = labor, X_2 = material, and X_3 = capital services, so that $Q = F(X_1, X_2, X_3, T)$. The variable T indexes the state of technology. Thus, the first term on the right hand side of (1) becomes

$$\dot{Q} = \sum_{i=1}^{3} \frac{\partial F}{\partial X_i}\frac{X_i}{Q}\frac{\partial X_i}{\partial t}\frac{1}{X_i} + \frac{\partial F}{\partial t}\frac{1}{Q}. \qquad (2)$$

Assume cost minimization and let the dual cost function be given by $C = C(Q, W_1, W_2, W_3, T)$. Nadiri and Schankerman (1981) show that the rate of change in output can be written as

$$\dot{Q} = \sum_{i=1}^{3} \frac{W_i X_i}{(MC)Q}\dot{X}_i - \frac{\partial C / \partial t}{(MC)Q}, \qquad (3)$$

where MC is industry marginal cost.

Substitution of (3) into (1) yields

$$TFPG = A\dot{Q} - \frac{1}{\theta}\dot{T} , \qquad (4)$$

where

$$A = (\theta - \varepsilon)/\theta = (P - MC)/P,\ \theta = P/AC ,$$

is the ratio of the output price to average cost, and

$$\varepsilon = d \ln C / d \ln Q = MC / AC ,$$

refers to economies of size, which is the inverse of economies of scale (Hanoch, 1975).

The first right-hand term in (4) is the scale markup effect and the second is the technological change effect. If we assume that technology exhibits constant returns to scale and the industry is competitive, i.e., $P = MC$, then $TFPG$ can be fully attributed to technical change as done in the conventional method applied by Heien (1983) and Lee, Maier, and Lynch (1987). Note that since marginal cost $MC = \varepsilon AC$, $A = (P - MC)/P$, which is the Lerner index of oligopoly power. However, when firms price above *MC*, *A* is positive regardless of economies of scale.[4]

As shown by Nadiri and Mamuneas (1998), an appropriate index starts with the supply relation of an oligopolistic industry,

$$P = \phi\, MC = \phi\, \varepsilon\, AC\ , \tag{5}$$

where ϕ is the markup over marginal cost (defined as one plus the percent mark up). The rate of growth of output price, based on (5), is

$$\dot{P} = \dot{\phi} + \dot{\varepsilon} + \dot{C} - \dot{Q}\,. \tag{6}$$

Invoking the dual cost function, the rate of change in cost is

$$\dot{C} = \varepsilon\dot{Q} + \sum_{i=1}^{3} k_i \dot{W}_i + \dot{T}\ , \tag{7}$$

where k_i is the proportion of total expenditures on inputs accounted for by the i[th] input.

Substitution of (7) into (6) yields the rate of growth of the industry supply relation,

$$\dot{P} = \dot{\phi} + \dot{\varepsilon} + (\varepsilon - 1)\dot{Q} + \sum_{i=1}^{3} k_i \dot{W}_i + \dot{T}\ . \tag{8}$$

On the demand side, we assume that the demand function for Q in growth rate form is

$$\dot{Q} = \lambda + \eta(\dot{P} - \dot{D}) + \gamma\dot{Y}\ , \tag{9}$$

where λ is the demand time trend, η is the price elasticity of demand, D is a deflator, γ is the income elasticity of demand, Y is real income, and other terms are as previously defined.

Substituting for $\dot{P}$ from (8) into (9), solving for $\dot{Q}$ and inserting the result in (4), the decomposition of $TFPG$ under imperfect competition is

$$\begin{aligned} TFPG &= B\eta\dot{\phi} + B(\lambda + \gamma\dot{Y}) + B\eta\dot{\varepsilon} \\ &\quad + B\eta\left[\sum_{i=1}^{3} (k_i\dot{W}_i - \dot{D})\right] + \left(B\eta - \frac{1}{\theta}\right)\dot{T}\ , \end{aligned} \tag{10}$$

where $B = A/[1-\eta(\varepsilon-1)]$. Equation (10) is analogous to equation (4) but further decomposes the sources of productivity growth. It is the main equation of interest.

From (10), note that if an industry is competitive, productivity growth is entirely assigned to technical change as *A* (and thus *B*) becomes zero. Since *A* is always positive for imperfectly competitive industries, it is of particular interest to sign the almost omnipresent term $B = A/[1-\eta(\varepsilon-1)]$. More specifically, for diseconomies of scale $(\varepsilon > 1)$, $B > 0$ since $(\varepsilon < 1)\eta < 0$. For the case of economies of scale $(\varepsilon > 1)$, *B* will be negative if $(\varepsilon > 1) > 1/\eta$ and positive otherwise. This situation is more likely to occur under strong economies of scale $(\varepsilon << 1)$, with relatively high price elasticity of demand (large η). However, the latter is not likely to be the case for the food processing industries. Therefore, the most relevant case for the food processing industries is the one for which *B* is positive.

It is instructive to focus on the role of markups in TFPG, given by $B\eta\dot{\phi}$ on the right-hand side of equation (10). Since $\eta < 0$, increases in markups (when industries become less competitive over time) lead to lower TFPG for $B > 0$. More specifically, when markups increase and output is restricted relative to the competitive level, TFPG must decrease in the presence of diseconomies of size and increase in the presence of strong economies of size (with elastic demand).

Next, we focus on the role of demand growth in TFPG, given by $B(\lambda + \gamma\dot{Y})$ in equation (10). If $B > 0$, demand growth translates into productivity growth. Otherwise, a slowdown in demand leads to a lower rate of growth of total factor productivity, as found by Nadiri and Schankerman (1981). The third term, $B\eta\dot{\varepsilon}$, is changes in economies of scale. An increase in scale economies $(\dot{\varepsilon} < 0)$ results in an increase in $TFPG$ through output expansion if *B>0*. The last two terms in

[4] When economies (diseconomies) of scale are present, TFPG indicates the extent of efficiency gain (loss) if scale economies are exploited (sacrificed). When imperfect competition is also present, it must be netted out of the TFPG to minimize the measurement bias of scale economies and technical changes as the sources of productivity growth.

(10) account, respectively, for changes in factor prices and production technology.

4. Empirical Results

Recall that the decomposition of TFPG given in equation (10) requires information about markups $(\dot{\phi})$, demand structure (η, γ, and λ), and cost structure (ε, $\dot{\varepsilon}$, $\dot{T}$). These parameters were estimated with annual data at the 4-digit SIC level for 1973-92 using data from Barstelman and Gray (1996). The system of equations used consisted of a pricing equation, three input demand equations, and an output demand equation. Details on the econometric model and data used are presented in the Appendix.[5]

Table 1 summarizes the results for the estimated parameters used in the TFPG decomposition. With few exceptions, the price elasticities of demand (η) are found to be inelastic, in consistency with the findings of Bhuyan and Lopez (1997) and Pagoulatos and Sorensen (1986). The income elasticities (γ) indicate that processed foods are either necessities or, in some cases, inferior goods. Demand trend parameters (λ) show strong growth for chicken products (SIC 2015 in contrast to red meats in SIC 2011) and negative growth in canned specialties (SIC 2032). The negative growth in refined sugar (SIC 2062 and 2063) reflects health concerns and technological innovation in sweetener production (the introduction of high fructose corn sweeteners in the 1970s and 1980s). These results also show that most industries have moderate economies of size (ε) and that technological change $(\dot{T})$ has been generally positive in most industries.

As Table 1 indicates, all industries have positive markups, as the estimated term *A* (the Lerner index) is always positive. This finding underscores the need to measure TFPG beyond the traditional Solow's residual. It is also interesting to note that the term *B* is always positive. This is not surprising since output demands are inelastic and economies of scale are not especially strong in this sector (Lopez, Azzam, and Lirón-España, 2001).

Table 1 also shows the rates of growth of output $(\dot{Q})$ in these industries, showing a positive rate for most industries. The rates of growth are particularly strong in poultry (SIC 2015), vegetable oils (2075), soybean oils (2074), cheese (2022), and prepared meats (2013), all of which exceeded 4% growth per year between 1973 and 1992.

The parameters in Table 1 were used to decompose TFPG by sources of productivity growth. Table 2 presents these results for 29 food processing industries for the 1973-92 period as well as the average percentage contributions (unweighted and sales-weighted) for all industries in the sample analyzed. For the purpose of comparison, the last column in Table 2 presents TFPG calculated using the conventional accounting methodology considering 3 inputs: labor, capital and materials.

Table 2 shows that TFP grew on average by slightly over one-third of a percent annually across the U.S. food industries in the 1973-92 period. This figure is significantly smaller than the one obtained from the conventional methodology (cf. 0.601). Changes in markups, scale and productivity growth contributed positively to TFPG. Changes in factor prices and disembodied technical change contributed negatively to TFPG in this period. In order to focus on the relative importance of the different sources of productivity growth, the contributions are presented as percentage of the change in TFPG during the period for all industries.

The mean percentage contributions indicate that demand growth was the leading factor shaping TFPG in the food industries. On average, productivity grew by 0.413 percent per year due to demand growth. Reflecting the trends discussed from Table 1, the largest increase in demand-induced productivity occurred in poultry processing, cheese, cereal breakfasts, and soybean oils. On the other hand, we found decreases in demand-induced productivity in cane-sugar refining (SIC 2062), distilled liquor (2085), creamery butter (2021) fluid milk (2026), roasted coffee (2095) and meatpacking (2011).

The second largest factor contributing to positive productivity growth is changes in markups. These are particularly important in prepared feed (2048), manufactured ice (2097), distilled liquor (2085) and cookies and crackers (2052). The largest negative contributions were found in beet sugar as well as animal fats and oils. The third positive contributor to TFPG was economies of size, with a more modest although still important impact.

The most important negative contributor to TFP growth was the disembodied technical change. This finding should not be confused with the impact of technology solely on cost presented in Table 1 (which was on average positive). As presented in equation (11), the effect of technical change $\dot{T}$ is transmitted via

[5] Unlike the conventional methods, the decomposition method applied in this article requires information about the production process and the market for the output in question. This information was obtained by estimating the econometric model found in the Appendix, which includes a dual cost function framework to estimate economies of scale, a pricing equation to estimate mark ups, and an output demand function to estimate demand growth and related parameters.

economies of scale and the elasticity of demand. Changes in factor prices were found to contribute negatively in nearly half the industries (e.g., beet sugar (SIC 2063)), but their average contribution (unweighted or sales-weighted) is nearly neutral.

Finally, Table 2 also presents the unweighted and sales-weigthed percent contributions, taking the corresponding mean TFPG as 100%. Focusing on the weighted contributions, real factor prices contributed only modestly to TFPG in the period of study (approximately 0.8 percent). On the other hand, the acceleration in demand growth was an important factor (94.5 percent). Furthermore, another 75% of the growth is accounted for by markup and economies of scale changes.

On the other hand, the only factor that at the aggregate level was a negative contributor to TFPG is the disembodied technical change component. This counter cyclical role of technical change is consistent with the findings of Nadiri and Schankerman (1981), meaning that the residual technical change contribution accelerates when TFPG declines, while demand growth drives it up when TFPG increases.

5. Concluding Remarks

In contrast to previous work measuring total factor productivity in the U.S. food processing industries, this article decomposes total factor productivity growth, taking into account cost as well as demand factors in an oligopolistic market. Thus, it relaxes the assumptions of constant returns to scale and perfect competition used in conventional measures.

Using data from 29 food industries over the 1973-92 period, the competition, demand, and cost parameters are estimated via a NEIO model and are then used to compute TFPG with the Naidiri and Mamumeas (1998) model. Empirical results show that although changes in markups and economies of size increased productivity, demand growth was the most important source of TFP growth in the food industries. We do not address the reasons explaining the rates of demand growth across industries, but it is obvious that changes in consumer preferences over time play a key role. For instance, poultry processing experienced the largest gain in demand-induced productivity while meat packing experienced negative growth, reflecting health trends.

This article illustrates how TFPG studies that incorporate markup behavior can be enriched from progress made by the NEIO literature. Ultimately, the results indicate that ignoring the demand-push factors as well as economies of scale in the computation of TFPG can lead to gross biases in the calculation of productivity growth and misidentification of its sources.

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Table 1: Estimated Markups, Demand and Cost parameters at Mean Values, 1973-92

SIC	Industry	$\dot{\phi}$	η	γ	λ	ε	$\dot{\varepsilon}$	B	A	$\dot{T}$	$\dot{Q}$
2011	Meat packing plants	0.004	-0.243	0.030	-0.008	0.929	-0.006	0.107	0.104	0.002	0.001
2013	Saus. & Prep. Meats	0.001	-0.392	0.635	0.012	0.857	-0.012	0.251	0.231	-0.002	0.036
2015	Poultry slaugt Process	0.002	-0.089	0.533	0.048	1.027	0.004	0.056	0.057	-0.023	0.063
2021	Creamery Butter	0.003	-0.289	-0.939	0.012	0.969	0.000	0.008	0.009	-0.021	-0.022
2022	Cheese	0.000	-0.194	-0.509	0.049	1.003	0.000	0.091	0.061	-0.003	0.040
2023	Cond. & Evap. Milk	-0.018	-0.555	-0.823	0.041	0.967	-0.002	0.245	0.051	0.014	0.016
2024	Ice Cream	-0.010	-0.674	0.803	-0.007	0.836	-0.004	0.279	0.349	0.012	0.023
2026	Fluid Milk	0.006	-0.677	0.154	-0.014	0.562	-0.003	0.690	0.152	0.007	0.001
2032	Canned Specialties	-0.016	-0.777	0.777	-0.015	0.797	0.001	0.485	0.456	0.021	0.008
2034	Dried Fruit & Veg	-0.005	-0.318	-0.416	0.029	1.008	-0.001	0.201	0.189	-0.003	0.026
2035	Pickled, Sauces, etc.	-0.002	-0.957	-2.232	0.088	0.932	-0.003	0.327	0.273	0.011	0.030
2038	Frozen specialties	-0.003	-1.135	0.913	0.003	0.984	-0.002	0.226	0.189	0.010	0.027
2043	Cereal Breakfast Prep.	-0.017	-0.344	0.599	0.024	0.710	0.005	0.685	0.599	0.053	0.036
2048	Prepared Feeds	-0.006	-0.228	-0.942	0.038	0.860	-0.008	0.217	0.198	-0.005	0.018
2052	Cookies & Crackers	-0.034	-0.660	0.012	0.018	0.895	0.003	0.451	0.419	0.035	0.011
2061	2061 Cane Sugar	-0.012	-0.221	-0.412	0.018	0.849	-0.007	0.280	0.258	0.006	0.019
2062	2062 Cane Sugar Ref..	0.000	-0.006	-0.461	-0.035	0.960	0.001	0.076	0.093	0.006	-0.032
2063	2063 Beet Sugar	-0.015	-0.221	-0.412	0.181	0.798	-0.007	0.847	0.604	0.006	0.019
2064	Candy & Confect	0.006	-0.128	0.401	0.013	0.929	-0.003	0.665	0.303	0.014	0.024
2066	Chocolate & C. Pr.	0.010	-0.012	0.255	0.013	1.052	0.003	0.203	0.202	-0.037	0.019
2075	Soybean Oil Mills	0.001	-0.041	-0.186	0.042	0.935	-0.005	0.093	0.071	-0.018	0.039
2076	Vegetable Oil Mills	-0.001	-0.416	-2.199	0.049	0.855	-0.015	0.189	0.154	-0.008	0.158
2077	An./Mar. Fats & Oils	0.012	-0.248	1.006	-0.022	0.819	-0.008	0.281	0.240	-0.012	0.009
2082	Malt Beverages	0.001	-1.139	-0.491	0.025	0.951	-0.004	0.198	0.151	-0.017	0.033
2085	Distilled Liquor	-0.014	-1.699	0.820	-0.051	0.881	-0.001	0.550	0.426	0.001	-0.124
2095	Roasted Coffee	-0.002	-0.310	-0.397	0.003	0.731	-0.000	0.458	0.395	-0.041	-0.008
2097	Manuftured Ice	-0.022	-1.451	0.867	-0.015	0.914	0.007	0.235	0.209	0.009	-0.014
2098	Macaroni & Spaghetti	0.002	-0.561	-0.405	0.033	0.974	-0.003	0.323	0.298	0.004	0.028
2099	Food Preparations	-0.023	-0.686	-0.491	0.037	0.891	-0.001	0.378	0.343	0.015	0.028
	Mean Average	-0.005	-0.506	-0.121	0.021	0.892	-0.002	0.314	0.244	0.001	0.018
	Mean weighted average	-0.002	-0.433	-0.046	0.015	0.882	-0.003	0.278	0.229	0.000	0.017

Table 2: Decomposition of TFPG in the U.S. Food Processing Industries, 1973-1992

SIC	Industry	Markup	Demand	Scale	Fac. Prices	Tech Ch.	TFPG	Conv. TFPG
2011	Meat packing plants	-0.019	-0.078	0.026	0.041	-0.222	-0.253	0.133
2013	Saus. & Prep. Meats	-0.002	0.746	0.124	0.084	0.151	1.103	0.869
2015	Poultry slaugt. & Process	0.000	0.359	-0.001	-0.016	2.122	2.465	1.398
2021	Creamery Butter	-0.000	0.008	0.004	-0.004	2.098	2.088	0.644
2022	Cheese	0.000	0.316	-0.000	0.019	0.317	0.652	0.129
2023	Cond. & Evap. Milk	0.173	0.428	0.028	0.111	-1.253	-0.514	-0.313
2024	Ice Cream	0.187	0.421	0.968	-0.053	-1.305	-0.653	0.501
2026	Fluid Milk	0.241	-0.688	0.346	0.334	-0.974	-0.741	0.19
2032	Canned Specialties	0.446	0.335	0.141	-0.128	-2.323	-1.534	0.525
2034	Dried Fruit & Veg	0.033	0.361	0.005	-0.050	0.252	0.599	0.759
2035	Pickled, Sauces, etc.	0.180	0.871	0.052	0.053	-1.149	0.008	1.464
2038	Frozen specialties	0.072	0.639	0.071	0.142	-1.035	-0.110	0.236
2043	Cereal Breakfast Prep.	0.360	2.778	-0.123	0.362	-4.078	-1.424	-0.46
2048	Prepared Feeds	0.838	2.937	0.314	-0.402	-2.346	1.342	0.761
2052	Cookies & Crackers	0.957	0.836	-0.077	0.130	-3.280	-1.695	-0.894
2061	Cane Sugar	0.173	0.204	0.015	-0.454	-0.609	-0.671	0.755
2062	Cane Sugar Ref.	-0.000	-0.350	-0.000	-0.010	-0.603	-0.964	-0.861
2063	Beet Sugar	0.173	0.204	0.015	-0.454	-0.609	-0.671	0.755
2064	Candy & Confect	0.011	0.791	0.014	-0.152	-1.078	-0.277	1.018
2066	Chocolate & C. Pr.	-0.003	0.409	-0.001	-0.001	2.781	3.186	0.742
2075	Soybean Oil Mills	0.000	0.339	0.002	-0.132	1.719	2.047	1.559
2076	Vegetable Oil Mills	0.139	-0.123	0.114	-0.362	0.772	0.539	0.887
2077	An./Mar. Fats & Oils	-0.191	0.176	0.104	-0.005	1.219	1.303	1.528
2082	Malt Beverages	-0.029	0.229	0.974	-0.012	1.817	2.102	2.82
2085	Distilled Liquor	1.399	-1.616	0.151	-0.541	-0.134	-0.742	1.036
2095	Roasted Coffee	0.017	-0.340	0.090	-0.154	3.711	3.324	1.823
2097	Manufactured Ice	0.959	0.169	-0.293	-0.552	-1.088	-0.804	-1.388
2098	Macaroni & Spaghetti	-0.055	0.715	0.064	0.051	-0.320	0.455	0.500
2099	Food Preparations	0.556	0.894	0.024	-0.046	-1.512	-0.083	0.300
	Mean Average	0.228	0.413	0.109	-0.076	-0.240	0.348	0.601
	Weighted mean average	0.169	0.389	0.143	0.003	-0.214	0.411	0.632
	Percent Contr.	65.657	118.787	31.265	-21.829	-69.056	100.000	-
	Weighted Percent Contr.	41.126	94.567	34.896	0.824	-52.008	100.000	-

Appendix: The NEIO Model

This appendix supports the time-series estimation of parameters in Table 1, required for the decomposition of *TFPG* in equation (10). The starting point of the econometric model is an industry of *N* firms producing a homogeneous good *Q* requiring factors x_r for $r = 1, \ldots, k$ and facing a derived market demand curve

$$Q = f(p, z), \qquad \text{(A1)}$$

where *p* is output price and *z* is a vector of demand shifters. Profit maximization by the j[th] firm yields the supply relation

$$p = -\frac{s_j}{\delta}(1+\mu_j) + \frac{\partial C_j(q_j, \underline{w}, t)}{\partial q_j}, \qquad \text{(A2)}$$

where $s_j = q_j / Q$ is the j[th] firm's market share, $\delta = (dQ/dP)(1/Q)$ is the semi-elasticity of demand $(\delta < 0)$, $\mu_j = d\sum_{i \neq j}^{n} q_i / dq_j$ is the j[th] firm's conjectural variation, $C_j(.)$ is the cost function, $\underline{w}$ is a vector of factor prices, and t is the state of technology. By Shephard's Lemma, the derived demand for the r^{th} factor by the j[th] firm is given by

$$x_{rj} = \frac{\partial C_j(q_j, \underline{w}, t)}{\partial w_j} \quad \text{for } r = 1, 2, \ldots, k. \qquad \text{(A3)}$$

Following Olson and Shieh (1989) and Baffes and Vasavada (1989), the cost function is assumed to take the modified generalized Leontief form

$$C_j(q_j, \underline{w}) = q_j \sum_i \sum_j \alpha_{ij} w_i^{1/2} w_j^{1/2} + q_j t \sum_i \gamma_i w_i + q_j^2 \sum_i \beta w_i. \qquad \text{(A4)}$$

Multiplying through equations (A2) and (A3) by s_j, using (A4), and summing across the industry yields, respectively, the industry-wide analogue of the supply relation

$$p = -\frac{H(1+\Phi)}{\partial} + \sum_i \sum_j \alpha_{ij} w_i^{1/2} w_j^{1/2} + t \sum_i \gamma_i w_i + 2HQ \sum_i \beta_i w_i, \qquad \text{(A5)}$$

and factor demand

$$\frac{X_r}{Q} = \sum_i \sum_j \alpha_{ij} \left(\frac{w_j}{w_i}\right)^{1/2} + t\gamma_i + HQ\beta_i \qquad \text{(A6)}$$
$$\text{for } r = 1, 2, \ldots, k,$$

where $H = \sum_j s_j^2$ is the Herfindahl index, Φ is the industry (weighted) conjectural variation and $X_r = \sum_j x_{rj}$ is total industry employment of the r[th] factor. By virtue of the expression for the semi-elasticity of demand, the demand function (A1) takes the semi-logarithmic form

$$\ln Q = d_0 + \delta p + d_2 y + \lambda t, \qquad \text{(A7)}$$

where y is real income, t is a time trend, and d_0,, d_2 , and δ are parameters to be estimated.

The markup over marginal cost (ϕ) can be computed from equation (A5):

$$\phi = P / MC = P / (D + 2HQE), \qquad \text{(A8)}$$

where

$$D = \sum_i \sum_j \alpha_{ij} w_i^{1/2} w_j^{1/2} + t \sum_i \gamma_i w_i$$

and

$$E = \sum_i \beta_i w_i.$$

Other parameters of interest are the price elasticity of demand $(\eta = \delta P)$, the income elasticity $(\gamma = d_2 \cdot Y)$ and demand trend (λ).

A measure for economies of scale (ε) is given by the ratio of industry average cost to marginal cost (the inverse of economies of size):

$$\varepsilon = \frac{D + HQE}{D + 2HQE}, \qquad \text{(A9)}$$

where all notation is as defined above. Expression (A9) is computed for each year and then $\dot{\varepsilon}$ is simply computed as the yearly changes. Recalling the share-weighted industry cost (*C*), another cost parameter of interest is the change in industry cost over time $\left(\dot{T} = \sum \gamma_i W_i / C\right)$.

The model is operationalized with data at the 4-digit SIC (1987 definitions) level for the 1972-92 period. The model assumes three variable inputs: materials, labor, and capital. Thus, the estimating model consists of five equations: the pricing equation (A5), three input demand equations (A6), and the output demand equation (A7). The latter is assumed to be a function of output price, income and a trend variable with price and income deflated by the consumer price index.

The main data source for prices and quantities of outputs and inputs was the online National Bureau of Economic Research database of Bartelsman and Gray (1996) on U.S. manufacturing industries. Given the endogeneity of output quantity and the price of output, the system of five equations is estimated with non-linear 3SLS using the SHAZAM 7.0 software. For more details, refer to the working paper by Lopez, Azzam, and Lirón-España (2001).

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