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The grain milling industry has undergone substantial change during the past several decades in technical as well as industry structure. This study seeks to determine how industry performance, as reflected in productivity growth, has varied since the 1950's. Productivity growth is represented primarily by its dual rate, the percentage reduction in total cost induced by technical progress. Using an econometric approach, I estimate productivity growth rates, rates of substitutability among inputs, and factor biases of technological change. Each are estimated for the short run, where the capital input is held fixed, and for the long run, where all inputs adjust optimally.

I focus on five grain milling industries: flour milling, rice milling, pet foods, animal feeds, and bread baking. Results indicate the important role that capital has played in inducing productivity growth. For example, capital's shadow price has increased every year in every industry, implying the quality of capital has risen relative to that of labor and materials. Technical change has been capital-using and, especially in recent years, material-saving.

Technical Structure and Productivity Change in the U.S. Grain Milling Industries

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Technical Structure and Productivity Change in the U.S. Grain Milling Industries

Chapter 1: Introduction

The U.S. grain milling industries have experienced dramatic changes in competitive and technical structure during the past several decades, because of both internal and external forces. In the early 1970's, foreign demand for U.S. grain exports became unexpectedly high because of the decline in world grain production and continuous world economic growth. In order to meet this large world demand, U.S. grain millers expanded capacity during the late 1970's. In the early 1980's, however, world grain demand declined sharply due to a strengthening of the U.S. dollar, decreased demand in Eastern Europe, and increased supply in EC countries. Excess capacity was severe until the late 1980's and adjustment to this smaller foreign demand was widely urged. Following a brief world demand increase in the late 1980's, excess capacity has grown throughout the 1990's (Jones, 1998).

In the domestic market, per-capita consumption of grain has been increasing dramatically since the 1980's, driven by a steady increase in consumer concern for healthful eating, increases in demand for convenience food, and effort to introduce new products (Harwood et al., 1989).

The first hypothesis of this study is that rates of capacity utilization will reflect the above changes in domestic and foreign grain demand. Relatively high capacity utilization levels should be found in years of demand boom, and low capacity utilization levels in years of low demand.

Ownership of grain milling firms has been changing. Until the 1970's, grain milling industries were dominated by local firms, while after the 1970's, fewer and larger firms have become dominant (Harwood et al., 1989). This trend has come about because of economies of scale in capital markets, which favor larger firms; because of tax policy on capital; and because of relaxed enforcement of antitrust law (Marion and Kim, 1991). Large-scale investments, which were made especially in the 1970's and 1980's, provided new, larger machinery and buildings (Jones, 1998). Thus, not only the processing technology itself, but also the packaging and marketing system has become more capital intensive. My second hypothesis, then, is that there is a positive relationship between capital intensity and short-run productivity growth. That is, if firms invest more in machinery and computers, labor and materials will become more productive. Also, greater capital intensity affects optimal combinations of inputs, and we will observe this effect in changes in input demand elasticities.

Because of fixed and indivisible capital inputs, larger firms have an advantage over smaller firms, and for this reason smaller firms generally have been forced out of business. On account of this trend and the relaxed enforcement of antitrust laws in the 1980's, the milling industries have become increasingly concentrated; that is, firm market power has grown. The net effect of increasing concentration and market power on productivity growth is ambiguous. It may contribute positively to productivity growth through greater efficiency in resource allocation or in greater scale economies; but it may affect productivity growth negatively through the resource misallocation known as x-inefficiency, resulting in substantial social welfare loss. The net effect will depend on the causes of the market share concentration and on the portion of the average total cost curve on which most firms are operating.

Scale economy is an important indicator of an industry's health. Increases in firm size lead firms to a more efficient point on the average total cost curve only if the firms are operating on the increasing-returns-to-scale portion of the curve. However, scale economies are affected not only by size of firm but by capital intensity. Greater capital intensity increases fixed cost relative to total cost, making the average total cost curve steeper than before; that is, scale economies increase.

Productivity growth rates may also reflect the macro-economic health of the nation. In the years of recession such as in the middle 1970's, early 1980's, and early 1990s, rates of growth in productivity probably remained low, while in years of economic boom, the reverse was likely the case. These, again, are hypotheses, which I test below.

In the following chapters, I provide a profile of the grain milling industries, then develop a conceptual framework which I employ to estimate productivity growth rates. I proceed to develop the econometric model, discuss the data, and present the econometric results. Finally, I discuss the principal conclusions and policy implications.

Chapter 2: Profile of Grain Milling Industry and Previous Studies

The grain milling industry has seen considerable changes in the past several decades, and current industry structure is quite different from that before 1970. As a result, industry performance, in terms of shipment value, has been improving over the study period. This dramatic change has drawn attention of many researchers and policy makers.

2. 1. Grain Milling Industry

In this thesis, my attention will be paid specifically to five industries; flour milling (SIC2041), rice milling (SIC2044), pet food (SIC2047), animal feeds (SIC2048), and bread baking (SIC2051). Note that SIC stands for standard industrial classification and categorizes industries based on definitions given by the Department of Commerce.

2. 1. 1. Characteristics of Grain Milling Industry

In table 2. 1. 1, various data on the grain milling industry are presented. The bread baking industry is the largest industry among these five in terms of number of establishments, number of employees, and value of shipment, while the rice milling industry is the smallest. Concentration ratios and Herfindahl-Hirschmann indexes indicate that flour milling, rice milling, and pet food are more concentrated than the other two, animal feeds and bread baking.

Table 2. 1. 1: Data on the U.S. Grain Milling Industry, 1992

Industry	Number of Establishments	Number of Employees (thousand)	Value of Shipments (billion dollars)	Top-four Concentration Ratio	Herfindahl-Hirschmann Index
Flour Milling (SIC2041)	230	13.1	6.3	56	972
Rice Milling (SIC2044)	44	3.9	1.7	50	881
Pet Food (SIC2047)	102	13.8	7.0	58	1229
Animal Feeds (SIC2048)	1160	35.5	14.4	23	203
Bread Bakery (SIC2051)	2180	155.1	18.1	34	396

Source: Department of Commerce, Census of Manufactures

2. 1. 2. Definition and Summary of Each Industry

2. 1. 2. 1) Flour Milling Industry (SIC2041)

This industry includes not only flour but also includes meal from all grains except rice. These are major inputs for other industries such as breakfast and bakery products (U.S. Department of Commerce). Both domestic and export demands contribute to industry growth. Domestic consumption has grown continuously since the mid-1970's. The possible factor is that consumers have become increasingly concerned with their diets and health, and have followed the recommendations of the American Heart Association and National Cancer Institute saying that fiber, bran, and whole grains may prevent cancer. Another factor is the greater variety in flour-based products, such as bagels, English muffins, and pita bread. Also, consumers have a growing preference for more prepared and convenient foods such as sandwiches, pizzas, and tortillas, mainly because of changes in labor force composition; in particular, the increasing number of women in the work force (Urisko, 1977, Harwood et al., 1989, Harwood, 1991a).

Although much smaller than domestic consumption, export demand plays an important role in maintaining millers' grind level and profit. Government programs, including Public Law (P.L.) 480, Commodity Credit Corporation (CCC), and the Export Enhancement Program (EEP), are instruments that encourage U.S. flour exports. P.L.480, the most important program, accounts for 40 to 90 % of total flour exports. The main purposes of this program are to supply food aid to developing nations and to encourage economic development, and to promote U.S. exports (Harwood et al., 1989).

Increasing concentration in the flour milling industry is a controversial issue. In order to meet increasing demand, the industry has increased its capacity by expanding the average plant size instead of increasing the number of firms. Mergers and consolidations have taken place since the late 1970's, and smaller firms have been acquired or have exited the business. Because of this, the market share of the top four firms has risen substantially, from 34% in 1974 to nearly 70% in 1992. Average plant capacity has doubled, while the number of plants has decreased from 280 to 204 during the same time (Wilson, 1998).

Based on the Herfindahl Index (HHI), Marion and Kim (1991) concluded that at least one of the mergers in the flour milling industry violated the merger guidelines of the Department of Justice.

2. 1. 2. 2) Bread Baking Industry (SIC2051)

This industry includes bread and cake products. They are characterized as perishable products as distinguished from cookies and crackers, which have relatively longer shelf life (SIC2052) (U.S. Department of Commerce). The bread baking industry is a major user of flour; it consumed about 72% of total U.S. flour in 1987. The variety of bakery products has become larger since the late 1980's. Over a thousand of new items were introduced in 1989 (Harwood et al., 1989). Wholesalers are dominant producers in the bread industry; their sales account for 56% of the total. Because introducing new items is costly, wholesalers who generally have substantial resources have an advantage over smaller bakeries such as retailers and in-store bakeries. However, wholesalers must confront the smaller bakeries' ability to offer higher quality and fresher products such as "specialty breads." On balance, then, industry remains highly competitive. In addition, the bread industry must face environmental concerns. In the process of baking, smog-producing ethyl alcohol is released from ovens, and installation of smog control equipment is expensive (Harwood, 1991b).

2. 1. 2. 3) Animal Feeds (SIC2048) and Pet Food Industry (SIC2047)

The animal feeds industry produces prepared feeds for poultry and livestock. Its products are made from feed grains such as corn, sorghum, oats, and wheat (U.S. Department of Commerce). The size of firm in this industry ranges from large nationwide firms to small, local feed firms (Kimle and Hayenga. 1993). Although the market share of the top largest firms is not very high, concentration has been increasing since the 1980's through mergers and acquisitions. Larger firms take advantage of their substantial resources, developing new products and diversifying into products such as human and animal medicine (Houston, 1998). However, smaller firms also have an advantage. On-farm feed mixing has become popular in the past two decades compared to easy commercial feeds. This trend is supported by the change in consumers' preference, as they switch from beef and pork consumption to poultry consumption. The declining demand for feeds from livestock operators, unfortunately, has not been replaced by the feed demand from poultry producers. Instead, demand for on-farm feeds has increased (Kimle and Hayenga. 1993).

The emerging issues in this industry are health and the environment. The increasing use of growth promotants and additives has been publicly questioned. And, because legislation has raised liability questions, labeling requirements haveincreased, requiring additional expenses (Houston, 1998).

The pet food industry produces canned, frozen, or dry foods made of grains, millfeed, and meat or fish byproducts (U.S. Department of Commerce). This industry has experienced a steady increase in demand associated with an increasing number of pets, especially cats, since 1980. The reason behind this increase is demographic change such as smaller family sizes, insecurity arising from increased social pressure, and a greater awareness of ecology. The rate of increase in the number of cats has been greater than that of dogs during the last two decades. The pet food industry faces a large potential export demand, the largest importing country being Canada, followed by Japan, Mexico, and the EU countries. Increases in pet owner income and being more knowledgeable about nutrition may shift demand to higher premium pet food (Hoepker, 1999).

2. 1. 2. 4) Rice Milling Industry (SIC2044)

Flour and grain mill products from rice are categorized in this industry, including brown rice, rice polish, and rice bran (U.S. Department of Commerce).

The rice milling industry, one of the most dynamic in the U.S has experienced substantial re-structuring since the 1970's. Historically, this industry has been supported and controlled by government programs. In the 1970's, the elimination of acreage controls and increasing export demand encouraged the industry to expand milling capacity. In 1985, the number of mills increased to 66 from the 40 in 1972 (Setia et al., 1994). In intervening years, the rice milling industry depended heavily on exports. The sudden decline in exports in the late 1980's resulted in excess capacity including non-operating facilities and machinery raised average costs, and lowered industry profitability. In the late 1980's and early 1990's, mills which were not well established in the domestic market or which failed to shift to domestic demand were forced out of business. The number of mills declined to 54 in 1992 (Setia et al., 1994). Although, some mills are small, they produce high-valued rices such as aromatic or specialty brown types, which enjoy relatively high price and growing market demand (Setia et al., 1994).

The rice milling industry is fairly concentrated. The concentration ratio of the top four firms was 50% in 1989. However, Wailes and Gauthier (1998) concluded that this industry remains competitive, both in the domestic and export market because government exerts less control over industry, and it leads to efficiency gain.

2. 2. Literature Review

2. 2. 1. Productivity Studies in the Food Manufacturing Industry

2. 2. 1. 1) Labor Productivity Growth

Partial factor productivity measures, especially labor productivity, are widely published in the food processing industry (SIC 20) and are even available at the 4-digit SIC level for some industries. They are presented in Table 2. 1. All industries during the 1988-1996 period displayed positive growth rates except in several meat product sub-sectors (SIC 201), dairy (SIC 202), grain mill products (SIC 204), and fresh or frozen prepared fish (SIC 2092). Unfortunately, partial productivity does not represent the contribution of the given specific factor, in this case labor, only but instead the joint effects of other elements such as material use, technological advances, capital investment per worker, capacity utilization, and managerial skills. (Bureau of Labor Statistics, 1998.)

Table 2. 2. 1: Average Annual Labor Productivity Growth[1] in the U.S. Food Processing Sector (%)

SIC	Industry	Period	Rate (%)
2011	Meat packing plants	1968-1987	3.11
		1988-1996	-0.47
2013	Sausages and other prepared meats	1968-1987	1.6
		1988-1996	-0.19
2015	Poultry slaughtering and processing	1964-1987	2.61
		1988-1996	2.11
2022	Cheese, natural and processed	1973-1987	2.35
		1988-1996	1.91
2023	Dry, condensed, and evaporated dairy products	1988-1996	-0.7
2024	Ice cream and frozen desserts	1988-1996	3.38
2026	Fluid milk	1959-1987	4.61
		1988-1996	1.34
2032	Canned specialties	1988-1996	2.58
2033	Canned fruits and vegetables	1959-1987	3.35
		1988-1996	0.64
2037	Frozen fruits and vegetables	1973-1987	2.23
		1988-1996	2.52
2038	Frozen specialties, n.e.c.	1988-1996	0.44
2041	Flour and other grain mill products	1948-1987	3.12
		1988-1996	2.63
2043	Cereal breakfast foods	1964-1987	2.55
		1988-1996	-1.41
2045	Prepared flour mixes and doughs	1988-1996	1.73
2047	Dog and cat food	1988-1996	-2.49
2048	Prepared feeds, n.e.c.	1988-1996	2.03
2051	Bread, cake, and related products	1988-1996	-1.73
2064	Candy and other confectionery products	1988-1996	1.73
2066	Chocolate and cocoa products	1988-1996	0.24
2082	Malt beverages	1948-1987	5.72
		1988-1996	1.9
2084	Wines, brandy, and brandy spirits	1988-1996	1.34
2086	Bottled and canned soft drinks	1959-1987	3.66
		1988-1996	5.6
2087	Flavoring extracts and syrups, n.e.c.	1988-1996	0.32
2092	Fresh or frozen prepared fish	1973-1987	0.25
		1988-1996	-2.02
2096	Potato chips and similar snacks	1988-1996	5.02
2099	Food preparations, n.e.c.	1988-1996	0.08

Source: U.S. Department of Labor, Bureau of Labor Statistics
Office of Productivity and Technology
(ftp://ftp.bls.bov/pub/special.requests/opt/dipts/oaeh4drt.txt)

1. The index of output over labor hours expended in producing that output.

2. 2. 1. 2) Total Factor Productivity

Heien (1983) applied Theil-Tornqvist indexes to measure the total factor productivity growth in the U.S. food processing and distribution sector during the 1950-1977 period. Sub-period 1950-1972 exhibited increases in productivity, whereas 1973-1977 exhibited decreases. The major cause of this decrease was substantial increases in energy cost.

2. 2. 2. Industry Structure

While some of the literature has focused on productivity, many researchers have been interested in the study of industrial structure, input substitutability, and market power in the food manufacturing sector.

Both Huang (1991) and Goodwin and Brester (1995) have shown that substitutability among inputs, especially between labor and capital, in food manufacturing is high, reflecting continuously increasing labor-to-capital price ratios and the introduction of new technology in the 1980's. Huang confirmed that capital demand is more elastic than is the demand for labor and energy.

Bhuyan and Lopez (1997) have reported Lerner indexes as measures of market power, and corresponding demand and scale elasticities, in food manufacturing industries at the 4-digit level. In order to compare their results with my own, I present the Bhuyan - Lopez output in my Results chapter below. However, in summary, these two researchers found that flour milling firms (SIC2041) have exercised fairly high levels of oligopoly power, while rice (SIC2044) and pet food (SIC2047) firms have shown lower levels.

Chapter 3: Conceptual Framework

Production theory permits at least two different approaches to productivity measurement: partial factor productivity and total factor productivity (TFP). Partial factor productivity is the index of total output divided by the change in a given input expended in producing that output. In contrast, total factor productivity is the index of aggregate output over an index of aggregate input.

3. 1. Total Factor Productivity

In recent research, the total factor productivity measure has more frequently been used because of the limitations of partial productivity measures. We will measure productivity changes based on total factor productivity (TFP), which can be represented by the primal measure derived from the production function or the dual measure calculated from the cost function. TFP is more accurate than a partial measure and allows us to distinguish between the three separate factors constituting productivity growth: technical efficiency, scale efficiency, and the state of technology.

3. 1. 1. Productivity Growth Measurement

In empirical research at the aggregate level, we assume single-output production. Suppose an industry faces a production function $Y = F(X, t)$ and corresponding dual cost function $C = g(Y, W, t)$, where Y is output, X is an input vector, W is the corresponding input price vector, and t represents time, which is a proxy for the state of technology. Both primal and dual productivity measures can be obtained in elasticity form.

3. 1. 1. 1) Primal Productivity Measurement

Taking the natural logarithm of the production function and differentiating both sides with respect to time gives the primal productivity measure. If production is efficient (Antle and Capalbo, 1988, p.35),

$$\frac{d\ln Y}{dt}=\frac{1}{Y}\left[\frac{\partial F}{\partial t}+\sum_i \frac{\partial Fi}{\partial Xi}\frac{dXi}{dt}\right] \tag{3.1}$$

Re-arranging this equation, we get the primal measure

$$\varepsilon_{Yt}=\frac{\partial\ln F}{\partial t}=\frac{d\ln Y}{dt}-\frac{1}{Y}\left[\sum_i \frac{\partial Fi}{\partial Xi}\frac{dXi}{dt}\right] \tag{3.2}$$

where $\frac{\partial F}{\partial Xi}$ is the marginal product of X_i.

If this industry is in competitive equilibrium, output price is equal to marginal cost (P = MC) and input prices are equal to the marginal products of the respective inputs ($W_i = P^* \partial F/\partial X_i$). Equation (3.2) can be rewritten as:

$$\varepsilon_{Yt}=\frac{d\ln Y}{dt}-\sum_{i=1}^{n} S_i\frac{d\ln X_i}{dt} \tag{3.3}$$

where $S_i \equiv \frac{W_iX_i}{\sum_i W_iX_i}$ is the factor cost share.

If we relax the constant returns to scale assumption, equation (3.3) can be rewritten further as:

$$\varepsilon_{Yt} = \frac{d\ln Y}{dt} - \left(\frac{\partial \ln C}{\partial \ln Y}\right)^{-1} \sum_{i=1}^{n} S_i \frac{d\ln X_i}{dt} \qquad (3.4)$$

where $\frac{\partial \ln C}{\partial \ln Y} = \varepsilon_{CY}$ is the elasticity of marginal cost and can be interpreted as a returns to scale measure. This expression says the primal measure is the rate of change in output minus a scale-adjusted index of the rate of change in inputs (Antle and Capalbo, 1988 p. 35).

3. 1. 1. 2) Dual Productivity Measurement

Recall the corresponding dual cost function

C = g (Y, W, t).

Again, by taking the natural log and differentiating with respect to time, we have the rate of change in total cost

$$\frac{d\ln C}{dt} = \frac{1}{C}\left[\frac{\partial g}{\partial t} + \sum_i \frac{\partial g}{\partial W_i}\frac{dW_i}{dt} + \frac{\partial g}{\partial Y}\frac{dY}{dt}\right]$$

(3.5)

Re-arranging the equation, we get the dual measure of productivity growth

$$\varepsilon_{Ct} = \frac{\partial \ln g}{\partial t} = \frac{d\ln C}{dt} - \sum_i \frac{\partial \ln g}{\partial \ln W_i}\frac{d\ln W_i}{dt} - \frac{\partial \ln g}{\partial Y}\frac{dY}{dt} \qquad (3.6)$$

Using Shephard's lemma, the cost minimizing input level is $X_i = \frac{\partial \ln C}{\partial \ln W_i}\frac{C}{W_i}$. Therefore, $\frac{W_i X_i}{C} = \frac{\partial \ln C}{\partial \ln W_i}$. Under the assumption of perfect competition in input markets, equation (3.6) becomes

$$\varepsilon_{Ct} = \frac{d\ln C}{dt} - \sum_i \frac{W_iX_i}{C}\frac{d\ln W_i}{dt} - \frac{\partial \ln g}{\partial Y}\frac{dY}{dt} \tag{3.7}$$

Substituting $\varepsilon_{CY} = \frac{\partial C}{\partial Y}\frac{Y}{C}$ into (3.7) gives us

$$\varepsilon_{Ct} = \frac{d\ln C}{dt} - \sum_i \frac{W_iX_i}{C}\frac{d\ln W_i}{dt} - \varepsilon_{CY}\frac{dY}{dt} \tag{3.8}$$

The dual rate of technological change is the rate of change in total cost minus an index of the rate of change in factor prices minus a scale effect (Antle and Capalbo, 1988, p. 36). Note that under constant returns to scale (CRTS), $\varepsilon_{CY} = 1$.

3. 1. 2. Primal and Dual Measure

The relationship between the primal and dual measure can be found by totally differentiating $C = \sum W_iX_i$ with respect to time and combining equations (3.4) and (3.8):

$$-\frac{d\ln C}{dt} = \frac{d\ln C}{d\ln Y}\frac{d\ln F}{dt} \tag{3.9}$$

or $-\varepsilon_{Ct} = \varepsilon_{CY}\varepsilon_{Yt}$

If and only if $\frac{d\ln C}{d\ln Y} = 1$, which means the technology exhibits constant returns to scale, the primal measure and negative of the dual measure of technological change are equivalent (Antle and Capalbo, 1988, p.36).

3. 2. Approaches to TFP measurement

3. 2. 1. Growth Accounting Approach

The underlying basic concept of this approach to total factor productivity measurement is the "residual." In the presence of technological advance, there is a "residual" in total output which could not be captured by the change in total input and that can be explained by productivity growth.

The TFP index can be calculated by aggregating the input and output indexes. In the process of aggregation, the choice of method is important because it implies underlying technology and economic assumptions. Laspeyres and Paasche indexing procedures are equivalent to either a linear production function, implying perfect substitutability among inputs, or a Leontief production function, implying that inputs are used in fixed proportions. The Geometric index implies a Cobb-Douglas production function, and the Tornqvist-Theil and Divisia indexes imply a homogeneous translog production function.

The growth accounting approach is useful for small samples because it has no degree-of-freedom or statistical reliability problems. However, the disadvantage of this approach is that these indexing methods require strong assumptions such as constant returns to scale, long-run competitive industry equilibrium, and Hicks neutral technological change. And because growth accounting is not based on statistical theory, we are unable to statistically evaluate the reliability of the calculations (Antle and Capalbo, 1988, p.50).

3. 2. 2. Econometric Approach

The econometric approach requires econometric estimation of the production technology, which can be measured by the primal production function or the corresponding dual cost or profit function. Utilizing duality theory, flexible functional forms, and econometric theory enables us to estimate productivity growth more efficiently.

The significant advantage is that we can relax some of the strong assumptions which are assumed in the growth accounting approach. Also, adopting flexible functional forms allows us to test or impose the theoretical properties such as linear homogeneity in prices, monotonicity, and curvature (Antle and Capalbo, 1988, p.57).

3. 3. Short-Run Equilibrium

Traditionally, productivity analysts assumed that all the inputs are instantaneously adjustable, and ignored the constraints which firms may face in the short run. The short-run response of a firm is different from that in the long run, which allows full adjustment. The distinction between subequilibrium (short-run) and full equilibrium (long-run) has not been clearly stated empirically except in Morrison (Morrison, 1986).

In order to be more realistic, we follow Morrison's approach, and distinguish short-run and long-run equilibrium. So, we need to recognize some inputs are not adjustable in the short run, i.e., quasi-fixed, and that all the inputs are adjustable in the long run. In this study, I assume that only the capital input is quasi-fixed in short run.

We specify the short-run total cost function as:

$$C = VC\ (W_i,\ Y,\ t,\ K)\ + FC \qquad (3.10)$$

where W_i is the *i*th variable input price. Equation (3.10) consists of variable cost and fixed cost. Note that variable cost depends on the level of capital, but not on the price of capital in the short run.

3. 3. 1. Shadow Value

Here we introduce the shadow value concept, which is necessary in the short run. The shadow value of the quasi-fixed input in this study capital and hereafter denoted Z_k, is the value to the firm of having one additional unit of capital in terms of the reduction in variable cost which produce the given level of output, i.e., opportunity cost (Morrison, 1992). And it has been shown by Lau (1976) that the negative of the derivative of variable cost with respect to capital is the shadow price, $-\partial VC/\partial K = Z_k$. In order to utilize the shadow value concept, we need two total cost functions. One, calculated at shadow value of capital instead of market price of capital and denoted as C^Z, is

$$C^Z = VC + Z_K K \qquad (3.11)$$

The other one is evaluated at market price of capital because in the long run the firm adjusts the capital level until its shadow value equals the market price, $Z_k = P_k$. Thus, in the long run, the total cost function is defined as

$$C^P = VC + P_k K \qquad (3.12)$$

and C^Z and C^P are identical in the long run. Therefore, the deviation of market price from shadow price is caused by the fixed nature of capital in the short run and indicates the magnitude of disequilibrium.

3. 3. 2. Capacity Utilization Measurement

Utilizing the shadow value concept, we are able to derive a capacity utilization measurement (CU). CU is an important indicator representing the relationship between short-run and long-run equilibrium and implying cyclical fluctuations. From the definition of long-run equilibrium ($Z_k = P_k$), CU is required to be unity in the long run, while CU can vary in the short run depending on the difference between these prices ($Z_k \neq P_k$). CU represents the deviation of short-run from long-run equilibrium. Specifically, the deviation of CU from unity can be interpreted as the degree of departure from equilibrium (Morrison, 1985b). CU can be computed as

$$CU = \frac{C^Z}{C^P} = \frac{VC + Z_k K}{VC + P_k K} \qquad (3.13)$$

If CU > 1, the shadow value of capital is greater than the market price, which shows that capital is overvalued relative to its market price, namely that capital is overutilized. This indicates there is an investment incentive and firms will operate more efficiently by expanding the capital level.

On the other hand, if CU < 1, $Z_k < P_k$, representing underutilization of capital. Here, there is an incentive to disinvest (Morrison, 1990). Note we are assuming static expectations in this analysis.

It is shown that CU also can be found from the derivative of the cost elasticity with respect to capital (Morrison, 1985b). The cost elasticity of capital is given by:

$$\varepsilon_{CK} = \frac{\partial \ln C^P}{\partial \ln K} = \frac{K}{C^P}\frac{\partial(VC + P_k K)}{\partial K} = \frac{(P_k - Z_k)K}{C^P} \tag{3.14}$$

Combining (3.14) with the CU measure, equation (3.13), yields

$$\begin{aligned} CU &= \frac{C^Z}{C^P} = \frac{VC + Z_k K}{VC + P_k K} = \frac{C^P - P_k K + Z_k K}{C^P} \\ &= 1 - \frac{K(P_k + \partial VC / \partial K)}{C^P} = 1 - \varepsilon_{CK} \end{aligned} \tag{3.15}$$

Chapter 4: Econometric Model and Other Computations

4. 1. Econometric Model

A system of equations which includes a variable cost function, the derived input demand functions, an equation for the shadow price of capital, the output supply equation, and an output demand equation is estimated simultaneously in this study by three stage least squares, using the SAS statistical package.

4. 1. 1. Variable Cost Function

I employ the Generalized Leontief (GL) form of a cost function to represent the grain milling industry technology. I distinguish short-run equilibrium (subequilibrium) and long-run equilibrium (full equilibrium) by recognizing the quasi-fixed nature of some inputs implying that we do not assume the instantaneous adjustment of these quasi-fixed inputs. I will assume that capital is the only quasi-fixed input. The most attractive feature of the GL functional form is that it gives us the closed-form solution for the optimal level of quasi-fixed input. With other flexible functional forms, such as translog function, it is difficult to do this.

If the variable inputs are labor and materials, the variable cost function can be written as

$$VC = VC\ (W_l, W_m, Y, K, t)$$

where W_l and W_m are input prices of labor and material respectively, Y is output, K is capital quantity, and t is time, representing technology. More specifically, form of the GL used for cost function will be (Morrison, 1988).

$$\begin{aligned} VC = Y\ [&(\alpha_{LL} W_l + 2\alpha_{LM} W_l{}^{0.5} + \alpha_{MM} W_m) \\ &+(\beta_{LY} W_l Y^{0.5} + \beta_{Lt} Wlt^{0.5} + \beta_{MY} W_m Y^{0.5} + \beta_{Mt} W_{mt}{}^{0.5}) \\ &+(\gamma_{YY} Y + 2\gamma_{Yt} Y^{0.5} t^{0.5} + \gamma_{tt} t)\ (W_l + W_m)] \\ &+Y^{0.5} K^{0.5}\ [(\beta_{LK} W_l + \beta_{MK} W_m) + (\gamma_{YK} Y^{0.5} + \gamma_{tK} t^{0.5})\ (W_l + W_m)] \\ &+\gamma_{KK} K\ (W_l + W_m) \end{aligned} \tag{4.1}$$

4. 1. 2. Input Demand Equation

Shepherd's lemma allows us easily to find an input demand equations by taking the derivative of the above variable cost equation with respect to the corresponding input prices. Thus, the labor and material demand equations are

$$\begin{aligned} L = \partial VC/\partial W_l = Y\ [&(\alpha_{LL} + \alpha_{LM} W_l^{-0.5} W_m{}^{0.5}) + (\beta_{LY} Y^{0.5} + \beta_{Lt} t^{0.5}) \\ &+(\gamma_{YY} Y + 2\ \gamma_{Yt} Y^{0.5} t^{0.5} + \gamma_{tt} t)] \\ &+Y^{0.5} K^{0.5}\ [\beta_{LK} + (\gamma_{YK} Y^{0.5} + \gamma_{tK} t^{0.5})] \\ &+\gamma_{KK} K \end{aligned} \tag{4.2}$$

$$\begin{aligned} M = \partial VC/\partial W_m = Y\ [&(\alpha_{MM} + \alpha_{LM} W_m^{-0.5} W_l{}^{0.5}) + (\beta_{MY} Y^{0.5} + \beta_{Mt} t^{0.5}) \\ &+(\gamma_{YY} Y + 2\ \gamma_{Yt} Y^{0.5} t^{0.5} + \gamma_{tt} t)] \\ &+Y^{0.5} K^{0.5}\ [\beta_{MK} + (\gamma_{YK} Y^{0.5} + \gamma_{tK} t^{0.5})] \\ &+\gamma_{KK} K \end{aligned} \tag{4.3}$$

4. 1. 3. Shadow Price of Capital Equation

In the single quasi-fixed input case, and under the assumptions of constant returns to scale in the long run and perfect competition, the return to the firm can be attributed to the fixed input after payments to all the variable inputs are made (Morrison, 1988). Thus, the unit return to the fixed input is its shadow price and it can be expressed as $\frac{PY-VC}{K}$. As we discussed above, the shadow price is also the negative of the derivative of the variable cost function with respect to the quantity of capital, K. Hence,

$$\begin{aligned} \frac{PY-VC}{K} = Z_k = -\frac{dVC}{dK} = \; & -0.5Y^{0.5}K^{-0.5}[(\beta_{LK}W_l + \beta_{MK}W_m) \\ & + (\gamma_{YK}Y^{0.5} + \gamma_{tK}t^{0.5})(W_l + W_m)] \\ & -\gamma_{KK}(W_l + W_m) \qquad (4.4) \end{aligned}$$

where PY means price times quantity, namely total value of shipments.

4. 1. 4. Output Demand Equation

The output demand function used here is in linear form.

$$P = \alpha_0 + \alpha_1 Y + \alpha_2 DPI + \alpha_3 t \qquad (4.5)$$

where DPI represents disposable personal income and t is a time trend representing consumer preferences. The own-price elasticity of demand is then

$$\varepsilon_{YP} = \frac{dY}{dP}\frac{P}{Y} = \frac{1}{a_1}\frac{P}{Y} \qquad (4.6)$$

4. 1. 5. Output Supply Relation

Degree of competitiveness represented by the market power measure is an important indicator of industry structure. Utilizing output demand equation (4.5), we are able to estimate the market power of each industry. Following the New Industrial Organization approach, the profit maximization condition for a representative firm is given as (Appelbaum, 1982):

$$MC = P\left[1 + \frac{\theta^j}{\varepsilon_{YP}}\right] \qquad (4.7)$$

where $\theta^j = \frac{\partial Y}{\partial Y^j}\frac{\partial Y^j}{Y}$ is the conjectural elasticity of the representative firm j, and in equilibrium, $\theta^j = \theta$ for all firms. Following Park and Kwon (1994), profit maximization condition is MC = MR. Combining equations (4.6) and (4.7) give us:

$$\begin{aligned} P &= MC - \frac{\theta\alpha_1 Y}{P} \\ MC &= P\left(1 + \frac{\theta\alpha_1 Y}{P}\right) = P + \theta\alpha_1 Y \\ MC - \theta\alpha_1 Y &= P \end{aligned} \qquad (4.8)$$

Therefore, the entire output supply relation becomes

$$\begin{aligned} P = {} & [(\alpha_{LL}W_l + 2\,\alpha_{LM}W_l^{\,0.5}\,Wm^{\,0.5} + \alpha_{MM}W_m) \\ & + (\beta_{Lt}\,W_l\,t^{\,0.5} + \beta_{Mt}W_m t^{\,0.5}) + (\gamma_{tt}\,t\,)(W_l + W_m) + (\gamma_{YK}K^{\,0.5})(W_l + W_m)] \\ & + 0.5Y^{-0.5}K^{\,0.5}[(\beta_{LK}W_l + \beta_{MK}W_m) + (\gamma_{tK}t^{\,0.5})(W_l + W_m)] \\ & + 1.5Y^{\,0.5}[(\,\beta_{LY}W_l + \beta_{MY}W_m) + (\gamma_{Yt}t^{\,0.5})(W_l + W_m)] \\ & + 2Y[\gamma_{YY}(W_l + W_m)] \\ & - \theta\alpha_1 Y \end{aligned} \qquad (4.9)$$

Equation (4.1), (4.2), (4.3), (4.4), (4.5), and (4.9) will be estimated simultaneously with three-stage least squares.

4. 2. Long-Run Equilibrium

In the long run, all variables are adjustable and the equilibrium is optimal. This implies that the shadow price of capital and market rental price of capital are equivalent. Thus, we are able to derive the optimal level of capital (K*) by equating Z_k in shadow price of capital equation and market rental price of capital (P_k) and solving for K. The GL variable cost function gives us the closed-form solution for the optimal level of the quasi-fixed input, and the equation is

$$K^* = \left\{ \frac{0.5Y^{0.5}\left[\left(\beta_{LK}W_l + \beta_{MK}W_m\right) + \left(\gamma_{YK}Y^{0.5} + \gamma_{tK}t^{0.5}\right)\left(W_l + W_m\right)\right]}{-P_k - \gamma_{KK}\left(W_l + W_m\right)} \right\}^2 \qquad (4.10)$$

K* is homogeneous of degree zero in variable input prices. There are two restrictions on this equation to be rational. In order for the own price elasticity of capital to be always negative in the long run γ_{KK} is required to be positive. If $\gamma_{KK} > 0$, the curvature conditions on K with respect to its price, P_k, will be satisfied, implying that stock of capital decreases as price of capital increases. We can test this restriction by checking signs of second derivatives for each sample year, that is $\partial^2 VC / \partial P_k^2 > 0$. The second restriction is that the variable inputs and fixed input are not complement, they may be substitutes in the short run. So the convexity conditions for K, which is $\partial^2 VC / \partial K^2 > 0$ must be satisfied, and it ensures substitutability, that is $\partial VC / \partial K < 0$. This requires β_{LK}, β_{MK} to be negative (Morrison, 1988).

By substituting this K* into all the equations in which K is included, we get the long-run equilibrium solution. This in turn allows us to distinguish short-run and long-run versions of productivity growth measure, the substitution elasticities, and the bias of technological change (Berndt, 1991).

4. 3. Regularity Conditions

The following regularity conditions must be satisfied on variable cost function in both short run and long run (McFadden, 1978).

1. Homogeneity: A cost function is homogeneous of degree one in variable input prices.

2. Curvature: Concave in variable input prices, and convex in quasi-fixed input.

3. Monotonicity: Non-decreasing in output and variable input prices.
Non-increasing in quasi-fixed inputs.

4. Symmetry: Symmetry in Hessian matrix.

The GL cost function allows nonhomotheticity; thus it is not restricted to homogeneity of degree one in output, but is restricted to homogeneity of degree one in variable input prices (Morrison, 1997). Fortunately, homogeneity of degree one in input prices is already satisfied in the GL function because as you can see from the variable cost equation in (4.1) when input prices increase by λ, variable cost increase by λ.

The concavity or convexity in input prices is not ensured in the GL function. We can check the condition by looking at the signs of the second derivatives of variable cost function with respect to input prices at each sample point, and that is $\partial^2 VC / \partial W_i^{\,2} < 0$ for concavity in variable input prices, and $\partial^2 VC / \partial P_k^{\,2} > 0$ for convexity in quasi-fixed input price (Morrison, 1988).

Monotonicity in output requires marginal cost to be positive, therefore, in the short run, it requires the derivatives of variable cost function with respect to output, that is the expression of MC in output supply equation (4.9) to be nonnegative number, $\partial VC / \partial Y > 0$. In the long run, marginal cost is the derivative of total cost with respect to output. Total cost function is given as

$$TC^* = VC\,(Y, W_i, K^*, t) + P_k K \tag{4.11}$$

therefore, marginal cost equation is

$$MC^* = \frac{\partial VC}{\partial Y}\Big|_{K=K^*} + \frac{\partial VC}{\partial K^*}\frac{\partial K^*}{\partial Y} + P_k\frac{\partial K^*}{\partial Y} \tag{4.12}$$

Note that capital can be adjusted fully in long run, and K* represents optimal level of capital. Recall the shadow value concept, $-\partial VC / \partial K = Z_k$, and $P_k = Z_k$ in the long run. Therefore, the last two terms cancel out. Hence, (4.11) can be reduced as

$$MC^* = \frac{\partial VC}{\partial Y}\Big|_{K=K^*} \tag{4.13}$$

That is, the long run, marginal cost MC* is found as the short-run marginal cost evaluated at K* instead of K. Thus, monotonicity in output in the long run requires $MC^* > 0$ to be satisfied.

Analogously, monotonicity in variable input prices requires the derivatives of total cost with respect to input prices, or equivalently the derived input demands by Shepherd's lemma, must be nonnegative. Therefore, in the short run, it requires equations (4.2) and (4.3) to be nonnegative. In the long run, the following equation must be nonnegative for the variable inputs, labor and materials.

$$X_i^* = \frac{\partial VC}{\partial W_i}\Big|_{K=K^*} + \frac{\partial VC}{\partial K^*}\frac{\partial K^*}{\partial W_i} + P_k\frac{\partial K^*}{\partial W_i} = \frac{\partial VC}{\partial Wi}\Big|_{K=K^*} \quad (4.14)$$

Again, the last two terms cancel each other out from the definition of the shadow price. Therefore, monotonicity requires the derivatives of variable cost, evaluated at K*, with respect to the variable input prices to be positive. In the long run, non-decreasingness of cost in quasi-fixed input's price has to be satisfied. This means K* must be positive.

Monotonicity in the quasi-fixed input's quantity requires Z_k be positive in the short run. That is $Z_k > 0$ in long run.

The regularity condition of symmetry in Hessian matrix will be discussed in the section (4.5).

4. 4. Productivity Growth Rate

4. 4. 1. Short-Run Productivity Growth Rate

4. 4. 1. 1) Dual Productivity Growth Rate

It is necessary to adjust the productivity measure for the existence of short-run equilibrium. Here, we derive the dual productivity measure, which takes the fixed nature of capital into account, and evaluate it at the market price of capital.

Recall from (3.10) and (3.12) that the total cost function is

$$C^P\,(W_i,\,Y,\,t,\,K,\,P_K) = VC\,(W_i,\,Y,\,t,\,K) + P_K K. \tag{4.14}$$

The short-run productivity growth measure, denoted $\varepsilon_{Ct}{}^F$, is found by taking the natural logarithm of (4.14) with respect to t:

$$\frac{d\ln C^P}{dt} = \frac{1}{C^P}\left[\frac{\partial VC}{\partial t} + \frac{\partial VC}{\partial Y}\frac{dY}{dt} + \sum_i \frac{\partial VC}{\partial W_i}\frac{dW_i}{dt} + \frac{\partial VC}{\partial K}\frac{dK}{dt} + P_k\frac{dK}{dt} + K\frac{dP_k}{dt}\right] \tag{4.15}$$

where $\frac{1}{C^P}\frac{\partial VC}{\partial t} = \frac{\partial \ln C^P}{\partial t} = \varepsilon^F_{Ct}$

Re-arranging (4.15), we are able to derive $\varepsilon_{Ct}{}^F$:

$$\varepsilon^F_{Ct} = \frac{d\ln C^P}{dt} - \frac{\partial \ln C^P}{\partial \ln Y}\frac{d\ln Y}{dt} - \sum_i \frac{W_i X_i}{C}\frac{d\ln W_i}{dt} - \frac{(P_k - Z_k)K}{C}\frac{d\ln K}{dt} - \frac{P_k K}{C}\frac{d\ln P_k}{dt} \tag{4.16}$$

Under the long-run constant returns to scale assumption, (4.16) can be rewritten by utilizing (3.14) as follows (Morrison, 1992):

$$\varepsilon^F_{Ct} = \frac{d\ln C^P}{dt} - \varepsilon^{SR}_{CY}\frac{d\ln Y}{dt} - \sum_i \frac{W_i X_i}{C}\frac{d\ln W_i}{dt} - \varepsilon_{CK}\frac{d\ln K}{dt} - \frac{P_k K}{C}\frac{d\ln P_k}{dt} \tag{4.17}$$

$$= \varepsilon_{Ct} + \varepsilon_{CK}\left[\frac{d\ln Y}{dt} - \frac{d\ln K}{dt}\right] \tag{4.18}$$

The last term is the bias correction. It depends on both the output and quasi-fixed input growth rates and on ε_{CK}. Note that $\varepsilon_{CK} = 0$ in the long run, so that $\varepsilon_{Ct}^{F} = \varepsilon_{Ct}^{LR}$.

4. 4. 1. 2) Adjusted Short-Run Productivity Growth Rate

Recognizing that the short-run dual productivity growth measure, ε_{Ct}^{F} in equation (4.16) is evaluated at a market rental price of capital instead of a shadow price of capital. However, the marginal contribution of the quasi-fixed input should be evaluated at its opportunity cost, that is the shadow price instead of a market price. In that way, we exclude the effect, which come from the full adjustment of capital in short run, and it represents the precise measurement of short-run productivity growth. We are able to derive it by employing CU measure. The adjusted dual productivity growth measure denoted as ε_{Ct}^{A} is

$$\begin{aligned}\varepsilon_{Ct}{}^{A} &= \frac{\varepsilon_{Ct}{}^{F}}{CU} \\ &= \frac{\dfrac{\partial VC}{\partial t}\dfrac{1}{C^{P}}}{\dfrac{C^{Z}}{C^{P}}} = \frac{\partial VC}{\partial t}\frac{1}{C^{Z}} = \frac{\partial C^{Z}}{\partial t}\frac{1}{C^{Z}} = \frac{\partial \ln C^{Z}}{\partial t}\end{aligned} \tag{4.19}$$

This is true in both CRTS and NCRTS cases. And, this equals to the primal measure of productivity growth, i.e., $\varepsilon_{Ct}^{A} = \varepsilon_{Yt}^{SR}$, if and only if we assume that the technology exhibits long-run CTRS, that is $\varepsilon_{CY}{}^{LR} = 1$. However, this is not the case in my study. (See details in Morrison, 1985b) Note that I present the short-run dual productivity growth rate obtained by this equation in my result chapter.

4. 4. 1. 3) Short-Run Primal Productivity Growth Rate

Following Ohta (1975), the primal measure can be decomposed as:

$$-\varepsilon_{Ct} / \varepsilon_{CY} = \varepsilon_{Yt} \qquad (4.20)$$

Utilizing this equation (3.20) derives the short-run primal rate of productivity growth. Primal rate of productivity growth rate in short run indicates the percentage increase in output induced by a change in technology holding input level, input prices, and capital level constant. We find it as

$$\varepsilon_{Yt}{}^{SR} = -\frac{\varepsilon_{Ct}{}^{SR}}{\varepsilon_{CY}{}^{SR}} \qquad (4.21)$$

where $\varepsilon_{CY}{}^{SR}$ is short-run cost elasticity with respect to output, and that is

$$\varepsilon_{CY}{}^{SR} = \frac{\partial \ln VC}{\partial \ln Y}\bigg|_{K=K^o} = \frac{\partial VC}{\partial Y}\bigg|_{K=K^o} \frac{Y}{VC} \qquad (4.22)$$

Note that, in short run, capital is not adjustable, thus capital level is fixed at predicted level, that is K.

4. 4. 2. Long-Run Productivity Growth Rate

4. 4. 2.1) Dual Productivity Growth Rate

Long-run productivity growth rate of both dual and primal can be found analogous to those in short run. The only difference between long run and short run is that capital is allowed to adjust to its optimal level. The long-run dual productivity growth rate which is rate of reduction in total cost induced by a change in technology holding only output and input prices constant is:

$$\varepsilon_{Ct}{}^{LR} = \frac{\partial \ln TC^*}{\partial t} = \frac{\partial TC^*}{\partial t}\frac{1}{TC^*} \tag{4.23}$$

where TC* is total cost function evaluated at the optimal level of capital. And the derivative of TC with respect to t is given as

$$\frac{\partial TC^*}{\partial t} = \left.\frac{\partial VC}{\partial t}\right|_{K=K^*} + \frac{\partial VC}{\partial K^*}\frac{\partial K^*}{\partial t} + P_k\frac{\partial K^*}{\partial t} \tag{4.24}$$

Recall, in long run, $P_k = Z_k$, and also by definition, $Z_k = -\frac{\partial VC}{\partial K}$, therefore the equation (4.24) can be rewritten in a simpler form as

$$\frac{\partial TC^*}{\partial t} = \left.\frac{\partial VC}{\partial t}\right|_{K=K^*} \tag{4.25}$$

that is the derivative of total cost with respect to time in long run can be found as the derivative of variable cost with respect to time evaluated at optimal level of capital.

4. 4. 2. 2) Primal Productivity Growth Rate

Again, analogous to short run, the primal rate of productivity growth is

$$\varepsilon_{Yt}{}^{LR} = -\frac{\varepsilon_{Ct}{}^{LR}}{\varepsilon_{CY}{}^{LR}} \qquad (4.26)$$

where $\varepsilon_{CY}{}^{LR}$ is long-run marginal cost given as

$$\varepsilon_{CY}{}^{LR} = \frac{\partial \ln TC^*}{\partial \ln Y} = \frac{\partial VC}{\partial Y}\bigg|_{K=K^*} + \frac{\partial VC}{\partial K^*}\frac{\partial K^*}{\partial Y} + P_k\frac{\partial VC}{\partial K^*} = MC^* \qquad (4.27)$$

Since the last two terms cancel out each other, the long-run marginal cost is easily derived as the marginal cost evaluated at the optimal level of capital.

4. 5. Input Demand Elasticities

4. 5. 1. Allen Partial Elasticity of Substitution

4. 5. 1. 1) Short-Run

Input demand elasticities are indicators of resource allocation. In order to find the short-run partial elasticity of substitution between labor and materials, we take partial derivatives of equation (4.2) and (4.3), which are the cost-minimizing input demand with respect to corresponding prices:

$$H_{ll}{}^{S} = \frac{\partial L}{\partial W_l} = -0.5Y\alpha_{LM}W_l{}^{-1.5}W_m{}^{0.5}$$

$$H_{mm}{}^{S} = \frac{\partial M}{\partial W_m} = -0.5Y\alpha_{LM}W_m{}^{-1.5}W_l{}^{0.5} \qquad (4.28)$$

These are diagonal elements of the input price Hessian matrix, which is the matrix of second derivatives of the variable cost function with respect to the input prices. Off-diagonal elements in such a matrix are symmetric and in this case are:

$$H_{lm}{}^{S} = H_{ml}{}^{S} = \frac{\partial L}{\partial W_m} = \frac{\partial M}{\partial W_l} = 0.5Y\alpha_{LM}W_l{}^{-0.5}W_m{}^{-0.5} \qquad (4.29)$$

In order for the cost function to be concave in input prices, the Hessian matrix must be negative semi-definite, requiring α_{LM} to be positive.

The partial elasticities of substitution are not symmetric and are as follows:

$$\varepsilon_{ll}{}^{s} = \frac{\partial L}{\partial W_l}\frac{W_l}{L} = \frac{-0.5Y\alpha_{LM}W_l{}^{-0.5}W_m{}^{0.5}}{L}$$

$$\varepsilon_{mm}{}^{s} = \frac{\partial M}{\partial W_m}\frac{W_m}{M} = \frac{-0.5Y\alpha_{LM}W_m{}^{-0.5}W_l{}^{0.5}}{M}$$

$$\varepsilon_{lm}{}^{s} = \frac{\partial L}{\partial W_m}\frac{W_m}{L} = \frac{0.5Y\alpha_{LM}W_l{}^{-0.5}W_m{}^{0.5}}{L}$$

$$\varepsilon_{ml}{}^{s} = \frac{\partial M}{\partial W_l}\frac{W_l}{M} = \frac{0.5Y\alpha_{LM}W_l{}^{0.5}W_m{}^{-0.5}}{M} \tag{4.30}$$

Note that labor and materials must be substitutes for one another because they are the only variable inputs in the short run.

4. 5. 1. 2) Long Run

In the long run, we have 3×3 Hessian matrix of input demand slopes and corresponding elasticities of substitution, where capital is adjusted to its optimal level, K*. Because we get the long-run optimal labor and material demands by substituting K* into equations (4.2) and (4.3), we also denote these demands as L* and M*. The long-run input demand slopes are derived with same procedure as in the short run; but note that we must include the capital price effects here as well.

The input demand slopes for capital are

$$H_{kl}{}^{L} = \frac{\partial K^*}{\partial W_l} = \frac{K^*}{D}\left(R_l K^{*0.5} + 2\gamma_{kk}\right)$$

$$H_{km}{}^{L} = \frac{\partial K^*}{\partial W_m} = \frac{K^*}{D}\left(R_m K^{*0.5} + 2\gamma_{kk}\right)$$

$$H_{kk}{}^{L} = \frac{\partial K^*}{\partial P_k} = \frac{2K^*}{D} \tag{4.31}$$

where $R_l = Y^{0.5}\left(\beta_{LK} + \gamma_{YK}Y^{0.5} + \gamma_{tK}t^{0.5}\right)$,

$R_m = Y^{0.5}\left(\beta_{MK} + \gamma_{YK}Y^{0.5} + \gamma_{tK}t^{0.5}\right)$,

and $D = -P_k - \gamma_{kk}(W_l + W_m)$.

The labor demand slopes are

$$H_{ll}{}^{L} = \frac{\partial L^*}{\partial W_l} = \frac{\partial L}{\partial W_l}\bigg|_{K=K^*} + \frac{\partial L^*}{\partial K^*}\frac{\partial K^*}{\partial W_l} = -0.5\alpha_{LM}W_l{}^{-1.5}W_m{}^{0.5}Y + (0.5K^{*-0.5}\ R_l + \gamma_{kk})H_{kl}$$

$$H_{lm}{}^{L} = \frac{\partial L^*}{\partial W_m} = \frac{\partial L}{\partial W_m}\bigg|_{K=K^*} + \frac{\partial L^*}{\partial K^*}\frac{\partial K^*}{\partial W_m} = -0.5\alpha_{LM}W_l{}^{-0.5}W_m{}^{-0.5}Y + (0.5K^{*-0.5}\ R_l + \gamma_{kk})H_{km}$$

$$H_{lk}{}^{L} = \frac{\partial L^*}{\partial W_k} = \frac{\partial L}{\partial W_k}\bigg|_{K=K^*} + \frac{\partial L^*}{\partial K^*}\frac{\partial K^*}{\partial W_k} = H_{kl} \tag{4.32}$$

The material demand slopes are

$$H_{ml}{}^{L} = \frac{\partial M}{\partial W_l} = \frac{\partial M}{\partial W_l}\bigg|_{K=K^*} + \frac{\partial M^*}{\partial K^*}\frac{\partial K^*}{W_l} = 0.5\alpha_{LM}W_l{}^{-0.5}W_m{}^{-0.5}Y + (0.5K^{*-0.5}\ R_m + \gamma_{kk})H_{kl}$$

$$H_{mm}{}^{L} = \frac{\partial M}{\partial W_m} = \frac{\partial M}{\partial W_m}\bigg|_{K=K^*} + \frac{\partial M^*}{\partial K^*}\frac{\partial K^*}{W_m} = -0.5\alpha_{LM}W_l{}^{0.5}W_m{}^{-1.5}Y + (0.5K^{*-0.5}\ R_m + \gamma_{kk})H_{km}$$

$$H_{mk}{}^{L} = \frac{\partial M}{\partial W_k} = \frac{\partial M}{\partial W_k}\bigg|_{K=K^*} + \frac{\partial M^*}{\partial K^*}\frac{\partial K^*}{W_k} = H_{km} \tag{4.33}$$

Again, off-diagonal elements are symmetric. And, in order to satisfy concavity in input prices, principal minors of the input price Hessian matrix must alternate in sign, starting with negative. The corresponding elasticities, which are non-symmetric, are

$$\begin{bmatrix} \varepsilon_{ll}{}^{L} = H_{ll}\dfrac{W_l}{L^*} & \varepsilon_{lm}{}^{L} = H_{lm}\dfrac{W_m}{L^*} & \varepsilon_{lk}{}^{L} = H_{lk}\dfrac{P_k}{L^*} \\ \varepsilon_{ml}{}^{L} = H_{ml}\dfrac{W_l}{M^*} & \varepsilon_{mm}{}^{L} = H_{mm}\dfrac{W_m}{M^*} & \varepsilon_{mk}{}^{L} = H_{mk}\dfrac{P_k}{M^*} \\ \varepsilon_{kl}{}^{L} = H_{kl}\dfrac{W_l}{K^*} & \varepsilon_{km}{}^{L} = H_{km}\dfrac{W_m}{K^*} & \varepsilon_{kk}{}^{L} = H_{kk}\dfrac{P_k}{K^*} \end{bmatrix} \qquad (4.34)$$

Note that in this more-than-two-input case, we must determine from the sign of an off-diagonal term whether the corresponding inputs are substitutes or complements.

4. 5. 2. Morishima Elasticity of Substitution (MES)

Blackorby and Russell (1989) have shown that the MES is an exact measure of curvature convexity which partial elasticity of substitution does not represent, measuring how easy it is to substitute one input for another. The MES is the change in the input ratio in response to a change in their price ratio. Let Q_{ij} be the MES between inputs i and j, X is input quantity, and W is input price.

$$Q_{ij} = \frac{d\ln\left(X_i/X_j\right)}{d\ln\left(W_j/W_i\right)} \qquad (4.35)$$

Therefore, Q_{ij} is the percentage change in input ratio induced by one-percent change in W_j holding output and other input prices constant. Note that $i \neq j$. It can be also derived by using the partial elasticity of substitution as follows.

$$Q_{ij} = \varepsilon_{ji} - \varepsilon_{ii} \qquad (4.36)$$

where $Qij > 0$ (< 0) indicates these two inputs are substitute (complement), and higher the elasticity, greater the substitutability if a number is positive.

The short-run Morishima elasticity substitution matrix, which is

$$\begin{bmatrix} - & Q_{lm} = \varepsilon_{ml}^{S} - \varepsilon_{ll}^{S} \\ Q_{ml} = \varepsilon_{lm}^{S} - \varepsilon_{mm}^{S} & - \end{bmatrix} \tag{4.37}$$

In the two-input case, $Q_{lm} = Q_{ml}$, that is, the matrix is symmetric.

The long-run MES matrix, which is not symmetric, is defined as follows:

$$\begin{bmatrix} - & Q_{lm} = \varepsilon_{ml}^{L} - \varepsilon_{ll}^{L} & Q_{lk} = \varepsilon_{kl}^{L} - \varepsilon_{ll}^{L} \\ Q_{ml} = \varepsilon_{lm}^{L} - \varepsilon_{mm}^{L} & - & Q_{mk} = \varepsilon_{km}^{L} - \varepsilon_{mm}^{L} \\ Q_{kl} = \varepsilon_{lk}^{L} - \varepsilon_{kk}^{L} & Q_{km} = \varepsilon_{mk}^{L} - \varepsilon_{kk}^{L} & - \end{bmatrix} \tag{4.38}$$

4. 6. Bias of Technological Change

Technological change may improve each input's productivity or utilization differently, changing the marginal contribution of each input to the production process. This concept leads us to classify technological change as neutral or biased. If technological change affects all inputs equiproportionately, it is neutral change. However, this is not the case in general. The dual cost measure of the bias of technological change can be derived as the change in relative factor shares as technology change occurs, allowing for substitution among inputs (Antle and Capalbo, 1988, p.40).

Under the assumption of a non-homothetic technology, implying the expansion path is not linear from the origin, the optimal input shares in total cost are a function of output. That is, input shares can be altered by not only the technological change, but any change in scale output. We therefore need to decompose the bias measure into two components, a scale effect which represents movements along the expansion path, and a bias effect which measures the effect of a shift in the expansion path (Antle and Capalbo, 1988, p.41).

The scale-adjusted bias of technological change, β_i^{CE}, is given as:

$$\beta_i^{CE} = \beta_i^{C} - \frac{\partial \ln S_i}{\partial \ln Y}\frac{d \ln Y}{dt} = \beta_i^{C} - \frac{\partial (W_i X_i / C)}{\partial Y}\frac{Y}{S_i}\frac{\partial \ln Y}{\partial \ln C}\frac{\partial \ln C}{\partial t}$$

$$= \beta_i^{C} - \frac{W_i Y}{S_i}\left[\frac{(\partial X_i / \partial Y)C - (\partial C / \partial Y)X_i}{C^2}\right]\frac{(-\varepsilon_{Ct})}{\varepsilon_{CY}}$$

where $\beta_i^{C} = \frac{\partial \ln S_i}{\partial t} = \frac{\partial \ln X_i}{\partial t} - \frac{\partial \ln C}{\partial t} = \frac{\partial X_i}{\partial t}\frac{1}{X_i} - \varepsilon_{Ct}$, and $S_i = \frac{W_i X_i}{C}$. (4.39)

β_i^C is the gross effect of bias, and the second term in the above equation is the scale effect. Note that in the homothetic technology case, the scale effect is zero. Therefore, there is no need to adjust for change in scale. Mathematically $\partial \ln S_i / \partial \ln Y = 0$ under homotheticity, so $\beta_i^{CE} = \beta_i^{C}$.

If $\beta_i^{CE} > 0$, technological change is factor *i*-using.

If $\beta_i^{CE} < 0$, technological change is factor *i*-saving.

and if $\beta_i^{CE} = 0$, technological change is Hicks neutral.

Note that neutral technological change occurs when any bias is caused purely by a scale effect.

4. 6. 1. Short-Run Bias of Technological Change

In the two-input case, the $\partial X_i / \partial Y$ in equation (4.39) can be derived from equations (4.2) and (4.3). They are

$$
\begin{aligned}
\partial L / \partial Y = {} & \alpha_{LL} + \alpha_{LM} W_l^{-0.5} W_m^{0.5} + Y^{0.5}(1.5\beta_{LY} + 3\gamma_{Yt} t^{0.5}) + Y^{-0.5}(0.5K^{0.5}\beta_{LK} + 0.5K^{0.5}\gamma_{tK} t^{0.5}) \\
& + 2\gamma_{YY} Y + \gamma_{YK} K^{0.5} + \gamma_{tt} t + \beta_{Lt} t^{0.5}
\end{aligned}
$$

$$
\begin{aligned}
\partial M / \partial Y = {} & \alpha_{MM} + \alpha_{LM} W_m^{-0.5} W_l^{0.5} + Y^{0.5}(1.5\beta_{MY} + 3\gamma_{Yt} t^{0.5}) + Y^{-0.5}(0.5K^{0.5}\beta_{MK} + 0.5K^{0.5}\gamma_{tK} t^{0.5}) \\
& + 2\gamma_{YY} Y + \gamma_{YK} K^{0.5} + \gamma_{tt} t + \beta_{Mt} t^{0.5}
\end{aligned}
\tag{4.40}
$$

The $\partial X_i / \partial t$ are also calculated from equation (4.2) and (4.3) as

$$\partial L / \partial t = Y\left(0.5\beta_{Lt} t^{-0.5} + \gamma_{Yt} Y^{0.5} t^{-0.5} + \gamma_{tt}\right) + Y^{0.5}\left(0.5\gamma_{tK} K^{0.5} t^{-0.5}\right)$$

$$\partial M / \partial t = Y\left(0.5\beta_{Mt} t^{-0.5} + \gamma_{Yt} Y^{0.5} t^{-0.5} + \gamma_{tt}\right) + Y^{0.5}\left(0.5\gamma_{tK} K^{0.5} t^{-0.5}\right) \tag{4.41}$$

Utilizing equations (4.39) and (4.40), we are able to find the scale-adjusted bias of technological change, and also decompose it into the gross effect and the scale effect. Note that in this two-input case, i = L, M, therefore, $C = LW_l + MW_m$.

4. 6. 2. Long-Run Bias of Technological Change

In the long run, we derive the bias of technological change for both the variable inputs and the quasi-fixed input. In so doing, we must include the effect of on output change on the quasi-fixed input. Derivatives $\partial X_i / \partial Y$ for labor and material demand in the long run are derived from equations (4.2) and (4.3) as

$$\frac{\partial L^*}{\partial Y} = \left[\left. \frac{\partial L^*}{\partial Y} \right|_{K=K^*} + \frac{\partial L^*}{\partial K^*} \frac{\partial K^*}{\partial Y} \right]$$

$$\frac{\partial M^*}{\partial Y} = \left[\left. \frac{\partial M^*}{\partial Y} \right|_{K=K^*} + \frac{\partial M^*}{\partial K^*} \frac{\partial K^*}{\partial Y} \right] \tag{4.42}$$

Derivatives $\partial X_i / \partial Y$ for capital, that is $\partial K^* / \partial Y$, can be derived from the equation for the optimal level of capital, (4.10):

$$\frac{\partial K^*}{\partial Y} = 0.5\left(\frac{N}{D}\right)^2 + \gamma_{YK}(W_l + W_m)Y^{0.5}\left(\frac{N}{D^2}\right) \tag{4.43}$$

where $N = 0.5\left[\beta_{LK}W_l + \beta_{MK}W_m + \left(\gamma_{YK}Y^{0.5} + \gamma_{tK}t^{0.5}\right)(W_l + W_m)\right]$

and D is defined in the equation (4.31).

Analogously, the $\partial X_i / \partial t$ in the long run are for variable inputs, found from equations (4.2) and (4.3), and must include the effect of technology change on capital:

$$\begin{aligned} \frac{\partial L^*}{\partial t} &= \left[\left.\frac{\partial L^*}{\partial t}\right|_{K=K^*} + \frac{\partial L^*}{\partial K^*}\frac{\partial K^*}{\partial t}\right] \\ \frac{\partial M^*}{\partial t} &= \left[\left.\frac{\partial M^*}{\partial t}\right|_{K=K^*} + \frac{\partial M^*}{\partial K^*}\frac{\partial K^*}{\partial t}\right] \end{aligned} \tag{4.44}$$

Again, derivative $\partial X_i / \partial t$ for capital, that is $\partial K^* / \partial t$, is found from equation (4.10):

$$\frac{\partial K^*}{\partial t} = 0.5\frac{N}{D^2}(W_l + W_m)\gamma_{tK}t^{-0.5}Y \tag{4.45}$$

In the long run, all inputs adjust optimally, so total cost is a minimum. Therefore, we can substitute ε_{Ct} and ε_{CY} for ε_{Ct}^{LR} and ε_{CY}^{LR}, which are the long-run dual productivity growth elasticity and the long-run cost elasticity. Finally, by utilizing equations (4.42) and (4.45) with (4.39), we are able to find the long-run bias of technological change.

Chapter 5: Data

My data comes from three sources. The main source is the SIC 4-digit productivity database provided by the National Bureau of Economic Research (NBER) and the Bureau of Census (U.S. Department of Commerce). The other data source are the SIC 2-digit food manufacturing database prepared by the U.S. Bureau of Labor, and the "Summary National Income and Products Series, 1929-1996" published in the *Survey of Current Business* (August 1997).

5. 1. SIC 4-digit NBER Productivity Database and 2-digit BLS Food Manufacturing Database

The SIC 4-digit NBER database is constructed under the 1972 SIC classifications and covers the 1958-94 period. It contains 450 manufacturing industries within the food and kindred product industry group (SIC20). Included in the data set are value of shipment, labor quantity, wage rate, material quantity, cost of material inputs, and real capital stock. As mentioned earlier, I will concentrate in this study on the grain milling industries (SIC204) and bakery industries (SIC205).

The SIC 2-digit manufacturing database includes capital rental cost at 2-digit level.

5. 1. 1. Output Quantity

The value of shipments in the 4-digit NBER data is price times quantity. In the same data, a shipment deflator is available. I obtained output quantity by dividing value of shipments by its price deflator. To get total output quantity, changes in inventory value must be taken into accounted. However, the value of inventory is small relative to value of shipments; thus, value of inventory is ignored in this study.

5. 1. 2. Labor

Total labor quantity is calculated as the sum of production worker hours and non-production worker hours. Hours of production workers are readily available in this dataset. Number of non-production workers is found by subtracting production workers from total employment, and we assume 2000 hours per year for each non-production worker. Therefore, the quantity of labor for non-production workers is found as 2000 times the number of non-production workers. To get the wage rate, we divided labor quantity by total employment compensation, obtaining a weighted-average wage rate.

5. 1. 3. Materials

Material quantity is found as cost of material inputs divided by a materials deflator. Note that energy expenditures are available in this dataset; however, they are ignored in this study because the numbers are small compared to the cost of material inputs, and because there is no accurate way of aggregating the cost of materials and energy. Energy cost accounts for about 3.2 % of material cost in the grain milling and bakery industries.

5. 1. 4. Capital

In the 4-digit NBER database, total real capital stock in constant dollars is available and is used as the quantity of capital (K). In the 2-digit BLS data, capital rental cost (P_kK) is also available. We allocate the 2-digit capital rental cost to each 4-digit industry according to the proportion of 4-digit total real capital stock, giving us a 4-digit capital rental cost (P_kK). Then, we divided the 4-digit capital rental cost by capital stock to obtain capital rental price at the 4-digit level. This essentially assumes that capital rental prices are the same across all 4-digit industries.

5. 2. Income Data

Income data which are needed for estimating of output demand come from the "Summary of National Income and Products Series, 1929-96" in *the Survey of Current Business.* It is reported as personal disposable income in billions of dollars.

The U.S. Producer Price Index is used to deflate all nominal prices to a constant-dollar basis.

Chapter 6: Results

This chapter presents model results by individual industry. Recall from chapter 2 that the research focuses on five industries: flour milling (SIC2041), rice milling (SIC2044), pet food (SIC2047), animal feeds (SIC2048), and bread baking (SIC2051). In each of following sub-sections, only the annual averages are presented. The results of annual observation are presented in appendix under the same table number.

6. 1. Estimated Parameters

Parameter estimates and t-statistics of the variable cost equations, and goodness of fit measures of the systems of equation, are presented for each of the five industries in table 6. 1. All industries' system-weighted R-squares indicate a close fit. The industry average is 0.99, that is, 99% of the data are explained by this model. The bread sector has the highest goodness of fit, with an R-square of 0.9984. The rice sector has the lowest goodness of fit, with an R-square of 0.9837. In bread, only three of the 15 parameter estimates are not significant at the 5% level. In flour, four are insignificant; in pet food, five are insignificant; in animal feeds, six are insignificant; and in rice, eight are insignificant. γ_{YY} and γ_{Yt} tend to be the least significant, except in rice and bread. Parameters related to material price, such as α_{MM}, β_{Mt}, and β_{MK}, tend to be the most significant in all five industries.

Table 6. 1: GL Variable Cost Function Estimates in the U.S. Grain Milling Industry

Industry	Flour (SIC 2041)		Rice (SIC 2044)		Pet food (SIC 2047)	
Parameter	Estimate	T-statistics	Estimate	T-statistics	Estimate	T-Statistics
α_{LL}	0.11963	7.193	-0.08148	*-1.519	0.13852	3.293
α_{LM}	0.00723	7.562	0.00132	*0.919	0.04144	6.214
α_{MM}	3.60935	34.177	3.78116	19.972	5.20427	32.204
β_{LY}	-0.00004	*-0.111	-0.00012	*-0.136	0.00149	2.413
β_{Lt}	-0.01413	-3.747	0.01879	*1.129	-0.05979	-4.185
β_{MY}	-0.00486	-9.219	-0.00001	*-0.005	-0.00531	-3.726
β_{Mt}	-0.24508	-20.295	-0.28312	-10.844	-0.42860	-14.735
γ_{YY}	0.00000	*-1.204	0.00002	2.931	-0.00001	*-1.13
γ_{Yt}	0.00000	*-0.114	-0.00015	*-1.802	-0.00002	*-0.214
γ_{tt}	0.00100	3.867	0.00052	*0.371	0.00429	2.403
β_{LK}	-0.13091	-4.313	0.03998	*0.732	0.26403	5.764
β_{MK}	-0.64419	-20.182	-0.72965	-11.222	-0.99007	-16.319
γ_{YK}	0.00090	*1.944	0.00229	3.463	-0.00053	*-0.58
γ_{tK}	-0.00968	-2.821	-0.03252	-3.127	-0.02517	*-1.609
γ_{KK}	0.12974	5.949	0.15901	7.289	-0.00187	*-0.047
System Weighted R^2		0.9919		0.9837		0.9878

Industry	Animal feeds (SIC 2048)		Bread (SIC 2051)	
Parameter	Estimate	T-Statistics	Estimate	T-Statistics
α_{LL}	0.02386	*0.683	0.30569	15.286
α_{LM}	0.01762	7.902	0.03611	8.725
α_{MM}	2.04196	23.092	1.17515	30.918
β_{LY}	-0.00175	-6.217	0.00007	*0.457
β_{Lt}	0.01862	2.029	-0.06218	-14.952
β_{MY}	-0.00146	-3.088	-0.00265	-12.273
β_{Mt}	-0.09063	-7.373	-0.06061	-15.422
γ_{YY}	0.00000	*1.99	0.00000	*-0.549
γ_{Yt}	0.00001	*0.449	-0.00003	-9.45
γ_{tt}	-0.00024	*-0.342	0.00548	22.424
β_{LK}	-0.00100	*-0.017	-0.06099	*-1.897
β_{MK}	-0.52492	-7.502	-0.52903	-14.012
γ_{YK}	0.00196	6.392	0.00097	7.28
γ_{tK}	-0.03404	-4.909	-0.04195	-20.116
γ_{KK}	0.08575	2.539	0.21463	10.548
System Weighted R^2		0.9954		0.9984

Industry-Wide Average R^2 = 0.99144

* represents insignificance at 5% siginificance level

6. 2. Elasticities

6. 2. 1. Short-Run Input Demand Elasticities (Partial Elasticity of Substitution)

Table 6. 2a gives the average own- and cross-price elasticities of short-run input demands on annual average, which are calculated by equation (4.28) and (4.29). In the short run, we analyze only two inputs: labor and materials. As is required in the two-input case, they are substitutes for one another. E_{ll} and E_{mm} are own-price partial elasticities giving the percentage change in input, in this case labor and materials, induced by a one-percent change in its own price. E_{lm} and E_{ml} are cross-price elasticities indicating the percentage change in labor input and material input induced by a one-percent change in material and labor price, respectively.

The industry-wide averages at the bottom of the table show that labor demand is considerably more sensitive to its own price than is material demand. That is, the own-price elasticities of labor demand are greater in absolute value than are the own-price elasticities of material demand, and this is true for each of the five industries. Specifically, the industry-wide average is -0.344 for labor demand and -0.067 for material demand. Therefore, the demand for labor decreases by 0.3% when labor wage rises by one percent, and the demand for materials declines when material cost increases by one percent.

The results indicate that pet food industry is quite responsive to changes in input prices, both labor and materials. Bread industry is also responsive to material prices, while the responsiveness is moderate in labor price. Animal feeds is sensitive to labor price, and insensitive to material price. Finally, flour and rice milling industries' ability to respond to price changes ranked low among five industries, especially rice milling shows inelastic demands for both labor and material inputs.

The annual results in appendix imply that the industries' ability to react to input price changes has been increasing. However, material demand elasticities remain very low in flour and in rice milling.

Turning to the cross-price elasticities, in all industries, the effect of a change in material price on demand for labor (Elm) is always much greater than the effect of change in labor price on material demand (Eml). The industry-wide averages are 0.344 for the former and 0.067 for the latter. A major reason that elasticities involving material prices are low is that the share of materials in variable costs is much higher than the share of labor.

Table 6. 2a: Average Short-Run Input Demand Elasticities in the U.S. Grain Milling Industry

Industry	E_{ll}	E_{lm}	E_{ml}	E_{mm}
Flour Milling (SIC2041)	-0.172	0.172	0.014	-0.014
Rice Milling (SIC2044)	-0.034	0.034	0.002	-0.002
Pet Food (SIC2047)	-0.823	0.823	0.108	-0.108
Animal Feeds (SIC2048)	-0.391	0.391	0.031	-0.031
Bread (SIC2051)	-0.300	0.300	0.181	-0.181
Industry-Wide Average	-0.344	0.344	0.067	-0.067

Note: Short-run input demand elasticities are computed from equation (4.30) in chapter 4.

6. 2. 2. Short-Run Morishima Substitution Elasticities

Average short-run Morishima substitution elasticities, which are calculated from the equation (4.36), are reported in table 6.2b. In the short run, only labor and material quantities can change. Therefore, Q_{lm} indicates the percentage change in the labor-to-material input ratio, induced by one-percent change in the price of materials. Analogously, Q_{ml} is the percentage change in the material-to-labor input ratio, caused by a change in labor price. In the two-input case, the substitution elasticities are symmetric, that is $Q_{lm} = Q_{ml}$, and the two inputs must be substitutes.

Note that Morishima substitution elasticity represents exact measure of curvature convexity of isoquant curve, while partial elasticity of substitution does not.

The pet food industry shows the highest substitutability between labor and materials among the five industries, its annual average elasticity being 0.931. Substitutability in animal feeds and bread is moderate, and it is low in flour and rice milling industries.

We observe that this elasticity has also tended to increase over time in all five industries, implying substitutability between labor and materials has been growing. In the pet food industry, the growth has been dramatic.

Table 6. 2b: Average Short-Run Morishima Substitution Elasticities in the U.S. Grain Milling Industry

Industry	$Q_{lm}=Q_{ml}$
Flour Milling (SIC2041)	0.18525
Rice Milling (SIC2044)	0.03677
Pet Food (SIC2047)	0.93102
Animal Feeds (SIC2048)	0.42151
Bread (SIC2051)	0.48101
Industry-Wide Average	0.41111

Note: Short-run Morishima substitution elasticities are computed from equation (4.37) in chapter 4.

6. 2. 3. Long-Run Input Demand Elasticities

The average long-run input demand elasticities are shown in table 6.2c. In the long run, all inputs are variable. A negative sign on the own-price elasticities is required for cost concavity. All own-price elasticities have negative signs, satisfying this regularity condition.

In the cross-price elasticities, positive signs indicate that inputs are substitutes, whereas negative signs imply that inputs are complements to one another. Industry-wide averages indicate all inputs are substitutes as well as each industry average except in the rice and pet food industries. In rice milling industry, labor and materials tend to be complements. In pet food, complementarity is indicated on average, between capital and labor. During the 1970's, capital and labor tended to be complements in all five industries except in bread, this implies capital and labor as aggregated one input are substitute for materials when whose prices were high.

The own-price elasticities imply that, in all five industries, capital is most responsive to its own price change, followed by labor and materials. The industry-wide average of capital's own-price elasticity is -0.945, of labor's own-price elasticity is -0.589, and of material's own-price elasticity is -0.442. Comparison with the short-run results shows that the absolute values of own-price elasticities are greater in the long run than in the short run, namely the Le Chatelier proposition. Specifically, the effect of an own-price change on labor or on material demand, especially on material demand, is greater if capital quantity is permitted to change optimally along with labor and material quantities. By varying capital levels, and thus productive capacity, firms can adjust their labor and material usage more than they could if capacity were fixed. Note that, in the early 1970's, labor price elasticities are quite high compared to other sample years, especially in the flour, rice, and pet food industries. The reason may be the oil crisis, which forced firms to adjust to their optimal input combinations by reducing employment levels.

Table 6. 2c: Average Long-Run Input Demand Elasticities in the U.S. Grain Milling Industry

Industry	E_{ll}	E_{lm}	E_{lk}	E_{ml}	E_{mm}
Flour Milling (SIC2041)	-0.246	0.065	0.181	0.002	-0.095
Rice Milling (SIC2044)	-0.156	-0.143	0.299	-0.016	-0.149
Pet Food (SIC2047)	-1.650	0.861	0.789	0.077	-1.533
Animal Feeds (SIC2048)	-0.455	0.167	0.288	0.012	-0.152
Bread (SIC2051)	-0.441	0.136	0.305	0.082	-0.282
Industry-Wide Average	-0.590	0.217	0.372	0.031	-0.442

Industry	E_{mk}	E_{kl}	E_{km}	E_{kk}
Flour Milling (SIC2041)	0.094	0.070	0.492	-0.562
Rice Milling (SIC2044)	0.165	0.097	0.721	-0.818
Pet Food (SIC2047)	1.456	-0.129	2.175	-2.047
Animal Feeds (SIC2048)	0.139	0.116	0.700	-0.816
Bread (SIC2051)	0.201	0.221	0.263	-0.484
Industry-Wide Average	0.411	0.075	0.870	-0.945

Note: Long-run input demand elasticities are computed from equation (4.34) in chapter 4.

6. 2. 4. Long-Run Morishima Substitution Elasticities

The long-run Morishima substitution elasticities are given in table 6.2d. The results, on average, indicate that all three inputs are substitutes for one another in all industries, and they are consistent with the partial substitution elasticities on table 6.2c, except in the rice and pet food industries. Industry-wide averages show that the change in capital-to-labor input ratio induced by a change in labor price, the material-to-capital ratio induced by a capital price change, and the capital-to-material ratio induced by a material price change are higher than are the sensitivities of the remaining ratios, namely labor-to-material, material-to-labor, and labor-to-capital. In the pet food industry, substitutability among the three inputs is especially high, and in the rice industry, it is especially low.

In the 1980's, Q_{kl}, that is a change in capital-to-labor input ratio induced by a change in the labor price, increased dramatically, while Q_{ml} decreased during the same period. This trend implies that capital has been more responsive to labor price changes in the 1980's than has materials. That is, substitutability between capital and labor has been increasing while substitutability between materials and labor has been decreasing.

Table 6. 2d: Average Long-Run Morishima Substitution Elasticities in the U.S. Grain Milling Industry

Industry	Q_{lm}	Q_{ml}	Q_{lk}	Q_{kl}	Q_{mk}	Q_{km}
Flour Milling (SIC2041)	0.247	0.160	0.316	0.743	0.587	0.656
Rice Milling (SIC2044)	0.140	0.006	0.253	1.117	0.870	0.983
Pet Food (SIC2047)	1.727	2.394	1.521	2.836	3.708	3.502
Animal Feeds (SIC2048)	0.467	0.319	0.571	1.104	0.852	0.955
Bread Bakery (SIC2051)	0.523	0.418	0.662	0.788	0.545	0.684
Industry-Wide Average	0.621	0.659	0.665	1.317	1.312	1.356

Note: Long-run Morishima substitution elasticities are computed from equation (4.38) in chapter 4.

6. 3. Capacity Utilization

Capacity Utilization indicates how much capital is currently used or idled within an industry, thus overutilization ($CU > 1.0$) implies current stock of capital is overused, that is capital shortage, and investment may adjust capital utilization level to an optimal level. On the contrary, underutilization ($CU < 1.0$) shows some capital stock is idled within an industry, that is excess capacity. The severe underutilization shows high fixed cost, and that lowers industry profitability. This reveals an unhealthy situation in the industry.

Annual capacity utilization measures on annual average, calculated from equation (3.13), are presented for the period 1958-1994 in table 6.3 and graphed in figure 6.3. I restricted the shadow price of capital and the market rental price of capital to be equal on average, that is, on average $Z_k = P_k$.

On average, the largest deviations from long-run equilibrium, namely $CU = 1.0$, are found in rice and bread industries, where the annual average CU's are 0.94 and 0.95. In the other industries, average capacity utilization is near one. That is, of course, unsurprising given the above restriction.

As shown in figure 6.3, all industries maintained rather stable capacity utilization until 1972. Pet food and bread industries underutilized capital stock during this period because $CU<1.0$ continuously, while the rice and animal feeds industries overutilized capital since $CU>1.0$. In the flour industry, capital was slightly overutilized until 1964, then slightly underutilized; however, it is very close to unitary CU in all years.

Abruptly in 1973, all the grain milling industries moved to overutilization of their capital stock. Possible reasons for this are the sudden increase in export demand caused by the decline in world grain production and steady economic growth, and rather optimistic behavior of firms toward oil crisis. As a result of the oil crisis, commodity prices went up, and the increased prices gave firms a strong incentive to produce more. Together, they encouraged firms to increase processing capacity and resulting in high CU in 1973 and in the following year. As a result, overutilization reached one of its highest levels in 1974.

Since 1975, the pet food industry began exhibiting a trend different from the others. Its capacity utilization again exceeded 1.0 in 1977, and continued to show a capacity shortage in the 1980's and 1990's. In the rice milling industry, utilization varies most over the years, reaching its highest at 1.09 in 1974 and its lowest at 0.7 in 1990. In 1978, capacity utilization in the rice milling industry falls below 1.0 and begins to decrease further in the 1980's and 1990's. This result confirms how severe the excess capacity is in this industry, and it reflects the industry's heavy export dependency. The slight recovery in CU in the late 1980's reflects the increase in world demand. However, CU still indicates severe excess capacity.

The flour milling industry shows a trend similar to the rice sector, but with less annual fluctuation. Utilization in the animal feeds and bread industries is relatively stable around its long-run optimum in the 1980's, then falls below capacity in the 1990's.

During the recession in the early 1980's, all industries but pet food showed declining trends in CU. And in the mid- and late-1980's these industries followed the recovery from the recession by moving toward either optimal or overutilization of capacity. However, again during the early 1990's, all industries but pet food have been in excess capacity because of a recession.

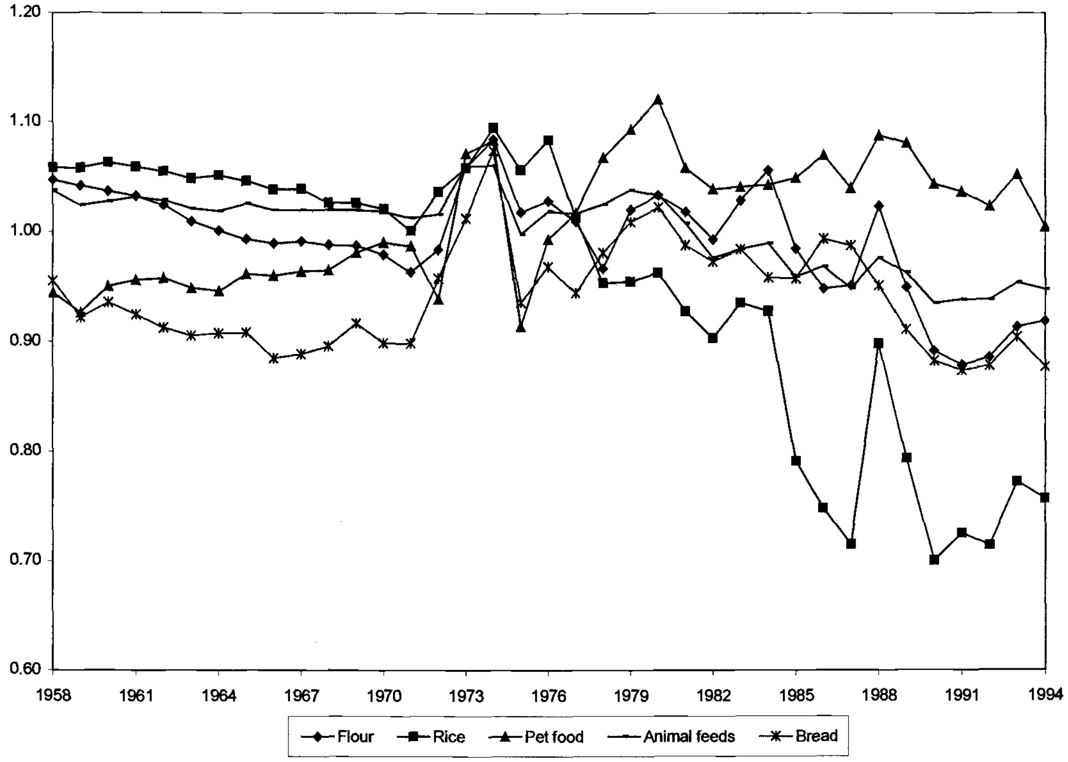
These capacity utilization estimates are based on static expectations, meaning that firms assume that output demand and the ratios of output to input prices in future years will remain the same as at present. In addition, they assume that capital adjustment cost is zero. Thus, the interpretation of the capacity utilization measure requires some caution.

Table 6. 3: Average Capacity Utilization Measures in the U.S. Grain Milling Industry

Industry	Capacity Utilization
Flour Milling (SIC2041)	0.9930
Rice Milling (SIC2044)	0.9494
Pet Food (SIC2047)	1.0113
Animal Feeds (SIC2048)	1.0025
Bread Bakery (SIC2051)	0.9404
Industry-Wide Average	0.9793

Note: CU is computed from equation (3.13) in chapter 3.

Figure 6.3: Capacity Utilization in the U.S. Grain Milling Industry



6. 4. Productivity Growth Rate

In tables 6.4a and 6.4b, short-run and long-run productivity growth rates as annual average are presented. Each result will be explained in corresponding section below. ε_{Ct} represents dual rate of productivity growth, ε_{CY} denotes cost elasticity with respect to output, and ε_{Yt} indicates primal rate of productivity growth. Recall that, in equation (3.9), the dual rate and primal rate are related to each other through the cost elasticity as $- \varepsilon_{Ct} / \varepsilon_{CY} = \varepsilon_{Yt}$. Note also that the reciprocal of the cost elasticity indicates the scale elasticity. In the following subsections, I begin with the dual productivity growth rate in short run and long run, then move to the primal rate in the short run and long run.

Table 6. 4a: Average Short-Run Dual and Primal Productivity Growth Rates in the U.S. Grain Milling Industry

Industry	ε_{Ct}	ε_{CY}	ε_{Yt}
Flour Milling (SIC2041)	-0.01345	0.79365	0.01720
Rice Milling (SIC2044)	-0.01562	0.96183	0.01636
Pet Food (SIC2047)	-0.01868	0.74293	0.02652
Animal Feeds (SIC2048)	-0.00659	0.97203	0.00677
Bread Bakery (SIC2051)	-0.00163	0.75068	0.00231
Industry-Wide Average	-0.01119	0.84422	0.01383

Note: Short-run ε_{Ct}, ε_{CY}, and ε_{Yt} are respectively computed from equations (4.19), (4.22), and (4.21) in chapter 4.

Table 6. 4b: Average Long-Run Dual and Primal Productivity Growth Rates in the U.S. Grain Milling Industry

Industry	ε_{Ct}	ε_{CY}	ε_{Yt}
Flour Milling (SIC2041)	-0.01335	0.79361	0.01692
Rice Milling (SIC2044)	-0.01430	0.94259	0.01517
Pet Food (SIC2047)	-0.01954	0.72340	0.03011
Animal Feeds (SIC2048)	-0.00676	0.97112	0.00689
Bread Bakery (SIC2051)	-0.00066	0.73961	0.00103
Industry-Wide Average	-0.01092	0.83407	0.01402

Note: Long-run ε_{Ct}, ε_{CY}, and ε_{Yt} are respectively calculated from equations (4.23), (4.27), and (4.26) in chapter 4.

6. 4. 1. Dual Productivity Growth Rate

6. 4. 1. 1) Short Run

The short-run dual productivity growth rates are specified by equation (4.19). Recall the table 6.4a, and annual results are graphed in figure 6. 4. 1a.

For the short-run, the industry-wide annual average productivity growth rate is -0.01. That is, on average a 1.0 % total cost reduction is induced by a change in technology holding output, input prices, and capital level constant. The highest annual average growth rate (at -0.019) has been in the pet food industry, followed by the rice industry at -0.016, flour at -0.013, animal feeds at -0.007, and bread at -0.002.

Until the early 1970's, all but the bread industry showed regular annual improvement in productivity growth. In the early 1970's, the rates of improvement in growth increased, then begin to fluctuate. Since the mid-1970's, short-run productivity growth has been decreasing in pet food and bread, increasing in rice milling, and relatively unchanged in the flour and animal feeds industries. Productivity growth trends in the bread industry are different from the other industries. We observe a continuously rising trend in absolute value in dual productivity growth rate in the bread industry; that is, productivity growth rate has decreased over the study period. In 1981, bread's dual productivity growth rate becomes positive, implying that technology change begins to induce increases in total cost for a given output and input prices.

6. 4. 1. 2) Long Run

Recall table 6. 4b, and annual results are graphed in figure 6. 4. 1b. In the long run, dual productivity growth rate is the rate of reduction in total cost induced by technological change, holding output and input prices fixed. That is, in the long run, capital is allowed to adjust optimally.

The industry-wide average long-run dual productivity growth rate is -0.01, very close to the short-run rate of -0.01094. The highest annual average productivity growth rate is found at-0.195 in the pet food industry, followed by the rice milling industry at -0.014, flour milling at -0.013, animal feeds at-0.007, and bread at -0.0007. The order, which I found in long-run productivity growth rate, is same as that in short run.

From 1972-1974, we observed a sudden increase in productivity growth rate in all the five industries, then in the following year 1975, we also observed a sudden decrease in productivity growth rate. Since then, productivity growth rates are relatively constant in flour milling, animal feeds, and bread baking industries until early 1980's, and they have begun falling in animal feeds and bread baking industries. Especially, bread industry has shown negative rate of growth in the 1980's and 1990's. The flour milling industry's productivity growth in the 1980's and 1990's is constant, thus, it has kept relatively constant productivity growth over the study period.

We observed some fluctuations in the1980's and 1990's in the pet food and rice industries, which have shown the highest productivity growth rate. The pet food industry has experienced dramatic increase in productivity growth rate in the late 1970's, then growth rate began to fall in the following decades.

Figure 6. 4. 1a: Short-Run Dual Productivity Growth Rate in the U.S. Grain Milling Industry

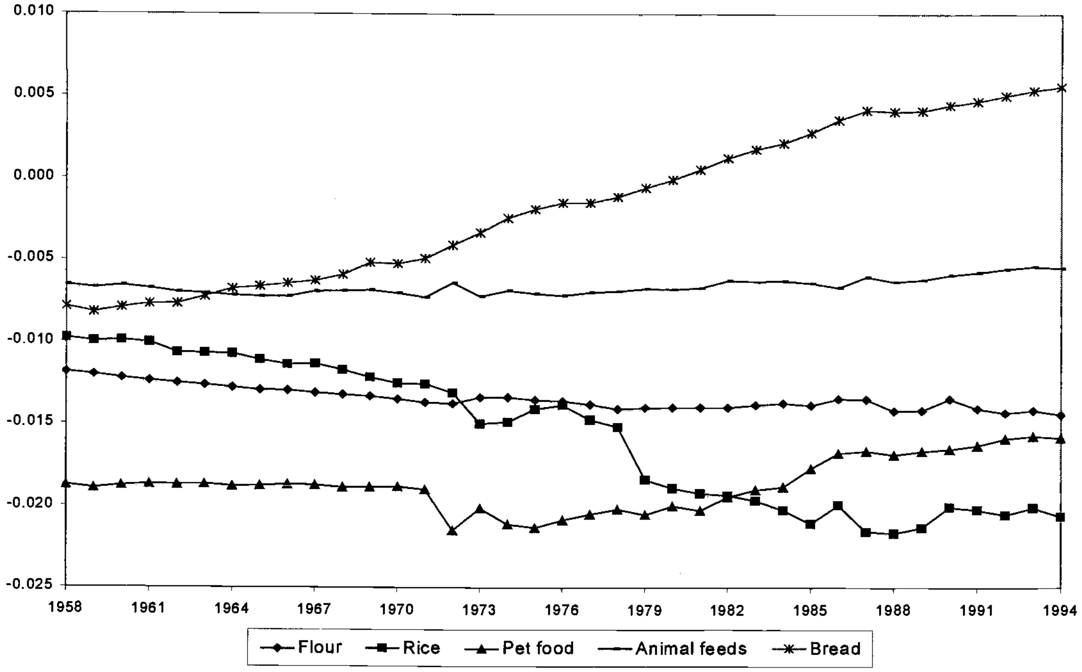
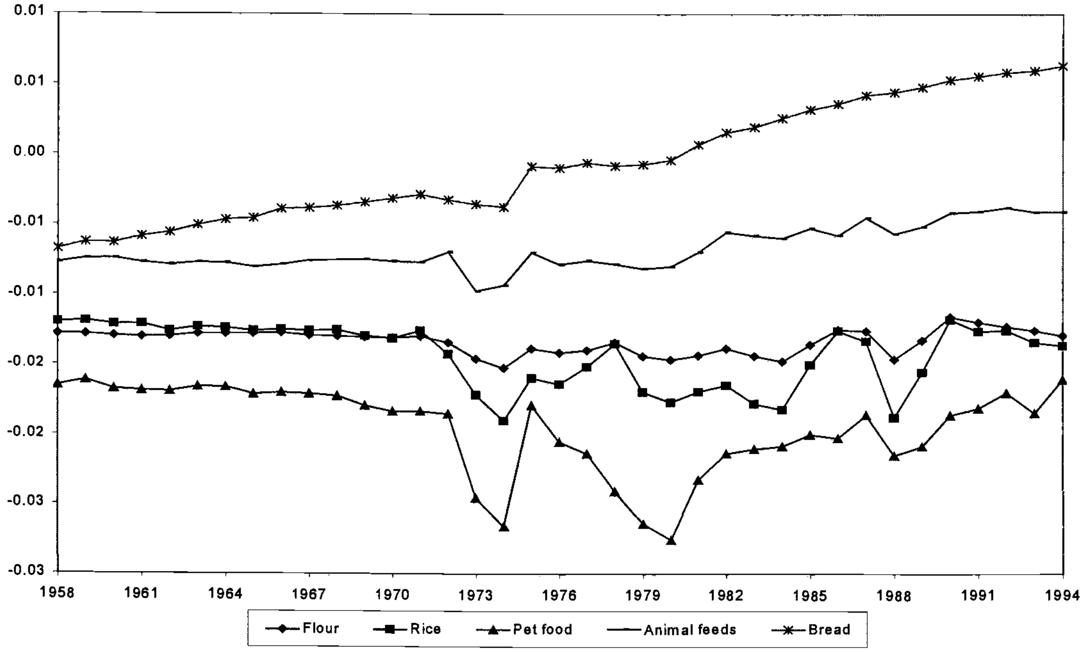


Figure 6. 4. 1b: Long-Run Dual Productivity Growth Rate in the U.S. Grain Milling Industry



6. 4. 2. Capital Intensity and Dual Productivity Growth Rate

In this section, the effect of capital intensity on dual productivity growth rate is analyzed. I hypothesized that capital intensity and productivity growth rate are positively related in chapter 1. That is, if an industry has more capital stock, it will demonstrate a higher productivity growth rate.

In order to examine this relationship, first we define an increase in capital intensity as the increase in the ratio of capital to the other two aggregated inputs. And, if the derivative of the dual productivity growth rate with respect to capital is negative, the implication is that an increase in productivity growth rate or reduction in cost is induced by higher capital intensity[1]. The derivative of dual productivity growth rate with respect to capital includes only one estimated parameter, that is γ_{tK}[2]. In order to confirm my hypothesis, then γ_{tK} must be negative.

Recall that, from the parameter estimates from table 6. 1., all industries have negative parameter estimates of γ_{tK}. Therefore, capital intensity is positively related to productivity growth rate in each industry.

Comparison between short-run and long-run rates of dual productivity growth and the capacity utilization measure reveals further details. When capital stock is underutilized, there is excess capacity and the current capital stock level is greater than the optimal level (K > K*). In this case, capital intensity is high. Since γ_{tK} is

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[1] As capital (K) rises and output (Y) is fixed, variable inputs materials (M) and labor (L) must fall in the aggregate.

[2] $$\frac{\partial(\partial VC/\partial t)}{\partial K} = 0.25Y^{0.5}\gamma_{tK}t^{-0.5}K^{-0.5}(W_l + W_m) = \frac{\partial(\partial VC/\partial K)}{\partial t} = \frac{\partial Z_k}{\partial t}$$

negative, the short-run productivity growth rate must be higher than the long-run productivity growth rate. When capital stock is overutilized, the reverse must be true.

Table 6.4.2 summarizes the annual average results of both the short-run and long-run productivity growth rates, and adds a column giving the corresponding capacity utilization measures, which I recall from section 6.3. The difference between the short-run and long-run rates is in the third column. If the difference is negative, the short-run productivity growth rate is greater than the long-run growth rate, whereas a positive sign indicates that the reverse is true.

In the flour milling, rice milling, and bread industries, the capital utilization measure indicates underutilization of capital stock; that is, on average, excess capacity prevails, and the short-run productivity growth rates are greater than the long run productivity growth rates. In the remaining two industries, namely pet food and animal feeds, the long-run productivity growth rate has been higher than the short-run growth rate. Consistent with this, the capacity utilization measures have indicated overutilization of capital stock.

Table 6. 4. 2: Comparison between Short-run and Long-run Rate of Dual Productivity Growth Rate

Industry	ε_{Ct}^{SR}	ε_{Ct}^{LR}	$\varepsilon_{Ct}^{SR} - \varepsilon_{Ct}^{LR}$	CU
Flour Milling (SIC2041)	-0.01345	-0.0134	-0.0001	0.993
Rice Milling (SIC2044)	-0.01562	-0.0143	-0.00132	0.949
Pet Food (SIC2047)	-0.01868	-0.0195	0.00086	1.011
Animal Feeds (SIC2048)	-0.00659	-0.0068	0.00017	1.002
Bread Bakery (SIC2051)	-0.00163	-0.0007	-0.00097	0.94

6. 4. 3. Primal Productivity Growth Rate

Average short-run and long-run primal measures of productivity growth are shown in tables 6. 4a and 6. 4b respectively, and annual rates are graphed in figure 6. 4. 3a and 6. 4. 3b.

The short-run primal rate shows the percentage increase in output induced by the change in t holding input levels, including capital, fixed. The industry-wide annual average primal growth rate is 0.014. Among the five industries, the highest annual average growth rate is 0.027, found in pet food industry. This is followed by 0.017 in the flour industry, 0.016 in the rice industry, 0.007 in the animal feeds industry, and 0.002 in the bread industry.

Primal productivity growth in the flour, rice, and pet food industries has been on an increasing trend, whereas in animal feeds it is relatively stable and is even declining in the bread industry. These results are consistent with the corresponding short-run dual productivity growth measures, except in the pet food industry. In the latter, there are increasing trends in both the dual and primal measure. Primal productivity growth in the bread industry has been falling continuously and became negative in 1981, implying that technology change has reduced the output achievable with given levels of the conventional labor and material inputs.

In the long run, the industry-wide average is 0.014, and it is greater than short-run average (0.0138). Long-run annual average growth rate is greater than short-run rate in pet food and animal feeds industries, while the reverse is true in other three industries, flour, rice, and bread industries. The highest annual average growth rate is found in pet food industry at 0.02652 followed by 0.01692 in flour, 0.01517 in rice, 0.00689 in animal feeds, and 0.00103 in bread.

The figure reveals that until 1970's, all five industries showed stable growth until 1972. In the following two years, all the industries increased the productivity growth rate. As I mentioned earlier, the large export demand and optimistic behavior toward oil crisis induced this result. In the late 1970's, all but pet food industry exhibited constant increase in productivity growth rate. Pet food industry shows an exceptionally high productivity growth rate in the same period. Even in the recession in early 1980's, all but the bread industry maintained a positive rate of productivity growth, although they are constant. Analogous to the short run, the productivity growth rate in bread industry has become negative since 1981, that is its obtainable level of output with given input level has been declining. In the late 1980's and 1990's, productivity growth in pet food industry has risen again, even though there are some declines, it has maintained the highest rate of productivity growth rate among five industries.

Figure 6. 4. 3a: Short-Run Primal Productivity Growth Rate in the U.S. Grain Milling Industry

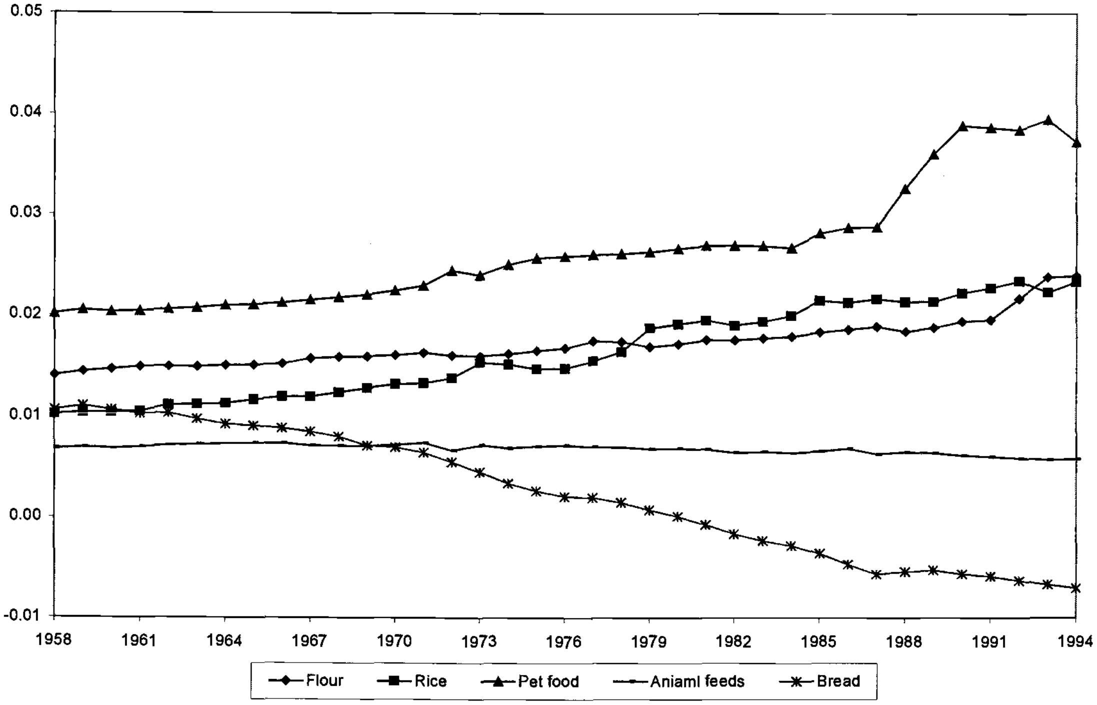
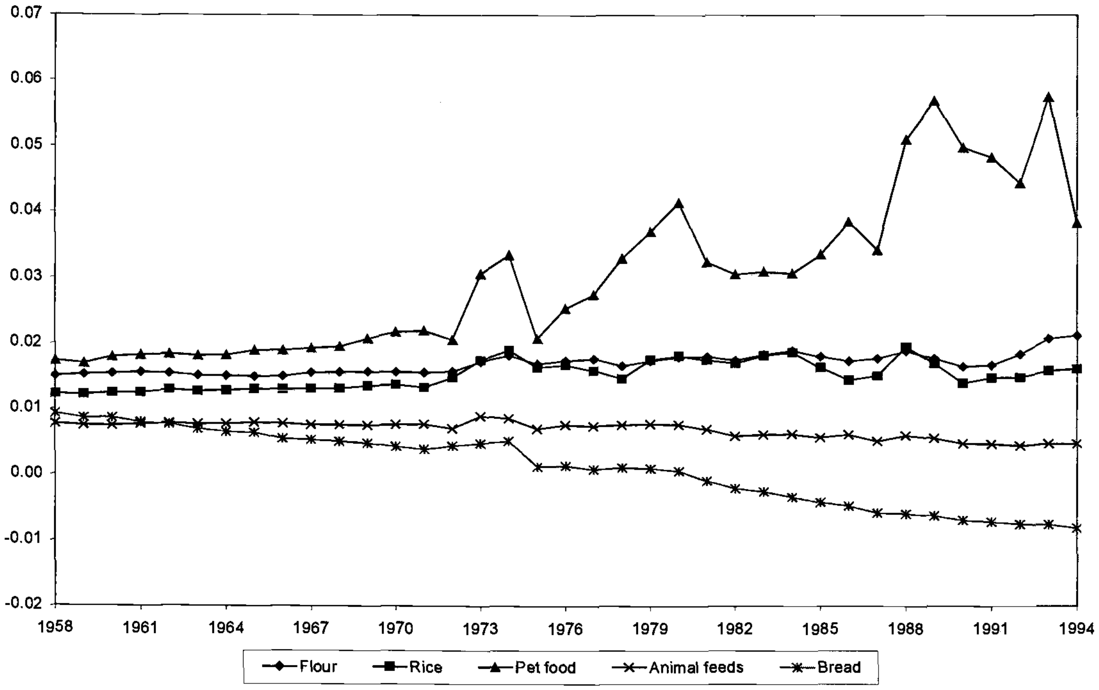


Figure 6. 4. 3b: Long-Run Primal Productivity Growth Rate in the U.S. Grain Milling Industry



6. 4. 4. Cost elasticities

Recall the table 6. 4a and 6. 4b, the average cost elasticities are reported in short run and long run respectively. The reciprocal of cost elasticity is interpreted as scale elasticity, therefore, if cost elasticity is below 1.0, an industry is on increasing-returns-to-scale proportion (IRTS) of average total cost.

In both short run and long run, flour milling, pet food, and bread industries' cost elasticities are relatively away below 1.0 in comparison to other two industries. Therefore, these industries are on the IRTS portion, which is relatively steeper than other two industries. That creates opportunity for firms to capture size economies, therefore, there are incentives to merge or consolidate each other among firms, and that leads to an increase in market concentration.

Rice milling and animal feeds industries operate on the constant-returns-to-scale portion, and there is less opportunity to take advantage of scale economy.

6. 5. Bias of Technological Change

6. 5. 1. Short-Run Bias of Technological Change

The results of my estimates of the short-run bias of technological change are presented in the table 6.5.1 and in the corresponding figures 6. 5. 1a - 6. 5. 1e. In the short-run two-input case, each sample year must contain positive and negative signs because if one of two inputs increases its cost share in total cost, the other input must decrease its cost share. Since the bias of technological change is the cetris paribus *percentage* change in the percent cost share, it need not sum to one, while the cost shares themselves must sum to one.

As an industry-wide average, technological change in the grain milling industries has been both labor- and material-using. The annual averages of each separate industry show that flour and rice milling technology change has been labor-using and material-saving. However, a closer look reveals that flour milling was labor-saving and material-using until 1980, and this was the case also in all five industries except rice milling. The rice milling industry was labor-using and material-saving until 1978, and became labor-saving and material-using after that.

We observe that, on average, technology change in pet food, animal feeds, and the bread industries has been labor-saving and material-using. These three industries exhibited labor-saving and material-using technology change until 1980 or 1981, then technology became labor-using and material-saving.

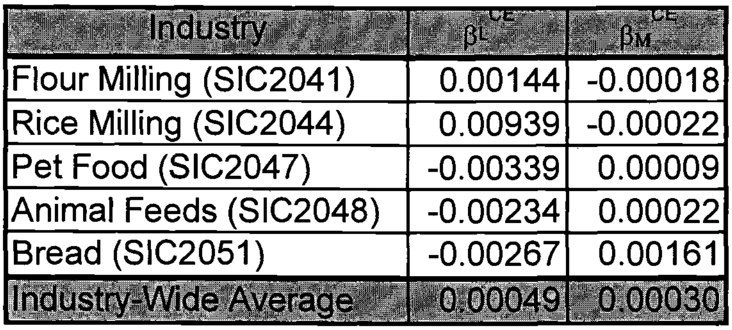
There are two possible reasons why all but rice milling have tended to become labor-using and material-saving in recent years. One reason is institutional:

firms have perhaps realized that increases in the labor quality, that is the marginal product of labor, have been higher than increases in labor wages. In this way, firms have stronger incentives than before to hire labor in order to reduce total cost.

The second reason is related to the nature of this measure. The bias of technological change represents a cetris paribus percentage change in cost share. Therefore, a particular change in cost share represents a higher bias to the extent that the cost share in the base year is smaller. In all five industries except bread bakery, labor share is very small relative to materials. Excluding the bread industry, the labor cost share is 7.7 %, the material cost share is 92.3 % in this sector on average. Thus, it is easy to register higher labor-saving bias of technological change.

Finally, real labor wages have been increasing over the study period, while real material prices have been rather constant. Therefore, increases not only in the quantity of labor, but also in its price have magnified increases in the cost share, and thus in the bias measure.

Table 6. 5. 1: Average Short-Run Bias of Technological Change



Industry	β_L^{CE}	β_M^{CE}
Flour Milling (SIC2041)	0.00144	-0.00018
Rice Milling (SIC2044)	0.00939	-0.00022
Pet Food (SIC2047)	-0.00339	0.00009
Animal Feeds (SIC2048)	-0.00234	0.00022
Bread (SIC2051)	-0.00267	0.00161
Industry-Wide Average	0.00049	0.00030

Note: Short-run bias of technological change is calculated by equation (4.39) in chapter 4.

Figure 6. 5. 1a: Short-Run Bias of Technological Change in the Flour Milling Industry (SIC2041)

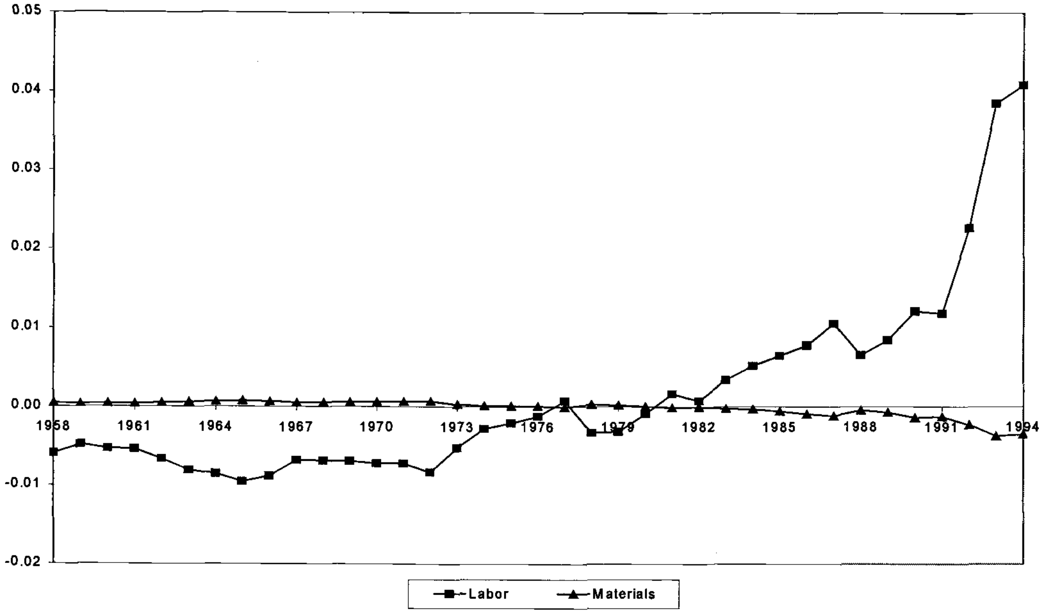


Figure 6. 5. 1b: Short-Run Bias of Technological Change in the Rice Milling Industry (SIC2044)

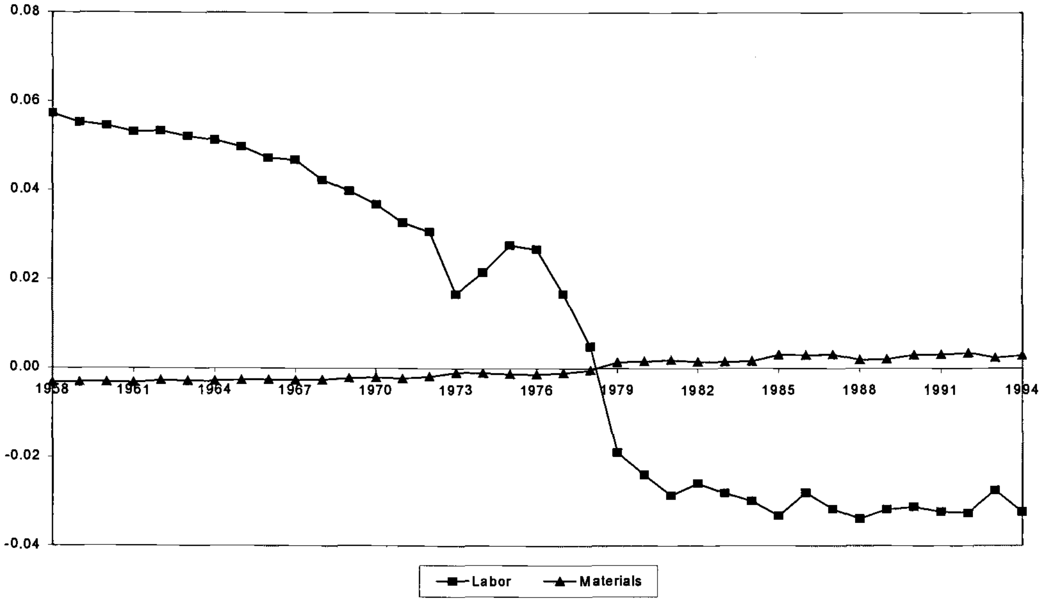


Figure 6. 5. 1c: Short-Run Bias of Technological Change in the Pet Food Industry (SIC2047)

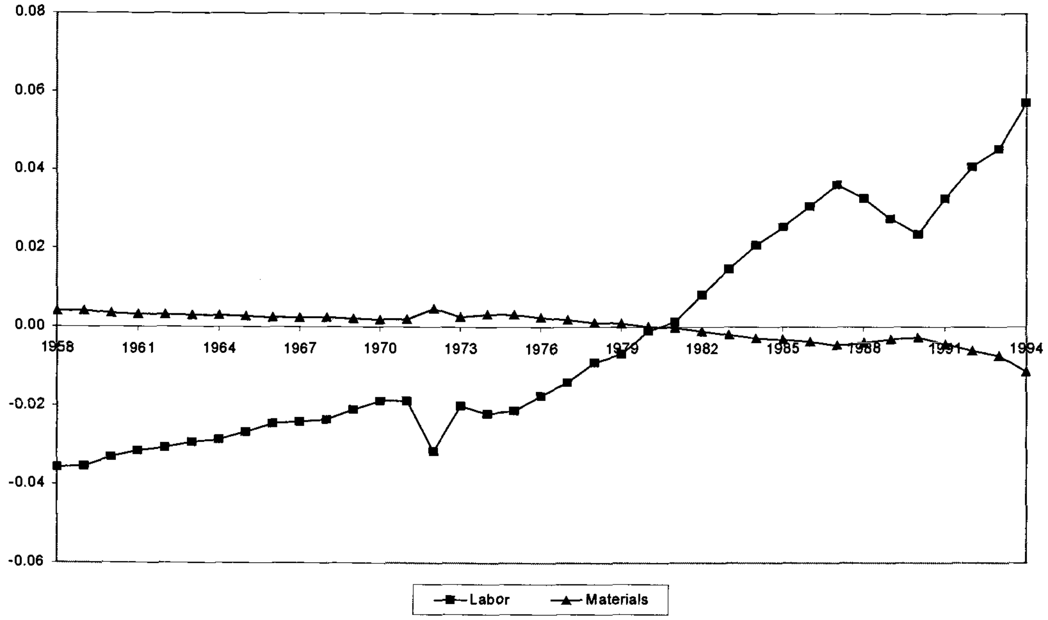


Figure 6. 5. 1d: Short-Run Bias of Technological Change in the Animal Feeds Industry (SIC2048)

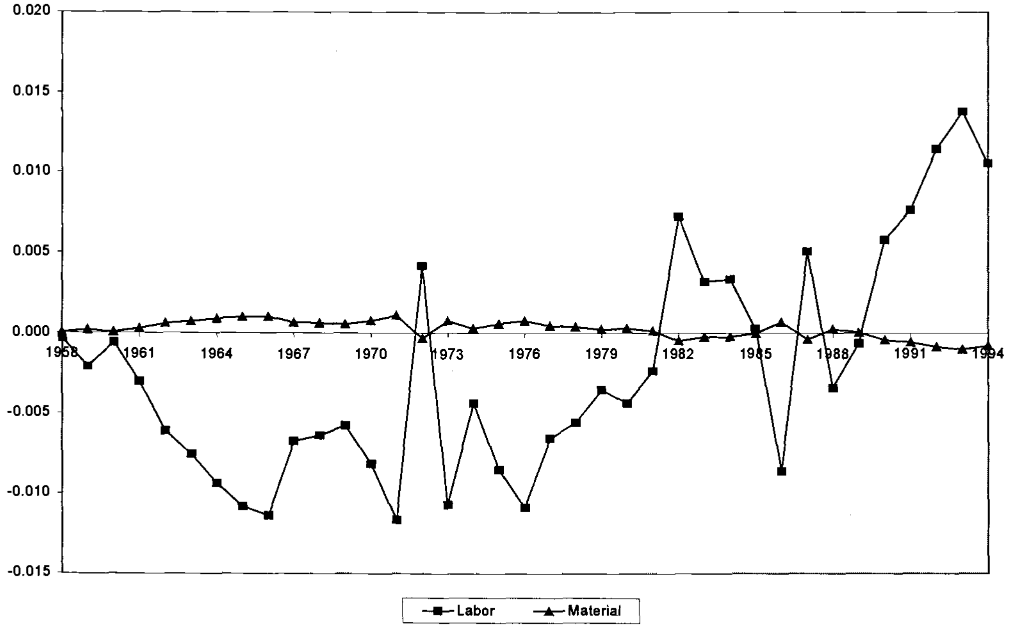
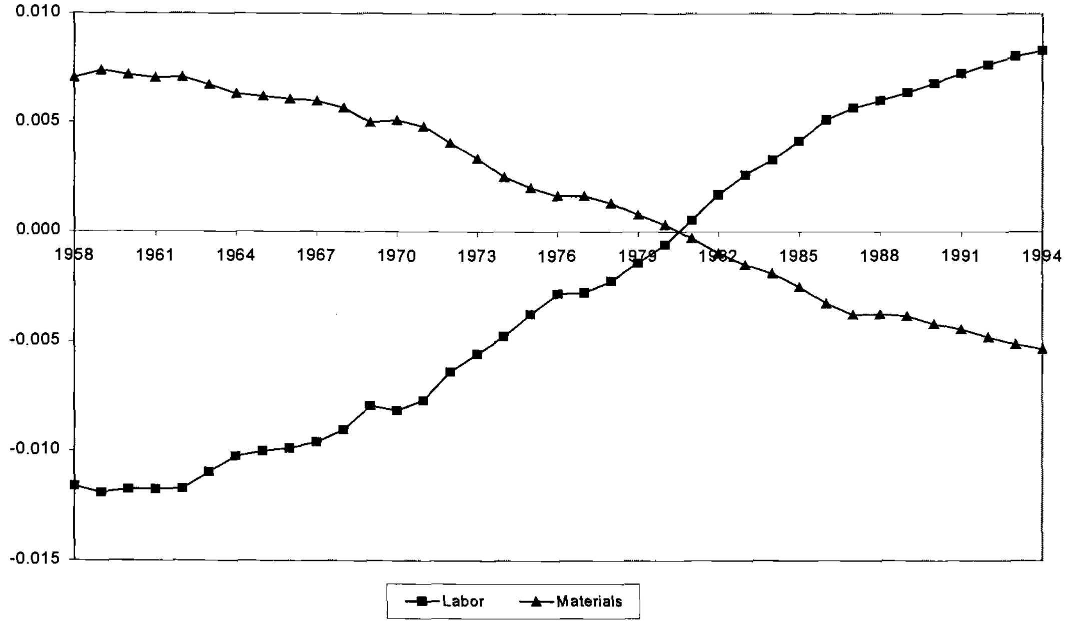


Figure 6. 5. 1e: Short-Run Bias of Technological Change in the Bread Baking Industry (SIC2051)



6. 5. 2. Long-Run Bias of Technological Change

Estimates of the long-run biases of technological change are shown in table 6. 5. 2 and in figures 6. 5. 2a - 6. 5. 2e. In the long run, all three inputs are adjustable, thus I obtain bias measures for all three. The sector-wide annual average bias shows that the grain milling industries exhibit labor- and capital-using and material-saving technology change. As an annual average, the rice milling and pet food industries have exhibited this very same type of technology change, that is labor- and capital-using and material-saving. However, the rice industry is exceptional in that it has consistently demonstrated labor-using technological shifts, whereas the pet food, flour, animal feeds, and bread industries exhibited labor-saving technology change until the early 1980's. Technology biases in the latter three industries have been labor-and material-saving and capital-using.

In all five industries, the long-run biases of technological change have had trends similar to those in the short run. Generally speaking, the cost share of materials has been decreasing and that of capital increasing. This implies that technology in the grain milling industries has become more capital-intensive. Except in the rice industry, recent technological change has shown a labor-using bias, implying that firms have cetris paribus, increased their labor cost shares for the reasons stated above in the short-run section.

Table 6. 5. 2: Average Long-Run Bias of Technological Change

Industry	β_L^{CE}	β_M^{CE}	β_K^{CE}
Flour Milling (SIC2041)	-0.00221	-0.00415	0.01901
Rice Milling (SIC2044)	0.03589	-0.01059	0.02970
Pet Food (SIC2047)	0.07806	-0.01993	0.04948
Animal Feeds (SIC2048)	-0.01481	-0.00658	0.03139
Bread (SIC2051)	-0.00988	-0.00543	0.01579
Industry-Wide Average	0.01741	-0.00934	0.02907

Note: Long-run bias of technological change is calculated by equation (4.39) in chapter 4.

Figure 6. 5. 2a: Long-Run Bias of Technological Change in the Flour Milling Industry (SIC2041)

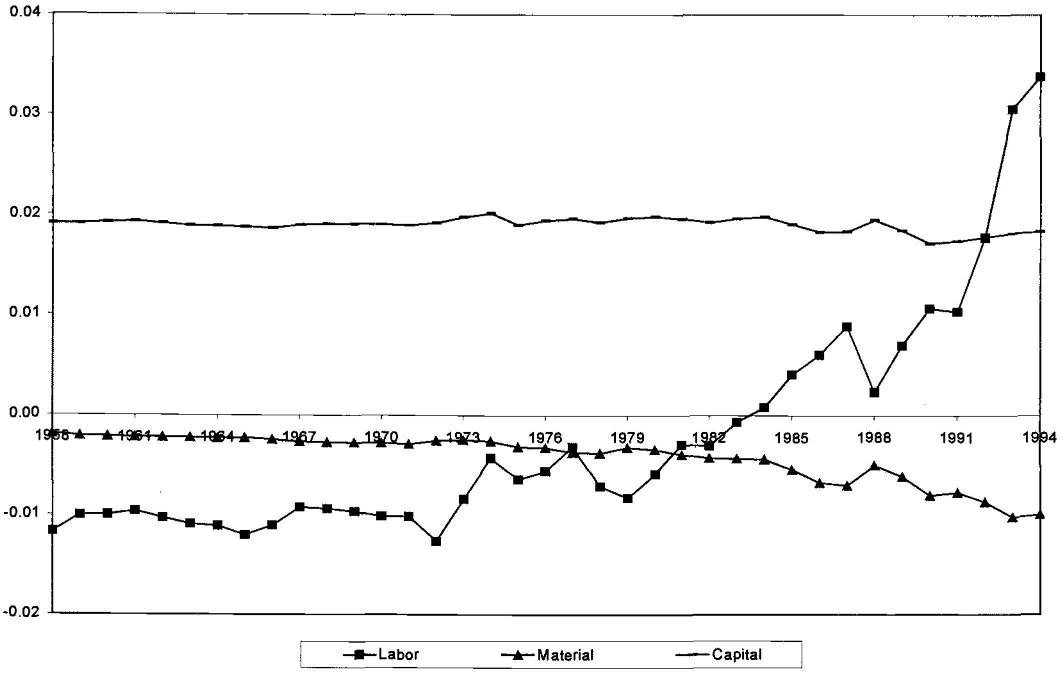


Figure 6. 5. 2b: Long-Run Bias of Technological Change in the Rice Milling Industry (SIC2044)

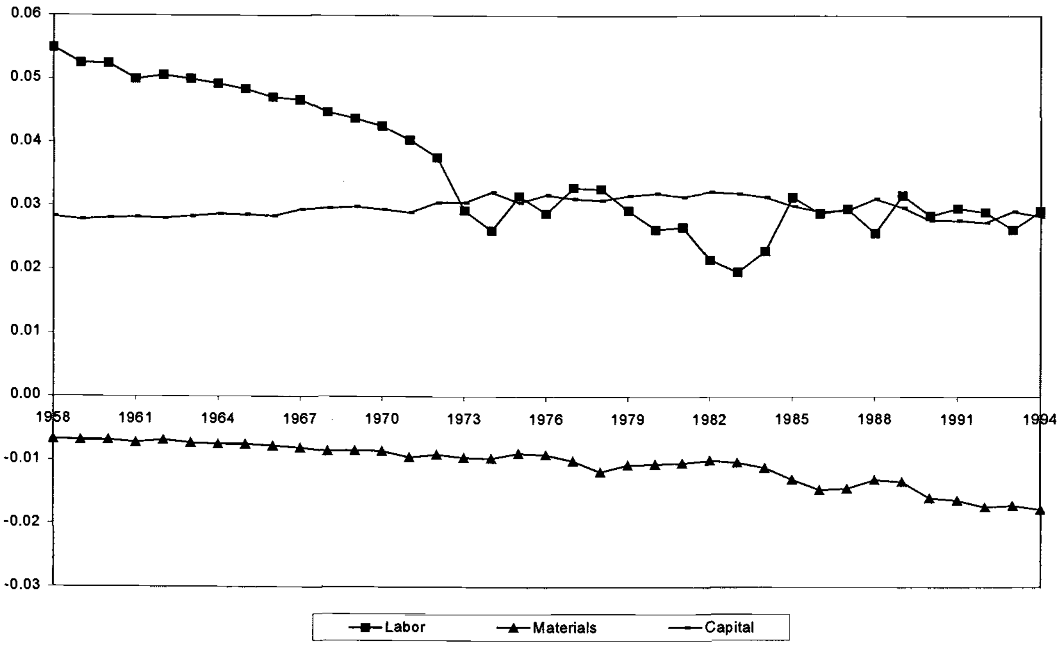


Figure 6. 5. 2c: Long-Run Bias of Technological Change in the Pet Food Industry (SIC2047)

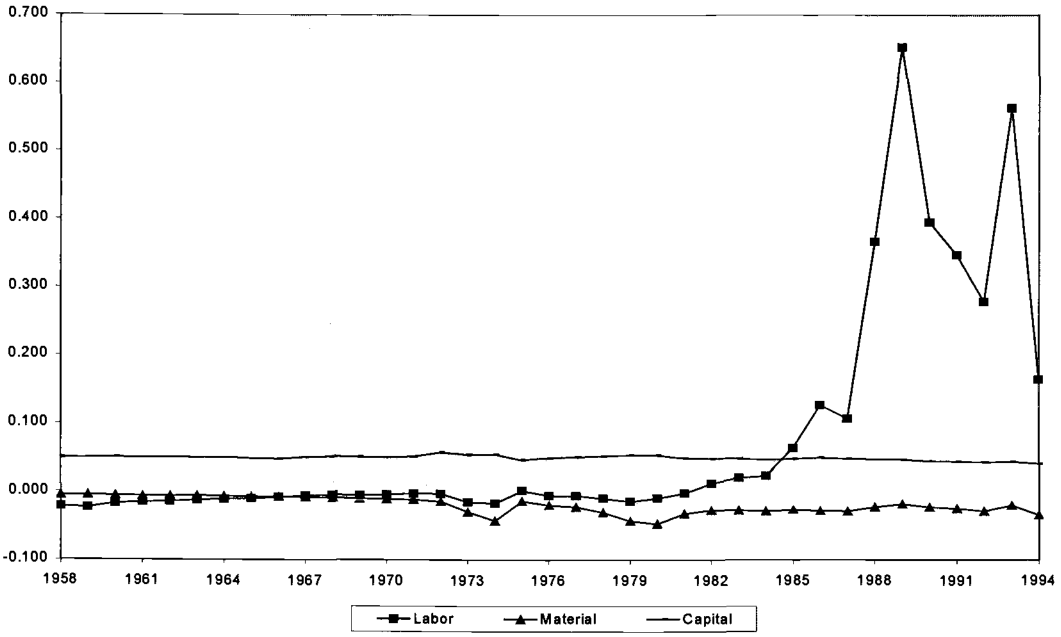


Figure 6. 5. 2d: Long-Run Bias of Technological Change in the Animal Feeds Industry (SIC2048)

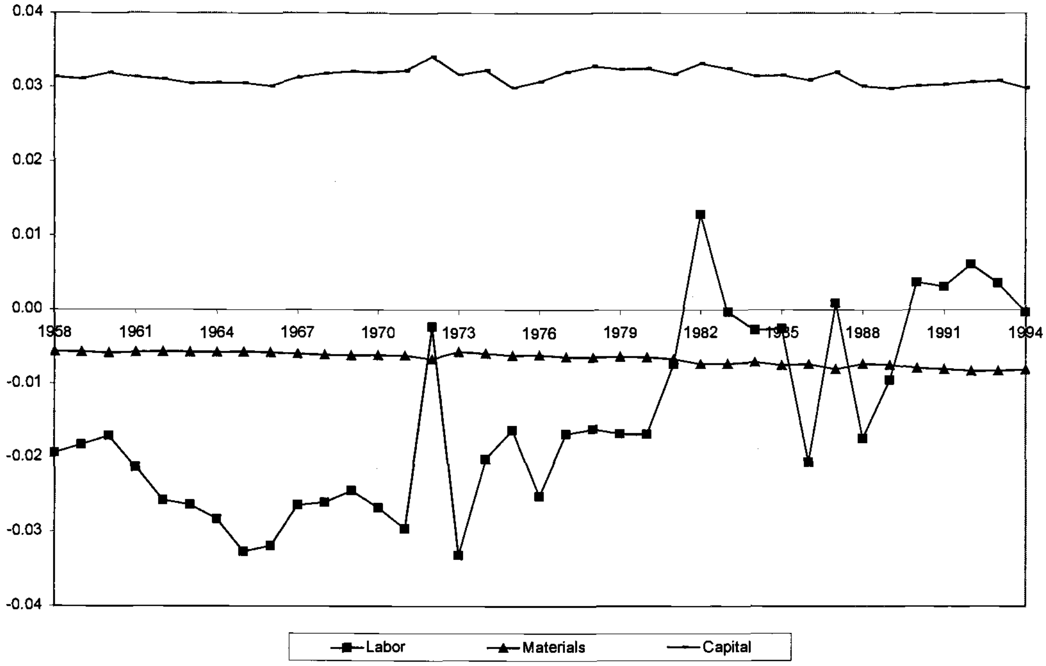
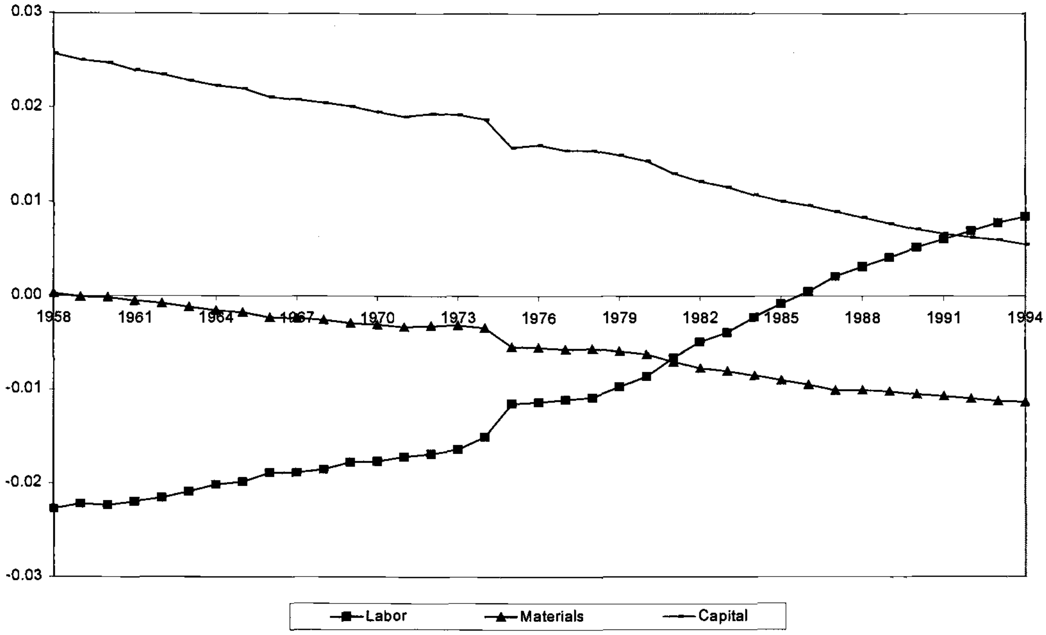


Figure 6. 5. 2e: Long-Run Bias of Technological Change in the Bread Baking Industry (SIC2051)



6. 6. Market Power

Market power is one of the controversial issues in some industries such as flour milling industry (Marion and Kim, 1991). Although the consequence of high market power on productivity growth may vary depending on each industry, it may have some effect on productivity growth.

In order to develop reasonable market power estimates, we restrict estimates of the slopes of output (Y) in the price-dependent output demand equation, based on output demand elasticities reported in Bhuyan and Lopez (1997). Demand elasticities which I used are -0.710 for flour; -0.294 for rice; -0.122 for pet food; -0.386 for animal feeds; and -0.661 for bread. These estimates were obtained using a translog cost function with four inputs: capital, labor, materials, and energy, together with a supply function with market power term similar to my own. In the following table, results from Bhyan and Lopez are presented next to my own results.

Bhuyan and Lopez (1997) found the flour millers exercised fairly high levels of oligopoly power, while rice and pet food firms exercised low. My results suggest that among these five industries, flour milling and bread baking have demonstrated relatively high market power, that rice and pet food have revealed somewhat low market power, and that market power in animal feeds has been close to zero. Therefore, both their and my results suggest that market power has been low in rice and pet food and high in flour milling and bread baking, even though the magnitudes of their and my results are quite different.

In regard to productivity growth, the pet food and rice milling industries, which exhibited the highest productivity growth rates, have shown low levels of market power in both studies. I conclude that these industries are highly competitive, and this keeps the industries' productivity growth high. The flour milling industry, which has exhibited high market power, also has had high productivity growth, although in recent years this growth rate has been rather constant. Thus, higher market power, mostly resulting from the mergers and consolidations during the past several decades, has increased efficiency. However, it has also served to keep productivity growth from rising.

The bread baking industry has exhibited rather high market power also, and this has been associated with relatively low productivity growth.

Table 6. 6: Comparison of Oligopoly Power

Industry	Market Power Estimate (This study)	Lerner Index (Bhuyan and Lopez)
Flour Milling (SIC2041)	0.1371	0.679
Rice Milling (SIC2044)	0.0106	0.109
Pet Food (SIC2047)	0.0276	0.115
Animal Feeds (SIC2048)	0.0094	0.448
Bread Bakery (SIC2051)	0.1499	0.219

Chapter 7: Conclusions

In all five grain-milling industries analyzed, significant structural changes have occurred during the past two decades. However, the five industries exhibit substantial variety in productivity growth rate, technical structure, and market structure. All but the bread industry have enjoyed positive productivity growth during the 1980's and 1990's. Here I summarize the results.

The highest mean productivity growth rate was found in the pet food industry, where substitutability among inputs is quite high, and therefore own-price input demand elasticities are high also. More than in the other five industries, technological change has been capital-using. Given the fact that this industry has been enjoying high productivity growth rates and market power has been very low, we may conclude that its technical and pricing efficiency have been very good.

The flour milling industry displays the third highest mean productivity growth rate of those studied here, although its rates have not changed much over the years. Substitutability among inputs and own-price input demand elasticities have been quite low. The controversial issue in the flour milling industry has been whether market power has been increasing, and in this study, evidence of market power is indeed fairly high. Although the effect of market power on productivity growth has not been clearly demonstrated by anyone, further research will be needed to determine whether high market power has reduced productivity growth in this industry.

Input substitutability has stayed low in the rice milling industry. The response of input use to input price changes has remained low also except in the case of the capital input. Productivity growth has ranked second highest among five the industries examined here. Historically, this industry has been heavily influenced by government programs, particularly by export subsidies and import controls. Export demand has been an important factor in rice milling industry growth. However, recent reductions in government intervention and severe excess capacity, combined with low firm-level market power, have forced rice millers to improve efficiency. If millers successfully survive this process, the rice milling industry will remain competitive in both international and domestic markets.

Rates of productivity growth in the animal feeds industry have been decreasing slightly since the late 1950's. A possible reason is the increasing use of on-site feed mixing in feed lots, instead of the purchase of commercial feeds. The resulting trend toward small-scale operations may discourage technological advance. Although the relationship has not been examined in this study, increases in government regulations regarding human health and the environment may have negatively affected productivity growth in this industry as well. Substitutability among inputs and input demand elasticities in animal feeds production have been moderate.

The lowest mean productivity growth rate in this study is found in the bread industry. Substitutability among inputs and own-price input demand elasticities are moderate in bread production, and market power is high. In a long-run sense, technology change in the bread industry has been biased in favor of capital, but this bias has been decreasing over time. In contrast, in the other industries, there has been a relatively constant capital-using bias of technology. Competition between bread wholesalers and retailers has encouraged the introduction of new bread products, including high-valued specialty products. These new products have required additional cost and may have contributed to the negative productivity growth rates estimated here.

Recall the hypotheses I stated in chapter 1:

1. Variations in capacity utilization, productivity growth, and scale economies reflect cyclical changes in demand.
2. Capital intensity positively affects productivity growth.
3. Market power affects productivity growth, although the sign of the effect is ambiguous.

Although I have provided some evidence about hypotheses (1) and (2), the third one will require further investigation. Importantly, I have shown that capital quality is crucial to productivity change. Technical change in these industries has invariably been capital-using; and capital's shadow price has been rising, implying the quality of capital has been rising relative to that of labor and materials. Policies, then, which keep capital prices low -- such as low capital gains taxes -- are likely to encourage dynamic productivity growth.

Recently, environmental and health concerns have increased government regulation of the food and feed processing sector. These regulations have increased processing costs and may have reduced productivity growth rates. I find no evidence that pollution abatement expenditures have affected costs to a significant degree. However, government-mandated food quality regulations may have done so.

Finally, a dynamic analysis, such as the inclusion of non-static expectations and capital adjustment costs, may reveal further insights about the grain milling industry.

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APPENDIX

Table A 6. 2a-1: Short-Run Input Demand Elasticities in the U.S. Grain Milling Industry (Flour, Rice, and Pet Food)

Industry	Flour (SIC2041)				Rice (SIC2044)				Pet food (SIC2047)			
Year	E_{ll}	E_{lm}	E_{ml}	E_{mm}	E_{ll}	E_{lm}	E_{ml}	E_{mm}	E_{ll}	E_{lm}	E_{ml}	E_{mm}
1958	-0.11192	0.11192	0.00926	-0.00926	-0.02262	0.02262	0.00123	-0.00123	-0.37050	0.37050	0.03822	-0.03822
1959	-0.11636	0.11636	0.00953	-0.00953	-0.02258	0.02258	0.00135	-0.00135	-0.37636	0.37636	0.03909	-0.03909
1960	-0.11641	0.11641	0.00937	-0.00937	-0.02289	0.02289	0.00136	-0.00136	-0.46563	0.46563	0.05008	-0.05008
1961	-0.11816	0.11816	0.00948	-0.00948	-0.02180	0.02180	0.00136	-0.00136	-0.49387	0.49387	0.05129	-0.05129
1962	-0.11761	0.11761	0.00911	-0.00911	-0.02253	0.02253	0.00128	-0.00128	-0.50556	0.50556	0.05102	-0.05102
1963	-0.12442	0.12442	0.00950	-0.00950	-0.02399	0.02399	0.00139	-0.00139	-0.54956	0.54956	0.05276	-0.05276
1964	-0.12456	0.12456	0.00963	-0.00963	-0.02597	0.02597	0.00152	-0.00152	-0.56693	0.56693	0.05523	-0.05523
1965	-0.12510	0.12510	0.00958	-0.00958	-0.02714	0.02714	0.00150	-0.00150	-0.59346	0.59346	0.05546	-0.05546
1966	-0.13284	0.13284	0.00928	-0.00928	-0.02858	0.02858	0.00161	-0.00161	-0.62392	0.62392	0.05455	-0.05455
1967	-0.13621	0.13621	0.00990	-0.00990	-0.03032	0.03032	0.00165	-0.00165	-0.62424	0.62424	0.05684	-0.05684
1968	-0.13464	0.13464	0.01052	-0.01052	-0.03006	0.03006	0.00175	-0.00175	-0.62345	0.62345	0.06095	-0.06095
1969	-0.13178	0.13178	0.01090	-0.01090	-0.03250	0.03250	0.00189	-0.00189	-0.63675	0.63675	0.06409	-0.06409
1970	-0.13413	0.13413	0.01138	-0.01138	-0.03214	0.03214	0.00194	-0.00194	-0.67740	0.67740	0.06767	-0.06767
1971	-0.13539	0.13539	0.01134	-0.01134	-0.03019	0.03019	0.00205	-0.00205	-0.71372	0.71372	0.06916	-0.06916
1972	-0.14509	0.14509	0.01176	-0.01176	-0.03497	0.03497	0.00202	-0.00202	-0.58241	0.58241	0.09903	-0.09903
1973	-0.18386	0.18386	0.01108	-0.01108	-0.02984	0.02984	0.00143	-0.00143	-0.70128	0.70128	0.09240	-0.09240
1974	-0.21364	0.21364	0.01015	-0.01015	-0.03493	0.03493	0.00140	-0.00140	-0.67972	0.67972	0.09185	-0.09185
1975	-0.19816	0.19816	0.01126	-0.01126	-0.04158	0.04158	0.00186	-0.00186	-0.67958	0.67958	0.09442	-0.09442
1976	-0.19189	0.19189	0.01246	-0.01246	-0.04232	0.04232	0.00267	-0.00267	-0.74717	0.74717	0.10362	-0.10362
1977	-0.19636	0.19636	0.01529	-0.01529	-0.03516	0.03516	0.00228	-0.00228	-0.74984	0.74984	0.10846	-0.10846
1978	-0.15313	0.15313	0.01261	-0.01261	-0.02774	0.02774	0.00173	-0.00173	-0.73762	0.73762	0.11563	-0.11563
1979	-0.17569	0.17569	0.01368	-0.01368	-0.03093	0.03093	0.00224	-0.00224	-0.72108	0.72108	0.11425	-0.11425
1980	-0.18807	0.18807	0.01349	-0.01349	-0.03361	0.03361	0.00204	-0.00204	-0.78661	0.78661	0.12878	-0.12878
1981	-0.19115	0.19115	0.01395	-0.01395	-0.03928	0.03928	0.00190	-0.00190	-0.82347	0.82347	0.13474	-0.13474
1982	-0.18654	0.18654	0.01575	-0.01575	-0.04447	0.04447	0.00283	-0.00283	-0.89591	0.89591	0.14263	-0.14263
1983	-0.20729	0.20729	0.01733	-0.01733	-0.04770	0.04770	0.00321	-0.00321	-0.94356	0.94356	0.13909	-0.13909
1984	-0.24263	0.24263	0.01981	-0.01981	-0.04698	0.04698	0.00349	-0.00349	-0.95251	0.95251	0.15207	-0.15207
1985	-0.21468	0.21468	0.01762	-0.01762	-0.03732	0.03732	0.00307	-0.00307	-1.08539	1.08539	0.18638	-0.18638
1986	-0.17899	0.17899	0.01714	-0.01714	-0.03316	0.03316	0.00319	-0.00319	-1.11000	1.11000	0.19412	-0.19412
1987	-0.19188	0.19188	0.01861	-0.01861	-0.03749	0.03749	0.00407	-0.00407	-1.14555	1.14555	0.17422	-0.17422
1988	-0.24951	0.24951	0.02316	-0.02316	-0.04922	0.04922	0.00418	-0.00418	-1.31355	1.31355	0.16718	-0.16718
1989	-0.22791	0.22791	0.01774	-0.01774	-0.04554	0.04554	0.00370	-0.00370	-1.41251	1.41251	0.17167	-0.17167
1990	-0.19822	0.19822	0.01600	-0.01600	-0.03932	0.03932	0.00321	-0.00321	-1.43812	1.43812	0.17312	-0.17312
1991	-0.19980	0.19980	0.01900	-0.01900	-0.03941	0.03941	0.00303	-0.00303	-1.39321	1.39321	0.16027	-0.16027
1992	-0.20348	0.20348	0.01780	-0.01780	-0.04024	0.04024	0.00319	-0.00319	-1.25896	1.25896	0.16808	-0.16808
1993	-0.21390	0.21390	0.01804	-0.01804	-0.04752	0.04752	0.00340	-0.00340	-1.23698	1.23698	0.16049	-0.16049
1994	-0.24172	0.24172	0.01850	-0.01850	-0.04316	0.04316	0.00327	-0.00327	-1.23381	1.23381	0.15857	-0.15857
Average	-0.17171	0.17171	0.01354	-0.01354	-0.03447	0.03447	0.00230	-0.00230	-0.82298	0.82298	0.10804	-0.10804
Std.dev	0.04188	0.04188	0.00390	0.00390	0.00814	0.00814	0.00088	0.00088	0.30635	0.30635	0.04953	0.04953

Note: Short-run input demand elasticities are computed from equation (4.30) in chapter 4.

Table A 6. 2a-2: Short-Run Input Demand Elasticities in the U.S. Grain Milling Industry (Animal Feeds and Bread)

Industry	Animal feeds (SIC2048)				Bread (SIC2051)			
Year	E_{ll}	E_{lm}	E_{ml}	E_{mm}	E_{ll}	E_{lm}	E_{ml}	E_{mm}
1958	-0.24532	0.24532	0.02532	-0.02532	-0.25445	0.25445	0.14771	-0.14771
1959	-0.25111	0.25111	0.02608	-0.02608	-0.24846	0.24846	0.14986	-0.14986
1960	-0.26214	0.26214	0.02821	-0.02821	-0.24396	0.24396	0.15065	-0.15065
1961	-0.26395	0.26395	0.02742	-0.02742	-0.24439	0.24439	0.15027	-0.15027
1962	-0.25628	0.25628	0.02587	-0.02587	-0.24621	0.24621	0.15439	-0.15439
1963	-0.26606	0.26606	0.02554	-0.02554	-0.26128	0.26128	0.16155	-0.16155
1964	-0.27419	0.27419	0.02670	-0.02670	-0.26440	0.26440	0.16296	-0.16296
1965	-0.28342	0.28342	0.02650	-0.02650	-0.27100	0.27100	0.16628	-0.16628
1966	-0.29349	0.29349	0.02567	-0.02567	-0.27139	0.27139	0.16401	-0.16401
1967	-0.30063	0.30063	0.02737	-0.02737	-0.27694	0.27694	0.16667	-0.16667
1968	-0.30609	0.30609	0.02994	-0.02994	-0.27833	0.27833	0.17200	-0.17200
1969	-0.30780	0.30780	0.03099	-0.03099	-0.28046	0.28046	0.17601	-0.17601
1970	-0.31031	0.31031	0.03100	-0.03100	-0.28501	0.28501	0.18217	-0.18217
1971	-0.32281	0.32281	0.03129	-0.03129	-0.28649	0.28649	0.18670	-0.18670
1972	-0.33204	0.33204	0.02863	-0.02863	-0.30013	0.30013	0.19422	-0.19422
1973	-0.33630	0.33630	0.02149	-0.02149	-0.31180	0.31180	0.18187	-0.18187
1974	-0.37099	0.37099	0.02311	-0.02311	-0.34651	0.34651	0.17216	-0.17216
1975	-0.36324	0.36324	0.02534	-0.02534	-0.34329	0.34329	0.17763	-0.17763
1976	-0.36077	0.36077	0.02479	-0.02479	-0.32421	0.32421	0.18341	-0.18341
1977	-0.40875	0.40875	0.02615	-0.02615	-0.32334	0.32334	0.19321	-0.19321
1978	-0.39758	0.39758	0.02843	-0.02843	-0.31377	0.31377	0.19524	-0.19524
1979	-0.43151	0.43151	0.02744	-0.02744	-0.31353	0.31353	0.18958	-0.18958
1980	-0.43428	0.43428	0.02827	-0.02827	-0.31749	0.31749	0.18646	-0.18646
1981	-0.47500	0.47500	0.02934	-0.02934	-0.31890	0.31890	0.18648	-0.18648
1982	-0.49955	0.49955	0.03389	-0.03389	-0.32302	0.32302	0.19870	-0.19870
1983	-0.47822	0.47822	0.03148	-0.03148	-0.32770	0.32770	0.20181	-0.20181
1984	-0.53059	0.53059	0.03465	-0.03465	-0.32430	0.32430	0.20206	-0.20206
1985	-0.52528	0.52528	0.03861	-0.03861	-0.31850	0.31850	0.20077	-0.20077
1986	-0.48649	0.48649	0.03845	-0.03845	-0.34153	0.34153	0.20686	-0.20686
1987	-0.48688	0.48688	0.03896	-0.03896	-0.34554	0.34554	0.21581	-0.21581
1988	-0.50642	0.50642	0.03527	-0.03527	-0.32800	0.32800	0.20440	-0.20440
1989	-0.50279	0.50279	0.03516	-0.03516	-0.32566	0.32566	0.19055	-0.19055
1990	-0.50686	0.50686	0.03775	-0.03775	-0.32771	0.32771	0.18830	-0.18830
1991	-0.50478	0.50478	0.03802	-0.03802	-0.31491	0.31491	0.18618	-0.18618
1992	-0.51215	0.51215	0.03844	-0.03844	-0.30593	0.30593	0.18601	-0.18601
1993	-0.53673	0.53673	0.04167	-0.04167	-0.29835	0.29835	0.17958	-0.17958
1994	-0.52903	0.52903	0.04263	-0.04263	-0.29944	0.29944	0.17839	-0.17839
Average	-0.39081	0.39081	0.03070	-0.03070	-0.30017	0.30017	0.18084	-0.18084
Std.dev	0.10238	0.10238	0.00559	0.00559	0.03114	0.03114	0.01762	0.01762

Note: Short-run input demand elasticities are computed from equation (4.30) in chapter 4.

Table A 6. 2b: Short-Run Morishima Substitution Elasticities in the U.S. Grain Milling Industry

Industry	Flour (SIC2041)		Rice (SIC2044)		Pet food (SIC2047)		Animal feeds (SIC20		Bread (SIC2051)	
Year	Q_{lm}	Q_{ml}	Q_{lm}	Q_{ml}	Q_{lm}	Q_{ml}	Q_{lm}	Q_{ml}	Q_{lm}	Q_{ml}
1958	0.12118	0.12118	0.02385	0.02385	0.40872	0.40872	0.27064	0.27064	0.40216	0.40216
1959	0.12589	0.12589	0.02394	0.02394	0.41545	0.41545	0.27719	0.27719	0.39833	0.39833
1960	0.12578	0.12578	0.02425	0.02425	0.51571	0.51571	0.29036	0.29036	0.39461	0.39461
1961	0.12764	0.12764	0.02316	0.02316	0.54517	0.54517	0.29136	0.29136	0.39466	0.39466
1962	0.12673	0.12673	0.02381	0.02381	0.55659	0.55659	0.28215	0.28215	0.40060	0.40060
1963	0.13392	0.13392	0.02537	0.02537	0.60231	0.60231	0.29159	0.29159	0.42283	0.42283
1964	0.13419	0.13419	0.02749	0.02749	0.62216	0.62216	0.30088	0.30088	0.42736	0.42736
1965	0.13468	0.13468	0.02864	0.02864	0.64892	0.64892	0.30992	0.30992	0.43728	0.43728
1966	0.14212	0.14212	0.03020	0.03020	0.67848	0.67848	0.31916	0.31916	0.43541	0.43541
1967	0.14611	0.14611	0.03197	0.03197	0.68108	0.68108	0.32800	0.32800	0.44362	0.44362
1968	0.14516	0.14516	0.03181	0.03181	0.68440	0.68440	0.33604	0.33604	0.45034	0.45034
1969	0.14269	0.14269	0.03439	0.03439	0.70084	0.70084	0.33879	0.33879	0.45647	0.45647
1970	0.14551	0.14551	0.03408	0.03408	0.74507	0.74507	0.34131	0.34131	0.46718	0.46718
1971	0.14674	0.14674	0.03224	0.03224	0.78287	0.78287	0.35410	0.35410	0.47319	0.47319
1972	0.15685	0.15685	0.03699	0.03699	0.68144	0.68144	0.36067	0.36067	0.49435	0.49435
1973	0.19494	0.19494	0.03127	0.03127	0.79368	0.79368	0.35779	0.35779	0.49367	0.49367
1974	0.22379	0.22379	0.03633	0.03633	0.77157	0.77157	0.39409	0.39409	0.51866	0.51866
1975	0.20943	0.20943	0.04344	0.04344	0.77400	0.77400	0.38858	0.38858	0.52091	0.52091
1976	0.20435	0.20435	0.04499	0.04499	0.85079	0.85079	0.38557	0.38557	0.50762	0.50762
1977	0.21165	0.21165	0.03743	0.03743	0.85831	0.85831	0.43490	0.43490	0.51654	0.51654
1978	0.16573	0.16573	0.02947	0.02947	0.85325	0.85325	0.42601	0.42601	0.50901	0.50901
1979	0.18937	0.18937	0.03317	0.03317	0.83532	0.83532	0.45895	0.45895	0.50311	0.50311
1980	0.20155	0.20155	0.03565	0.03565	0.91539	0.91539	0.46255	0.46255	0.50395	0.50395
1981	0.20510	0.20510	0.04118	0.04118	0.95821	0.95821	0.50435	0.50435	0.50538	0.50538
1982	0.20229	0.20229	0.04731	0.04731	1.03854	1.03854	0.53345	0.53345	0.52172	0.52172
1983	0.22462	0.22462	0.05091	0.05091	1.08265	1.08265	0.50970	0.50970	0.52951	0.52951
1984	0.26244	0.26244	0.05047	0.05047	1.10459	1.10459	0.56524	0.56524	0.52636	0.52636
1985	0.23230	0.23230	0.04039	0.04039	1.27176	1.27176	0.56389	0.56389	0.51927	0.51927
1986	0.19613	0.19613	0.03635	0.03635	1.30413	1.30413	0.52494	0.52494	0.54839	0.54839
1987	0.21048	0.21048	0.04156	0.04156	1.31977	1.31977	0.52584	0.52584	0.56135	0.56135
1988	0.27266	0.27266	0.05339	0.05339	1.48073	1.48073	0.54169	0.54169	0.53240	0.53240
1989	0.24565	0.24565	0.04924	0.04924	1.58419	1.58419	0.53795	0.53795	0.51621	0.51621
1990	0.21422	0.21422	0.04253	0.04253	1.61124	1.61124	0.54461	0.54461	0.51601	0.51601
1991	0.21880	0.21880	0.04244	0.04244	1.55348	1.55348	0.54280	0.54280	0.50109	0.50109
1992	0.22128	0.22128	0.04344	0.04344	1.42704	1.42704	0.55058	0.55058	0.49194	0.49194
1993	0.23193	0.23193	0.05092	0.05092	1.39747	1.39747	0.57839	0.57839	0.47793	0.47793
1994	0.26022	0.26022	0.04644	0.04644	1.39238	1.39238	0.57166	0.57166	0.47783	0.47783
Average	0.18525	0.18525	0.03677	0.03677	0.93102	0.93102	0.42151	0.42151	0.48101	0.48101
Std.dev	0.04527	0.04527	0.00889	0.00889	0.35219	0.35219	0.10684	0.10684	0.04707	0.04707

Note: Short-run Morishima substitution elasticities are computed from equation (4.37) in chapter 4.

Table A 6. 2.c-1: Long-Run Input Demand Elasticities in the U.S. Grain Milling Industry (Flour Milling)

Industry	Flour (SIC2041)								
Year	E_{ll}	E_{lm}	E_{lk}	E_{ml}	E_{mm}	E_{mk}	E_{kl}	E_{km}	E_{kk}
1958	-0.12067	0.05704	0.06363	0.00423	-0.08021	0.07598	0.03740	0.60193	-0.63932
1959	-0.12999	0.04152	0.08846	0.00293	-0.08236	0.07943	0.04861	0.61883	-0.66744
1960	-0.12902	0.05646	0.07256	0.00415	-0.08155	0.07740	0.04084	0.59313	-0.63397
1961	-0.13075	0.06211	0.06863	0.00465	-0.08144	0.07679	0.03864	0.57794	-0.61659
1962	-0.13327	0.06529	0.06797	0.00477	-0.08384	0.07907	0.03651	0.58180	-0.61832
1963	-0.14111	0.01496	0.12615	0.00113	-0.08190	0.08077	0.06657	0.56395	-0.63052
1964	-0.14421	0.00969	0.13452	0.00075	-0.08160	0.08085	0.07046	0.54925	-0.61971
1965	-0.14576	0.00760	0.13816	0.00060	-0.08097	0.08037	0.07218	0.52961	-0.60179
1966	-0.15691	-0.01560	0.17251	-0.00120	-0.08274	0.08394	0.08536	0.53936	-0.62472
1967	-0.15826	-0.00546	0.16372	-0.00044	-0.08089	0.08133	0.08392	0.51375	-0.59767
1968	-0.15900	-0.00313	0.16213	-0.00027	-0.07917	0.07944	0.08499	0.48711	-0.57211
1969	-0.15758	0.01278	0.14480	0.00109	-0.08063	0.07955	0.07459	0.48179	-0.55638
1970	-0.15892	0.01653	0.14239	0.00142	-0.08104	0.07962	0.07246	0.47137	-0.54383
1971	-0.16872	-0.01020	0.17893	-0.00093	-0.07843	0.07936	0.09179	0.44669	-0.53847
1972	-0.14961	0.11359	0.03602	0.00946	-0.08641	0.07695	0.01804	0.46306	-0.48110
1973	-0.28219	0.61184	-0.32964	0.04051	-0.12210	0.08160	-0.15864	0.59312	-0.43448
1974	-0.42804	0.89733	-0.46929	0.05938	-0.14388	0.08449	-0.23839	0.64857	-0.41018
1975	-0.19232	0.26727	-0.07495	0.01520	-0.11899	0.10379	-0.02544	0.61949	-0.59405
1976	-0.19530	0.30762	-0.11232	0.01936	-0.11461	0.09525	-0.04239	0.57125	-0.52886
1977	-0.18130	0.14184	0.03947	0.01063	-0.09831	0.08768	0.01644	0.48765	-0.50409
1978	-0.18561	0.01524	0.17037	0.00155	-0.07979	0.07824	0.08359	0.37693	-0.46053
1979	-0.19757	0.32264	-0.12507	0.02353	-0.10954	0.08601	-0.05262	0.49617	-0.44355
1980	-0.21825	0.39349	-0.17524	0.02721	-0.11794	0.09073	-0.06975	0.52222	-0.45247
1981	-0.19985	0.22863	-0.02878	0.01576	-0.11339	0.09764	-0.01042	0.51277	-0.50236
1982	-0.20392	0.06107	0.14285	0.00484	-0.10080	0.09595	0.05375	0.45528	-0.50903
1983	-0.20700	0.18278	0.02422	0.01282	-0.11427	0.10146	0.00837	0.50017	-0.50854
1984	-0.22334	0.29998	-0.07663	0.01916	-0.12761	0.10845	-0.02443	0.54121	-0.51679
1985	-0.26427	-0.06565	0.32992	-0.00574	-0.09685	0.10259	0.11866	0.42211	-0.54077
1986	-0.36471	-0.14936	0.51407	-0.01867	-0.07834	0.09701	0.21491	0.32454	-0.53945
1987	-0.38113	-0.16778	0.54891	-0.01985	-0.08225	0.10209	0.21692	0.34106	-0.55799
1988	-0.23513	0.15146	0.08367	0.00974	-0.13329	0.12355	0.02336	0.53657	-0.55993
1989	-0.34078	-0.18647	0.52724	-0.01657	-0.10436	0.12093	0.17033	0.43966	-0.60999
1990	-0.51525	-0.24831	0.76355	-0.03545	-0.08069	0.11615	0.31140	0.33177	-0.64317
1991	-0.48629	-0.25699	0.74328	-0.03330	-0.08723	0.12053	0.28353	0.35484	-0.63837
1992	-0.50315	-0.25916	0.76232	-0.03198	-0.09020	0.12218	0.27413	0.35607	-0.63020
1993	-0.54539	-0.25914	0.80453	-0.03045	-0.09126	0.12170	0.26716	0.34399	-0.61115
1994	-0.55511	-0.31026	0.86536	-0.03243	-0.10091	0.13334	0.26545	0.39129	-0.65674
Average	-0.24567	0.06490	0.18077	0.00183	-0.09540	0.09357	0.07049	0.49152	-0.56202
Std.dev	0.13273	0.24436	0.3141	0.02011	0.01823	0.01691	0.11953	0.09145	0.06971

Note: Long-run input demand elasticities are computed from equation (4.34) in chapter 4.

Table A 6. 2.c-2: Long-Run Input Demand Elasticities in the U.S. Grain Milling Industry (Rice Milling)

Industry	Rice (SIC2044)								
Year	E_{ll}	E_{lm}	E_{lk}	E_{ml}	E_{mm}	E_{mk}	E_{kl}	E_{km}	E_{kk}
1958	-0.04866	-0.18750	0.23616	-0.00735	-0.12164	0.12899	0.06246	0.87036	-0.93282
1959	-0.05862	-0.25259	0.31121	-0.01061	-0.12325	0.13386	0.08487	0.86879	-0.95367
1960	-0.05392	-0.22184	0.27576	-0.00897	-0.12551	0.13447	0.07205	0.86933	-0.94138
1961	-0.05352	-0.21717	0.27069	-0.00986	-0.12449	0.13434	0.07624	0.83348	-0.90972
1962	-0.05022	-0.19320	0.24342	-0.00735	-0.13417	0.14152	0.05819	0.88890	-0.94709
1963	-0.06334	-0.25882	0.32217	-0.01133	-0.12483	0.13615	0.08646	0.83512	-0.92158
1964	-0.06366	-0.25180	0.31546	-0.01134	-0.12338	0.13472	0.08596	0.81506	-0.90102
1965	-0.06477	-0.26003	0.32480	-0.01143	-0.12741	0.13884	0.08498	0.82662	-0.91161
1966	-0.07686	-0.30865	0.38551	-0.01461	-0.12707	0.14168	0.10476	0.81338	-0.91813
1967	-0.07389	-0.27146	0.34534	-0.01342	-0.11854	0.13196	0.09857	0.76208	-0.86065
1968	-0.07463	-0.26056	0.33519	-0.01445	-0.11543	0.12988	0.10301	0.71973	-0.82273
1969	-0.06632	-0.23260	0.29892	-0.01216	-0.12054	0.13270	0.08637	0.73347	-0.81984
1970	-0.06842	-0.25069	0.31911	-0.01324	-0.12767	0.14091	0.08937	0.74706	-0.83643
1971	-0.09193	-0.30300	0.39493	-0.02070	-0.12098	0.14169	0.13015	0.68337	-0.81352
1972	-0.03580	-0.01336	0.04916	-0.00077	-0.13775	0.13852	0.01438	0.70392	-0.71830
1973	-0.17394	0.71311	-0.53917	0.04883	-0.22189	0.17306	-0.16806	0.78784	-0.61977
1974	-0.39373	1.11718	-0.72345	0.08642	-0.25229	0.16587	-0.27117	0.80370	-0.53253
1975	-0.05651	0.28438	-0.22787	0.01325	-0.18026	0.16701	-0.05094	0.80154	-0.75060
1976	-0.07267	0.36448	-0.29181	0.01856	-0.17070	0.15214	-0.07320	0.74953	-0.67633
1977	-0.04154	-0.05977	0.10131	-0.00361	-0.14616	0.14978	0.02773	0.67795	-0.70567
1978	-0.09851	-0.25922	0.35773	-0.02301	-0.11167	0.13468	0.12857	0.54541	-0.67398
1979	-0.05714	0.27837	-0.22123	0.01758	-0.18472	0.16714	-0.05879	0.70320	-0.64441
1980	-0.08561	0.43603	-0.35042	0.02504	-0.20034	0.17531	-0.08466	0.73759	-0.65293
1981	-0.04679	0.11717	-0.07038	0.00590	-0.18589	0.17999	-0.01474	0.74937	-0.73462
1982	-0.05785	-0.11118	0.16903	-0.00531	-0.15887	0.16418	0.03569	0.72644	-0.76214
1983	-0.06092	0.24677	-0.18585	0.01067	-0.20279	0.19212	-0.03313	0.79232	-0.75919
1984	-0.06033	0.26929	-0.20897	0.01205	-0.22924	0.21720	-0.03492	0.81144	-0.77652
1985	-0.16838	-0.46804	0.63642	-0.03656	-0.15099	0.18755	0.16681	0.62939	-0.79620
1986	-0.34722	-0.50282	0.85004	-0.06019	-0.10766	0.16785	0.31027	0.51183	-0.82210
1987	-0.33866	-0.55074	0.88939	-0.05907	-0.11925	0.17832	0.29349	0.54863	-0.84213
1988	-0.05363	-0.01701	0.07064	-0.00080	-0.25667	0.25747	0.01042	0.80789	-0.81832
1989	-0.27206	-0.69368	0.96574	-0.04891	-0.16497	0.21388	0.21835	0.68591	-0.90426
1990	-0.49701	-0.54708	1.04409	-0.08126	-0.10472	0.18598	0.42998	0.51563	-0.94561
1991	-0.46801	-0.59178	1.05978	-0.08214	-0.12164	0.20378	0.38963	0.53974	-0.92938
1992	-0.47365	-0.57751	1.05116	-0.08817	-0.12537	0.21355	0.39082	0.52003	-0.91085
1993	-0.50005	-0.61589	1.11594	-0.08098	-0.11885	0.19983	0.37445	0.50997	-0.88443
1994	-0.49117	-0.64966	1.14083	-0.08750	-0.13604	0.22355	0.36941	0.53742	-0.90682
Average	-0.15567	-0.14327	0.29894	-0.01586	-0.14929	0.16515	0.09713	0.72063	-0.81776
Std.dev	0.15954	0.39533	0.47689	0.03771	0.04134	0.03275	0.16055	0.11821	0.10929

Note: Long-run input demand elasticities are computed from equation (4.34) in chapter 4.

Table A 6. 2.c-3: Long-Run Input Demand Elasticities in the U.S. Grain Milling Industry (Pet Food)

Industry	Pet food (SIC2047)								
Year	E_{ll}	E_{lm}	E_{lk}	E_{ml}	E_{mm}	E_{mk}	E_{kl}	E_{km}	E_{kk}
1958	-1.68872	3.94964	-2.26092	0.19549	-0.58553	0.39004	-0.81873	2.85368	-2.03495
1959	-1.95838	4.47687	-2.51850	0.18246	-0.54303	0.36057	-0.80921	2.84263	-2.03341
1960	-1.40116	3.26939	-1.86823	0.19166	-0.60450	0.41283	-0.73521	2.77129	-2.03609
1961	-1.28745	3.02585	-1.73839	0.18887	-0.62301	0.43414	-0.67847	2.71462	-2.03614
1962	-1.25935	2.95734	-1.69799	0.18849	-0.63702	0.44853	-0.64769	2.68440	-2.03671
1963	-1.30083	2.97490	-1.67406	0.17390	-0.59723	0.42333	-0.61185	2.64689	-2.03504
1964	-1.28260	2.92021	-1.63760	0.17376	-0.61068	0.43692	-0.58433	2.62004	-2.03571
1965	-1.11513	2.60810	-1.49297	0.18193	-0.68936	0.50743	-0.52612	2.56350	-2.03738
1966	-1.07507	2.46475	-1.38968	0.17048	-0.67983	0.50935	-0.47360	2.50964	-2.03604
1967	-1.08471	2.42688	-1.34217	0.17411	-0.69140	0.51729	-0.46631	2.50509	-2.03878
1968	-1.06967	2.37974	-1.31006	0.17914	-0.72728	0.54814	-0.44777	2.48878	-2.04101
1969	-0.93625	2.08545	-1.14920	0.18292	-0.82216	0.63923	-0.38242	2.42513	-2.04271
1970	-0.86834	1.86323	-0.99489	0.17649	-0.87432	0.69783	-0.31903	2.36233	-2.04330
1971	-0.87963	1.81987	-0.94023	0.17386	-0.88653	0.71267	-0.29493	2.33991	-2.04498
1972	-1.15645	2.72612	-1.56967	0.25592	-1.04175	0.78583	-0.47521	2.53420	-2.05899
1973	-0.62659	1.57502	-0.94844	0.36411	-2.35710	1.99300	-0.25535	2.32113	-2.06578
1974	-0.58455	1.52915	-0.94460	0.48091	-3.37739	2.89648	-0.23657	2.30658	-2.07001
1975	-0.87624	1.74429	-0.86805	0.16626	-1.00456	0.83830	-0.22367	2.26616	-2.04249
1976	-0.75759	1.40546	-0.64788	0.19138	-1.44105	1.24967	-0.15585	2.20764	-2.05179
1977	-0.76145	1.23768	-0.47623	0.18307	-1.61023	1.42717	-0.10669	2.16161	-2.05492
1978	-0.74712	1.04539	-0.29826	0.20038	-2.33834	2.13796	-0.05659	2.11635	-2.05976
1979	-0.72886	0.97649	-0.24763	0.25155	-3.44164	3.19009	-0.04212	2.10627	-2.06415
1980	-0.82298	0.73846	0.08451	0.20180	-4.12021	3.91842	0.01209	2.05125	-2.06334
1981	-0.83950	0.70875	0.13075	0.12802	-2.37260	2.24458	0.02139	2.03279	-2.05417
1982	-0.96061	0.47315	0.48746	0.07009	-1.83029	1.76020	0.08084	1.97038	-2.05121
1983	-1.04421	0.28161	0.76260	0.04084	-1.80735	1.76651	0.12081	1.92972	-2.05053
1984	-1.04983	0.16738	0.88245	0.02509	-1.85559	1.83050	0.13807	1.91055	-2.04862
1985	-1.49737	-0.34141	1.83878	-0.04234	-1.64666	1.68900	0.24374	1.80521	-2.04895
1986	-2.25241	-1.02984	3.28225	-0.10754	-1.75514	1.86268	0.31894	1.73333	-2.05227
1987	-1.94686	-0.89406	2.84092	-0.10532	-1.55461	1.65993	0.34383	1.70547	-2.04931
1988	-3.99062	-2.74578	6.73640	-0.22075	-2.17902	2.39977	0.37704	1.67064	-2.04768
1989	-5.69716	-4.17006	9.86722	-0.26196	-2.09335	2.35531	0.42623	1.61962	-2.04585
1990	-3.73513	-2.54395	6.27908	-0.22689	-1.70490	1.93179	0.45889	1.58295	-2.04184
1991	-3.47830	-2.45923	5.93753	-0.25820	-1.77023	2.02843	0.48010	1.56217	-2.04228
1992	-3.09460	-2.19885	5.29345	-0.27924	-1.73747	2.01670	0.51069	1.53211	-2.04280
1993	-5.00685	-4.00962	9.01647	-0.42034	-2.27194	2.69228	0.53134	1.51341	-2.04475
1994	-2.17986	-1.59551	3.77538	-0.30793	-1.83629	2.14422	0.51760	1.52320	-2.04080
Average	-1.64980	0.86062	0.78918	0.07736	-1.53296	1.45560	-0.12881	2.17542	-2.04661
Std.dev	1.24903	2.20401	3.26943	0.20697	0.88795	0.93452	0.42279	0.4196	0.00969

Note: Long-run input demand elasticities are computed from equation (4.34) in chapter 4.

Table A 6. 2.c-4: Long-Run Input Demand Elasticities in the U.S. Grain Milling Industry (Animal Feeds)

Industry	Animal feeds (SIC2048)								
Year	E_{ll}	E_{lm}	E_{lk}	E_{ml}	E_{mm}	E_{mk}	E_{kl}	E_{km}	E_{kk}
1958	-0.27822	0.06185	0.21637	0.00575	-0.16135	0.15560	0.10082	0.77966	-0.88048
1959	-0.29376	0.01988	0.27388	0.00186	-0.15692	0.15507	0.12761	0.77345	-0.90106
1960	-0.28904	0.05942	0.22962	0.00568	-0.15264	0.14696	0.11242	0.75239	-0.86481
1961	-0.29972	0.06395	0.23576	0.00587	-0.15983	0.15396	0.10601	0.75439	-0.86040
1962	-0.31800	0.03300	0.28500	0.00303	-0.16099	0.15796	0.12142	0.73280	-0.85422
1963	-0.34184	-0.01606	0.35790	-0.00145	-0.16009	0.16154	0.14682	0.73172	-0.87854
1964	-0.35480	-0.02394	0.37873	-0.00218	-0.15870	0.16088	0.15318	0.71412	-0.86730
1965	-0.36344	-0.00459	0.36803	-0.00041	-0.16322	0.16363	0.14034	0.70789	-0.84823
1966	-0.37891	-0.02478	0.40369	-0.00214	-0.16304	0.16518	0.15058	0.71463	-0.86521
1967	-0.36349	0.02225	0.34124	0.00204	-0.15213	0.15009	0.14325	0.68683	-0.83008
1968	-0.36637	0.03808	0.32829	0.00358	-0.14784	0.14426	0.14202	0.66438	-0.80639
1969	-0.36348	0.07554	0.28794	0.00698	-0.14756	0.14059	0.12591	0.66570	-0.79160
1970	-0.37232	0.08978	0.28253	0.00807	-0.15014	0.14207	0.11881	0.66454	-0.78335
1971	-0.38781	0.07699	0.31082	0.00709	-0.14678	0.13970	0.13000	0.63482	-0.76481
1972	-0.36843	0.42108	-0.05266	0.03324	-0.15028	0.11705	-0.02655	0.74761	-0.72106
1973	-0.41775	0.70402	-0.28627	0.05390	-0.20592	0.15202	-0.11045	0.76621	-0.65576
1974	-0.44781	0.80457	-0.35676	0.06304	-0.20221	0.13917	-0.15975	0.79540	-0.63565
1975	-0.40709	0.18890	0.21819	0.01317	-0.16608	0.15291	0.07882	0.79230	-0.87111
1976	-0.40711	0.33035	0.07676	0.02338	-0.17396	0.15058	0.02721	0.75424	-0.78145
1977	-0.40732	0.41509	-0.00777	0.03030	-0.16528	0.13498	-0.00311	0.74011	-0.73700
1978	-0.41873	0.50709	-0.08836	0.03771	-0.16547	0.12776	-0.03722	0.72359	-0.68637
1979	-0.44148	0.62729	-0.18581	0.04513	-0.17665	0.13153	-0.07650	0.75272	-0.67623
1980	-0.44549	0.59750	-0.15201	0.04279	-0.17253	0.12973	-0.06193	0.73796	-0.67603
1981	-0.45007	0.47827	-0.02820	0.03167	-0.16440	0.13273	-0.01090	0.77492	-0.76402
1982	-0.48289	0.40565	0.07724	0.02611	-0.14155	0.11544	0.03272	0.75959	-0.79231
1983	-0.48222	0.25619	0.22603	0.01828	-0.13977	0.12149	0.09243	0.69619	-0.78862
1984	-0.49080	0.25564	0.23516	0.01733	-0.14686	0.12954	0.08958	0.72804	-0.81761
1985	-0.53768	0.08572	0.45196	0.00658	-0.13207	0.12549	0.18157	0.65715	-0.83872
1986	-0.62055	-0.03457	0.65512	-0.00293	-0.13074	0.13367	0.24091	0.58013	-0.82105
1987	-0.59271	0.02893	0.56377	0.00244	-0.12099	0.11855	0.24008	0.59771	-0.83779
1988	-0.63377	-0.04359	0.67737	-0.00343	-0.13578	0.13921	0.23744	0.61989	-0.85733
1989	-0.63706	-0.06025	0.69731	-0.00477	-0.13283	0.13761	0.25589	0.63740	-0.89330
1990	-0.64177	-0.06330	0.70507	-0.00527	-0.12292	0.12818	0.29209	0.63842	-0.93051
1991	-0.66173	-0.06332	0.72505	-0.00539	-0.12109	0.12648	0.30076	0.61585	-0.91660
1992	-0.67220	-0.04460	0.71680	-0.00382	-0.11854	0.12236	0.30249	0.60297	-0.90546
1993	-0.67332	-0.01106	0.68439	-0.00091	-0.12201	0.12291	0.27389	0.60147	-0.87537
1994	-0.71042	-0.08231	0.79273	-0.00705	-0.12248	0.12952	0.31278	0.59700	-0.90978
Average	-0.45458	0.16688	0.28770	0.01230	-0.15167	0.13936	0.11598	0.69984	-0.81583
Std.dev	0.12659	0.24758	0.30167	0.01837	0.02091	0.01434	0.121	0.0644	0.07847

Note: Long-run input demand elasticities are computed from equation (4.34) in chapter 4.

Table A 6. 2.c-5: Long-Run Input Demand Elasticities in the U.S. Grain Milling Industry (Bread Baking)

Industry	Bread SIC(2051)								
Year	E_{ll}	E_{lm}	E_{lk}	E_{ml}	E_{mm}	E_{mk}	E_{kl}	E_{km}	E_{kk}
1958	-0.27850	0.12645	0.15205	0.07598	-0.25742	0.18145	0.18822	0.37381	-0.56203
1959	-0.29233	0.11896	0.17337	0.07249	-0.25592	0.18342	0.20800	0.36115	-0.56915
1960	-0.29180	0.13342	0.15837	0.08032	-0.26110	0.18078	0.18596	0.35260	-0.53856
1961	-0.30410	0.13177	0.17232	0.07785	-0.26127	0.18342	0.19256	0.34691	-0.53947
1962	-0.31112	0.13469	0.17643	0.07987	-0.26394	0.18407	0.19267	0.33897	-0.53164
1963	-0.32676	0.12622	0.20054	0.07648	-0.26176	0.18528	0.21299	0.32475	-0.53774
1964	-0.33521	0.12701	0.20821	0.07736	-0.26550	0.18814	0.21635	0.32097	-0.53732
1965	-0.33629	0.13700	0.19929	0.08371	-0.27042	0.18671	0.20437	0.31336	-0.51773
1966	-0.35505	0.12760	0.22745	0.07761	-0.26953	0.19192	0.22297	0.30934	-0.53231
1967	-0.35816	0.13659	0.22158	0.08409	-0.26979	0.18570	0.21385	0.29110	-0.50495
1968	-0.36105	0.14434	0.21671	0.08986	-0.27238	0.18252	0.20660	0.27951	-0.48611
1969	-0.36232	0.15211	0.21021	0.09527	-0.27854	0.18327	0.19866	0.27652	-0.47518
1970	-0.37439	0.15449	0.21990	0.09618	-0.27434	0.17816	0.19951	0.25963	-0.45914
1971	-0.38234	0.15836	0.22398	0.09909	-0.27447	0.17538	0.19837	0.24826	-0.44663
1972	-0.35843	0.19149	0.16694	0.12175	-0.28697	0.16522	0.15538	0.24186	-0.39724
1973	-0.34650	0.22850	0.11800	0.13813	-0.29888	0.16075	0.11094	0.25002	-0.36096
1974	-0.34423	0.28888	0.05535	0.15576	-0.32725	0.17149	0.05098	0.29298	-0.34396
1975	-0.42213	0.15097	0.27116	0.08118	-0.29858	0.21740	0.20033	0.29870	-0.49904
1976	-0.40518	0.17699	0.22818	0.10357	-0.30212	0.19855	0.17880	0.26588	-0.44467
1977	-0.42247	0.17408	0.24838	0.10484	-0.29136	0.18652	0.18943	0.23619	-0.42562
1978	-0.40659	0.20536	0.20123	0.12112	-0.29765	0.17653	0.15467	0.23007	-0.38473
1979	-0.40404	0.22338	0.18066	0.12441	-0.30703	0.18261	0.13463	0.24433	-0.37896
1980	-0.41074	0.22968	0.18106	0.12313	-0.31085	0.18773	0.12939	0.25025	-0.37964
1981	-0.45306	0.18129	0.27177	0.09774	-0.30128	0.20354	0.17882	0.24841	-0.42722
1982	-0.48306	0.15315	0.32991	0.08844	-0.29366	0.20522	0.21426	0.23080	-0.44506
1983	-0.49794	0.15067	0.34726	0.08730	-0.29085	0.20356	0.21909	0.22166	-0.44074
1984	-0.52970	0.12690	0.40279	0.07407	-0.28692	0.21284	0.24486	0.22167	-0.46653
1985	-0.54951	0.11435	0.43516	0.06998	-0.28448	0.21450	0.26327	0.21207	-0.47534
1986	-0.54718	0.11316	0.43403	0.07203	-0.28820	0.21617	0.26567	0.20786	-0.47352
1987	-0.55661	0.09324	0.46338	0.06250	-0.29217	0.22967	0.28925	0.21386	-0.50311
1988	-0.58592	0.07633	0.50959	0.04876	-0.28696	0.23820	0.30109	0.22035	-0.52144
1989	-0.62243	0.06173	0.56070	0.03921	-0.27918	0.23997	0.31832	0.21446	-0.53279
1990	-0.65077	0.04645	0.60432	0.03097	-0.27427	0.24330	0.34339	0.20736	-0.55074
1991	-0.66334	0.04144	0.62190	0.02776	-0.27301	0.24525	0.34773	0.20468	-0.55241
1992	-0.66712	0.03915	0.62797	0.02678	-0.27361	0.24683	0.35035	0.20132	-0.55166
1993	-0.65469	0.04867	0.60603	0.03316	-0.27747	0.24431	0.33362	0.19741	-0.53103
1994	-0.67339	0.02420	0.64919	0.01707	-0.27533	0.25826	0.36390	0.20523	-0.56913
Average	-0.44120	0.13646	0.30474	0.08151	-0.28201	0.20050	0.22106	0.26255	-0.48361
Std.dev	0.1241	0.05831	0.16849	0.03174	0.01643	0.02642	0.07121	0.05164	0.06391

Note: Long-run input demand elasticities are computed from equation (4.34) in chapter 4.

Table A 6. 2d-1: Long-Run Morishima Substitution Elasticities in the Grain Milling Industry (Flour and Rice)

	Flour (SIC2041)						Rice (SIC2044)					
Year	Q_{lm}	Q_{ml}	Q_{lk}	Q_{kl}	Q_{mk}	Q_{km}	Q_{lm}	Q_{ml}	Q_{lk}	Q_{kl}	Q_{mk}	Q_{km}
1958	0.12490	0.13725	0.15807	0.70296	0.68214	0.71530	0.04131	-0.06586	0.11112	1.16898	0.99200	1.06181
1959	0.13291	0.12388	0.17860	0.75590	0.70118	0.74686	0.04800	-0.12935	0.14349	1.26488	0.99204	1.08753
1960	0.13317	0.13801	0.16986	0.70653	0.67468	0.71138	0.04495	-0.09634	0.12597	1.21714	0.99483	1.07585
1961	0.13539	0.14355	0.16939	0.68522	0.65938	0.69338	0.04366	-0.09268	0.12976	1.18041	0.95796	1.04406
1962	0.13803	0.14913	0.16978	0.68629	0.66564	0.69739	0.04287	-0.05903	0.10841	1.19051	1.02307	1.08862
1963	0.14224	0.09686	0.20768	0.75667	0.64585	0.71129	0.05202	-0.13400	0.14981	1.24375	0.95995	1.05774
1964	0.14495	0.09129	0.21467	0.75423	0.63085	0.70057	0.05231	-0.12842	0.14962	1.21648	0.93844	1.03574
1965	0.14636	0.08857	0.21793	0.73995	0.61058	0.68216	0.05335	-0.13262	0.14976	1.23641	0.95403	1.05044
1966	0.15571	0.06715	0.24228	0.79723	0.62210	0.70866	0.06225	-0.18158	0.18162	1.30365	0.94045	1.05981
1967	0.15782	0.07543	0.24219	0.76140	0.59464	0.67901	0.06047	-0.15291	0.17246	1.20600	0.88062	0.99261
1968	0.15873	0.07604	0.24400	0.73424	0.56629	0.65155	0.06018	-0.14513	0.17764	1.15792	0.83516	0.95262
1969	0.15867	0.09341	0.23216	0.70118	0.56243	0.63593	0.05416	-0.11207	0.15269	1.11876	0.85401	0.95254
1970	0.16034	0.09757	0.23138	0.68622	0.55241	0.62345	0.05518	-0.12302	0.15779	1.15554	0.87473	0.97735
1971	0.16779	0.06823	0.26051	0.71740	0.52512	0.61783	0.07122	-0.18202	0.22207	1.20845	0.80436	0.95521
1972	0.15907	0.20000	0.16766	0.51712	0.54946	0.55805	0.03503	0.12439	0.05018	0.76747	0.84167	0.85682
1973	0.32270	0.73394	0.12355	0.10484	0.71522	0.51608	0.22277	0.93500	0.00588	0.08060	1.00973	0.79284
1974	0.48742	1.04121	0.18965	-0.05911	0.79245	0.49468	0.48015	1.36948	0.12256	-0.19092	1.05599	0.69840
1975	0.20752	0.38626	0.16688	0.51911	0.73848	0.69784	0.06975	0.46463	0.00557	0.52273	0.98180	0.91761
1976	0.21466	0.42223	0.15290	0.41653	0.68586	0.62411	0.09123	0.53519	-0.00053	0.38452	0.92024	0.82847
1977	0.19193	0.24014	0.19775	0.54356	0.58595	0.59177	0.03792	0.08639	0.06926	0.80699	0.82411	0.85545
1978	0.18716	0.09503	0.26920	0.63089	0.45672	0.53877	0.07551	-0.14754	0.22708	1.03171	0.65709	0.80866
1979	0.22110	0.43218	0.14495	0.31848	0.60571	0.52956	0.07472	0.46309	-0.00165	0.42318	0.88792	0.81155
1980	0.24546	0.51143	0.14850	0.27723	0.64016	0.54320	0.11064	0.63637	0.00095	0.30251	0.93793	0.82824
1981	0.21561	0.34203	0.18944	0.47358	0.62617	0.59999	0.05269	0.30306	0.03205	0.66424	0.93526	0.91462
1982	0.20876	0.16187	0.25766	0.65187	0.55608	0.60498	0.05254	0.04769	0.09354	0.93116	0.88531	0.92631
1983	0.21981	0.29705	0.21537	0.53276	0.61444	0.61000	0.07158	0.44956	0.02779	0.57334	0.99510	0.95131
1984	0.24250	0.42758	0.19892	0.44015	0.66882	0.62523	0.07237	0.49853	0.02541	0.56755	1.04068	0.99371
1985	0.25853	0.03121	0.38293	0.87068	0.51896	0.64336	0.13182	-0.31705	0.33519	1.43262	0.78038	0.98375
1986	0.34605	-0.07102	0.57962	1.05353	0.40288	0.63646	0.28703	-0.39516	0.65749	1.67214	0.61950	0.98995
1987	0.36128	-0.08553	0.59805	1.10689	0.42331	0.66008	0.27958	-0.43149	0.63215	1.73152	0.66788	1.02045
1988	0.24487	0.28475	0.25850	0.64360	0.66985	0.68348	0.05283	0.23965	0.06405	0.88896	1.06456	1.07578
1989	0.32421	-0.08211	0.51111	1.13723	0.54402	0.73091	0.22315	-0.52871	0.49041	1.87000	0.85088	1.11814
1990	0.47980	-0.16761	0.82665	1.40672	0.41246	0.75932	0.41574	-0.44236	0.92699	1.98970	0.62035	1.13160
1991	0.45299	-0.16976	0.76982	1.38166	0.44207	0.75890	0.38586	-0.47014	0.85764	1.98916	0.66138	1.13315
1992	0.47117	-0.16896	0.77729	1.39252	0.44627	0.75238	0.38548	-0.45214	0.86447	1.96201	0.64540	1.12440
1993	0.51495	-0.16788	0.81255	1.41568	0.43524	0.73285	0.41907	-0.49705	0.87450	2.00037	0.62882	1.08425
1994	0.52268	-0.20935	0.82055	1.52210	0.49220	0.79007	0.40367	-0.51361	0.86058	2.04765	0.67346	1.13037
Average	0.24749	0.16030	0.31616	0.74278	0.58692	0.65559	0.13981	0.00602	0.25280	1.11671	0.86992	0.98291
Std.dev	0.12365	0.25755	0.22293	0.36070	0.09926	0.07539	0.13863	0.42831	0.29313	0.56044	0.13762	0.11272

Note: Long-run Morishima substitution elasticities are computed from equation (4.38) in chapter 4.

Table A 6. 2d-2: Long-Run Morishima Substitution Elasticities in the Grain Milling Industry (Pet Food and Animal Feeds)

	Pet food (SIC2047)						Animal feeds (SIC2048)					
Year	Q_{lm}	Q_{ml}	Q_{lk}	Q_{kl}	Q_{mk}	Q_{km}	Q_{lm}	Q_{ml}	Q_{lk}	Q_{kl}	Q_{mk}	Q_{km}
1958	1.88421	4.53517	0.86998	-0.22600	3.43922	2.42499	0.28397	0.22321	0.37904	1.09685	0.94102	1.03608
1959	2.14084	5.01991	1.14916	-0.48510	3.38566	2.39399	0.29562	0.17680	0.42137	1.17494	0.93038	1.05613
1960	1.59282	3.87389	0.66595	0.16790	3.37579	2.44892	0.29473	0.21207	0.40147	1.09443	0.90503	1.01177
1961	1.47632	3.64885	0.60898	0.29770	3.33762	2.47028	0.30558	0.22378	0.40573	1.09616	0.91422	1.01436
1962	1.44784	3.59436	0.61167	0.33870	3.32142	2.48524	0.32103	0.19400	0.43942	1.13922	0.89379	1.01219
1963	1.47473	3.57212	0.68899	0.36100	3.24411	2.45837	0.34039	0.14403	0.48866	1.23644	0.89181	1.04009
1964	1.45636	3.53088	0.69828	0.39810	3.23072	2.47263	0.35262	0.13476	0.50797	1.24603	0.87282	1.02818
1965	1.29706	3.29746	0.58901	0.54440	3.25287	2.54482	0.36304	0.15863	0.50378	1.21626	0.87111	1.01186
1966	1.24555	3.14458	0.60147	0.64640	3.18947	2.54539	0.37678	0.13826	0.52950	1.26891	0.87767	1.03039
1967	1.25883	3.11828	0.61840	0.69660	3.19649	2.55606	0.36553	0.17438	0.50674	1.17132	0.83896	0.98017
1968	1.24882	3.10702	0.62190	0.73090	3.21606	2.58915	0.36995	0.18592	0.50838	1.13468	0.81222	0.95066
1969	1.11918	2.90761	0.55383	0.89350	3.24729	2.68195	0.37045	0.22310	0.48938	1.07954	0.81326	0.93219
1970	1.04483	2.73755	0.54931	1.04840	3.23665	2.74113	0.38039	0.23993	0.49113	1.06588	0.81468	0.92542
1971	1.05350	2.70640	0.58471	1.10470	3.22644	2.75765	0.39490	0.22377	0.51781	1.07563	0.78160	0.90451
1972	1.41237	3.76788	0.68124	0.48930	3.57596	2.84482	0.40166	0.57137	0.34188	0.66841	0.89789	0.83811
1973	0.99069	3.93212	0.37123	1.11730	4.67824	4.05878	0.47165	0.90994	0.30730	0.36949	0.97213	0.80778
1974	1.06546	4.90655	0.34798	1.12540	5.68397	4.96649	0.51085	1.00678	0.28806	0.27889	0.99761	0.77482
1975	1.04250	2.74885	0.65257	1.17440	3.27073	2.88079	0.42026	0.35497	0.48591	1.08931	0.95837	1.02402
1976	0.94896	2.84651	0.60174	1.40390	3.64868	3.30146	0.43049	0.50431	0.43432	0.85820	0.92820	0.93203
1977	0.94452	2.84791	0.65475	1.57870	3.77184	3.48208	0.43762	0.58038	0.40421	0.72923	0.90540	0.87199
1978	0.94751	3.38373	0.69053	1.76150	4.45470	4.19772	0.45644	0.67256	0.38151	0.59801	0.88906	0.81413
1979	0.98041	4.41813	0.68675	1.81650	5.54790	5.25424	0.48661	0.80394	0.36498	0.49042	0.92938	0.80776
1980	1.02478	4.85868	0.83507	2.14790	6.17146	5.98176	0.48829	0.77003	0.38357	0.52402	0.91048	0.80576
1981	0.96752	3.08135	0.86089	2.18490	4.40539	4.29875	0.48174	0.64267	0.43917	0.73582	0.93933	0.89676
1982	1.03070	2.30344	1.04144	2.53870	3.80067	3.81141	0.50901	0.54720	0.51561	0.86956	0.90115	0.90775
1983	1.08505	2.08896	1.16502	2.81310	3.73707	3.81705	0.50050	0.39596	0.57465	1.01466	0.83596	0.91011
1984	1.07492	2.02297	1.18790	2.93110	3.76615	3.87912	0.50812	0.40250	0.58037	1.05277	0.87490	0.94715
1985	1.45503	1.30525	1.74110	3.88770	3.45187	3.73794	0.54426	0.21779	0.71925	1.29068	0.78921	0.96421
1986	2.14487	0.72530	2.57135	5.33450	3.48847	3.91495	0.61762	0.09617	0.86146	1.47617	0.71087	0.95471
1987	1.84154	0.66055	2.29069	4.89020	3.26009	3.70924	0.59515	0.14992	0.83279	1.40156	0.71870	0.95633
1988	3.76987	-0.56677	4.36766	8.78410	3.84966	4.44744	0.63034	0.09218	0.87121	1.53470	0.75567	0.99654
1989	5.43521	-2.07671	6.12339	11.91310	3.71297	4.40116	0.63229	0.07258	0.89295	1.59061	0.77024	1.03090
1990	3.50824	-0.83905	4.19402	8.32090	3.28785	3.97363	0.63651	0.05962	0.93386	1.63558	0.76134	1.05869
1991	3.22010	-0.68900	3.95840	7.97980	3.33240	4.07070	0.65634	0.05777	0.96249	1.64165	0.73694	1.04309
1992	2.81537	-0.46138	3.60530	7.33630	3.26958	4.05951	0.66838	0.07394	0.97469	1.62226	0.72151	1.02782
1993	4.58651	-1.73767	5.53820	11.06120	3.78535	4.73703	0.67242	0.11094	0.94721	1.55975	0.72348	0.99828
1994	1.87193	0.24078	2.69747	5.81620	3.35949	4.18502	0.70337	0.04017	1.02320	1.70251	0.71948	1.03931
Average	1.72716	2.39358	1.52098	2.83578	3.70839	3.50221	0.46689	0.31855	0.57057	1.10353	0.85151	0.95519
Std.dev	1.07931	1.90591	1.53576	3.26996	0.73042	0.94159	0.12342	0.26311	0.21896	0.37133	0.08243	0.08246

Note: Long-run Morishima substitution elasticities are computed from equation (4.38) in chapter 4.

Table A 6. 2d-3: Long-Run Morishima Substitution Elasticities in the Grain Milling Industry (Bread)

	Bread (SIC2051)					
Year	Q_{lm}	Q_{ml}	Q_{lk}	Q_{kl}	Q_{mk}	Q_{km}
1958	0.35447	0.38387	0.46672	0.71408	0.63123	0.74347
1959	0.36482	0.37488	0.50033	0.74252	0.61706	0.75257
1960	0.37212	0.39453	0.47775	0.69693	0.61371	0.71934
1961	0.38195	0.39304	0.49666	0.71180	0.60818	0.72289
1962	0.39099	0.39863	0.50379	0.70807	0.60292	0.71571
1963	0.40324	0.38798	0.53975	0.73828	0.58651	0.72302
1964	0.41258	0.39251	0.55157	0.74553	0.58647	0.72546
1965	0.42000	0.40742	0.54065	0.71702	0.58379	0.70444
1966	0.43266	0.39713	0.57802	0.75976	0.57887	0.72423
1967	0.44225	0.40637	0.57201	0.72652	0.56089	0.69064
1968	0.45091	0.41672	0.56765	0.70282	0.55189	0.66863
1969	0.45760	0.43065	0.56098	0.68539	0.55506	0.65845
1970	0.47057	0.42883	0.57390	0.67904	0.53396	0.63729
1971	0.48142	0.43283	0.58071	0.67061	0.52273	0.62201
1972	0.48018	0.47845	0.51381	0.56418	0.52882	0.56245
1973	0.48463	0.52738	0.45744	0.47896	0.54890	0.52171
1974	0.49999	0.61614	0.39521	0.39930	0.62023	0.51545
1975	0.50331	0.44955	0.62247	0.77020	0.59728	0.71643
1976	0.50874	0.47911	0.58397	0.67286	0.56799	0.64322
1977	0.52731	0.46544	0.61190	0.67400	0.52755	0.61214
1978	0.52771	0.50302	0.56126	0.58597	0.52772	0.56127
1979	0.52845	0.53040	0.53866	0.55962	0.55136	0.56157
1980	0.53386	0.54053	0.54013	0.56070	0.56110	0.56736
1981	0.55080	0.48257	0.63188	0.69899	0.54968	0.63076
1982	0.57150	0.44681	0.69732	0.77498	0.52446	0.65028
1983	0.58523	0.44153	0.71702	0.78801	0.51251	0.64430
1984	0.60377	0.41382	0.77456	0.86933	0.50859	0.67938
1985	0.61949	0.39883	0.81278	0.91050	0.49655	0.68984
1986	0.61921	0.40136	0.81285	0.90755	0.49606	0.68969
1987	0.61912	0.38541	0.84587	0.96649	0.50603	0.73278
1988	0.63467	0.36329	0.88701	1.03103	0.50731	0.75965
1989	0.66165	0.34091	0.94076	1.09349	0.49365	0.77276
1990	0.68174	0.32073	0.99415	1.15506	0.48163	0.79404
1991	0.69110	0.31445	1.01107	1.17431	0.47769	0.79766
1992	0.69391	0.31276	1.01747	1.17964	0.47493	0.79849
1993	0.68785	0.32613	0.98831	1.13706	0.47488	0.77534
1994	0.69047	0.29953	1.03729	1.21833	0.48056	0.82739
Average	0.52271	0.41847	0.66226	0.78835	0.54456	0.68411
Std.dev	0.10472	0.06952	0.18692	0.20588	0.04642	0.08061

Note: Long-run Morishima substitution elasticities are computed from equation (4.38) in chapter 4.

Table A 6. 3: Capacity Utilization Measure in the U.S. Grain Milling Industry

Year	Flour	Rice	Pet food	Animal feeds	Bread
1958	1.04706	1.05834	0.94457	1.03739	0.95536
1959	1.04172	1.05806	0.92646	1.02391	0.92212
1960	1.03684	1.06331	0.95064	1.02760	0.93575
1961	1.03262	1.05927	0.95617	1.03165	0.92481
1962	1.02431	1.05514	0.95784	1.02881	0.91271
1963	1.00942	1.04848	0.94906	1.02117	0.90562
1964	1.00104	1.05150	0.94647	1.01902	0.90787
1965	0.99307	1.04647	0.96158	1.02586	0.90849
1966	0.98935	1.03843	0.96008	1.01967	0.88510
1967	0.99146	1.03907	0.96428	1.02010	0.88904
1968	0.98809	1.02648	0.96539	1.02015	0.89637
1969	0.98763	1.02648	0.98120	1.01998	0.91712
1970	0.97960	1.02111	0.99070	1.01899	0.89917
1971	0.96346	1.00117	0.98723	1.01279	0.89890
1972	0.98413	1.03682	0.93931	1.01629	0.95802
1973	1.05886	1.05858	1.07174	1.06020	1.01270
1974	1.08458	1.09504	1.08384	1.06067	1.07403
1975	1.01829	1.05673	0.91454	0.99828	0.93634
1976	1.02862	1.08412	0.99375	1.01915	0.96863
1977	1.00972	1.01328	1.01735	1.01714	0.94496
1978	0.96706	0.95394	1.06800	1.02559	0.98119
1979	1.02058	0.95531	1.09349	1.03836	1.00948
1980	1.03355	0.96328	1.12092	1.03370	1.02287
1981	1.01880	0.92839	1.05860	1.00831	0.98832
1982	0.99359	0.90388	1.03935	0.97684	0.97344
1983	1.02873	0.93588	1.04114	0.98458	0.98445
1984	1.05618	0.92833	1.04297	0.99006	0.95894
1985	0.98510	0.79184	1.04962	0.95986	0.95822
1986	0.94896	0.74818	1.07026	0.96905	0.99389
1987	0.95204	0.71536	1.04027	0.94923	0.98786
1988	1.02387	0.89880	1.08837	0.97705	0.95187
1989	0.95033	0.79403	1.08126	0.96338	0.91171
1990	0.89257	0.70071	1.04400	0.93588	0.88321
1991	0.87961	0.72583	1.03702	0.93942	0.87464
1992	0.88648	0.71463	1.02371	0.93909	0.87910
1993	0.91404	0.77281	1.05256	0.95451	0.90493
1994	0.91973	0.75739	1.00507	0.94847	0.87800
Average	0.99300	0.94936	1.01132	1.00249	0.94041
Std.dev	0.04932	0.12747	0.05567	0.03480	0.04787

Note: CU is computed from equation (3.13) in chapter 3.

Table A 6. 4a-1: Short-Run Dual and Primal Productivity Growth Rates in the U.S. Grain Milling Industry (Flour, Rice, and Pet Food)

Industry	Flour (SIC2041)			Rice (SIC2044)			Pet food (SIC2047)		
Year	ε^{Ct}	ε^{CY}	ε^{Yt}	ε^{Ct}	ε^{CY}	ε^{Yt}	ε^{Ct}	ε^{CY}	ε^{Yt}
1958	-0.01185	0.84548	0.01407	-0.00977	0.95703	0.01023	-0.01872	0.93608	0.02017
1959	-0.01199	0.83368	0.01444	-0.00994	0.95767	0.01044	-0.01891	0.93235	0.02055
1960	-0.01219	0.8314	0.01469	-0.00989	0.95443	0.01042	-0.01874	0.91837	0.02038
1961	-0.01236	0.82786	0.01494	-0.01002	0.95269	0.01054	-0.01866	0.91143	0.02045
1962	-0.01250	0.83639	0.01493	-0.01064	0.95602	0.01114	-0.01868	0.90674	0.02061
1963	-0.01262	0.84556	0.01493	-0.01067	0.95197	0.01122	-0.01865	0.89926	0.02074
1964	-0.01279	0.84799	0.01508	-0.01070	0.94908	0.01130	-0.01878	0.8943	0.02100
1965	-0.01292	0.85578	0.01511	-0.01109	0.95059	0.01168	-0.01874	0.88997	0.02107
1966	-0.01294	0.85078	0.01523	-0.01135	0.95064	0.01197	-0.01867	0.88102	0.02123
1967	-0.01309	0.83242	0.01574	-0.01131	0.94471	0.01198	-0.01871	0.87142	0.02152
1968	-0.01321	0.83201	0.01589	-0.01171	0.94424	0.01240	-0.01886	0.86677	0.02180
1969	-0.01330	0.83401	0.01596	-0.01215	0.94727	0.01284	-0.01884	0.855	0.02205
1970	-0.01347	0.83879	0.01608	-0.01252	0.94927	0.01321	-0.01881	0.83725	0.02247
1971	-0.01369	0.84138	0.01634	-0.01256	0.94333	0.01331	-0.01899	0.82748	0.02296
1972	-0.01375	0.8559	0.01608	-0.01308	0.94824	0.01381	-0.02148	0.87559	0.02445
1973	-0.01338	0.8392	0.01600	-0.01499	0.96649	0.01534	-0.02012	0.84235	0.02401
1974	-0.01336	0.82756	0.01622	-0.01487	0.96487	0.01518	-0.02110	0.84424	0.02503
1975	-0.01352	0.81866	0.01653	-0.01408	0.95689	0.01474	-0.02132	0.82999	0.02570
1976	-0.01360	0.81059	0.01681	-0.01384	0.95284	0.01479	-0.02084	0.8053	0.02587
1977	-0.01380	0.79062	0.01747	-0.01474	0.95126	0.01550	-0.02048	0.78797	0.02601
1978	-0.01408	0.81474	0.01741	-0.01518	0.94502	0.01642	-0.02018	0.77576	0.02611
1979	-0.01400	0.828	0.01692	-0.01838	0.98296	0.01876	-0.02052	0.78136	0.02631
1980	-0.01399	0.81418	0.01720	-0.01890	0.99083	0.01917	-0.01998	0.75766	0.02662
1981	-0.01398	0.79493	0.01760	-0.01921	0.99925	0.01954	-0.02025	0.75517	0.02693
1982	-0.01399	0.79561	0.01757	-0.01933	1.00726	0.01905	-0.01945	0.7243	0.02694
1983	-0.01384	0.78234	0.01776	-0.01966	1.00072	0.01940	-0.01900	0.70858	0.02688
1984	-0.01373	0.77636	0.01793	-0.02023	0.9947	0.01999	-0.01882	0.70726	0.02672
1985	-0.01386	0.75501	0.01835	-0.02107	0.98709	0.02146	-0.01770	0.63345	0.02815
1986	-0.01346	0.72827	0.01862	-0.01993	0.96894	0.02127	-0.01677	0.59009	0.02870
1987	-0.01349	0.71535	0.01892	-0.02156	0.97516	0.02164	-0.01665	0.58034	0.02877
1988	-0.01419	0.77477	0.01844	-0.02166	0.9864	0.02138	-0.01687	0.51958	0.03261
1989	-0.01416	0.75353	0.01879	-0.02131	0.97787	0.02135	-0.01665	0.4635	0.03600
1990	-0.01346	0.71343	0.01941	-0.02005	0.95722	0.02220	-0.01652	0.42485	0.03887
1991	-0.01406	0.72658	0.01957	-0.02022	0.95031	0.02272	-0.01631	0.42055	0.03866
1992	-0.01432	0.67664	0.02165	-0.02053	0.93869	0.02339	-0.01588	0.41207	0.03844
1993	-0.01417	0.60816	0.02379	-0.02009	0.94089	0.02226	-0.01573	0.39548	0.03946
1994	-0.01441	0.61108	0.02389	-0.02063	0.93492	0.02331	-0.01584	0.42535	0.03720
Average	-0.01345	0.79365	0.01720	-0.01562	0.961831	0.01636	-0.01868	0.742925	0.02652
Std.dev	0.00067	0.063929	0.002319	0.004304	0.019492	0.004509	0.001603	0.174049	0.005965

Note: Short-run ε_{Ct}, ε_{CY}, and ε_{Yt} are respectively computed from equations (4.19), (4.22), and (4.21) in chapter 4.

Table A 6. 4a-2: Short-Run Dual and Primal Productivity Growth Rates in the U.S. Grain Milling Industry (Animal Feeds and Bread)

Industry	Animal feeds (SIC2048)			Bread (SIC2051)		
Year	ε_{Ct}	ε_{CY}	ε_{Yt}	ε_{Ct}	ε_{CY}	ε_{Yt}
1958	-0.00653	0.96403	0.00680	-0.00786	0.73489	0.01067
1959	-0.00670	0.96755	0.00694	-0.00818	0.73789	0.01107
1960	-0.00656	0.96182	0.00684	-0.00789	0.73872	0.01067
1961	-0.00673	0.96848	0.00697	-0.00766	0.74417	0.01031
1962	-0.00696	0.9738	0.00715	-0.00766	0.74236	0.01033
1963	-0.00703	0.97661	0.00721	-0.00723	0.74079	0.00975
1964	-0.00715	0.97921	0.00731	-0.00675	0.72949	0.00925
1965	-0.00721	0.98176	0.00735	-0.00660	0.7258	0.00910
1966	-0.00723	0.98348	0.00735	-0.00642	0.72759	0.00885
1967	-0.00691	0.97134	0.00711	-0.00625	0.73851	0.00849
1968	-0.00687	0.96854	0.00710	-0.00589	0.73869	0.00799
1969	-0.00683	0.9681	0.00707	-0.00515	0.72368	0.00713
1970	-0.00700	0.97491	0.00719	-0.00521	0.75098	0.00695
1971	-0.00726	0.98114	0.00740	-0.00488	0.75909	0.00644
1972	-0.00637	0.95974	0.00664	-0.00407	0.74035	0.00550
1973	-0.00720	0.99576	0.00716	-0.00330	0.73549	0.00448
1974	-0.00684	0.98801	0.00688	-0.00240	0.71341	0.00337
1975	-0.00703	0.99485	0.00706	-0.00186	0.71185	0.00261
1976	-0.00714	0.99767	0.00715	-0.00147	0.70805	0.00208
1977	-0.00695	0.99082	0.00700	-0.00146	0.74486	0.00196
1978	-0.00689	0.98901	0.00695	-0.00111	0.75411	0.00147
1979	-0.00672	0.98728	0.00680	-0.00055	0.74819	0.00074
1980	-0.00676	0.98935	0.00683	-0.00007	0.7505	0.00009
1981	-0.00668	0.99093	0.00674	0.00055	0.75399	-0.00073
1982	-0.00624	0.96992	0.00642	0.00125	0.75552	-0.00166
1983	-0.00628	0.96843	0.00649	0.00179	0.76644	-0.00233
1984	-0.00624	0.97143	0.00642	0.00217	0.77111	-0.00281
1985	-0.00638	0.97109	0.00655	0.00278	0.77108	-0.00361
1986	-0.00666	0.97715	0.00681	0.00356	0.75725	-0.00471
1987	-0.00599	0.95018	0.00630	0.00414	0.73234	-0.00565
1988	-0.00630	0.97053	0.00650	0.00408	0.75556	-0.00538
1989	-0.00618	0.9686	0.00638	0.00412	0.78186	-0.00527
1990	-0.00589	0.95636	0.00615	0.00446	0.7898	-0.00566
1991	-0.00573	0.94851	0.00603	0.00469	0.79911	-0.00588
1992	-0.00550	0.93826	0.00586	0.00504	0.80084	-0.00632
1993	-0.00535	0.93179	0.00572	0.00536	0.80385	-0.00669
1994	-0.00545	0.93858	0.00579	0.00559	0.797	-0.00705
Average	-0.00659	0.972028	0.00677	-0.00163	0.750681	0.00231
Std.dev	0.000523	0.016257	0.00045	0.004698	0.024954	0.006246

Note: Short-run ε_{Ct}, ε_{CY}, and ε_{Yt} are respectively computed from equations (4.19), (4.22), and (4.21) in chapter 4.

Table A 6. 4b-1: Long-Run Dual and Primal Productivity Growth Rates in the U.S. Grain Milling Industry (Flour, Rice and Pet Food)

Industry	Flour (SIC2041)			Rice (SIC2044)			Pet food (SIC2047)		
Year	ε_{Ct}	ε_{CY}	ε_{Yt}	ε_{Ct}	ε_{CY}	ε_{Yt}	ε_{Ct}	ε_{CY}	ε_{Yt}
1958	-0.01283	0.85386	0.01502	-0.01197	0.97205	0.01232	-0.01649	0.95017	0.01736
1959	-0.01284	0.84075	0.01528	-0.01189	0.97038	0.01226	-0.01613	0.95077	0.01696
1960	-0.01295	0.83798	0.01546	-0.01214	0.97024	0.01252	-0.01675	0.93220	0.01797
1961	-0.01303	0.83374	0.01563	-0.01212	0.96761	0.01252	-0.01687	0.92450	0.01825
1962	-0.01299	0.84070	0.01545	-0.01261	0.97109	0.01298	-0.01692	0.92022	0.01839
1963	-0.01280	0.84714	0.01511	-0.01232	0.96526	0.01276	-0.01659	0.91578	0.01812
1964	-0.01281	0.84816	0.01510	-0.01240	0.96341	0.01287	-0.01662	0.91211	0.01822
1965	-0.01279	0.85460	0.01497	-0.01260	0.96372	0.01308	-0.01711	0.90361	0.01894
1966	-0.01274	0.84898	0.01501	-0.01252	0.96053	0.01303	-0.01700	0.89593	0.01897
1967	-0.01293	0.83093	0.01556	-0.01258	0.95713	0.01314	-0.01709	0.88679	0.01927
1968	-0.01298	0.82994	0.01564	-0.01254	0.95261	0.01317	-0.01725	0.88223	0.01955
1969	-0.01306	0.83191	0.01570	-0.01296	0.95550	0.01356	-0.01793	0.86409	0.02075
1970	-0.01309	0.83540	0.01566	-0.01314	0.95530	0.01376	-0.01835	0.84214	0.02179
1971	-0.01300	0.83508	0.01557	-0.01259	0.94363	0.01334	-0.01834	0.83467	0.02197
1972	-0.01344	0.85332	0.01575	-0.01425	0.96003	0.01484	-0.01852	0.89972	0.02058
1973	-0.01459	0.84699	0.01723	-0.01717	0.98386	0.01745	-0.02456	0.80058	0.03068
1974	-0.01525	0.83815	0.01820	-0.01900	1.00017	0.01900	-0.02660	0.79431	0.03349
1975	-0.01387	0.82077	0.01690	-0.01596	0.97611	0.01635	-0.01790	0.86287	0.02075
1976	-0.01416	0.81405	0.01740	-0.01639	0.97891	0.01674	-0.02054	0.80849	0.02540
1977	-0.01399	0.79181	0.01766	-0.01516	0.95591	0.01586	-0.02139	0.77780	0.02749
1978	-0.01342	0.80882	0.01660	-0.01353	0.92226	0.01467	-0.02410	0.72996	0.03301
1979	-0.01441	0.83069	0.01735	-0.01697	0.96811	0.01752	-0.02641	0.71383	0.03699
1980	-0.01467	0.81831	0.01792	-0.01769	0.97716	0.01811	-0.02756	0.66517	0.04143
1981	-0.01435	0.79714	0.01801	-0.01694	0.96966	0.01747	-0.02327	0.71847	0.03239
1982	-0.01386	0.79484	0.01744	-0.01648	0.96982	0.01699	-0.02138	0.69843	0.03061
1983	-0.01439	0.78515	0.01832	-0.01781	0.98099	0.01815	-0.02105	0.67946	0.03098
1984	-0.01477	0.78070	0.01893	-0.01820	0.97636	0.01865	-0.02085	0.67857	0.03073
1985	-0.01358	0.75347	0.01803	-0.01503	0.91984	0.01634	-0.02001	0.59554	0.03360
1986	-0.01251	0.72228	0.01732	-0.01261	0.87325	0.01444	-0.02027	0.52662	0.03849
1987	-0.01261	0.71056	0.01774	-0.01334	0.88252	0.01512	-0.01861	0.54315	0.03426
1988	-0.01462	0.77627	0.01884	-0.01878	0.96351	0.01949	-0.02152	0.42108	0.05111
1989	-0.01326	0.74911	0.01770	-0.01555	0.91600	0.01697	-0.02086	0.36604	0.05698
1990	-0.01159	0.70266	0.01649	-0.01179	0.84299	0.01398	-0.01861	0.37325	0.04986
1991	-0.01196	0.71587	0.01671	-0.01262	0.85193	0.01481	-0.01811	0.37445	0.04837
1992	-0.01229	0.66877	0.01837	-0.01254	0.84328	0.01488	-0.01701	0.38259	0.04446
1993	-0.01257	0.60548	0.02076	-0.01343	0.84725	0.01585	-0.01847	0.32107	0.05752
1994	-0.01293	0.60921	0.02122	-0.01367	0.84737	0.01613	-0.01607	0.41918	0.03833
Average	-0.01335	0.79361	0.01692	-0.01430	0.94259	0.01517	-0.01954	0.72340	0.03011
Std.dev	0.00086	0.06648	0.00157	0.00227	0.04617	0.00215	0.00314	0.20141	0.01198

Note: Long-run ε_{Ct}, ε_{CY}, and ε_{Yt} are respectively calculated from equations (4.23), (4.27), and (4.26) in chapter 4.

Table A 6. 4b-2: Long-Run Dual and Primal Productivity Growth Rates in the U.S. Grain Milling Industry (Animal Feeds and Bread)

Industry	Animal feeds (SIC2048)			Bread (SIC2051)		
Year	ε_{Ct}	ε_{CY}	ε_{Yt}	ε_{Ct}	ε_{CY}	ε_{Yt}
1958	-0.00772	0.99179	0.00778	-0.00675	0.72611	0.00930
1959	-0.00743	0.98502	0.00754	-0.00626	0.72220	0.00867
1960	-0.00740	0.98303	0.00753	-0.00630	0.72561	0.00868
1961	-0.00770	0.99296	0.00776	-0.00584	0.72895	0.00802
1962	-0.00788	0.99723	0.00790	-0.00557	0.72466	0.00768
1963	-0.00770	0.99375	0.00775	-0.00505	0.72200	0.00700
1964	-0.00774	0.99465	0.00778	-0.00467	0.71138	0.00656
1965	-0.00803	1.00342	0.00800	-0.00455	0.70780	0.00643
1966	-0.00785	1.00047	0.00784	-0.00389	0.70501	0.00552
1967	-0.00756	0.99049	0.00763	-0.00383	0.71591	0.00535
1968	-0.00751	0.98790	0.00760	-0.00366	0.71738	0.00511
1969	-0.00747	0.98794	0.00756	-0.00342	0.70709	0.00483
1970	-0.00761	0.99412	0.00765	-0.00315	0.73003	0.00431
1971	-0.00767	0.99460	0.00772	-0.00286	0.73773	0.00388
1972	-0.00695	0.98202	0.00708	-0.00325	0.73166	0.00445
1973	-0.00971	1.08435	0.00896	-0.00354	0.73805	0.00480
1974	-0.00930	1.08076	0.00861	-0.00374	0.72550	0.00516
1975	-0.00697	0.99284	0.00702	-0.00085	0.70243	0.00121
1976	-0.00781	1.02296	0.00763	-0.00096	0.70280	0.00137
1977	-0.00756	1.01554	0.00744	-0.00059	0.73455	0.00080
1978	-0.00780	1.02681	0.00759	-0.00081	0.75049	0.00108
1979	-0.00811	1.04585	0.00776	-0.00069	0.74989	0.00093
1980	-0.00797	1.04127	0.00766	-0.00040	0.75444	0.00053
1981	-0.00695	1.00280	0.00693	0.00071	0.75205	-0.00094
1982	-0.00553	0.93672	0.00591	0.00158	0.75105	-0.00210
1983	-0.00578	0.94493	0.00612	0.00196	0.76380	-0.00257
1984	-0.00595	0.95808	0.00621	0.00261	0.76428	-0.00341
1985	-0.00525	0.91919	0.00572	0.00320	0.76402	-0.00419
1986	-0.00575	0.93675	0.00614	0.00362	0.75627	-0.00479
1987	-0.00450	0.87735	0.00512	0.00424	0.73058	-0.00581
1988	-0.00563	0.93911	0.00599	0.00446	0.74846	-0.00596
1989	-0.00513	0.91823	0.00559	0.00483	0.76793	-0.00628
1990	-0.00414	0.86853	0.00477	0.00535	0.77097	-0.00693
1991	-0.00404	0.86179	0.00468	0.00560	0.77849	-0.00719
1992	-0.00377	0.84653	0.00445	0.00588	0.78086	-0.00753
1993	-0.00408	0.86469	0.00472	0.00600	0.78773	-0.00761
1994	-0.00408	0.86689	0.00471	0.00635	0.77755	-0.00817
Average	-0.00676	0.97112	0.00689	-0.00066	0.73961	0.00103
Std.dev	0.00155	0.06017	0.00123	0.00416	0.02431	0.00559

Note: Long-run ε_{Ct}, ε_{CY}, and ε_{Yt} are respectively calculated from equations (4.23), (4.27), and (4.26) in chapter 4.

Table A 6. 5. 1-2: Short-Run Bias of Technological Change (Flour, Rice and Pet Food)

Industry	Flour (SIC2041)		Rice (SIC2044)		Pet food (SIC2047)	
Year	β_L^{CE}	β_M^{CE}	β_L^{CE}	β_M^{CE}	β_L^{CE}	β_M^{CE}
1958	-0.00591	0.00047	0.05726	-0.00313	-0.03568	0.00396
1959	-0.00480	0.00036	0.05523	-0.00308	-0.03536	0.00413
1960	-0.00531	0.00041	0.05454	-0.00309	-0.03298	0.00345
1961	-0.00538	0.00042	0.05313	-0.00319	-0.03144	0.00321
1962	-0.00662	0.00049	0.05333	-0.00266	-0.03059	0.00313
1963	-0.00805	0.00061	0.05208	-0.00281	-0.02927	0.00295
1964	-0.00851	0.00066	0.05124	-0.00284	-0.02855	0.00293
1965	-0.00952	0.00075	0.04978	-0.00261	-0.02661	0.00271
1966	-0.00880	0.00067	0.04723	-0.00253	-0.02448	0.00247
1967	-0.00677	0.00055	0.04686	-0.00263	-0.02401	0.00242
1968	-0.00684	0.00058	0.04232	-0.00250	-0.02348	0.00243
1969	-0.00692	0.00059	0.03984	-0.00220	-0.02094	0.00216
1970	-0.00720	0.00062	0.03690	-0.00202	-0.01873	0.00191
1971	-0.00718	0.00065	0.03281	-0.00225	-0.01877	0.00197
1972	-0.00830	0.00070	0.03075	-0.00181	-0.03147	0.00474
1973	-0.00521	0.00030	0.01671	-0.00092	-0.01995	0.00259
1974	-0.00277	0.00014	0.02164	-0.00102	-0.02196	0.00326
1975	-0.00204	0.00011	0.02772	-0.00127	-0.02117	0.00321
1976	-0.00122	0.00007	0.02681	-0.00132	-0.01741	0.00245
1977	0.00075	-0.00006	0.01675	-0.00101	-0.01396	0.00189
1978	-0.00325	0.00033	0.00487	-0.00043	-0.00898	0.00119
1979	-0.00315	0.00022	-0.01892	0.00137	-0.00682	0.00096
1980	-0.00088	0.00006	-0.02400	0.00159	-0.00097	0.00013
1981	0.00165	-0.00011	-0.02865	0.00185	0.00133	-0.00019
1982	0.00075	-0.00006	-0.02594	0.00149	0.00826	-0.00110
1983	0.00341	-0.00024	-0.02813	0.00143	0.01474	-0.00196
1984	0.00521	-0.00033	-0.02993	0.00160	0.02079	-0.00287
1985	0.00652	-0.00056	-0.03320	0.00306	0.02543	-0.00319
1986	0.00783	-0.00090	-0.02801	0.00298	0.03082	-0.00372
1987	0.01060	-0.00116	-0.03169	0.00308	0.03630	-0.00466
1988	0.00659	-0.00042	-0.03396	0.00190	0.03283	-0.00408
1989	0.00851	-0.00071	-0.03182	0.00207	0.02757	-0.00328
1990	0.01213	-0.00137	-0.03125	0.00303	0.02361	-0.00283
1991	0.01188	-0.00125	-0.03232	0.00313	0.03285	-0.00439
1992	0.02264	-0.00226	-0.03254	0.00350	0.04098	-0.00599
1993	0.03848	-0.00369	-0.02752	0.00234	0.04545	-0.00734
1994	0.04086	-0.00349	-0.03241	0.00288	0.05737	-0.01127
Average	0.00144	-0.00018	0.00939	-0.00022	-0.00339	0.00009
Std.dev	0.01189	0.00108	0.03625	0.00239	0.02761	0.00377

Note: Short-run bias of technological change is calculated by equation (4.39) in chapter 4.

Table A 6. 5. 1-2: Short-Run Bias of Technological Change (Animal Feeds and Bread)

Industry	Animal feeds (SIC2048)		Bread (SIC2051)	
Year	β_L^{CE}	β_M^{CE}	β_L^{CE}	β_M^{CE}
1958	-0.00034	0.00003	-0.01161	0.00704
1959	-0.00208	0.00020	-0.01191	0.00737
1960	-0.00059	0.00006	-0.01175	0.00718
1961	-0.00300	0.00029	-0.01175	0.00705
1962	-0.00610	0.00058	-0.01171	0.00708
1963	-0.00755	0.00071	-0.01096	0.00672
1964	-0.00936	0.00088	-0.01026	0.00631
1965	-0.01082	0.00100	-0.01002	0.00620
1966	-0.01137	0.00102	-0.00988	0.00608
1967	-0.00674	0.00064	-0.00961	0.00598
1968	-0.00638	0.00062	-0.00904	0.00567
1969	-0.00575	0.00054	-0.00793	0.00499
1970	-0.00815	0.00075	-0.00816	0.00510
1971	-0.01164	0.00109	-0.00768	0.00482
1972	0.00416	-0.00032	-0.00637	0.00406
1973	-0.01070	0.00075	-0.00555	0.00335
1974	-0.00434	0.00029	-0.00475	0.00251
1975	-0.00849	0.00059	-0.00374	0.00201
1976	-0.01087	0.00077	-0.00281	0.00164
1977	-0.00654	0.00047	-0.00275	0.00165
1978	-0.00554	0.00040	-0.00223	0.00131
1979	-0.00351	0.00024	-0.00140	0.00078
1980	-0.00435	0.00030	-0.00059	0.00032
1981	-0.00234	0.00015	0.00054	-0.00029
1982	0.00726	-0.00048	0.00170	-0.00097
1983	0.00320	-0.00023	0.00261	-0.00150
1984	0.00334	-0.00023	0.00328	-0.00188
1985	0.00026	-0.00002	0.00415	-0.00249
1986	-0.00859	0.00068	0.00511	-0.00324
1987	0.00508	-0.00039	0.00566	-0.00377
1988	-0.00340	0.00025	0.00602	-0.00374
1989	-0.00064	0.00005	0.00638	-0.00383
1990	0.00582	-0.00042	0.00682	-0.00418
1991	0.00767	-0.00056	0.00725	-0.00443
1992	0.01147	-0.00084	0.00767	-0.00479
1993	0.01382	-0.00101	0.00805	-0.00511
1994	0.01058	-0.00078	0.00832	-0.00534
Average	-0.00234	0.00022	-0.00267	0.00161
Std.dev	0.00692	0.00055	0.00708	0.00437

Note: Short-run bias of technological change is calculated by equation (4.39) in chapter 4.

Table A 6. 5. 2-1: Long-Run Bias of Technological Change (Flour, Rice, and Pet Food)

Industry	Flour (SIC2041)			Rice (SIC2044)			Pet food (SIC2047)		
Year	$\beta_L^{CE,LR}$	$\beta_M^{CE,LR}$	$\beta_K^{CE,LR}$	$\beta_L^{CE,LR}$	$\beta_M^{CE,LR}$	$\beta_K^{CE,LR}$	$\beta_L^{CE,LR}$	$\beta_M^{CE,LR}$	$\beta_K^{CE,LR}$
1958	-0.01167	-0.00188	0.01916	0.05490	-0.00670	0.02827	-0.02165	-0.00501	0.04956
1959	-0.01002	-0.00208	0.01912	0.05251	-0.00684	0.02780	-0.02333	-0.00472	0.04981
1960	-0.00998	-0.00213	0.01926	0.05243	-0.00685	0.02806	-0.01727	-0.00557	0.05056
1961	-0.00962	-0.00221	0.01934	0.04999	-0.00722	0.02816	-0.01574	-0.00593	0.04993
1962	-0.01029	-0.00220	0.01914	0.05061	-0.00683	0.02800	-0.01439	-0.00627	0.05001
1963	-0.01091	-0.00223	0.01890	0.04999	-0.00729	0.02835	-0.01274	-0.00607	0.04985
1964	-0.01111	-0.00228	0.01886	0.04925	-0.00748	0.02867	-0.01092	-0.00644	0.05002
1965	-0.01200	-0.00227	0.01880	0.04839	-0.00748	0.02857	-0.01036	-0.00744	0.04894
1966	-0.01104	-0.00242	0.01867	0.04707	-0.00773	0.02836	-0.00848	-0.00754	0.04797
1967	-0.00922	-0.00266	0.01899	0.04671	-0.00806	0.02941	-0.00604	-0.00814	0.05050
1968	-0.00937	-0.00272	0.01907	0.04479	-0.00854	0.02964	-0.00465	-0.00890	0.05150
1969	-0.00967	-0.00275	0.01908	0.04379	-0.00845	0.02984	-0.00537	-0.01017	0.05077
1970	-0.01015	-0.00277	0.01905	0.04256	-0.00856	0.02941	-0.00454	-0.01106	0.05050
1971	-0.01017	-0.00289	0.01898	0.04036	-0.00950	0.02894	-0.00254	-0.01173	0.05162
1972	-0.01262	-0.00255	0.01919	0.03761	-0.00909	0.03052	-0.00316	-0.01457	0.05788
1973	-0.00842	-0.00248	0.01977	0.02925	-0.00957	0.03051	-0.01537	-0.02947	0.05459
1974	-0.00430	-0.00262	0.02015	0.02610	-0.00967	0.03213	-0.01706	-0.04266	0.05509
1975	-0.00643	-0.00316	0.01900	0.03152	-0.00889	0.03047	0.00146	-0.01392	0.04653
1976	-0.00562	-0.00325	0.01944	0.02883	-0.00913	0.03173	-0.00572	-0.01978	0.04989
1977	-0.00318	-0.00371	0.01961	0.03284	-0.01007	0.03109	-0.00582	-0.02235	0.05129
1978	-0.00712	-0.00380	0.01928	0.03264	-0.01179	0.03084	-0.00992	-0.03031	0.05258
1979	-0.00829	-0.00321	0.01969	0.02924	-0.01068	0.03159	-0.01441	-0.04290	0.05372
1980	-0.00590	-0.00343	0.01984	0.02630	-0.01056	0.03197	-0.00954	-0.04700	0.05392
1981	-0.00292	-0.00394	0.01960	0.02663	-0.01040	0.03143	-0.00221	-0.03209	0.04941
1982	-0.00306	-0.00427	0.01926	0.02149	-0.01000	0.03218	0.01235	-0.02696	0.04887
1983	-0.00070	-0.00435	0.01961	0.01958	-0.01032	0.03193	0.02032	-0.02735	0.04856
1984	0.00081	-0.00440	0.01981	0.02286	-0.01112	0.03136	0.02320	-0.02833	0.04723
1985	0.00404	-0.00546	0.01906	0.03136	-0.01298	0.02998	0.06448	-0.02678	0.04843
1986	0.00602	-0.00676	0.01830	0.02879	-0.01464	0.02911	0.12780	-0.02775	0.05016
1987	0.00887	-0.00704	0.01833	0.02951	-0.01440	0.02929	0.10773	-0.02842	0.04829
1988	0.00234	-0.00502	0.01948	0.02573	-0.01304	0.03110	0.36729	-0.02262	0.04796
1989	0.00699	-0.00615	0.01848	0.03165	-0.01333	0.02974	0.65274	-0.01830	0.04710
1990	0.01069	-0.00801	0.01719	0.02846	-0.01592	0.02774	0.39599	-0.02292	0.04462
1991	0.01035	-0.00772	0.01741	0.02962	-0.01628	0.02773	0.34789	-0.02494	0.04412
1992	0.01777	-0.00867	0.01779	0.02899	-0.01736	0.02737	0.27971	-0.02864	0.04350
1993	0.03053	-0.01021	0.01819	0.02629	-0.01712	0.02913	0.56347	-0.02013	0.04426
1994	0.03377	-0.00994	0.01837	0.02915	-0.01777	0.02834	0.16498	-0.03424	0.04119
Average	-0.00221	-0.00415	0.01901	0.03589	-0.01059	0.02970	0.07806	-0.01993	0.04948
Std.dev	0.01135	0.00233	0.00065	0.01043	0.00329	0.00148	0.17263	0.01191	0.00336

Note: Long-run bias of technological change is calculated by equation (4.39) in chapter 4.

Table A 6. 5. 2-2: Long-Run Bias of Technological Change (Animal Feeds and Bread)

Industry	Animal feeds (SIC2048)			Bread (SIC2051)		
Year	$\beta_L^{CE,LR}$	$\beta_M^{CE,LR}$	$\beta_K^{CE,LR}$	$\beta_L^{CE,LR}$	$\beta_M^{CE,LR}$	$\beta_K^{CE,LR}$
1958	-0.01934	-0.00562	0.03134	-0.02273	0.00027	0.02565
1959	-0.01825	-0.00568	0.03108	-0.02219	-0.00009	0.02500
1960	-0.01703	-0.00581	0.03189	-0.02234	-0.00014	0.02473
1961	-0.02131	-0.00571	0.03131	-0.02197	-0.00051	0.02392
1962	-0.02579	-0.00568	0.03104	-0.02156	-0.00078	0.02346
1963	-0.02640	-0.00569	0.03050	-0.02088	-0.00117	0.02283
1964	-0.02830	-0.00572	0.03057	-0.02014	-0.00155	0.02230
1965	-0.03268	-0.00568	0.03051	-0.01983	-0.00174	0.02201
1966	-0.03186	-0.00572	0.03015	-0.01884	-0.00228	0.02110
1967	-0.02644	-0.00595	0.03130	-0.01885	-0.00235	0.02084
1968	-0.02607	-0.00606	0.03182	-0.01849	-0.00254	0.02051
1969	-0.02448	-0.00614	0.03209	-0.01771	-0.00287	0.02014
1970	-0.02676	-0.00611	0.03195	-0.01762	-0.00302	0.01954
1971	-0.02961	-0.00615	0.03221	-0.01713	-0.00328	0.01904
1972	-0.00230	-0.00662	0.03410	-0.01683	-0.00316	0.01937
1973	-0.03317	-0.00567	0.03166	-0.01637	-0.00311	0.01926
1974	-0.02022	-0.00586	0.03227	-0.01505	-0.00338	0.01877
1975	-0.01624	-0.00615	0.02993	-0.01150	-0.00542	0.01577
1976	-0.02520	-0.00610	0.03075	-0.01134	-0.00551	0.01604
1977	-0.01676	-0.00635	0.03203	-0.01107	-0.00569	0.01550
1978	-0.01612	-0.00640	0.03279	-0.01082	-0.00563	0.01546
1979	-0.01673	-0.00629	0.03240	-0.00970	-0.00591	0.01496
1980	-0.01676	-0.00637	0.03250	-0.00858	-0.00623	0.01435
1981	-0.00735	-0.00661	0.03171	-0.00658	-0.00703	0.01306
1982	0.01288	-0.00730	0.03317	-0.00490	-0.00770	0.01220
1983	-0.00028	-0.00726	0.03247	-0.00386	-0.00802	0.01161
1984	-0.00271	-0.00704	0.03149	-0.00223	-0.00849	0.01076
1985	-0.00255	-0.00746	0.03159	-0.00081	-0.00899	0.01009
1986	-0.02062	-0.00735	0.03093	0.00048	-0.00948	0.00962
1987	0.00091	-0.00801	0.03198	0.00211	-0.01008	0.00897
1988	-0.01738	-0.00728	0.03012	0.00313	-0.01007	0.00836
1989	-0.00947	-0.00742	0.02985	0.00412	-0.01019	0.00773
1990	0.00375	-0.00783	0.03018	0.00517	-0.01052	0.00708
1991	0.00314	-0.00800	0.03034	0.00606	-0.01071	0.00664
1992	0.00616	-0.00822	0.03070	0.00693	-0.01098	0.00624
1993	0.00364	-0.00820	0.03085	0.00779	-0.01124	0.00597
1994	-0.00033	-0.00808	0.02990	0.00846	-0.01136	0.00548
Average	-0.01481	-0.00658	0.03139	-0.00988	-0.00543	0.01579
Std.dev	0.01268	0.00087	0.00100	0.01035	0.00378	0.00630

Note: Long-run bias of technological change is calculated by equation (4.39) in chapter 4.