SOURCES OF TOTAL FACTOR PRODUCTIVITY

FOR JAPANESE MANUFACTURING INDUSTRIES, 1964-1988: ISSUES IN SCALE ECONOMIES, TECHNICAL PROGRESS, INDUSTRIAL POLICIES AND MEASUREMENT METHODOLOGIES

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Our institute is named the 'Keio Economic Observatory', even though an 'observatory' usually means an astronomical or meteorological institute for the observation of natural phenomenon. We call our institute an 'observatory' because we wish to treat economics as an empirical science and thereby intend to analyze economic phenomena objectively, being completely detached from any ideologies, by making use of economic theory as an equivalent to theories of other physical empirical sciences. The K.E.O. monograph series, of which this book is one, is designed to publicly demonstrate this spirit. We hope that this book presents a tangible example of economics as an empirical science.

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Chapter 1. Introduction

1.1 Labor Productivity and GNP Growth

Productivity analysis has a long history in economics. In his Wealth of Nations Adam Smith states that growth in economic prosperity is measured by an increase in the production of goods per capita, which in turn depends on labor force participation rate and labor productivity. Smith thought, however, that in most nations, economic prosperity seems to depend more on labor productivity that labor force participation rate. Japan's economic growth since the Meiji Restoration in 1868, for example, seems consistent with this hypothesis put forward by Smith.

Decomposition of Per Capita GNP Growth Rate for Japan*: 1890–1985

	1890–1913	1913–20	1920–40	1947–55	1956–73	1974–85
Labor Force Participate Rate*	**0.19**	**-0.62**	**-0.11**	**0.22**	**0.24**	**0.16**
Labor Productivity*	**1.57**	**2.93**	**2.23**	**6.59**	**8.16**	**3.32**

* Annual average growth rates (%) calculated using data from *Long-Term Economic Statistics*, Toyo Keizai Shimpo Sha, Tokyo.

The table above shows a simple decomposition of Japan's annual per capita GNP growth into the contributions of the growth in Japan's annual labor force participation and labor productivity growth rates. The contribution of labor productivity growth to GNP growth is much larger than the contribution of growth in the labor force participation rate, the latter of which is sometimes negative prior to World War II. Despite rapid increases in Japan's labor force participation rate after World War II because of the post war demobilization and ensuing baby boom, growth in labor force participation rate has not had much impact on Japan's post war economic growth.

Another important observation Adam Smith makes about labor productivity is that it is affected by costless and invisible increases in productive efficiency accompanying increases in inputs of machinery and other factors of production. From Smith's point of view, these costless gains in productive efficiency are the benefits of division of labor. In modern terms, this invisible factor is referred to as Total Factor Productivity (TFP). TFP denotes those portions of gains in productivity that cannot be accounted for by increases in production inputs.

The methodologies of productivity analysis have become highly sophisticated thanks to the efforts of researchers all over the world. In developing countries, productivity analysis is often used to find domestic factors which help economic growth. In industrialized countries, on the other hand, productivity measurements are frequently used for explaining the sources of international competitiveness for specific industries such as automobile and electric machinery industries. For these purposes, aggregate macroeconomic time-series data are usually used.

In this book, however, we are interested in productivity analysis at the firm level. In particular, we are interested in answering the following questions at the firm level. Is there a significant scale economy in Japan's manufacturing industry? If there is, how much is its contribution to Japan's productivity growth? Our analysis utilizes establishment level data which are more suitable than aggregate data for testing the types of hypotheses that we deal with in this book.

1.2 Organization of this Book

The organization of this book is as follows. Chapter 2 provides a literature review on productivity analysis and TFP. Chapter 3 discusses measurement of economies of scale in production. We present our estimates for the effects of economies of scale for the two-digit manufacturing industries in Japan for the period 1964–1988 using establishment data classified by size.

Our method of estimation, which is discussed in detail in Chapter 3, is based on index number theory and suffers little from multicollinearity problems which often cause inprecise estimates for the economy of scale effects. In Chapter 4 we estimate the contributions of scale economies and technical progress to TFP growth. Our estimation method for this Chapter is an extension of the estimation method used in Chapter 3.

1.3 Main Findings

In order to help the reader understand the types of issues discussed in the chapters to follow, we summarize our main findings as follows.

(1) For more than half of Japanese 2-digit manufacturing industries, statistically significant economies of scale are found for the period 1964–1988. (See Chapter 3.)

(2) For the industries for which economies of scale are observed, the main factor which explains TFP growth at the establishment (micro) level is scale economies. On the other hand, the effects of technical progress on TFP are negligible. (See Chapter 4.)

(3) However, the main factor which explains TFP growth at the aggregate (macro) level is technical progress, whereas the effects of scale economies are negligible. (See Chapter 4.)

(4) Significant positive correlation exists between TFP growth in the short run and the stages of the business cycle at the macro level. This finding is consistent with many previous studies. (See Chapter 2.)

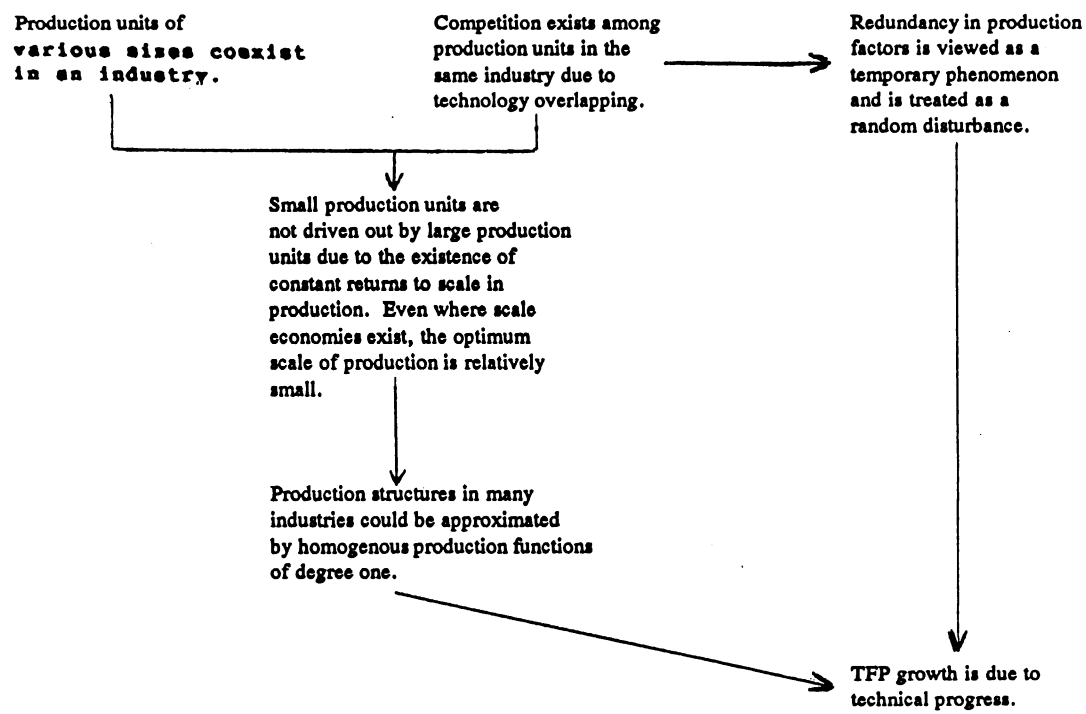
1.4 Discussion of Main Findings

While these four findings are discussed in detail in respective chapters of this book, the relationships among the four findings need some analysis. Moreover, (2) and (3) above seem contradictory to each other. In this subsection we briefly discuss these issues.

Robert Solow and some other researchers whose work predates Solow's emphasize that, in many countries, production units of large and small sizes coexist in the same industry. These production units of different sizes are considered to be competitive within their respective industries where they share overlapping technologies. Analysis of production functions and TFP is then carried out based on these assumptions. These assumptions would also be valid even if economies of scale existed in the production structure so long as the optimum size for a production unit were relatively small. In studies based on these assumptions production structures are approximated by constant returns to scale production functions, and hence productivity growth is attributed entirely to technical progress (see Figure 1.1).

Figure 1.1

Sources of TFP Growth: Traditional Walrasian Approach



Our finding (1) above states that more than half of the Japanese two-digit manufacturing industries enjoy statistically significant economies of scale. This casts doubt on the appropriateness of using constant returns to scale production functions. Furthermore, since the rise in productivity does not equal technical progress in this case, we need to examine if productivity growth is affected by economies of scale. In fact, Berndt and Khaled show that, even at the aggregate level, productivity growth for the U.S. economy is due mainly to the effects of scale economies.

Our finding (2) states that, at the micro level, productivity growth is due to the effects of scale economies. However, we find unexpectedly that when establishment level data are aggregated to the macro level, scale economy effects disappear for Japan. That is, the conclusion by Berndt and Khaled does not hold for Japan.

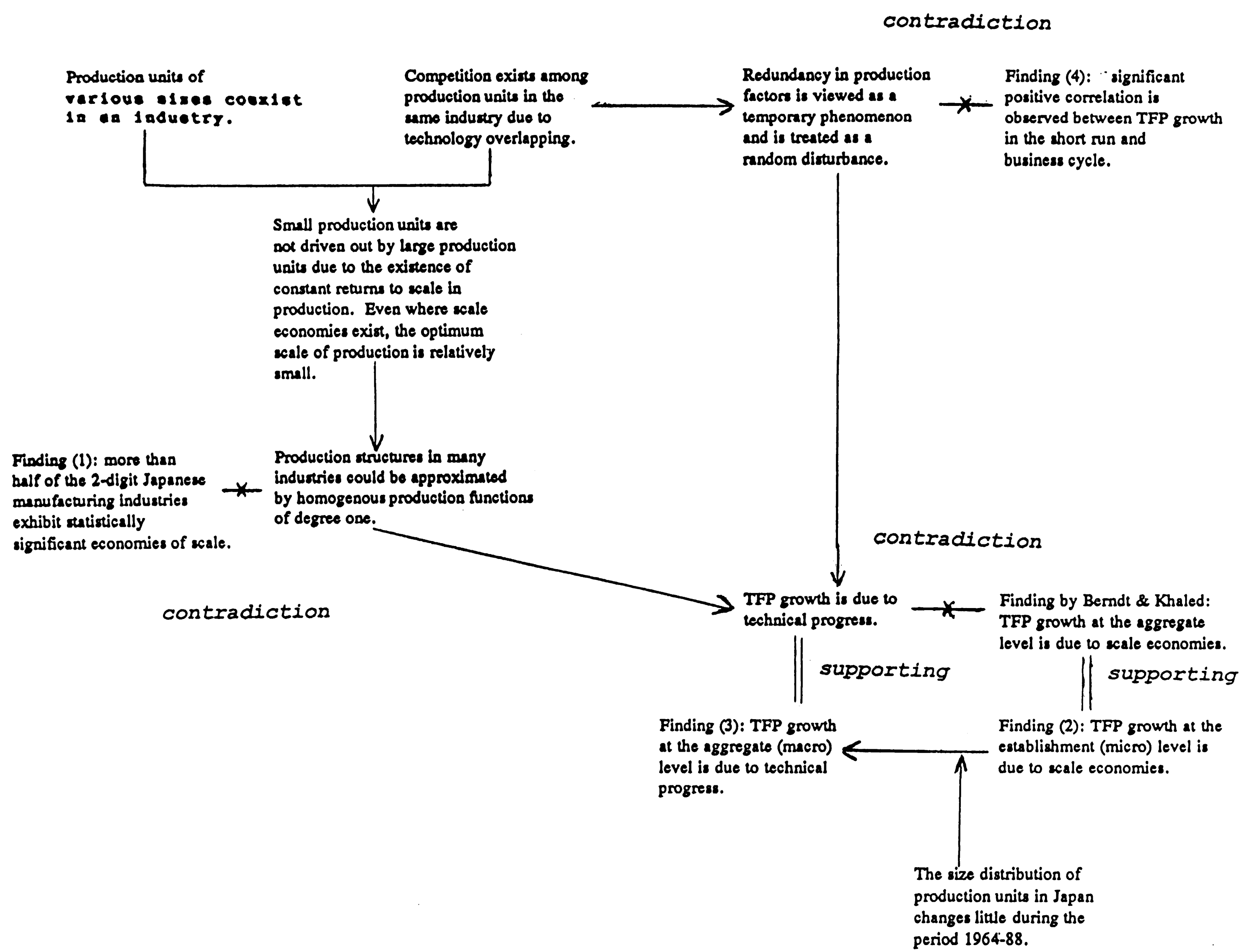
Our finding (3) states that, at the aggregate level, productivity growth is due to technical progress. This finding is consistent with the fact that the size distribution of Japanese production units has been relatively stable from the 1960s to the 1980s. Thus, although economies of scale are observed at the establishment level, productivity growth at the aggregate level is attributed to technical progress. This is consistent with the traditional approach by Solow and others in support of using constant returns to scale production functions.

The implications of these findings are rather complex, however. While, at the aggregate level, production structures can be approximated by constant returns to scale production functions, it is questionable that production units within the same industry for which we observe scale economies can be regarded as competitive. These contradictory findings can be explained by the fact that specialization which occurs among production units of different sizes through production of differentiated or/and different goods keeps both large and small production units competitive.

We also observe very large fluctuations in productivity growth. In our views, these fluctuations are too large to be considered as a temporary disturbance. We also find a high positive correlation between productivity growth and business cycle (Finding (4)). Our four findings are summarized in Figure 1.2.

Figure 1.2

Traditional Walrasian Approach and Our Main Findings



1.5 Policy Issues and Main Findings

Up to the present, it has been customary for mainstream economists to cite the efficiency of perfect competitive markets as a primary reason for justifying use of constant returns to scale production functions. If monopoly power is observed in some parts of an industry, it is regarded as an issue of market power and use of anti-monopoly policies is suggested. In addition, policy intervention is seen as a means to remove factors that impede perfect competition. Here, based on our four findings, we raise three questions regarding policy choices. Based on the presumption of constant returns to scale production functions, it is true that having atomistic competition will lead to Pareto efficiency. However, this becomes unjustifiable where economies of scale are observed. The first policy issue is whether or not Japanese industrial policy encourages industries which benefit from economies of scale to return the benefits back to the society (see Question (1) in Figure 1.3). This question, which is in contrast to public policies emphasizing anti-monopoly laws, has also been raised in other industrialized nations.

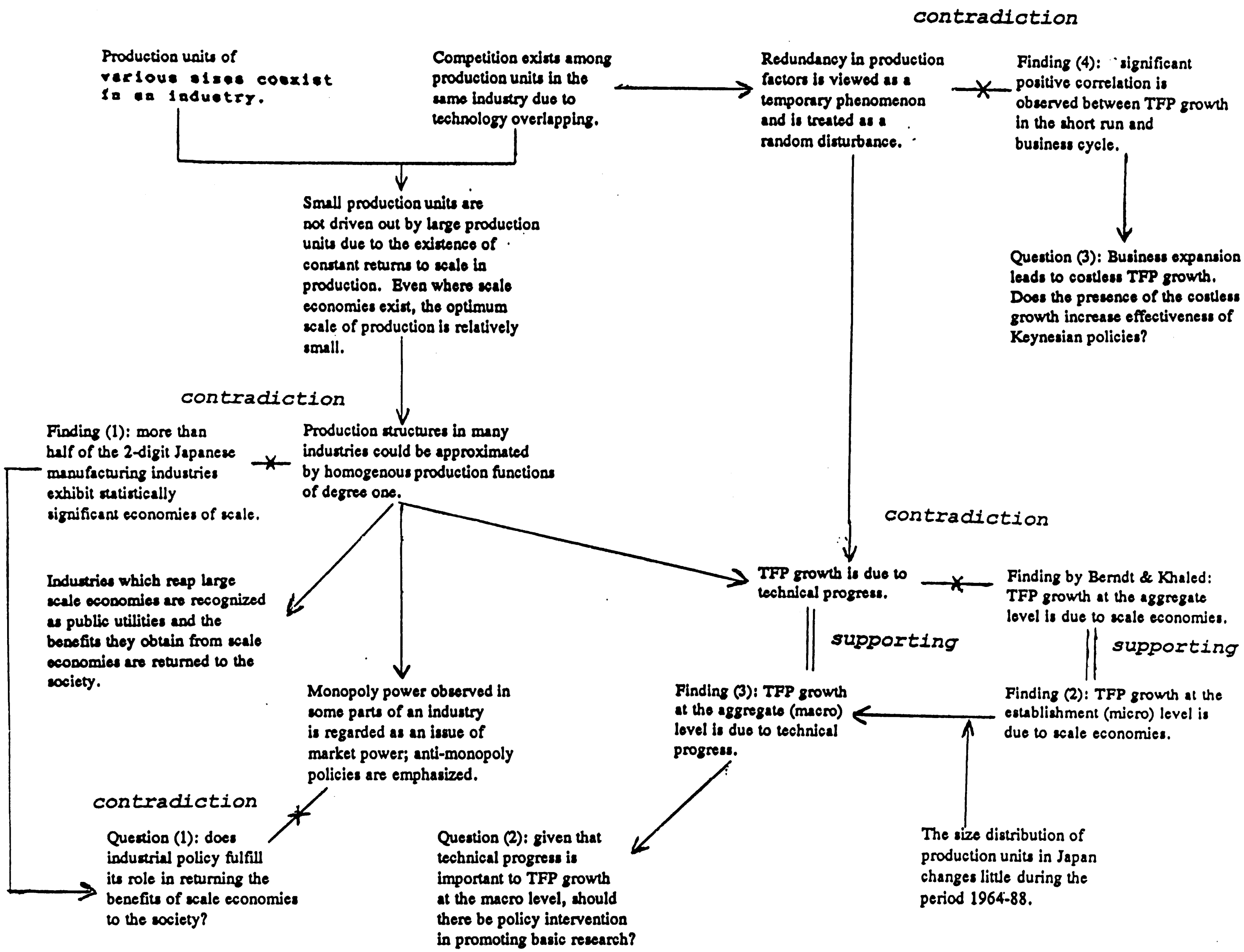
Secondly, given that productivity growth at the macro level is mostly attributable to technical progress, expansion of this costless factor seems very important in maintaining economic growth. Does this imply that it is necessary to have policy intervention particularly in basic research for which market mechanisms often fail to function (Question (2) in Figure 1.3).

Finally we find significant positive correlation between productivity growth and business cycle in the short run. This implies that business expansion leads to the enlargement of the costless factor for productivity gains. Our third policy question is: would this increase the effectiveness of Keynesian policies? (See Question (3) in Figure 1.3.)

Although we do not address answering these policy Questions (1)–(3) in this book, we believe that our main findings (1)–(4) summarized in this Chapter provide additional reasons why these policy issues should receive research attention.

Figure 1.3

Policy Questions and our Main Findings



Chapter 2. Productivity Analysis

2.1 Productivity Analysis – A Survey

2.1.1 Introduction

The purpose of this section is to survey the developments in productivity analysis since the first oil crisis in 1973 and to re-examine some of them.

In productivity analysis, "growth accounting theory" developed by Solow (1957) has been most widely used as an analytical tool. The purpose of the growth accounting theory is to search for the main factors of economic growth, and to make a balance sheet which reveals each factor's contribution to it. If labor, capital, material and energy are input factors for production, for example, their degrees of contribution to the growth of production can be derived under the assumption that they are efficiently used in the production process. In this case, total factor productivity (TFP) is defined as the residual after removing the contributions of input factors from output growth. Using this definition Solow estimates that TFP's contribution to output growth in the U.S. non-agricultural sector is 87.5% and that the U.S. economic growth is mostly due to the residual factor.

The productivity analysis after Solow's research made an effort to reduce TFP's contribution. Jorgenson's research group has tried to pursue consistency as strictly as possible between data and theory concerning the fundamental input factors of labor, capital, material and energy. Their empirical results show, for the observation period which is different from that of Solow (1957), that TFP's contribution to economic growth was mere 2.8%. Denison (1983), on the other hand, estimates TFP's contribution to be 22.4% which was obtained by adding the effect of resource allocation to the usual input factors. [1]

It is certainly consistent with an accepted scientific principle to attempt to reduce unexplained residual factors. It is difficult, however, to explain a production process, upon

[1] Jorgenson and Griliches (1967) calculated the rate of technical change in the U.S. private sector for the period 1945 to 1965 to be 2.8%, which would be 45.8% using Solow's methodology. Denison's result (22.4%) using Japanese SNA data was derived by subtracting the effect of resource allocation and economies of scale from the residual contribution of 55.2%.

which technological factors have great influence, only using economic variables.[2] Excessive persistence in pursuing a theoretical consistency in economic explanation may lead to a "seeming law" in economics. This may be particularly of concern since we often have at best incomplete data sets. An alternative approach would be to focus on productivity as a residual, and analyze its rates of change among different observation periods, industries or countries.

In this survey we pay particular attention to the change in methodology that took place after the first oil crisis. Before the crisis, economic growth in advanced countries had been quite satisfactory, and especially Japan's post war growth was a suitable subject for productivity analysis. In the period of stable growth in productivity, there was no room for questioning the method originated by Solow or the resulting empirical results. The empirical results after the first oil crisis, however, showed negative growth rate or a sharp drop in producitivy for many advanced countries. While negative economic growth can occur because of a serious recession, it does not seem realistic that productivity as an indicator of the state of technology falls suddenly. In order to explain these apparently incomprehensible results, new factors which were ignored earlier were introduced in productivity analysis. This section focuses on explaining such a change in the methodology of productivity analysis and discusses differences in empirical results derived before and after the first oil crisis.

2.1.2 Structural Change in Industries

Although economic growth is usually defined for a whole country, plural factors in fact contribute to the fluctuations and growth of a national economy. Such factors are often adequately captured at the industry level. Kuroda (1986), Baily (1981), and Kuroda et al. (1987), analyzed macroeconomic productivity by first calculating productivity growth rates at the industry level and then aggregating them after taking into account structural changes in industries.

Kuroda (1986), broke Japan's macroeconomic productivity change into the effects of

[2] Cherney (1949), among others, tries to describe a production function technologically.

aggregate technical change and structural changes in industries under the assumption that each industry has its own production function. First the former effect is subtracted from the aggregates of the productivity growth rates for all industries. This gives the latter effect, which is called the "bias of structural change" representing the unequal allocation of resources among industries. The bias of structural change is zero if the rates of change in input and output for all industries are the same. In Kuroda (1986) the latter effect is broken down into three kinds of effects: the biases of structural change in value added, in labor input and in capital input. Kuroda estimates that the total bias from 1960 to 1972 is -1.555%, which in turn is divided into -1.111% for output bias, -0.072% for labor input bias and -0.371% for capital input bias. The total bias from 1973 to 1985 is 0.935%, which is divided into 1.094% for output bias, 0.007% for labor input bias and -0.166% for capital input bias. These values show that the fall of aggregate productivity growth by -2.307% after the first oil crisis was compensated for with the effects of structural change in industries[3].

Baily (1981) also focused on the change in labor productivity along with the structural change in the U.S. industries. He applied a more direct methodology to the breaking down of the slowdown in labor productivity growth after the first oil crisis. According to his method, labor productivity growth for a country can be broken down into the effects at the industry level of (1) a change in labor productivity, (2) a change in output share and (3) a change in input share.[4]. The second effect means the growth of industries with relatively higher labor productivity, and the third effect indicates the degree of labor's allocation into higher labor productivity. Baily (1981) shows that more than 90% of the slowdown in labor productivity growth of -1.99% points after 1973 is due to the first effect. The effect

[3] Note that the sign of a "bias of structural change" just means the *effect* of a structural change on macroeconomic productivity but not the *efficiency* of a resource allocation.

[4] The decomposition equation for labor productivity growth rate in Baily's model is written as $alp = \sum \bar{\theta}_i alp_i + \sum(\theta_i - \bar{\theta}_i) alp_i + \sum \left(\frac{ALP_i}{ALP} - 1\right) \frac{dS_i}{dt}$, where alp is labor productivity growth rate, subscript i denotes an industry, θ_i is output share, $\bar{\theta}_i$ is output share in a reference year, ALP is labor productivity level and S is labor input. The first, the second and the third terms in the equation above correspond to the effects of (1), (2), and (3) respectively.

of structural change is quite small: 0.09% for the second effect and -0.22% for the third[5].

Kuroda et al. (1987), unlike the two studies cited above, makes use of an input-output model to grasp the structural change in industries. This analysis describes the spread effect of productivity growth from one industry to another as a result of a reduction in material price using an input-output table. A high degree of productivity growth in an industry whose products are used as inputs into many other industries, therefore, has an effect of reducing the aggregate price for the whole country through direct and indirect influences. Kuroda et al. (1987) used the time-series of the input-output tables for Japan from 1960 to 1979 and calculated the contribution of total factor productivity growth to the total price reduction. Results show that the TFP contribution to the inflation rate of 5.64% during this period is -3.32%, which means the inflation rate would have been 8.96% without productivity growth. In addition, their results show that the steel industry had the greatest influence, on average, on other industries during this period. After the first oil crisis, however, the TFP contribution to the price change became positive (0.2%). It is of interest to find out the industries which contributed most to this price change.

2.1.3 Subdivision of Data

In the previous section, productivity growth was calculated using data at the industry level. Productivity analysis has also been conducted using more detailed data at the establishment level. Nakajima and Yoshioka (1989) estimated the production function at the establishment level for the Japanese manufacturing industries and calculated the TFP growth rate for each manufacturing industry.

There are two possible merits in using data on establishments. One is the possibility of being able to distinguish between the contribution of the economies of scale and technical change to the TFP growth. As is well known, there is a high degree of correlation between production scale and a time variable (a proxy for technical progress) for aggregate time series data. This correlation leads to a multicollinearity problem in the estimation of production and cost functions, and lowers the statistical significance for the estimates

[5] The effect of the agricultural sector is -0.18% out of -0.22%.

of scale elasticity and technical change. Using pooled data of cross-section and time-series at the establishment level, this problem could be avoided. Another merit of using establishment-level data is to be able to separate out the effect of plant expansion from the increase in the number of plants for a particular industry.

Nakajima and Yoshioka (1989) find that the slowdown in productivity growth since 1973 was observed for almost all manufacturing industries except for wood and lumber, coal and petroleum and precision machinery industries. The slowdown was mostly due to technical change. The contribution of scale effect, albeit quite small, also declined after 1973, implying the slowdown in the expansion of establishment size.

The following Chapters 3 and 4 of this book will discuss more recent developments in the econometric productivity analysis for Japanese manufacturing industries using establishment data.

2.1.4 "Criminal Investigation" of the Productivity Slowdown

When an economy is on a smooth growth path, growth accounting analysis seeks for the factors which contribute to the economic growth. Facing declines in productivity growth, productivity research begins to resemble a "criminal investigation." We investigate suspected factors one after another and estimate the degree of contribution to the "crime" of a productivity decline. In the following table the suspected factors mentioned in Northworthy (1979), Nodhaus (1982), Denison (1983), Lindbeck (1983), Giersch and Wolter (1983) and Maddison (1987) are summarized.

In Table 2.1, numbers below the macroeconomic indicators in the column labeled "victims" are the observed degrees of slowdown (% points). Each factor's contribution to the slowdown is given in the last column. The factors which are difficult to assess quantitatively have no numbers given. Giersch and Wolter (1983), provides only a descriptive analysis. One characteristic of this kind of "criminal investigation" analysis is that they are not based on sophisticated economic theories. It would be quite difficult to systematically integrate the various factors considered in Table 1 within economic theories. The "criminal investigation" analyst, considers that observed slowdowns in growth rates in output and productivity are important, tries to find the suspected factors of slowdowns quantitatively, and breaks them down into their constituent contributions using their growth rates and weights in GDP.

This method is convenient for an intuitive factor breakdown, but has several problems. The first problem is that an analyst's subjectivity highly influences empirical results. One piece of evidence is the lack of uniformity in suspected factors among researches. The rise in energy prices, for example, was picked out by Nordhous (1982), Lindbeck (1983) and Maddison (1987) but not by Northworthy (1979) and Denison (1983). Secondly, the calculated degree of the contribution of a factor varies widely depending on the analyst, which makes it difficult to choose among possible factors. This problem is apparent in Wolff (1984), where the contributions of the capital/labor ratio to slowdowns in labor productivity range from 4% to 71%[6]. The third problem is that the interrelationships among suspected factors are ignored. After the first oil crisis, for example, pollution restrictions, substitution effects for energy and capital accumulation became so closely interdependent that the partial effect of each factor might convey little information.

It is certainly important to search for the "criminals" that caused slowdowns in several macroeconomic indicators. Identifying "criminals", however, does not solve the problem. What is more important is to consider how to "arrest" them. For this purpose we need theoretical models that shed light on observed economic phenomena.

[6] See Wolff (1984, Table 2, p.50).

Table 2.1: Who are "Criminals"?

Authors	Period	victims	suspected factors	effect
Northworthy (1979)	65-73/73-78 U.S.	LP −2.12	(1)capital labor ratio	−0.55
			(2)pollution abatement capital	−0.09
			(3)intersectoral shift of capital	−0.09
			(3)interindustry shift of labor	−0.22
			(4)labor utilization effect	−0.04
Nordhaus (1982)	48-65/73-80 U.S.	LP −2.2	(1)growth in the capital stock	−0.3
			(2)labor quality	−0.1
			(3)energy	−0.2
			(4)regulation	−0.2
			(5)intensity of R&D expenditure	−0.1
			(6)role of sectoral shift	−0.3
			(7)shift in taste of consumers	–
			(8)market failure caused by tax system	–
			(9)regulations	–
			(10)decline in investment opportunities	–
			(11)exhausted economies of scale	–
			(12)end of industrial structural change	–
			(13)decline in demand	–
			(14)less frequent inventions	–
			(15)technological catch-up	–
Denison (1983)	48-73/73-81 U.S.	TFP −2.32	(1)advances in knowledge	−1.68
			(2)resource allocation	−0.33
			(3)pollution abatement	−0.11
			(4)worker safety and health	−0.04
			(5)dishonesty and crime	−0.02
			(6)economies of scale	−0.12
			(7)intensity of demand	−0.04
			(8)loss of diligence in work	–
			(9)declining productivity in government	–
Lindbeck (1983)	60-73/73-79 OECD	LP −2.6	(1)capital labor substitution	−0.2
			(2)substitution away from energy	−0.1
			(3)capacity slack and output growth	−0.5
			(4)allocation of resources	−0.9
			(5)technological progress and catch-up	–
Maddison (1987)	50-73/73-84 Japan	GNP −5.59	(1)labor quality	−0.11
			(2)labor hoarding	−1.12
			(3)non-residential capital quantity	−0.34
			(4)capital quality	−0.20
			(5)capacity use effect	−0.39
			(6)catch-up effect	−0.58
			(7)structural effect	−1.01
			(8)foreign trade effect	−0.21
			(9)economies of scale	−0.17
			(10)energy effect	−0.14
Giersch-Wolter (1983)	64-73/73-79 OECD	GNP	(1)quantitative growth to qualitative growth	–
			(2)technological catch up	–
			(3)end of export-led growth	–
			(4)limitation of energy supply	–
			(5)accelerating inflation	–
			(6)pessimistic business mind-set	–
			(7)struggle over income distribution	–
			(8)high real interest rate	–

LP=labor productivity growth, TFP=total factor productivity growth, GNP=GNP growth

2.1.5 Capital Utilization

In the process of short-run adjustment of production, it is usually observed that a business upturn raises equipment's capacity usage while a business downturn reduces it. In economics this phenomenon is explained by the change in the utilization rate of capital stock or the change in the flow of capital services. If capital stock is a production factor, the change in capital service flow caused by short-run business fluctuations will be ignored. For example, after the first oil crisis, the utilization rate fell drastically. Productivity analysis ignoring capacity utilization would, under such conditions, overestimate the contribution of capital stock and hence underestimate productivity growth. In the following we will introduce capacity utilization in productivity analysis. There are two ways to introduce capacity utilization: exogenous utilization model and endogenous utilization model.

2.1.5.1 Exogenous Utilization Model

In an exogenous utilization model, capital utilization ratio directly enters the production or cost functions as an explanatory variable. (For example, see Nadiri (1981), Fuss and Waverman (1985), Baily (1982) and Kaufman and Jacoby (1984).)

Nadiri (1981) modified the original growth accounting model by including a capital utilization variable in the Cobb-Douglas production function[7]. In his model, capital utilization rate is defined as the ratio of actual production to production capacity. This ratio is a reasonable proxy for utilization rate, if we assume linear homogeneity in the production function and producer's rational behavior. Nadiri estimated this equation and calculated the contribution of capital utilization rate to labor productivity. Results show that the contribution is positive in communication and financial industries and negative in transportation, manufacturing, and construction industries. This is consistent with the observation that a decline in utilization rate is a factor for declining labor productivity. As Nadiri (1981) notes, however, it is quite difficult to estimate the contributions of all the

[7] The equation for estimation in Nadiri (1981) is $lnP = \alpha_0+\alpha_1 lnk+\alpha_2 ln\frac{k^*}{k}+\alpha_3\Delta ln\frac{k^*}{k}+\alpha_4 lnR + \alpha_5 t$, where P is labor productivity, k is capital/labor ratio, k^* is capital/labor ratio adjusted by capital utilization rate, R is R&D stock, and t is time variable.

effects using only one equation. In fact, the estimated positive contribution of utilization rate for communication and financial industries is obviously inconsistent with economic theories[8]. One approach to solve this problem, is to estimate a system of structural equations, while reducing the number of unknown parameters by using index number theory.

Fuss and Waverman (1985), also included an actually observed capital utilization rate as an explanatory variable in the cost function. They formulated linear restrictions on the unknown parameters based on microeconomic theory. In this model a 100% capital utilization rate is defined to be the point where the short-run average cost curve with fixed capital is tangent to the long-run average cost curve with variable capital. Their cost function of translog form includes an index of capital utilization as an explanatory variable and was estimated with imposed parameter restrictions[9]. They applied this methodology to the analysis of productivity growth for the automobile industry after the first oil crisis for Japan, the U.S., and Canada. Their results show that the contribution of capacity utilization to productivity growth was negative for the U.S. and Canada, illustrating the effectiveness of this approach. As mentioned above, Fuss and Waverman (1985) not only include capital utilization in the cost function but also derive a theoretical restriction on unknown parameters. In their model, however, utilization rate is still exogenous and affects parameter estimates through a theoretical restriction.

In the two models discussed above, capacity utilization rate is directly observed as an actual machine's operating hours. Baily (1982) and Kaufman and Jacoby (1984), on the other hand, assume that the capital stock adjusted by its utilization rate is evaluated in the stock market and estimate capital service flows using stock price data[10]. Using

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[8] This undesirable result may be due to multicollinearity problems in estimation.

[9] The cost function used in Fuss and Waverman (1985) can be written as $C = G(w, Q, T_1, T_2, T_3)$, where w is input price vector, Q is production capacity, T_1 is capital utilization index, T_2 is R&D stock, and T_3 is an index of product mix. Because an increase in Q means expansion of capacity itself, its effect on cost is equal to long-run marginal cost. The effect of an increase in T_1 on cost, on the other hand, is equal to short-run marginal cost. When utilization rate is 100%, that is, $T_1 = 1$, $\frac{\partial lnC}{\partial lnQ} = \frac{\partial lnC}{\partial lnT_1}$ has to hold. This equality provides a restriction on the unknown parameters.

[10] If their models include the financial market, utilization rate can be an endogenous variable. Their models, however, do not consider the feedback from product market to financial market.

"Tobin's q" which is the ratio of the capital value evaluated in the goods' market, C, to that evaluated in the financial market, Baily (1982) estimated the capital utilization rate indirectly[11]. Kaufman and Jacoby (1984) assumed that stock price V, reflect real capital service flows and calculated capital service flows as the average between a stock price index and the capital stock. Kaufman and Jacoby (1984) reestimated the slowdown in productivity growth after 1973 for the U.S., the U.K., Germany, France, Canada, and Japan by taking into account the fall in stock prices[12]. These exogenous utilization models are, strictly speaking, closely related to the endogenous utilization models discussed in the following subsection. The potential problems of this approach include the calculation of q and the relevance of using a stock price index. Stock prices fluctuate according to investors' expectations about firms' future profits and may not exactly reflect current capital service flows[13]. In addition, stock prices also fluctuate according to the financial policy of a central bank and investors' speculative mentality regardless of actual capital utilization rates. In this sense, it would be interesting to verify the robustness of these models using data for the period when stock prices are continually rising.

2.1.5.2 Endogenous Utilization Model

As we discussed in the previous subsection, it is difficult to measure, within the framework of exogenous utilization models, actual facilities' utilization rates. It is also not clear what a 100% utilization rate means. These problems can be dealt with somewhat more satisfactorily using endogenous capital utilization models, in which utilization rates are theoretically determined. In this subsection we will discuss three kinds of endogeneous capital utilization models.

The first model is based on microeconomic theory concerning short-run and long-run

[11] Tobin's q is given by $q = \frac{V}{C}$, where capital good's price is normalized as unity. In order for q to be the utilization rate exactly, however, we have to specify the form of the production function.

[12] For Japan, for example, TFP growth rate from 1973 to 1978 is estimated to be 4.48%, which compares with an estimate from a model without a capacity utilization variable of 2.91%.

[13] One practical solution to this problem is to assume static expectations with respect to firms' future profits.

cost functions[14]. The 100% utilization rate is defined to be the point of tangency between short-run and long-run cost functions. According to this theory, if the production level is realized on points other than the full utilization point, then we adjust the capital cost so that this level becomes the point of tangency[15]. The analytical procedure underlying basic endogenous models is explained as follows. First, a variable cost function with fixed capital stock is specified. Second, a variable cost function is estimated using actual data, and the marginal productivity of capital is theoretically calculated. And finally, the growth accounting procedure is introduced using the marginal productivity of capital instead of the capital cost[16]. In the standard productivity analysis capital cost is assumed to be equal to the marginal efficiency of capital. This assumption implies that the capital stock level can be instantaneously adjusted to its optimal level. The actual capital stock level, however, is not always at optimum, because adjustment takes time. Suppose a firm has to expand its production in a short run according to an increase in the demand for its products. The firm will meet the immediate needs by increasing the variable input while its capital stock remains unchanged. In this case, the production level may be where the long-run cost intersects the short-run cost. Furthermore, the marginal efficiency of capital may be also greater than the capital cost. If we proceed with growth accounting using the capital cost, the contribution of the capital stock will be underestimated and TFP will be overestimated. By using the marginal efficiency of capital instead of the capital cost, we can remove the bias in the calculated productivity growth rate.

As an example of the first model, consider Morrison (1988)[17] who estimates TFP

[14] Fuss and Waverman (1985) also made use of this theory. While they derived utilization rates from actual observations, endogenous models calculate utilization rates theoretically from estimated cost functions.

[15] See Hulten (1986) for details.

[16] Berndt and Fuss (1986) calculated the marginal productivity of capital using Tobin's q which they define to be the ratio between the marginal efficiency of capital to the cost of capital without estimating a variable cost function.

[17] In addition to Morrison (1988), see also Morrison (1985, 1986) and Nadiri and Prucha (1980, 1985). Bruno and Sachs (1982), which is known as a "supply shock model", explains a slowdown in economic growth by the producer's reaction to a steep rise in energy price. In the B-S model the capital adjustment process is based on Tobin's q theory, and the case of $q < 1$ occurs when the rate of economic growth is declining. Since this case implies

growth sequentially by adding the following modifications one at a time: (1) economies of scale as discussed in Ohta (1975), (2) fixed capital stock, (3) the adjustment cost of investment and (4) the utilization rate of capital stock. These modifications lead to an estimate for the rate of technical change of 0.36% for the U.S. manufacturing industry before 1973 compared to an estimate of 0.87% without these modifications. The new estimate is very close to an estimate for the period after 1973. For Japan also the slowdown in TFP growth after 1973 was estimated to be 0.9% compared to 1.2% prior to modifications. The productivity growth rate for Canada for the same period is estimated to be negative.

The second endogenous utilization model is Epstein and Denny (1980). Their basic idea that capital utilization decreases available capital stock in the next time period through depreciation. Their theoretical framework can be summarized as follows. The production function includes both the beginning of period capital stock and the end of period capital stock. The former is treated as a predetermined variable. Given the beginning of period capital stock, increases in other variable inputs increase capital utilization rates and production, while decreasing the end of period capital stock by excess use. The beginning of period capital stock in the next period is given by adding the current investment to the end of period capital stock. Epstein and Denny derive a profit function by applying the firm's dynamic profit maximization principle to this process, and calculate the depreciation rate for the capital stock using an estimated profit function. This model's distinctive characteristic is that capital utilization is treated as a source of capital stock depreciation and is reflected in the end of period capital stock. Their approach of choosing between current usage and future usage is similar to the one found for the theory of savings in economics. While the first model (Morrison (1988) and others) determines utilization rates endogenously within the framework of capital investment, E-D model does not seem to be able to explain investment which is an exogenous variable in their model. Furthermore, under the present economic conditions where rapid technical change is common, depreciation occurs not only because of actual use but also because of rapid technical advancement. The E-D model may not be suitable for analyzing the economy after the first oil crisis which made

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that the capital utilization rate is less than 100%, the B-S model can explain a fall in productivity growth after the first oil crisis.

the energy using capital stock obsolete. In this sense the productivity slowdown since 1973 provides the E-D model with a test of its theoretical robustness.

The third type of endogenous utilization model discussed here is Berndt et al. (1985). While the first two types of models discussed above define capital utilization indirectly using production or cost functions, Berndt et al. relates utilization rates to the fluctuation in oil prices. The Berndt model is summarized as follows. Capital stock is accumulated by investment in each time period, the amount of which is determined based on the relative price of capital stock to the energy price so as to minimize the firm's total cost. Once investment has been done, the firm controls the utilization rate of its capital stock by realizing its most efficient usage. The capital stock after the oil crisis, for example, consists of facilities invested when the energy price was low as well as of those when it was high. Facing low energy prices, the firm will increase its utilization of energy using type facilities. Therefore, the departure of the capital/energy relative price observed when facilities are used from the relative price observed when facilities were purchased is an important factor for the determination of the capital utilization rate. Berndt et al. (1985) estimate the capital stock taking into account the utilization rate, and re-estimated the productivity growth rate. Their results show that the TFP growth rate was modified upward because of a steep decline in the utilization rate after 1973. The average annual productivity growth rate for Japanese manufacturing industries from 1973 to 1981 is 0.896%, while the growth rate without the utilization adjustments is 0.419%. The Berndt model related the utilization rate to the fluctuation of energy price and succeeded in explaining the dramatic decline in productivity growth after the first oil crisis in advanced countries. At the same time, we should point out that this model was estimated using a *selected* observation period of a steep rise in energy price. After the second oil crisis, the oil price declined from 36.94 dollars per barrel in 1981 to 14.79 in 1988. Did the firm really stop using energy saving facilities and restart using the energy consuming facilities purchased when the energy price was low? It is quite important to investigate the robustness of this model using data from time periods covering different oil price movements.

2.1.6 R&D Investment

As mentioned at the beginning of this chapter, productivity is defined as the residual after removing the contributions to the growth of fundamental production factors. If we specify the production or cost function, the TFP growth rate can be broken down into the effects of scale economy and technical change. Whichever estimation method is used, technical change is treated as an exogenous factor. While some technologies arise spontaneously, for example, as a result of "learning by doing effect," there are technological advances firms get by investing in them. It is desirable then to introduce the process of developing technologies in the productivity analysis. The Research and Development (R&D) investment models we summarize here can be regarded as an analytical tool for treating technology explicitly.

2.1.6.1 Basic Model

The basic model concerning the relationship between R&D investment and productivity originates in Griliches (1970). His model is based on the Cobb-Douglas production function with an R&D expenditure as an input. In its simplest form of the model the depreciation of R&D stock is ignored and current R&D investment can be used as an input in the next period. Under these two assumptions, an increase in the R&D stock corresponds to the R&D investment. Hence we can use the R&D expenditure as an input in our growth accounting instead of the R&D stock. Griliches assumed that the production function is of the Cobb-Douglas form[18]. The assumptions made for the basic model, however, do not

[18] The production function in Griliches' model was specified as $lnQ = lnA + \sum_{i=1}^{3} a_i lnx_i + blnR + \lambda_t$, where $\sum_{i=1}^{3} a_i = 1$ holds, Q is output, x_1 is tangible capital stock, x_2 is labor input, x_3 is material input (including energy), R is knowledge stock about technology, and λ is a Hicks neutral technical change effect other than R. The TFP growth rate based on this production function is defined as $\frac{dlnTFP}{dt} = \frac{dlnQ}{dt} - \sum_{i=1}^{3} s_i \frac{dlnx_i}{dt}$, where $s_i = \frac{p_i x_i}{\sum_j p_j x_j}$. By the marginal productivity principle, output elasticity with respect to each input is equal to its cost share in total cost. Therefore, we can rewrite the equation above as $\frac{dlnTFP}{dt} = \lambda + \rho \frac{dR}{dt} \frac{1}{Q} + \mu$, where ρ is the marginal productivity, that is, the rate of return to R&D stock, and μ is an error term. According to the two assumptions made above, $\frac{dR}{dt}$ is equal to the R&D investment, and ρ can be estimated using the TFP growth rate.

seem realistic given the speed of current technical change and the long-term nature of R&D in the present day. This problem leads to the question of how to estimate R&D stock. R&D stock is defined as the "technological knowledge stock currently owned by a firm and an industry." It is quite difficult to quantitatively grasp the process of developing a technology and its contribution to production. To solve this problem Griliches considered R&D stock as an accumulation of lagged R&D investments[19]. This idea implies that past R&D investment might be accumulated, using the weight of its probability of success and with the length of its pre-use development period. Recent studies in productivity analysis with R&D stock are mostly based on this basic model. The empirical results in Griliches, among other studies, show that a fall in the labor productivity growth for the U.S. since the 1960s was mainly caused by a decline in the speed of the R&D stock accumulation[20].

2.1.6.2 Removal of Double Accounting

In the Griliches model R&D expenditures were used for estimating the R&D stock. R&D expenditures, in fact, consist of payments for labor, capital, materials and so forth. Unless we distinguish these input factors used for production from those used for the R&D stock formation, the estimated contribution of R&D stock to productivity might be biased because of "double accounting" of the R&D expenditure. Schankerman (1981) pointed out this problem and estimated the degree of double accounting bias in the rate of return to the R&D stock.

Shankerman (1981) suggested two kinds of possible biases in the Griliches model. One is an input bias. For calculating the TFP growth rate, input factors are aggregated using

[19] Griliches' R&D stock estimation function is written as $K_t = f[W(B)R_t, v]$, where K_t is R&D stock at time t, R_t is real R&D investment, B is a lag operator, W is a function of B, and v is an error term. Therefore, $W(B)R_t$ stands for a polynomial of lagged R&D investments.

[20] Griliches (1980) re-estimated the contribution of R&D stock because the results in his 1979 paper were underestimated, and concluded that the main reason for the slowdown in productivity growth was not the decline in R&D stock but the decline in the rate of return to R&D stock. Englander and Mittlestadt (1988) and Englander, Evanson, and Hanazaki (1988) also show that the R&D stock has been increasing smoothly but has not led to a productivity growth.

a discrete form of divisia index. If they include inputs for the R&D stock formation, the input index may be overestimated. The other bias occurs in the evaluation of value added as output. Since value added is usually derived by subtracting intermediate input from gross production, output will be underestimated if intermediate input includes inputs for the R&D stock formation. Shankerman (1981) estimates that, because input bias and output bias partly cancel out each other, the sizes of the two biases are only -6% and -9% of TFP, respectively. These biases seem negligible given inaccuracies contained in reported R&D expenditures. Such inaccuracies are particularly severe for Japan.

2.1.6.3 Interindustrial Technology Flow

The Griliches model treats the R&D stock as a source of technical change. Technical change, however, does not depend solely on the firm's own development of technology. When a firm starts a technological development, there exist both the possibility of success and the risk of failure. If the latter is perceived to be significantly greater than the former, the firm might try to buy an already developed technology or intermediate goods where a developed technology is embodied. The firm makes a choice between its own R&D investment and the purchase of technologies developed by other firms based on its expectations of success.

Schmookler (1966) was the first to distinguish between "industries with their own R&D" and "industries depending on already developed technologies." Scherer (1982a) made a technology flow matrix which shows intersectoral transactions of technologies embodied in intermediate inputs on the basis of the R&D expenditure data for more than 400 firms. He investigated the relationship between the technologies brought in from other industries through intermediate goods and the TFP growth rate. His empirical results show that the R&D investment embodied in intermediate goods has a greater contribution to TFP growth than an industry's own R&D.

Griliches and Lichtenberg (1983), on the other hand, point out that the utility value, quality and marginal productivity of the technology embodied in intermediate goods should be reflected in their prices. They argue that "the effect of introduced technology" in Scherer

(1982a) assumes the imperfection of the intermediate goods market which monopolistic developers of technologies can control. They call the deviation of a monopolistic price from a normal price an "error" and suggest we perform the TFP regression analysis after removing the "error" effect. Assuming that this error is proportional to R&D intensity (the ratio of R&D expenditure to production) in each industry, Griliches and Lichtenberg (1983) compared the effect of an industry's own R&D on productivity with the effect of the "error." They find that the contribution of an industry's own R&D to TFP growth is significant, but so is the "error" effect. The former contribution weakened after the first oil crisis.

According to economic theory, the technology embodied in intermediate goods is reflected in its market price if the market is perfect. Kuroda et al. (1987), discussed in Subsection 2.2, applied this idea to the input-output analysis of a TFP's spread effect. From this point of view, the contribution of Griliches and Lichtenberg (1983) is to treat explicitly the TFP indicator, which was a residual factor in Kuroda et al. (1987), as R&D intensity.

2.1.6.4 Simultaneous Equation System

The R&D investment models discussed so far are based on a single equation system using a production function. Odagiri (1985) introduced a "learning effect" on productivity and a "price effect" on the demand for product in an attempt to reveal the relationship between R&D and productivity in a simultaneous equation system. The "learning effect" means that an expansion of production leads to enhanced productivity due to the accumulation of knowledge. The "price effect," on the other hand, means that a decline in price caused by an advance in productivity creates a demand for products and leads to an expansion of production. He obtained consistent estimates for the parameters for this simultaneous equations system using a structural estimation method.

A number of earlier studies suggested that the decline in R&D investment was the main reason for the slowdown in productivity growth observed for the U.S. since the second half of the 1960s. In Japan, however, the slowdown in productivity was not observed even though R&D investment was not significantly greater than that for the United States. The reason for this inconsistency, Odagiri (1985) argues, is a simultaneous equation bias which occurs in productivity analysis using a single equation. To deal with this problem he used the two stage least square method for estimating unknown parameters. His empirical results show that the contribution of the R&D intensity to TFP growth is overestimated in the usual single equation settings.

It has been observed for advanced economies that there is a high correlation between output growth and productivity growth[21]. This correlation was viewed as a "learning effect" in Odagiri (1985). In case of a relatively small supply bottleneck, however, the expansion of an effective demand can stimulate production, leading to improved productivity gains due to economies of scale. It is unclear, then, to what degree Odagiri (1985) separated out the "learning effect" from the effect of scale economy.

2.1.7 Regulation

Previous studies concerning the relationship between regulation and productivity can be classified into two types. One type of studies reveals the effect of regulation on productivity by estimating productivity regressions directly[22]. The other type treats regulation as a constraint imposed on the firm and shows what kind of modification has to be made in solving the firm's optimization problem with a constraint. The first type of studies includes Christainsen and Haveman (1981a) and Crandall (1981) while Cowing, Small, and Stevenson (1981) belongs to the latter type.

Christainsen and Haveman (1981a) measured the effect of government regulation on macroeconomic productivity. Their method is quite simple and summarized as follows. They estimated a regression equation with productivity as the dependent variable and regulations as independent variables. Estimated parameters show the effects of regulations. What's important here is which regulations to enter the regression and how to measure them quantitatively. Christainsen and Haveman, uses the number of effective regulative

[21] For example, see Yoshioka (1989, chapter 4).

[22] Productivity regression is a single equation composed of productivity as the dependent variable and some factors as independent variables.

laws, expenditures used by regulators and the number of regulatory department full-time employees as regulation variables. The regression coefficients of these variables show to what degree regulation lowers the productivity growth rate. Their empirical results show that the existence of regulation lowers productivity and that the lowering effect has been increasing since the first oil crisis. According to their calculations, regulation is a significant factor for the slowdown in productivity growth after 1973.

Crandall (1981) investigated the effect of pollution control on labor productivity in the U.S. manufacturing industries. This analysis is based on the notion that pollution control in the U.S. was so strict for manufacturing industries that it disturbed investment in plant and equipment, and in the development of new technology, leading to the decline in productivity. He included expenditures for pollution control as an explanatory variable in the productivity regression equation and measured the degree of its influence on labor productivity. The estimated coefficients for expenditures for pollution control were significantly negative.

These two types of analyses try to estimate the effect of pollution control on productivity using a quite simple and intuitive equation. It is certainly true that regulations which guarantee acquired rights disturb free competition and restrain an advance in productivity. In such a case, an effective deregulation policy leads to an expansion of the market and an improvement in national welfare. Regulations, however, do not always have undesirable effects. In an extreme case where all regulations were removed in our society, would the national welfare really be improved? Would macroeconomic productivity progress? Unless these issues are adequately addressed, we cannot derive meaningful policy implications from these empirical results.

Cowing, Small, and Stevenson (1981) focused on the effect of the "rate of return constraint," which is frequently imposed on public utility firms in regulated industries. The rate of return constraint requires a firm to keep its profit under a designated rate of return[23]. They applied growth accounting analysis to the firm which operates under cost

[23] Averch and Johnson (1962) is a classical research which reveals an effect of the rate of return constraint on firm behavior. Its effect is usually called the "Averch-Johnson effect." Fuss and Waverman (1975) and Denny, Fuss, and Waverman (1981) discuss a theoretical relationship between productivity and the rate of return constraint.

minimization subject to this constraint. Their simulation results suggest that a decline in productivity growth could occur as the constraint becomes tighter.

2.1.8 Environmental Problems

Recently the destruction of the ozone layer, global warming, an increase in CO_2, and acid rain are seen as international environmental problems. The influence of environmental destruction on productivity can be considered within a simple model described below[24]. The basic idea of this model is to introduce the state of the environment as an input factor for production and consider the cost for keeping its condition at a constant level. If a model has two distinct sectors, one which damages the environment, and the other which keeps the environment, the problem of externality occurs. On the other hand, externality effects are internalized within a one-sector model, and an optimal production level for a country will be determined. This simple model is of the latter type and describes the choice of whether a factor endowment in a country is used for production or the maintenance of the environment. When a factor input is used only for production activities without consideration of the environment, the marginal productivity of input gradually declines and the state of the environment becomes worse. If a part of input is used for maintenance of the environment, its state is improved and the marginal productivity shifts upward. An optimal situation for a country, therefore, is realized at the point where the marginal productivity of input for production is equal to the marginal productivity of improvement in the environment caused by the usage of input for its maintenance. In the framework of this model, if a great deal of cost is needed for maintenance, productivity might decline[25]. In other words, decline in productivity is regarded as a deterioration of technology in the

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[24] On the details of the model, see Sakamoto (1971) and Barnett and Morse (1963).

[25] Suppose the production function has the following inputs: labor input L_1, the state of the environment E, the state of technology T; then output y is $y = f(L_1, E, T)$, and the cost function for environment maintenance is given by $L_2 = g(E)$, where L_2 is the labor used for the maintenance. If we define L^* to be the labor endowment, the growth rate of labor productivity can be given as follows (by solving the production maximization problem with the constraints of labor endowment and maintenance cost for environment):

usual productivity model[26].

2.1.9 Introduction of Demand Side

The basic form of productivity analysis consists of a production function and a producer's optimization principle. In this sense growth accounting theory is based on a producer's autonomous equilibrium. The real economy, however, depends on market transactions between supply and demand. Hence it would be desirable to take account of demand side factors in analyzing macroeconomic productivity. Nadiri and Schankerman (1989) and Jaffe (1988) performed productivity analysis involving demand side factors.

Nadiri and Schankerman (1989) estimate the effect of the demand side using a simple simultaneous equations model. Their methodology is summarized as follows. First, they estimate a supply function of goods using the standard growth accounting methodology and a pricing rule based on a mark-up principle. Second, a macroeconomic demand function is estimated. Finally, a reduced form equation for productivity is derived from these two equations. The effects of the two demand factors included in this equation system, national income and population, are estimated using the reduced form equation. Their results show that the contribution of the demand factors to the decline in TFP growth was 68.3% after the first oil crisis. This result also means that the decline in productivity growth could have been avoided with a demand expanding policy.

Jaffe (1988) modified the original growth accounting model with the Cobb-Douglas production function by adding the following three new factors: "spillovers," "market positions," and "technological position." The first "spillovers" effect means that a firm's

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$$\frac{dln\frac{y}{L^*}}{dt} = \left[\frac{\frac{\partial lnf}{\partial lnE}}{\frac{\partial lng}{\partial lnE}} \frac{L^*}{L_2} - 1 \right] \frac{dlnL^*}{dt} + \frac{\partial lnf}{\partial lnT} \frac{dlnT}{dt},$$

where a first term on the right-hand side shows the effect of E on productivity. Suppose that the state of environment becomes worse and it costs more to maintain it. This case means an increase in $\frac{\partial lng}{\partial lnE}$, which has an effect to reduce growth rate of labor productivity.

[26] Kopp and Smith (1981) chose the state of atmospheric and water pollution as the variable of environment and measured the influence of the state of the environment on productivity. Their results show that the influence is significant.

technological knowledge on production spills over and gives positive effects on other firms' productivity. Jaffe (1988) assumes that the magnitude of spillovers depends on how similar the contents of R&D investments are among companies and introduces the coefficient of correlation between the contents of R&D investments as a proxy for the spillovers effect[27]. The "market position" and "technological position" effects correspond to, respectively, demand pull and supply push factors for a technological evolution. The former represents what kinds of goods are needed in the market and is treated as a stimulation factor from the demand side. The latter, on the other hand, is the content of a firm's R&D investment and represents the motive power for technical change. Jaffe calculated the effects of these factors on productivity by estimating regression equations involving proxies for these effects. His empirical results indicate the difficulty in identifying demand pull and supply push effects. (His estimates suggest the spillovers effects of R&D raised TFP by 0.1%.)

While Jaffe's analysis provides a useful way of incorporating three demand factors in the original model, the full effect of the demand side factors on productivity can only be analyzed using an integrated economic model involving regulation effects. Identifying such a system appears quite difficult.

2.1.10 Concluding Remarks

The common purpose underlying the recent research on productivity has been to explain the slowdown in productivity growth since the first oil crisis by modifying the original growth accounting model developed by Solow (1957). The modifications proposed are summarized as follows.

(1) structural change in industries

(2) subdivision of data

(3) intuitive search for hidden factors

(4) capital utilization

(5) R&D investment

(6) regulation

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[27] Spillovers effects correspond to externality in economic theory, because they spread without pecuniary transactions.

(7) environmental problems

(8) demand side factors

(9) miscellaneous factors[28]

As a consequence of these modifications, the slowdown was explained systematically to a certain extent. But much remains unexplained[29]. It is also the case that the theoretical framework in some studies is *ad hoc* or is not consistent with the data, in part because desirable empirical results were excessively pursued[30]. The oil crisis in 1973 certainly "shocked" the world economy, resulting in a sudden steep rise in energy prices. It may not be a real contribution to economics, however, to make special economic models only for explaining the "oil shock", particularly for explaining a great deal of economic fluctuation since 1973. To the extent that a true economic model should possess the robust explanatory power not only for a special period of the oil crisis but also for other time periods, productivity analysis still has a lot of specification search to do.

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[28] For example, M&A, a firm's business diversification, externality and so forth. See Benhabib and Jovanovic (1989), Lichtenberg and Siegel (1989b) and Lichtenberg (1990).

[29] Denison (1987, Table 1), for example, shows that "knowledge" contributes the most to productivity growth: -1.68%. This seems numerically too small to be taken seriously.

[30] Productivity analysis involving R&D investment is such an example. Inaccurate and incomplete data on firms' R&D expenditures seem incompatible with the theoretical modeling frameworks proposed in the literature.

2.2 Inter-industry Propagation of Productivity Growth

The productivity analysis of the sort surveyed in the previous section deals primarily with the sources of productivity growth for specific industries in aggregate economies. This will also be the case for our analysis in the following Chapters 3 and 4. Transmission of productivity gains from one industry to another is not typically discussed in standard productivity analysis. In measuring productivity growth for an aggregate economy such an inter-industry propagation of productivity growth is irrelevant since all transmitted productivity changes across industries will be netted out. Inter-industry productivity transmissions, however, play a major role in the development of a national economy.

For example, the success of the Japanese automobile industry is often attributed to the availability of high-quality and competitively-priced steel products as well as the high technologies developed by Japanese plastic and semiconductor industries. It is of interest to know the degrees to which the productivity gains in the Japanese automobile industry depended on the productivity gains in the Japanese steel and chemical industries as well as on their own technical progress.

There are three ways by which productivity gains are transmitted from one industry to another. First, new technological developments in a particular industry may stimulate new technological developments in another industry without any market transaction of final or intermediate capital or other types of goods between the two industries. This case is not suitable for economic modeling and is often treated as a given externality. The second way of transmission of new technology developments from one industry to another is via capital goods. If new technologies in an industry are embodied in the capital goods (e.g. machines and tools) sold to another industry where they are used to produce consumer products, production efficiency for the latter industry will likely rise. The third way of transmission is via intermediate goods. The automobile industry, for example, could take advantage of the intermediate goods it purchases from other industries which enjoy high levels of technological advances and scale economies in production. In this section we will present a model for inter-industry transmissions of productivity gains via intermediate goods (the third case above). While the second type of transmission could also be important, the lack of data on the flows of capital goods makes it impractical to integrate it within our framework, although extending our model to the case involving transmissions via capital goods is straightforward.

2.2.1 Measuring Inter-industry Transmissions of Productivity Gains via Intermediate Goods

In this subsection we present a model in which productivity gains are transmitted from one industry to another via intermediate goods the latter industry purchases from the former industry. We assume that factor prices for each industry are given and derive relationships which relate industry-specific productivity gains to industry-specific price indexes as well as gross domestic product.

Suppose industry j produces V_{ji} quantities of products i with prices $p_{ci}(i = 1, 2, \dots, n)$. The total output value of industry j is $\Sigma_i p_{ci} V_{ji} (j = 1, \dots, n)$. Suppose also that industry j uses intermediate goods U_{ij} with prices p_{oi}, imported intermediate good d_j with price p_d, non-household consumption good b_j with price p_b, labor input L_j with wage rate s_j and capital input k_j with the cost of capital ρ_j, pays indirect taxes Tax_j and receives excess profit π_j. Then the accounting indentity that must hold for industry j is given by

$$(1) \qquad \Sigma_i p_{ci} V_{ji} = p_{Ij} X_{Ij} = \Sigma_i p_{oi} U_{ij} + p_d d_j + p_b b_j + s_j L_j + \rho_j k_j + \text{Tax}_j + \pi_j$$

where X_{Ij} is the product output index with price index p_{Ij} for industry j.

Using the Divisia index we describe the rates of increase for output index X_{Ij} and its price index p_{Ij} as follows.

$$(2) \qquad d \ln p_{Ij}/dt = \Sigma_i W_{vji} (d \ln p_{ci}/dt)$$

$$(3) \qquad d \ln X_{Ij}/dt = \Sigma_i W_{vji} (d \ln V_{ji}/dt)$$

where W_{vji} is the output share for product i

$$(4) \qquad W_{vji} = p_{ci} V_{ji} / \Sigma_i p_{ci} V_{ji}$$

Using Divisia indexes we define Total Factor Productivity (TFP) for industry j as follows:

$$\text{TFP}_j = X_{Ij}/Q_j \qquad j = 1, 2, \ldots, n \tag{5}$$

where Q_j is a production input index for industry j. The growth of Q_j is given by

$$\begin{aligned} d\ln Q_j/dt = {} & \Sigma_i W_{ij}(d\ln U_{ij}/dt) + W_{dj}(d\ln d_j/dt) + W_{bj}(d\ln b_j/dt) \\ & + W_{Lj}(d\ln L_j/dt) + W_{kj}(d\ln k_j/dt), \end{aligned} \tag{6}$$

where the coefficients W's are the cost shares for industry j given by

$$W_{ij} = p_{oi}U_{ij}/c_j \tag{7}$$

$$W_{dj} = p_d d_j/c_j \tag{8}$$

$$W_{bj} = p_b b_j/c_j \tag{9}$$

$$W_{Lj} = s_j L_j/C_j \tag{10}$$

$$W_{kj} = \rho_j k_j/C_j \tag{11}$$

$$\begin{aligned} C_j &= \text{cost of production for industry } j \\ &= \Sigma_i p_{oi}U_{ij} + p_d d_j + p_b b_j + s_j L_j + \rho_j k_j \end{aligned} \tag{12}$$

The growth in TFP is given by

$$\begin{aligned} \frac{d\ln \text{TFP}_j}{dt} &= \frac{d\ln X_{Ij}}{dt} - \frac{d\ln Q_j}{dt} \\ &= \frac{d\ln X_{Ij}}{dt} - \left(\Sigma_i W_{ij}\frac{d\ln U_{ij}}{dt} + W_{dj}\frac{d\ln d_j}{dt} + W_{bj}\frac{d\ln b_j}{dt} \right. \\ & \qquad \left. + W_{Lj}\frac{d\ln L_j}{dt} + W_{kj}\frac{d\ln k_j}{dt}\right). \end{aligned} \tag{13}$$

The growth in output for industry j is given by

$$
(14) \qquad \begin{aligned}
\frac{d\ln x_{Ij}}{dt} = \Sigma_j W_{ij} \underset{\text{(A)}}{\frac{d\ln U_{ij}}{dt}} + W_{dj} \underset{\text{(B)}}{\frac{d\ln d_j}{dt}} + W_{bj} \underset{\text{(C)}}{\frac{d\ln b_j}{dt}} + W_{Lj} \underset{\text{(D)}}{\frac{d\ln L_j}{dt}} \\
+ W_{kj} \underset{\text{(E)}}{\frac{d\ln k_j}{dt}} + \underset{\text{(F)}}{\frac{d\ln \text{TFP}_j}{dt}}
\end{aligned}
$$

where the terms (A) through (F) represent the contributions to the growth of industry j of (A) intermediate goods, (B) non-competing imported goods, (C) non-household consumption, (D) labor input, (E) capital input and (F) TFP growth, respectively.

In order to assess the impact of inter-industry effects it is more convenient to represent the TFP growth using price changes (in the dual space) as the difference between the unit revenue change and the unit cost change as follows:

$$
(15) \qquad \begin{aligned}
\frac{d\ln \text{TFP}_j}{dt} = \Bigg\{ \frac{d\ln(1+T_j+\pi_j)}{dt} + \Sigma_i W_{ij} \frac{d\ln p_{oi}}{dt} + W_{dj} \frac{d\ln p_d}{dt} \\
+ W_{bj} \frac{d\ln p_b}{dt} + W_{Lj} \frac{d\ln s_j}{dt} + W_{kj} \frac{d\ln \rho_j}{dt} \Bigg\} - \left\{ \frac{d\ln p_{Ij}}{dt} \right\} \\
= \{\text{unit revenue change}\} - \{\text{unit cost change}\}
\end{aligned}
$$

where $T_j = \text{Tax}_j / C_j$ and $\pi_j = \pi_j / C_j$. Using (2) and (15), we get

$$
(16) \qquad \Sigma_i W_{vji} \frac{d\ln p_{ci}}{dt} = \{\text{unit revenue change}\} - \frac{d\ln \text{TFP}_j}{dt}.
$$

Another accounting indentity for good i is that its demand, the sum of intermediate goods (U_{ji}) and final demand (f_i), is equal to the supply, the sum of domestic production $p_{ci}X_{ci}$ and imports $p_{mi}M_i$:

$$
(17) \qquad p_{oi}(\Sigma_j U_{ij} + f_i) = p_{ci}X_{ci} + p_{mi}M_i.
$$

The Devisia index for p_{oi} is

$$
(18) \qquad \frac{d\ln p_{oi}}{dt} = W_{ci} \frac{d\ln p_{ci}}{dt} + W_{mi} \frac{d\ln p_{mi}}{dt}
$$

where

$$W_{ci} = \frac{p_{ci}x_{ci}}{p_{ci}x_{ci} + p_{mi}M_i} \tag{19}$$

$$W_{mi} = \frac{p_{mi}M_i}{p_{ci}x_{ci} + p_{mi}M_i}. \tag{20}$$

We write (16) and (18) in matrix form as follows:

$$\begin{aligned} W_v \frac{d \ln p_c}{dt} =& \frac{d \ln \phi}{dt} + W' \frac{d \ln p_0}{dt} + W_d \frac{d \ln p_d}{dt} + W_b \frac{d \ln p_b}{dt} \\ &+ W_L \frac{d \ln s}{dt} + W_k \frac{d \ln \rho}{dt} - \frac{d \ln \mathrm{TFP}}{dt} \end{aligned} \tag{21}$$

$$\frac{d \ln p_o}{dt} = W_c \frac{d \ln p_c}{dt} + W_m \frac{d \ln p_m}{dt}, \tag{22}$$

where

$$W_v = \begin{pmatrix} & \vdots & \\ \cdots & W_{vij} & \cdots \\ & \vdots & \end{pmatrix}, \quad W = \begin{pmatrix} & \vdots & \\ \cdots & W_{ij} & \cdots \\ & \vdots & \end{pmatrix}, \quad W_d = \begin{pmatrix} W_{d1} & & 0 \\ & \ddots & \\ 0 & & W_{dn} \end{pmatrix}$$

$$W_b = \begin{pmatrix} W_{b1} & & 0 \\ & \ddots & \\ 0 & & W_{bn} \end{pmatrix}, \quad W_L = \begin{pmatrix} W_{L1} & & 0 \\ & \ddots & \\ 0 & & W_{Ln} \end{pmatrix}, \quad W_k = \begin{pmatrix} W_{k1} & & 0 \\ & \ddots & \\ 0 & & W_{kn} \end{pmatrix}$$

$$W_c = \begin{pmatrix} W_{c1} & & 0 \\ & \ddots & \\ 0 & & W_{cn} \end{pmatrix}, \quad W_m = \begin{pmatrix} W_{m1} & & 0 \\ & \ddots & \\ 0 & & W_{mn} \end{pmatrix}$$

$$\frac{d \ln \phi}{dt} = \begin{pmatrix} \vdots \\ \frac{d \ln(1+T_j+\pi_j)}{dt} \\ \vdots \end{pmatrix}.$$

Combining (21) and (22) and rearranging the resulting terms, we get

$$\begin{aligned}\frac{d\ln p_c}{dt} = &[W_v - W'W_c]^{-1}\left\{\frac{d\ln\phi}{dt} + W'W_m\frac{d\ln p_m}{dt}\right.\\ &+ W_d\frac{d\ln p_d}{dt} + W_b\frac{d\ln p_b}{dt} + W_L\frac{d\ln s}{dt}\\ &\left.+W_k\frac{d\ln\rho}{dt} - \frac{d\ln \mathrm{TFP}}{dt}\right\}.\end{aligned} \tag{23}$$

Equation (23) allows us to assess the influences on domestic price change $\left(\frac{d\ln p_c}{dt}\right)$ of TFP change $\left(\frac{d\ln \mathrm{TFP}}{dt}\right)$, factor price changes $\left(\frac{d\ln s}{dt}, \frac{d\ln\rho}{dt}\right)$ and import price changes $\left(\frac{d\ln p_m}{dt}, \frac{d\ln p_d}{dt}\right)$ through intermediate goods. In particular the impact on the prices of all goods of a one percent change in TFP for each industry is summarized in the inverse matrix $\Omega = [W_v - W'W_c]^{-1}$. The (i,j)th element of this matrix, Ω_{ij}, denotes the degree of price fall for good i given a one percent increase in TFP for industry j. In order to estimate (23) we approximate continuous time derivatives by the following translog approximation for time periods t and $t+1$:

$$\begin{aligned}\ln p_{c,t+1} - \ln p_{ct} = &\left[\tilde{W}_v - \tilde{W}'\tilde{W}_c\right]^{-1}\{(\ln\phi_{t+1} - \ln\phi_t)\\ &+ \tilde{W}'\tilde{W}_m(\ln p_{m,t+1} - \ln p_{mt}) + \tilde{W}_d(\ln p_{d,t+1} - \ln p_{dt})\\ &+ \tilde{W}_b(\ln p_{b,t+1} - \ln p_{bt}) + \tilde{W}_L(\ln s_{t+1} - \ln s_t)\\ &+\tilde{W}_k(\ln\rho_{t+1} - \ln\rho_t) - (\ln \mathrm{TFP}_{t+1} - \ln \mathrm{TFP}_t)\big\},\end{aligned} \tag{24}$$

where $\tilde{W}$ denotes the time average of matrix W : $\tilde{W} = \left[\tilde{W}_{t+1} + \tilde{W}_t\right]/2$.

Figures 2.1 and 2.2 show elements of the inverse matrix $\tilde{\Omega} = [\tilde{W}_v - \tilde{W}'\tilde{W}_c]^{-1}$ for 31 industries $(i,j = 1,2,\ldots,31)$ for the time periods 1960-61 and 1978-79, respectively. These time periods were chosen so that any change in the inter-industry propagation of productivity growth that might have taken place during the period 1960-1979 could be observed. Shaded areas generally denote large degrees of inter-industry effects. We see that inter-industry productivity propagation patterns remained relatively constant over the 20-year period. Two notable changes, however, are: the effects of chemical and iron and steel industries on other industries declined somewhat, and the effects of productivity

Figure 2.1

Transmission of Productivity Gains via Intermediate Goods 1960-61 $[W_v - W'W_c]^{-1}$

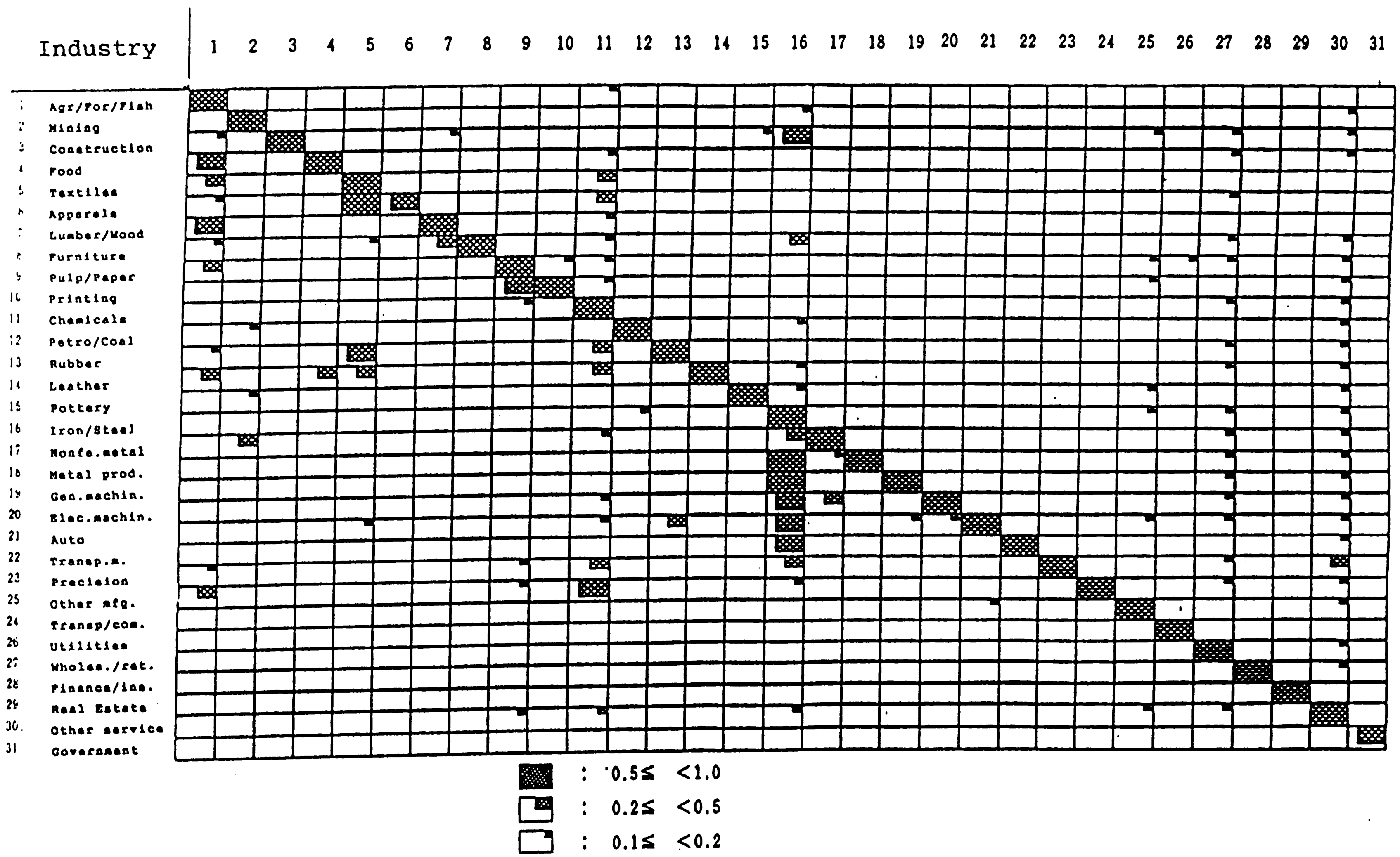
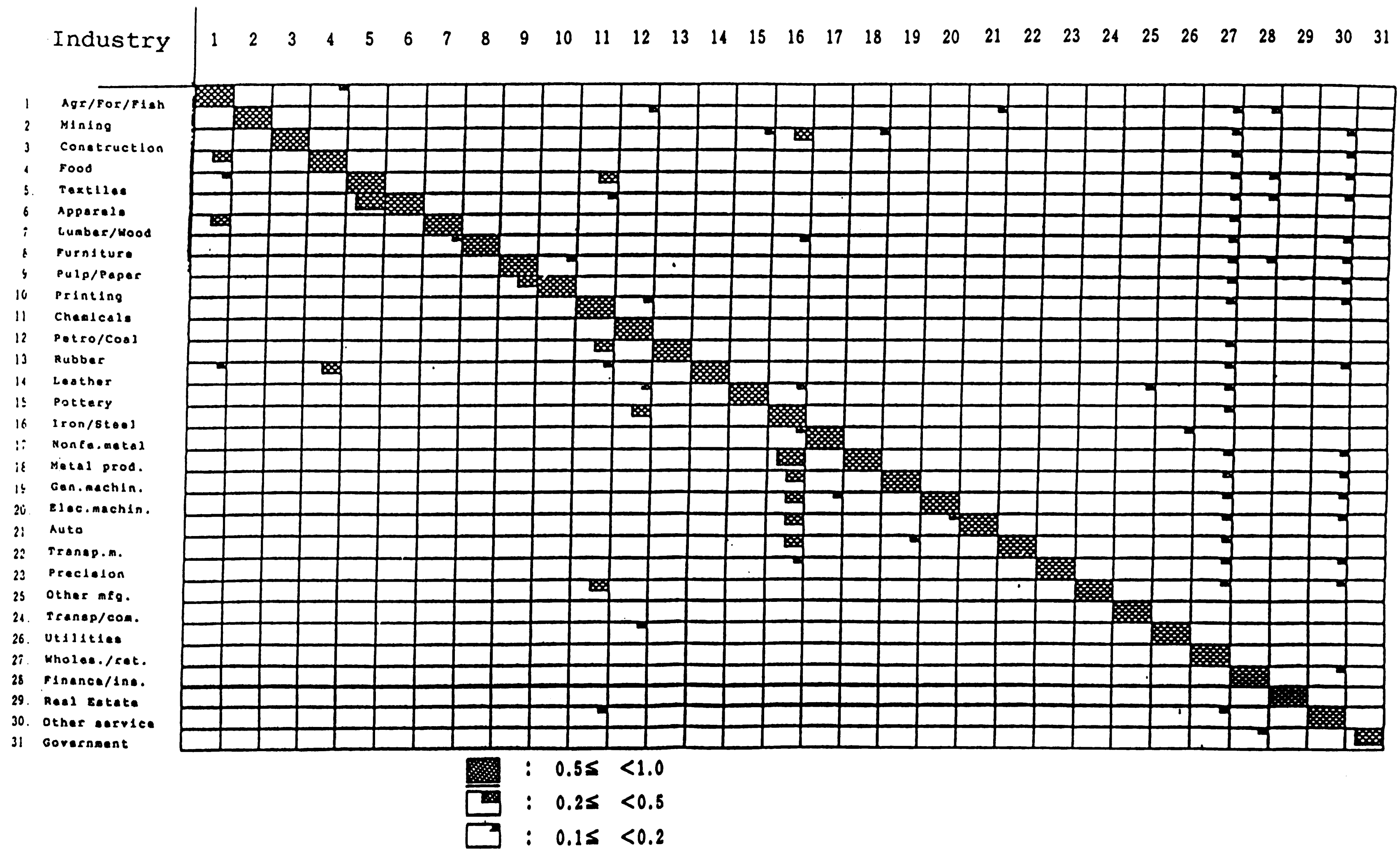


Figure 2.2

Transmission of Productivity Gains via Intermediate Goods 1978-79 $[W_v - W'W_c]^{-1}$



gains in the retail/wholesale sector on other industries became more significant during this period.

These inter-industry propagation effects are numerically presented in Table 2.2 for five time periods: 1960-61, 1965-66, 1970-71, 1975-76 and 1978-79. The numbers in Table 2.2 for industry j, are $(\Sigma_i \tilde{\Omega}_{ij})$/(industry average), where industry average $= (\Sigma_j \Sigma_i \tilde{\Omega}_{ij})/n$. These numbers represent the degree of influence on the fall of prices for all industries given a one percent increase in TFP for industry i adjusted for the industry average. The numbers exceeding one in Table 2.2 denote industries which have inter-industry propagation effects greater than the average.

We note from Table 2.2 that forestry/fishing, textile, paper, chemicals and iron/steel experienced the decline in their inter-industry propagation effects over the time periods covered. On the other hand, retail/wholesale and finance/insurance industries increased the influence of their productivity gains on other industries. Of all the industries, the iron and steel industry has had by far the largest inter-industry TFP propagation influence on other industries. This is particularly interesting since the number of workers employed, value added and stock market performance, among other performance measures, are relatively unimpressive for the iron and steel industry compared to other major industries. It is not clear whether or not our estimates for the inter-industry productivity gains influence for the iron and steel industry means a signal demanding a more resource allocation (e.g. for technology development) for this industry despite the negative signals other performance measures appear to send us.

2.2.2 Industry-Specific Contributions to the Gross Domestic Expenditure Growth

In order to measure the contributions of various industries to growth in gross domestic expenditure (GDE), we define the following accounting identity:

$$\text{(25)} \qquad \text{GDE } = p_F \cdot F = \Sigma_i p_{I_i} X_{Ii} - \Sigma_i \Sigma_j p_{oj} u_{ij} - p_d \Sigma_j d_j$$

Table 2.2

Inter-industry Transmission of Productivity Gains

	Industry	1960~61	1965~66	1970~71	1975~76	1978~79
1.	Agr/For/Fish	2.009389	1.775347	1.415330	1.338340	1.200330
2.	Mining	0.911489	0.803893	0.691585	0.669269	0.630394
3.	Construction	0.613665	0.627408	0.597713	0.566653	0.593452
4.	Food	0.459736	0.493960	0.826268	0.835201	0.763206
5.	Textiles	2.512799	2.194178	1.658731	1.752031	1.045362
6.	Apparels	−0.205060	−0.162697	−0.116825	−0.102369	0.422233
7.	Lumber/Wood	0.756394	0.807074	0.763627	0.777080	0.730027
8.	Furniture	0.310026	0.312444	0.295056	0.333238	0.363810
9.	Pulp/Paper	1.508828	1.524225	1.421797	1.241633	1.227229
10.	Printing	0.650109	0.738310	0.794101	0.854534	0.830543
11.	Chemicals	2.301303	2.387811	1.983719	1.880773	1.840903
12.	Petro/Coal	0.928463	1.051245	0.838409	1.389957	1.316406
13.	Rubber	0.596224	0.583952	0.508755	0.569180	0.568837
14.	Leather	0.434805	0.510208	0.482480	0.556191	0.504712
15.	Pottery	0.592281	0.672352	0.724372	0.787051	0.680552
16.	Iron/Steel	4.319207	3.255032	4.082219	2.768855	2.866225
17.	Nonfe.metal	1.006439	1.061750	0.885255	0.864689	0.888881
18.	Metal prod.	0.345314	0.496523	0.602849	0.651738	0.614695
19.	Gen.machin.	0.937116	0.910732	1.124189	1.045875	0.993779
20.	Elec.machin.	0.952964	0.928575	1.047245	0.995130	0.935505
21.	Auto	1.133308	1.102357	0.915578	0.930044	1.279115
22.	Transp.m.	0.212465	0.345443	0.465549	0.567482	0.322112
23.	Precision	0.100443	0.208666	0.498801	0.580061	0.499842
24.	Other mfg.	−0.026927	0.253056	0.464813	0.624953	0.760217
25.	Transp/com.	1.361923	1.519361	1.254291	1.277787	1.422224
26.	Utilities	0.902062	0.926273	0.813981	0.922170	0.994174
27.	Wholes./ret.	1.608805	1.835802	1.931241	1.970546	2.031983
28.	Finance/ins.	0.868979	1.061754	1.061976	1.363692	1.479973
29.	Real Estate	0.567608	0.657078	0.742668	0.831502	0.845060
30.	Other service	1.942172	1.729388	1.809354	1.682974	1.890821
31.	Government	0.387671	0.418485	0.414672	0.476737	0.457378
	Average	2.579506	2.389569	2.411979	2.100709	2.186373

where F and p_F are, respectively, real GDE and its deflator. From (25) we obtain

$$p_F\frac{dF}{dt} = p_F F\frac{d\ln F}{dt} = \Sigma_i p_{Ii} X_{Ii}\frac{d\ln X_{Ii}}{dt} - \Sigma_j\left(\Sigma_i p_{oi} U_{ij}\frac{d\ln U_{ij}}{dt} + p_d d_j\frac{d\ln d_j}{dt}\right)$$

or

$$\frac{d\ln F}{dt} = \frac{1}{\text{GDE}}\left\{\Sigma_i p_{Ii} X_{Ii}\frac{d\ln X_{Ii}}{dt} - \Sigma_j\left(\Sigma_i p_{oi} U_{ij}\frac{d\ln U_{ij}}{dt} + p_d d_j\frac{d\ln dj}{dt}\right)\right\}. \tag{26}$$

From (1) and (12), we have

$$p_{Ij} X_{Ij} = C_j + \text{Tax}_j + \pi_j. \tag{27}$$

Substituting (27) into (26), we obtain

$$\begin{aligned}\frac{d\ln F}{dt} = \frac{1}{\text{GDE}}&\left\{\Sigma_j(\text{Tax}_j + \pi_j)\frac{d\ln X_{Ij}}{dt} + \Sigma_j C_j\frac{d\ln X_{Ij}}{dt}\right.\\ &\left.-\Sigma_j\left(\Sigma_i p_{oi} U_{ij}\frac{d\ln U_{ij}}{dt} + p_d d_j\frac{d\ln d_j}{dt}\right)\right\}.\end{aligned} \tag{28}$$

Substituting (14) as well as (7)-(11) into (28), we get

$$\begin{aligned}\frac{d\ln F}{dt} = \frac{1}{\text{GDE}}&\left\{\Sigma_j(\text{Tax}_j + \pi_j)\frac{d\ln X_{Ij}}{dt} + \Sigma_j C_j\frac{d\text{TFP}_j}{dt}\right.\\ &\left.+\Sigma_j\left(p_b b_j\frac{d\ln b_j}{dt} + s_j L_j\frac{d\ln L_j}{dt} + \rho_j K_j\frac{d\ln K_j}{dt}\right)\right\}.\end{aligned} \tag{29}$$

Equation (29) means that the contributions of the TFP growth in various industries to macro GDE growth $\frac{d\ln F}{dt}$ are given by the weighted average of the TFP growth for each industry with the weights being the costs of production for industries divided by GDE. The sum of C_j over industries ordinarily exceeds one. The difference $(\Sigma_j C_j - 1)$ represents the effect of the inter-industry propagation of productivity growth. Other terms in (29), $\frac{1}{\text{GDE}}\Sigma_j s_j L_j\frac{d\ln L_j}{dt}$ and $\frac{1}{\text{GDE}}\Sigma_j \rho_j k_j\frac{d\ln k_j}{dt}$, represent the contributions of labor input and capital input, respectively, to macro GDE growth.

Using translog approximations, (29) was estimated using data for 31 industries $(i, j = 1, 2, \ldots, 31)$ for the period 1960-1979. Then the industry-specific terms on the right-hand side of (29) were aggregated into three larger industry sectors: the primary, secondary, and tertiary sectors.

These gross contributions of the three sectors to macro GDE growth over time are illustrated in Figure 1. From Figure 2.3 it is evident that the primary sector contributed very little to the Japanese economic growth during this period. The secondary and tertiary sectors accounted for 60% and 40% of the Japanese economic growth, respectively, during this period.

Finally Figures 2.4, 2.5 and 2.6 show, respectively, the contributions to GDE growth of labor input, capital input and TFP growth for three industrial sectors. These are the terms $(\Sigma_j s_j L_j)/\mathrm{GDE}$, $(\Sigma_j \rho_j k_j)/\mathrm{GDE}$ and $(\Sigma_j C_j)/\mathrm{GDE}$ in equation (29) where index j is summed over industries relevant for each of the three aggregate industrial sectors. Both Figures 2.4 and 2.5 show that the contribution of the secondary sector has declined over the 20-year period 1960-79 to the point where the contribution of the tertiary sector exceeds that of the secondary sector. It is of interest to note also that the contribution to GDE growth of the growth in labor input fell drastically for both the secondary and tertiary sectors (Figure 2.4) after the first oil crisis (1973-75) while there is no such sudden change in the contribution of the growth in capital stock during the same time period. Figure 2.6 shows that both the second and tertiary sectors' growth in TFP during the period 1965-70 contributed significantly to macro GDE growth, but the contribution of the TFP growth in the tertiary sector became negative after the first oil crisis and remained that way during the period 1975-79. During the periods 1973-75 and 1975-79, the growth in the secondary sector contributed positively to macro GDE growth. We conclude then that the secondary and tertiary sectors contributed to macro GDE growth in quite different ways. While the tertiary sector contributed to macro growth in terms of both production input factors, the secondary sector's contributions are in terms of capital input and its TFP growth. It is of interest to see if these different sectoral growth patterns observed for Japan were also observed for other advanced economies for the period following the first oil crisis.

Figure 2.3
Contributions to Macroeconomic Growth by Sector

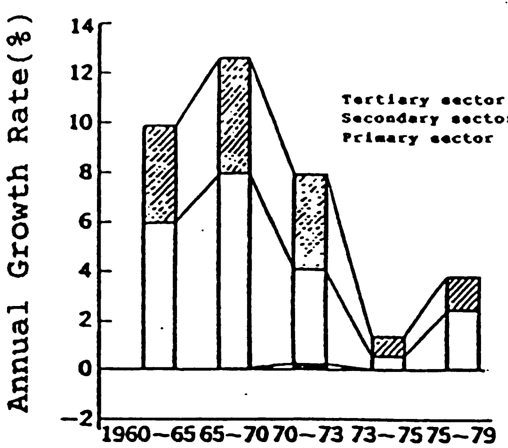


Figure 2.5
Contributions of Capital Input to Macroeconomic Growth by Sector

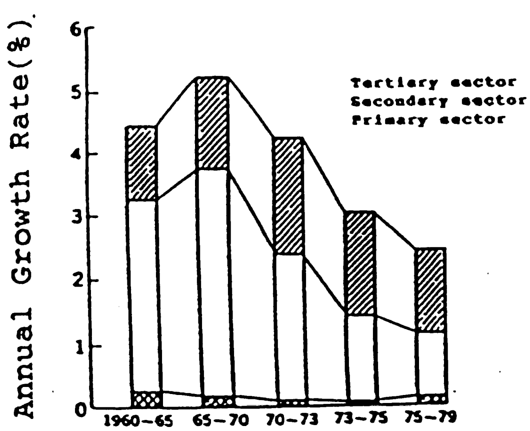


Figure 2.4
Contributions of Labor Input to Macroeconomic Growth by Sector

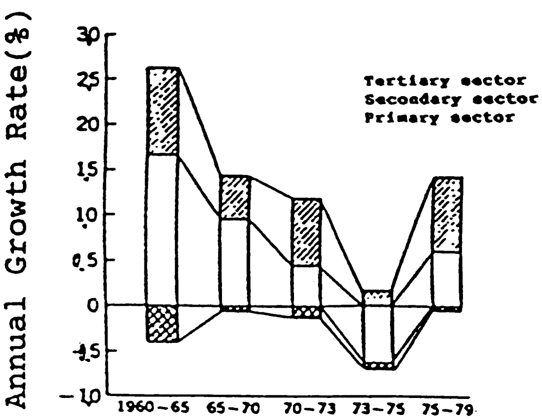
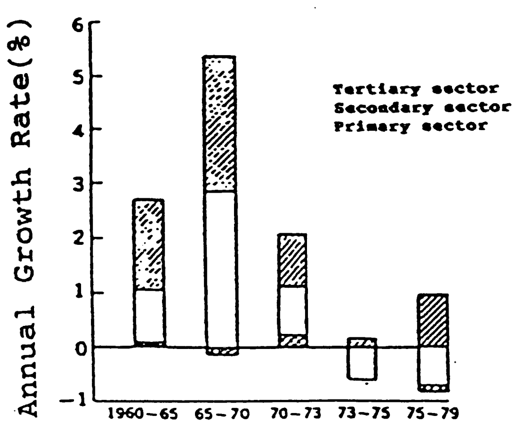


Figure 2.6
Contributions of Productivity Gains to Macroeconomic Growth by Sector



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Chapter 3. Measuring Economies of Scale

3.1. Introduction

In some policy studies, economies of scale play an essential role. For example, there is some evidence that the horizontal trade of manufactured goods among developed countries can be explained by scale economies, among other factors (Helpman and Krugman (1985)). If a nation's markets for strategically important goods were served by foreign oligolopolists enjoying scale economies and hence were not contestable from the point of view of domestic producers (Baumol, Panzar and Willig (1982)), then policies to protect domestic producers might be justified on infant industry ground (Timbergen (1945) and Kemp (1969)). In the policy debate on the Canada-U.S. Free Trade Agreement, Canadian proponents of the treaty based their arguments primarily on the benefits of scale economies that Canadian manufacturers would enjoy if they had access to an enlarged North American market (Harris and Cox (1984)). Estimates for scale economy parameters are important inputs to policy-oriented applied general equilibrium models such as the one used by Harris and Cox.

If data on manufacturing establishments were available, economies of scale could in principle be estimated using a production function of some flexible form. Normally, however, significant multicollinearity exists among certain inputs, their prices and output in cross-section data for establishments. The sample multicollinearity problem often prevents us from identifying with sufficient statistical precision scale economies and other (often many) unknown parameters.[1]

[1] A standard method to estimate these unknown parameters is to estimate a flexible cost function using cost share equations. However, estimating scale economies using a translog cost function, for example, requires the estimation of the cost function itself as well as the share equation system (Berndt (1991, p. 476)). Since output, its squares and its cross products with input prices are all in the cost function, multicollinearity can potentially cause serious estimation problems. Banker, Charnes, Cooper and Maindiratta (1988, p. 40) also note that their procedure is likely to provide unreliable estimates for returns to scale when there is a collinearity problem in estimating flexible form production functions.

In Sections 2 and 3 of this chapter we present an econometric procedure to estimate the return to scale in production using establishment data. Assuming that scale economy effects are stable, our method utilizes generalized least squares to estimate the return to scale as well as its lower and upper bounds. Our estimation method also uses index number theory to aggregate inputs at establishments of different sizes and can be interpreted as a generalization of Frisch's (1965) approximation formula for his passus coefficient (scale elasticity).

Although we will assume a flexible form production function to capture price and substitution effects at establishments in the derivation of our estimation method, we do not explicitly estimate these substitution parameters. The reasons for not estimating these parameters are twofold. First, estimating these numerous parameters together with scale economy effects often results in statistically unreliable estimates because of multicollinearity problems encountered in the data sets currently available at the establishment level. Secondly, for the types of policy studies related to scale economy effects we have in mind, it is not essential to obtain estimates for price and substitution parameters.[2] These parameters are nevertheless important in recovering optimal strategies for establishments regarding, for instance, cost minimization. For our application problems, however, it is sufficient to assume that the observed production inputs are the results of the optimizing behavior of establishments.[3] Our hope is that the proposed method provides stable estimates for returns to scale, avoiding the multicollinearity problem but at the expense of

[2] Policy-oriented empirical studies emphasizing estimating scale effects with little attention paid to price effects include Komiya (1962), Ozaki (1969, 1976), and Giles and Wyatt (1992). Scale economy parameter estimates were stand alone inputs to the Canada-U.S. Free Trade Model by Harris and Cox (1984).

[3] Virtually all Japanese industrial policies deal with scale economy effects also. In promoting specific manufacturing industries such as the steel, automobile and chemical industries, the Ministry of International Trade and Industry (MITI) always specified the level of production scale required for an internationally competitive production facility. Exactly the same sort of thinking underlies the policy put forward by the Ministry of Finance (MOF) to strengthen the Japanese banking industry as liberalization (deregulation) in finance industries is currently being implemented. Economies of scale considerations led MOF to encourage mergers and acquisitions among Japanese banks (e.g. the recent merger between the Mitsui Bank and the Taiyo Kobe Bank).

the statistical efficiency which could be attained only by a fully simultaneous estimation of all unknown parameters included in the production function (or the cost function). Our empirical results show that our estimation method can identify scale effects quite well using the kind of establishment data that is available for Japanese manufacturing industries; we find substantial, statistically significant scale economies among establishments. The organization of this chapter is as follows. In the next section we present a procedure for estimating lower and upper bounds for the return to scale (scale elasticity) as well as scale elasticity itself using establishment data. Application of this method to time series of cross section data for Japanese manufacturing industries is discussed in Section 3.

3.2. Elasticity of Scale and Its Lower and Upper Bounds

Suppose the scalar output, x, of an establishment in period (year) t is characterized by

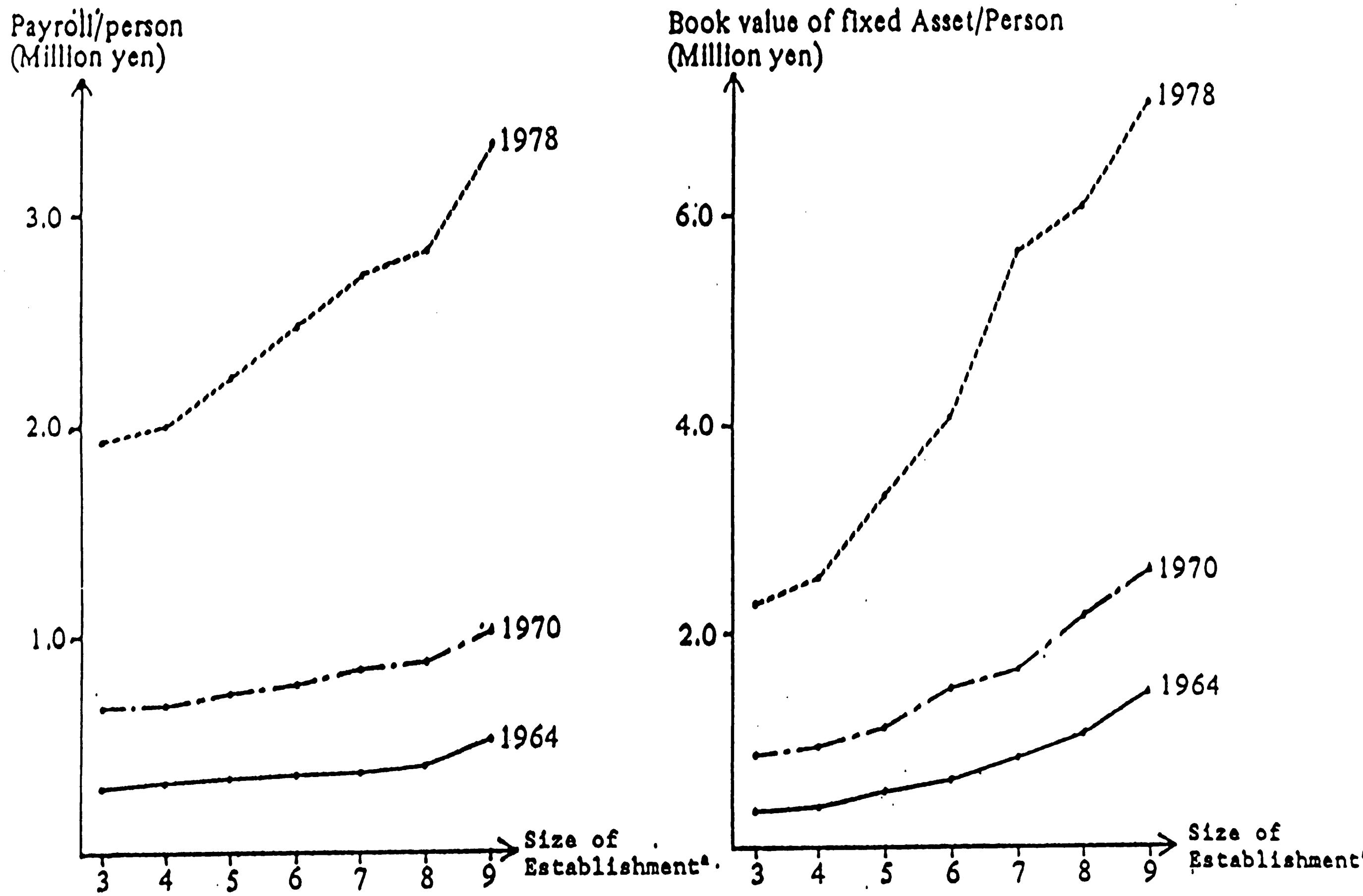
$$x_t = f(v_t) \qquad t = 1, 2, ..., T,$$

where v_t is the n–dimensional production input vector, $v = (v^1, v^2, \ldots, v^n)$, and $f(v)$ is the production function. The time subscript t will be omitted except when our discussion requires the explicit treatment of time. For a given fixed input vector v_0 and a positive scalar μ, the elasticity of scale, k, is defined by

$$k = (dx/x)/(d\mu/\mu) = d\ln x/d\ln \mu$$

where $x = f(\mu v_0) = f(v)$ and k depends on v_0 in general. In many empirical applications involving cross-sectional data we usually observe high correlations among some of the inputs $(v^1, v^2, \ldots, v^n)$ and their prices. For example, in the application to be discussed below we will use the Japanese establishment data on three production inputs: employment (the number of workers), capital stock and raw material ($n = 3$). Only group means by establishment size are published for these variables. Since large establishments employ more workers, own more capital stock and utilize more raw material than small establishments,

Figure 3.1. WAGES AND CAPITAL STOCK BY ESTABLISHMENT SIZE



[a]Establishment size is defined by the number of workers at establishment as follows

3: 30 ~ 49 workers 4: 50 ~ 99 workers 5: 100 ~ 199 workers

6: 200 ~ 299 workers 7: 300 ~ 499 workers 8: 500 ~ 999 workers

9: 1000 ~ workers

we expect these production inputs and output to be highly correlated. (See Figure 3.1.) A similar multicollinearity problem is also found between output and workers' wages, for example, which rise as establishment size increases (Oi (1983)). When production inputs (input prices) and output are highly correlated it is difficult to identify the parameters including scale parameters in the production function (cost function).

Suppose the objective of a particular empirical study is to estimate the elasticity of scale, and suppose there is reason to believe that, because of the multicollinearity problem, the elasticity of scale cannot be estimated with precision using the simultaneous estimation of a flexible form involving all unknown parameters including the scale elasticity.[4] Then we propose the following estimation strategy. First, we derive lower and upper bounds for scale elasticity under the homotheticity assumption, which is likely to be satisfied when observed production inputs are highly multicollinear. If our assumption is correct, our estimated lower bounds should be less than estimated upper bounds and lower and upper bounds should be close to each other. Our second step is to test the hypothesis that lower and upper bounds for scale elasticity are independent of establishment output. Suppose we accept the hypothesis that scale elasticity bounds do not depend on output. Then we can appropriately assume that the production function is homogeneous of degree k which also equals scale elasticity.[5] Our third step is to estimate the elasticity of scale k (which is now assumed to be constant) by generalized least squares (GLS) assuming a production function which is homogeneous of degree k. We make use of index number theory and flexible functional forms in our procedure to estimate lower and upper bounds for scale

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[4] This situation is not uncommon in econometric practice. For example, in studying the efficiency of U.S. manufacturing industries, Caves and Barton (1990, p. 34) note that "The idea of an intensive examination of scale economies was dropped after the results for the twelve-industry panel were analyzed. The behavior of the estimated coefficients, especially in the translog functions, did not inspire confidence in our ability to determine the minimum efficiency scales ..."

[5] Given a production function $X = f(v)$, the elasticity of scale is given by $k = \sum_{j=1}^{n}(\partial \ln X/\partial \ln v_j) = \sum_{j=1}^{n}(1/X)(\partial X/\partial v_j)v_j = (1/X)\Delta f(v)'v$, where $\Delta f(v)' = (\partial f/\partial v_i, \partial f/\partial v_2, \ldots, \partial f/\partial v_n)$. This implies $kX = \Delta f(v)'v$. On the other hand, Euler's Theorem for homogeneous functions of $m-$th order implies $mX = \Delta f(v)'v$. Thus $k = m$.

elasticity as well as the scale elasticity itself.

3.2.1 Derivation of Lower and Upper Bounds for Scale Elasticity

Suppose we observe (x_i, v_i, p_i) for small $(i = 1)$ and large $(i = 2)$ establishments, where x_i is output such that $x_2 > x_1$ and $x_i = f(v_i)$. The production function $f(v)$ is assumed to be homothetic, v_i denotes an $n-$dimensional input vector at establishment i with price vector p_i $(i = 1, 2)$. The homotheticity assumption is justified for the observed range of input vector v where the elements of v exhibit severe multicollinearity.

We derive lower and upper bounds for the elasticity of scale k based on the two assumptions: (1) the production function $x = f(v)$ is homothetic and hence the elasticity of scale depends on the size of output (x) only, and (2) each establishment chooses its production input vector v so as to minimize the total cost of production.

Consider two rays in the input (v) space $R_i(i = 1, 2) : R_i$ passes through the origin and v_i. The rays R_1 (for the small establishment, $n = 1$) and R_2 (for the large establishment, $n = 2$) are depicted in Figure 3.2 together with the supporting cost hyperplanes (lines) C_i at v_i and isoquants $Q_i(i = 1, 2)$. (Note that no convexity property is assumed for the production function at this point.)

We denote the intersections of isoquants Q_i with ray R_j $(i \neq j)$ by v_{*i} $(i, j = 1, 2)$. The intersections of cost lines C_i with ray R_j $(i \neq j)$ are denoted by $\tilde{v}_i$ $(i, j = 1, 2)$. The points v_{*i} and $\tilde{v}_i$ $(i = 1, 2)$ are shown in Figure 3.2. We also define another isoquant Q_0 corresponding to some fixed output x_0 and denote by v_{01} and v_{02} the intersections of Q_0 with rays R_1 and R_2, respectively. (See Figure 3.2.) The homotheticity assumption implies that isoquants Q_0, Q_1 and Q_2 are isomorphic with respect to the origin.

Since $f(v)$ is homothetic, we have, for any positive scalar μ,

$$x = f(\mu v_{01}) = f(\mu v_{02}).$$

Let μ_1 and μ_2 be defined by $v_2 = \mu_2 v_{02}$ and $v_1 = \mu_1 v_{01}$. Then we have

(1) $$x_i = f(\mu_i v_{01}) = f(\mu_i v_{02}) \quad i = 1,2$$

and

(2) $$v_{*1} = \mu_1 v_{02} \quad \text{and} \quad v_{*2} = \mu_2 v_{01}.$$

Hence we have

(3) $$v_{*2} = (\mu_2/\mu_1)v_1 \quad \text{and} \quad v_2 = (\mu_2/\mu_1)v_{*1}.$$

If v_{*1} and v_{*2} were observable, then the mean elasticity[6] of scale, $E(k)$, measured on Rays 1 and 2 would be given, respectively, by

$$E(k)^1 = (\ln x_2 - \ln x_1)/(\ln \mu_2 - \ln \mu_1) = (\ln x_2 - \ln x_1)/(\ln v_{*2}^j - \ln v_1^j)$$

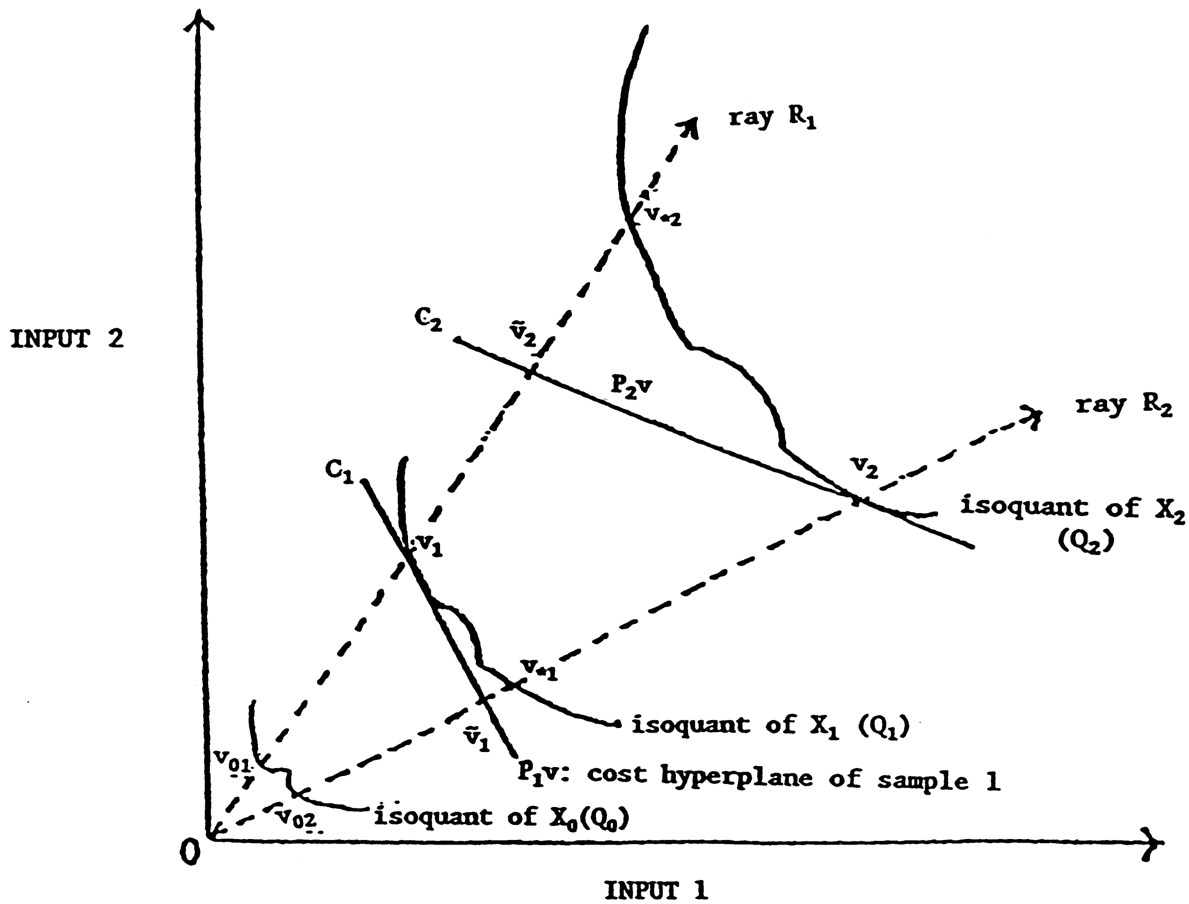
and

$$E(k)^2 = (\ln x_2 - \ln x_1)/(\ln \mu_2 - \ln \mu_1) = (\ln x_2 - \ln x_1)/(\ln v_2^j - \ln v_{*1}^j), \quad \text{any } j = 1,2,\ldots,n,$$

[6] $E(k)^i$ is the mean elasticity of scale measured along Ray i (R_i) between isoquants Q_1 and Q_2, and serves as a discrete approximation to the true elasticity of scale.

FIGURE 3.2. PRODUCTION INPUT SPACE

$n = 2$



where v^j is the j^{th} element of input vector v ($j = 1, 2, \ldots, n$). Since the denominator of $E(k)^i$ is $\ln(\mu_2/\mu_1)$ for $i = 1, 2$, we have $E(k)^1 = E(k)^2$. That is, the mean elasticity of scale does not depend on the ray along which it is measured.

In practice we do not observe v_{*1} and v_{*2}. We do observe $\tilde{v}_1$ and $\tilde{v}_2$, however, since we have

(4) $$\tilde{v}_1 = (p_1 v_1 / p_1 v_2) v_2 \quad \text{and} \quad \tilde{v}_2 = (p_2 v_2 / p_2 v_1) v_1.$$

We show that cost minimization implies

(5) $$\tilde{v}_i \leq v_{*i} \qquad i = 1, 2.$$

(Proof)

Define a positive scalar λ_i such that $\tilde{v}_i = \lambda_i v_{*i} (i = 1, 2,)$. By definition we have (Figure 1)

$$p_i v_i = p_i \tilde{v}_i \quad \text{and} \quad x_i = f(v_{*i}).$$

Cost minimization implies

$$p_i v_i = \min_v \{p_i v;\ x_i \leq f(v)\}$$

from which we have

$$\lambda_i p_i v_{*i} = p_i v_i = p_i \tilde{v}_i \leq p_i v_{*i}.$$

Thus we have $\lambda_i \leq 1$ and hence $\tilde{v}_i \leq v_{*i}$. QED

Define k_1 and k_u by

(6) $$k_1 = (\ln x_2 - \ln x_1)/(\ln v_2^j - \ln \tilde{v}_1^j),$$

and

$$k_u = (\ln x_2 - \ln x_1)/(\ln \tilde{v}_2^j - \ln v_1^j), \quad \text{for any} \quad j = 1, 2, \ldots n. \tag{7}$$

Then we have $k_1 \leq E(k)^2 = E(k)^1 \leq k_u$ or

$$k_1 \leq k \leq k_u, \tag{8}$$

where the expectation operator for k will be dropped for notational convenience in the following.

If we view establishments 1 and 2 as a base and a compared points, respectively, then we can define Laspeyres and Paasche input indexes, Q_L and Q_P, as follows:

$$Q_L = p_1 v_2 / p_1 v_1 \quad \text{and} \quad Q_P = p_2 v_2 / p_2 v_1. \tag{9}$$

Substituting (4) into the denominators of (6) and using (9), we get

$$k_1 = (\ln x_2 - \ln x_1)/\ln Q_L \tag{10}$$

and

$$k_u = (\ln x_2 - \ln x_1)/\ln Q_P. \tag{11}$$

Frisch (1965, p. 68) proposed the following approximation formula for the elasticity of scale (called the "passus coefficient" by Frisch)

$$k = (\ln x_2 - \ln x_1)/(\ln v_2^j - \ln v_1^j), \quad \text{any} \quad j,$$

which would be an exact formula for k under the perfect multicollinearity among production inputs ($j = 1, 2, \ldots, n$). Our lower and upper bounds formulas (10) and (11), which are exact under our assumptions, may be viewed as generalizations of Frisch's approximation formula.[7]

[7] The inequality $k_1 \leq k_u$ (where k_1 and k_u are given by (10) and (11)) implies $Q_L \geq Q_P$,

3.2.2 Estimation of k_1, k_u and k Based on Flexible Functional Forms

For establishments 1 and 2 and the production function $x = f(v)$, (10) and (11) imply

$$k_1 = \{\ln f(v_2) - \ln f(v_1)\} / \ln Q_L^{1,2} \tag{12a}$$

and

$$k_u = \{\ln f(v_2) - \ln f(v_1)\} / \ln Q_P^{1,2}, \tag{12b}$$

where $Q_L^{1,2}$ and $Q_P^{1,2}$ are Laspeyres and Paasche indexes calculated, respectively, for establishments 1 and 2.

In our econometric specification we assume that the error term u enters the production function in multiplicative form

$$x_i = f(v_i)e^{ui} \qquad i = 1, 2, \ldots, I \tag{13}$$

where $E(u') = E\{u_1, u_2, \ldots, u_I)\} = 0$, $E(uu') = (\sigma^2/2)F$ and F is the I by I unit matrix.

Using (13) we rewrite (12a-b) as follows:

$$\ln x_2 - \ln x_1 = k_1 \ln Q_L^{1,2} + (u_2 - u_1) \tag{14a}$$

$$\ln x_2 - \ln x_1 = k_u \ln Q_P^{1,2} + (u_2 - u_1) \tag{14b}$$

---

that is, the Laspeyres input quantities index is greater than or equal to the corresponding Paasche index. This follows from Bortkiewicz's index number theorem which holds if price changes and input quantity changes are negatively correlated (Bortkiewicz (1922) and Allen (1975)). This assumption seems satisfied in our case. For example, as establishment size increases, the wage rate (price of labor) increases (Oi (1983)). The price increase is accompanied by utilizing less labor and more capital, that is, the capital labor ratio increases as establishment size increases. This is illustrated in Figure 3.1 for a number of years.

We can generalize (14) to $I-1$ pairs of consecutive establishments ordered by size as follows:

$$\text{(15a)} \qquad \ln x_{i+1} - \ln x_i = k_1 \ln Q_L^{i,i+1} + (u_{i+1} - u_i)$$

$$\text{(15b)} \qquad \ln x_{i+1} - \ln x_i = k_u \ln Q_P^{i,i+1} + (u_{i+1} - u_i) \qquad i = 1, 2, \ldots, I-1$$

The unknown parameters k_1 and k_u can be estimated using (15a) and (15b), respectively, by generalized least squares (GLS) with the variance-covariance matrix for the error term $(u_{i+1} - u_i)$ as follows:

$$\Omega = \sigma^2 \begin{bmatrix} 1 & -\frac{1}{2} & \cdots & 0 \\ & & \ddots & \vdots \\ -\frac{1}{2} & & & -\frac{1}{2} \\ \vdots & \ddots & & \\ 0 & \cdots -\frac{1}{2} & 1 & \end{bmatrix}.$$

Since the same error term enters both (15a) and (15b) we expect estimated values for σ^2 from both equations to be quite close. Estimates for σ^2 which are far apart would imply potential specification problems for equations (15a) and (15b).

Since the values of k_1 and k_u estimated using equations (15a) and (15b) are expected to be quite close, it would be useful if we could directly estimate the value of k by regression by assuming a certain flexible functional form for $f(v)$.[8] This is done in the following.

Case 1. Diewert's (1976) quadratic form:

(16) $\qquad x = f(v) = (v'Av)^{k/2}$, A is a symmetric matrix such that isoquants are convex with respect to the origin.

[8] The assumption of a flexible functional form which allows adequate substitution possibilities among production inputs is essential for a consistent estimation of the return to scale. Using a production function with too few parameters will result in a biased estimation of scale economy effects.

By Euler's theorem we have $kx = \nabla f(v)'v$. Cost minimization implies the input price vector p is proportional to $\nabla f(v)$, i.e. $p \propto \nabla f(v)$. Thus we have

$$\nabla f(v)'/kx = \nabla f(v)'/(\nabla f(v)'v) = p'/p'v. \tag{17}$$

Using (16) and (17) Fisher's ideal index of inputs can be given as follows:

$$\begin{aligned} Q_I &= (Q_L Q_P)^{1/2} = ((p_1 v_2/p_1 v_1)(p_2 v_2/p_2 v_1))^{1/2} \\ &= \left(\frac{\nabla x_1' v_2}{kx_1} \frac{kx_2}{\nabla x_2' v_1}\right)^{1/2} \\ &= \left(\frac{x_2(v_1'\nabla v_1)}{x_1(v_2'\nabla v_2)} \frac{v_1'\nabla v_2)}{v_2'\nabla v_1}\right)^{1/2} \\ &= (x_1/x_2)^k. \end{aligned} \tag{18}$$

or

$$k = (\ln x_2 - \ln x_1)/\ln Q_I. \tag{19}$$

From (10) and (11) we get

$$\ln Q_I = (1/2)(\ln x_2 - \ln x_1)((1/k_1) + (1/k_u)). \tag{20}$$

Combining (19) and (20), we obtain

$$k = 2/\{(1/k_1) + (1/k_u)\}. \tag{21}$$

Thus under the quadratic production function assumption, scale elasticity, k, can be calculated using Fisher's ideal index of inputs and it is also the harmonic mean of its lower and upper bounds, k_1 and k_u.

Case 2. Translog production function:

$$k^{-1} \ln f(v) = b_0 + b_1' \ln v + 1/2 \ln v' R \ln v, \tag{22}$$

where the unknown parameters are scalar b_0, vector b_1 with its column sum equal to one, and non-positive definite matrix R with all row sums equal to zero and, where the dimensions of b_1 and R conform to that of v (see Christensen, Jorgenson and Lau (1973)). If we apply the Quadratic Approximation lemma (Diewert (1976)) to (22) and evaluate it at the 1st and 2nd smallest establishments, we get

$$\begin{aligned} k^{-1}\{\ln x_2 - \ln x_1\} & \\ &= 1/2\{k^{-1}\nabla \ln x_2 + k^{-1}\nabla \ln x_1\}'(\ln v_2 - \ln v_1) \\ &= 1/2\{(kx_2)^{-1}V_2\nabla x_2 + (kx_1)^{-1}V_1\nabla x_1\}'(\ln v_2 - \ln v_1), \end{aligned} \tag{23}$$

where $\nabla \ln x_1$ ($\nabla \ln x_2$) and ∇x_1 (∇x_2) are the gradients of x_1 (x_2) with respect to $\ln v_1$ ($\ln v_2$) and $v_1(v_2)$, respectively, and where V_1 (V_2) denotes the diagonal matrix with its (j,j)th element equal to the j–th element of $\ln v_1$ ($\ln v_2$).

By applying (17) to (23), we get

$$\begin{aligned} k^{-1}\{\ln x_2 - \ln x_1\} & \\ &= \frac{1}{2}\left\{\frac{v_2 p_2'}{p_2' v_2} + \frac{v_1 p_1'}{p_1' v_1}\right\}(\ln v_2 - \ln v_1) \end{aligned} \tag{24}$$

or

$$k = (\ln Q^{1,2})^{-1}\{\ln x_2 - \ln x_1\}$$

or

$$k = (\ln Q^{1,2})^{-1}\{\ln f(v_2) - \ln f(v_1)\}, \tag{25}$$

where

$$\ln Q_T^{1,2} = (1/2)(w_1 + w_2)'(\ln v_2 - \ln v_1) \tag{26}$$

is the log of Translog (Theil-Törnqvist) input quantity index (Theil (1965), Törnqvist (1936) and Fisher (1922)). w_1 and w_2 in (26) are the cost share vectors for the 1st and

2nd smallest establishments given by

$$w_1 = \frac{v_1 p_1'}{p_1' v_1} \quad \text{and} \quad w_2 = \frac{v_2 p_2'}{p_2' v_2}.$$

Thus scale elasticity can be estimated using Fisher's ideal index ((19) or (21)) if $f(v)$ is of Diewert's quadratic form, or using Translog input index (25) if $f(v)$ is of translog form. Both (19) and (25) can be rewritten for successive establishments i and $i+1$ as regression equations for estimating k using the multiplicative error term specification given in (13) (see also (15a) and (15b)):

$$\text{(27)} \qquad \ln x_{i+1} - \ln x_i = k_I \ln Q_I^{i,i+1} + (u_{i+1} - u_i), \qquad i = 1, 2, \ldots, I-1,$$

Diewert quadratic form production function

$$\text{(28)} \qquad \ln x_{i+1} - \ln x_i = k_T \ln Q_T^{i,i+1} + (u_{i+1} - u_i), \qquad i = 1, 2, \ldots, I-1,$$

Translog form production function.

3.3 Estimation of Lower and Upper Bounds for Scale Elasticity Using Japanese Manufacturing Establishments Data Grouped by Establishment Size

The Japanese Ministry of International Trade and Industry (MITI) conducts annually the Census of Manufacturing by Industry. For each year this Census consists of the cross-section of establishments chosen based on the number of employees. Typical size groups (the numbers of employees) used are: (1) 30–49, (2) 50–99, (3) 100–199, (4) 200–299, (5) 300–499, (6) 500–999 and (7) 1000 and more. (The number of these groups and hence the definitions of size groups vary somewhat over time, however.) Henceforth "the size" refers to the size of establishment measured in terms of the number of employees. (See Data Appendix for details on the sources of data used.) MITI publishes only average figures for each of the size groups by industry.

In the following these grouped data on establishments will be viewed as ordered cross-sectional observations ($i = 1, 2, \ldots, I$); that is, establishments are ordered in the ascending order of size: $i = 1$ and $i = I$ correspond to the smallest and largest size groups, respectively. The production inputs included are: the number of workers (v^1) as labor, the fixed assets at the beginning of each year (v^2) as capital, and the intermediate goods (v^3) as raw material, all measured per establishment.[9] The corresponding input prices used are: the average annual cash earnings per worker (p^1) for v_1, the depreciation rate for fixed assets plus the average interest rate for one-year term-deposit (p^2) for v_2. Intermediate goods price p_3 is assumed to be one since it is common for all observations for each industry and for each year. Output (x) is measured as net sales plus net increases in the inventories of final products.

We estimated upper and lower bounds for the scale elasticity for each of the manufacturing industries for the period 1964-1988. (See Data Appendix for included manufacturing industries.) Our estimation results are reported in Table 3.1 at the end of the book. (We have 500 industry-year observations.)

For each industry we denote by $\hat{k}_1^i$ and $\hat{k}_u^i$ estimated values for k_1^i and k_u^i, respectively. k_1^i and k_u^i denote population lower and upper bounds for scale elasticity measured using the ith and $(i+1)$st smallest establishments data (establishment $(i+1)$ is larger than establishment i, $i = 1, 2, \ldots, I-1$). We tested the following null hypotheses:

H(I): The serial correlations between k_1^i and k_1^{i+1} and between k_u^i and k_u^{i+1} are zero, i.e.

$$\rho(k_1^i, k_1^{i+1}) = 0 \quad \text{and} \quad \rho(k_u^i, k_u^{i+1}) = 0.$$

H(II): The distribution of k_1 is the same as the distribution of k_u.

[9] Establishment data of this sort exist, for example, for Japan and Norway. In the following the input price vector is denoted by $p = (p^1, p^2, \ldots, p^n)$ where p^j is the price for the j-th input v^j, $j = 1, 2, \ldots, n$.

In order to show that lower and upper bounds for scale elasticity k do not depend on output size, we test H(I) which states that successive estimates for lower and upper bounds for k measured for establishment groups ordered by size are uncorrected. H(II) states that k_l and k_u are sufficiently close to each other in statistical distribution. If hypotheses H(I) and H(II) are both accepted, we conclude that scale elasticity can be viewed as constant and that the multicollinearity problem among inputs is so serious that it is reasonable, for the sake of statistical efficiency, to assume a homogeneous production function to estimate scale elasticity.

Our results are the following. H(I) is accepted for all 500 industry-year cases at a 5% significance level. Only 25 cases exhibit positive correlation at a 25% level. Numerically only 79 out of 500 cases show any positive correlation. These observed positive correlations are not concentrated in any particular industries. H(II) is also accepted at conventional significance levels using the Mann-Whitney (1947)-Wilcox (1945) test which is one of the most powerful nonparametric tests and does not require strong distributional assumptions (e.g. normality).[10] For all 500 cases estimated lower and upper bound are identical up to the second decimal point. Now that we have shown that scale elasticity can be viewed as constant over establishment size groups and that lower and upper bounds are quite close to each other, we can proceed to estimate k_l, k_u and k in statistically more efficient manner.

GLS estimates for lower and upper bounds (k_l and k_u) for scale elasticity as well as scale elasticity estimates k_I (based on Fisher's ideal index and Diewert's quadratic form) and k_T (based on Translog index and translog production function) are presented in Table 1 for a number of industries for 1964-1988. (Complete estimation results are available from the authors on request.)

We find that estimated lower bounds are generally smaller than estimated upper bounds and that their differences are quite small. Out of 496 cases for which regressions ran,

---

[10] The standard t test cannot be applied here since the covariance between $\hat{k}_l$ and $\hat{k}_u$ is shown to be zero under the null hypothesis H(II). Complete statistical test results are available from the authors on request.

estimated upper bounds exceeded estimated lower bounds for 405 cases. Furthermore for the 91 cases for which estimated lower bounds ($\hat{k}_1$) exceeded estimated upper bounds ($\hat{k}_u$), the relative difference between $\hat{k}_1$ and $\hat{k}_u$ is extremely small, that is, $|(\hat{k}_1 - \hat{k}_u)/\hat{k}_1| < .005$ for all the 91 cases. For the 405 cases for which $\hat{k}_1 < \hat{k}_u$, the difference between $\hat{k}_1$ and $\hat{k}_u$ is also small: $|(\hat{k}_u - \hat{k}_1)/\hat{k}_1| < .01$ for all the 405 cases. The null hypothesis that $k_1 = k_u$ is accepted for all cases at a 1% level.

Another indication for the correctness of our specification is given by the difference beween standard errors (σ) for the error term given by equations (15a) and (15b) for lower and upper bounds. We find that the standard errors $\hat{\sigma}_1$ and $\hat{\sigma}_u$ estimated from equations (15a) and (15b), respectively, are quite close (the absolute relative difference is less than 10% for all cases: $|(\hat{\sigma}_1 - \hat{\sigma}_u)/\hat{\sigma}_1| < 0.1$).

Thus there is ample empirical evidence to believe that our restricted estimators, k_I and k_T, will provide statistically more efficient estimates for scale elasticity. Table 1 shows that estimated k_I and k_T are extremely close to each other and statistically highly significant and that considerable increasing returns to scale exist (i.e. $k > 1$) for the Japanese manufacturing industries. Observed economies of scale will be further discussed in Chapter 4, where we will discuss estimating the effects of scale economy and technical progress within the simultaneous framework.

Data Appendix

The Census of Manufacturing by Industry published annually by the Ministry of International Trade and Industry gives for each of the seven size groups distinguished by the number of employees, the average figures for: the number of employees, labor compensation, the cost of intermediate input, the value of output, investment expenditure, depreciation, and the book value of capital stock. Because of the new additions of establishments as well as the closures and mergers of existing establishments, the numbers of establishments included in the seven establishment groups do change over time. The manufacturing industries covered by the Census are: food/kindred products, textiles, apparels, lumber/wood products, furniture/fixture, pulp/paper, printing, chemicals, petroleum/coal products, rubber/plastic products, leather/leather products, pottery/glass products, iron/steel, non-ferrous metals, metal products, general machinery, electrical machinery, transportation machinery, precision, other. Most of our regression results in Chapters 3 and 4 are presented for all the industries except printing and other industries. The latter two industries could not be included in our analysis since there are no published deflators for these industries.

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Chapter 4. Sources of Productivity Growth: Economies of Scale versus Technical Progress

4.1. Introduction

In the preceding chapter we have found that, for the kind of data that is currently available for Japanese manufacturing industries, it is reasonable to assume a homogeneous production function of degree k. Our empirical results show that it makes little difference as far as scale elasticity estimates are concerned whether we use Translog or Diewert's quadratic production functions.

Another issue related to scale economy in empirical productivity analysis is to distinguish between the contributions of economies of scale and technical change in the growth of total factor productivity (TFP). Such a distinction, however, is not possible when a production function with constant returns to scale is assumed (Solow (1957), Jorgenson and Grilliches (1967), Jorgenson, Gollop and Fraumeni (1987) and Kuroda, Yoshioka and Jorgenson (1984)). This is because under the assumptions of constant returns to scale and perfect competition, the TFP growth coincides with technical change. The constant returns to scale assumption has been imposed on the specification of production functions in many empirical studies which utilize aggregate time series data.

Some empirical results suggest that economies of scale, rather than technical change, may explain the variation in TFP. Denison (1974), among others, concluded that economies of scale are a significant reason for TFP growth in the U.S.[1] More recently, using aggregate time series for the U.S., Berndt and Khaled (1979) found the apparent presence of substantial economies of scale and relatively little technological progress. Separating out the effects on TFP of scale economies and technical progress is important for policy decisions. For example, when promoting an industry, the government must decide how subsidies

[1] Komiya (1962) also found that economies of scale are the primary reason for the TFP growth in the U.S. steam power production.

should be divided between the promotion of scale economies and the promotion of technical progress (e.g. research and development). Technology-based firms also face the same choice in making their own investment decisions.

The difficulty in distinguishing between the impact of economies of scale and technical change when using time series data has long been recognized (e.g. Solow (1959) and Koizumi (1968)). There are two main reasons for this difficulty. One is the multicollinearity, for example, among certain production inputs, their prices, output, and the time parameter (a proxy for technical progress) which enter the production (or cost) function as arguments. This problem of multicollinearity is often confounded by the limited variation and ranges of values observed for aggregate time series. The second is the question of whether an increase in aggregate output actually represents an increase in production scale at the level of individual establishments rather than an increase in the number of establishments. Regarding their findings Berndt and Khaled (1979, p. 1221) acknowledge the inherent difficulty of separating the effects of scale economies from technical change when using aggregate time series data and caution the reader by noting that "these results should be interpreted cautiously. In our judgement, more precise estimates of return to scale and rates of technical progress may require use of pooled cross-section and time-series data." Since scale economy effects can be more precisely measured using cross-sectional data rather than aggregate time series data, use of cross-section data should be very effective in identifying econometrically the simultaneous effects of scale economies and technical progress.

In this chapter we will present a method to estimate both scale elasticity and technical progress using time-series of cross section data based on the production function of Translog type. Our estimation method is an extension of the index number method presented in Chapter 3 to a dynamic framework.

Our aim is to obtain statistically significant and consistent estimates for both scale economy and technical progress. We will not attempt to estimate other parameters involved in the production function. We will use cross-sectional information to estimate scale elasticity as before, while we use time-series information to estimate technical progress. We feel that the parsimonious nature of our econometric model is essential for estimating the two parameters of policy interest given serious multicollinearity problems we encounter in estimating flexible form production functions with many unknown parameters. Such multicollinearity problems are often found for both cross sectional and time series data.[2] We find that while significant scale economy effects are found for Japanese manufacturing establishments in the cross-sectional sense, they do not explain the gains in TFP over time; the gains in TFP over 1964-88 are mostly due to technical progress. The organization of the rest of this chapter is as follows.

In Section 2 we generalize our method given in Section 2 to a dynamic framework and present a method for estimating both of return to scale and technical change. Application of these methods to time series of cross section data for Japanese manufacturing industries and empirical results are discussed in Section 3. Aggregation issues related to measuring the contributions to TFP of returns to scale and technical progress are discussed in Section 4. The chapter ends with concluding remarks in Section 5.

4.2. Estimation of Return to Scale and Technical Change Effects Using Pooled Cross Section and Time-Series Data

In order to estimate the effects on total factor productivity (TFP) of scale economies and technical change using time series of cross section data, we assume that the production function for the i−th establishment in period t ($i = 1, 2, \ldots, I,\ t = 1, 2, \ldots, T$) is given by

[2] Efficient estimation based on the fully simultaneous estimation of all unknown parameters is desirable but our computational experiences as well as others' suggest the difficulty of implementing it because of the presence of serious multicollinearity. For example, in a study to estimate scale economies and technical progress (approximated by time) using time series data and a translog production function Chan and Mountain (1983, p. 665) state that "... All these problems point towards the difficulty of distinguishing between scale economies and time at such an aggregate level."

a homogeneous function of degree k

$$(1) \qquad x_{it} = f(v_{it}, t) = \lambda^{-k} f(\lambda v_{it}, t)$$

where x_{it} and v_{it} are, respectively, a scalar output and the production input vector for the i–th establishment in period t, and λ is some positive constant. It will be assumed that the establishments $i = 1, 2, \ldots, I$ are ordered in the ascending order of the size of establishment as before; that is, $i = 1$ denotes the smallest establishment and $i = I$ denotes the largest establishment. (For homogeneous function (1) of degree k, the elasticity of scale is also given by k.)

In order to derive econometric specifications, we assume that the homogeneous production function (1) is of Translog type and that technical progress can be described, as a first-order approximation, by

$$\partial \ln x_{it}/\partial t = \partial \ln f(v_{i,t}, t)/\partial t = r \quad \text{(constant)}.$$

Then we can rewrite (1) as follows:

$$(2) \qquad x_{it} = f(v_{it}, t) = \lambda^{-k} f(\lambda v_{it}, t) = f(v_{it}) e^{rt},$$

where r is the rate of technical progress,[3]

$$(3) \qquad k^{-1} \ln x_{it} = k^{-1} \ln f(v_{it}) + (k^{-1}) rt,$$

and $k^{-1} \ln f(v_{it})$ is given by the Translog function (Equation (22) in Chapter 3).

Suppose an error term enters our specification (2) in multiplicative form:

$$x_{it} = f(v_{it}) e^{rt} e^{u_{it}}, \qquad i = 1, 2, \ldots, I, \; t = 1, 2, \ldots, T,$$

[3] Hicks neutrality as a first approximation is assumed here because severe multicollinearity among input factors and time makes it difficult to estimate the bias of technical change. The change over time of technical change (i.e. $\partial/\partial t(\partial \ln X/\partial t)$) will, however, be identified in our procedure by estimating the period-to-period technical change.

or

$$(4) \qquad \ln x_{it} = \ln f(v_{it}) + rt + u_{it},$$

where the u_{it} satisfy

$$(5a) \qquad E(u_{it}) = 0$$

$$(5b) \qquad E(u_{it}u_{jt}) = \begin{cases} \sigma^2 & \text{if} \quad i = j \\ 0 & \text{otherwise} \end{cases}$$

$$(5c) \qquad E(u_{it}u_{j,t+k}) = \begin{cases} \rho^2 \quad \text{if} \quad i = j,\ k = 1,\ i,j = 1,2,\ldots,I, \\ \qquad 0 \quad \text{otherwise} \quad t = 1,2,\ldots,T, \\ \qquad\qquad\qquad k = 1,2,\ldots,T-t \end{cases}$$

Thus the u_{it} have mean zero, have common variance σ^2, are independently distributed over establishments and have autocovariance ρ^2 between two successive periods. Using Equation (28) in Chapter 3 and (4), we obtain

$$(6) \quad \ln x_{i+1,t} - \ln x_{it} = k(\ln Q_t^{i,i+1}) + \{u_{i+1,t} - u_{it}\},\ i = 1,2,\ldots,I-1,\ t = 1,2,\ldots,T,$$

where $Q^{i,i+1}t$ denotes the Translog input index for period t measured for establishments i and $i+1$.

In order to estimate both the rate of technical progress r and the elasticity of scale k using an econometric specification, it will become necessary to define production input chain index numbers over two successive time periods $t = S,\ S+1$ $(1 \leq S \leq T-1)$, and over establishments of different sizes $i = 1,2,\ldots,I$, as follows. Using the smallest establishment $(i = 1)$ as a base, we define chain index numbers for establishments of different sizes for any time period t

$$
\begin{aligned}
&q_{1t} = 1 \\
&q_{2t} = q_{1t} Q_t^{1,2} = Q_t^{1,2} \\
&q_{3t} = q_{2t} Q_t^{2,3} = Q_t^{1,2} Q_t^{2,3} \\
&\vdots \\
&q_{It} = q_{I-1,t} Q_t^{I-1,I} = \prod_{i=1}^{I-1} Q_t^{i,i+1}
\end{aligned} \tag{7}
$$

Also, using the Translog input quantity index defined for two consecutive time periods S and $S+1$ $(1 \leq S \leq T-1)$ for the i–th establishment

$$
\ln Q^i_{S,S+1} = (1/2)(w_{iS} + w_{i,S+1})'(\ln v_{i,S+1} - \ln v_{i,S}), \tag{8}
$$

we can define chain index numbers for time period $S+1$ as follows:

$$
\begin{aligned}
&q_{1,S+1} = q_{1S} Q^1_{S,S+1} = Q^1_{S,S+1} \\
&q_{2,S+1} = q_{1,S+1} Q^{1,2}_{S+1} = Q^1_{S,S+1} Q^{1,2}_{S+1} \\
&\quad \vdots \\
&q_{I,S+1} = q_{I-1,S+1} Q^{I-1,I}_{S+1} = Q^1_{S,S+1} \prod_{i=1}^{I-1} Q^{i,i+1}_{S+1}
\end{aligned} \tag{9}
$$

It is possible that both the rate of technical change r and the elasticity of scale k vary over time. Our estimation method given below allows for the possibility for such a time-varying nature of r and k by estimating these parameters using establishment data over two consecutive years, starting from years 1 and 2, and then by repeating the estimation task until years $T-1$ and T are reached.

We denote by $a(S)$ and $a(S+1)$ the amounts of theoretical output in years S and $S+1$ $(1 \leq S \leq T-1)$ for the smallest establishment $(i = 1)$ corresponding to input v_{1S}

as follows:

$$(10a) \qquad a(S) = f(v_{1S})e^{rS}$$

$$(10b) \qquad a(S+1) = f(v_{1S})e^{r(S+1)}.$$

Then it is shown (see Appendix A) that the log of output for the i-th establishment for two consecutive time periods $t = S,\ S+1$ satisfies the following equations:

$$(11a) \qquad \ln x_{iS} = \ln a(S) + k \ln q_{iS} + u_{iS}$$

$$(11b) \quad \ln x_{i,S+1} = \ln a(S+1) + k \ln q_{i,S+1} + u_{i,S+1} \ i = 1, 2, \ldots, I, S = 1, 2, \ldots, T-1.$$

Since we have by (10) $r = \ln a(S+1) - \ln a(S)$, we can write (11a) and (11b) in combined regression form

$$(12) \quad \ln x_{it} = b_0 + b_1 D_{it} + b_2 \ln q_{it} + u_{it},\ i = 1, 2, \ldots, I, t = S,\ S+1\ (1 \leq S \leq T-1),$$

where

$$\begin{aligned} D_{it} &= 1 \quad \text{if} \quad t = S+1 \\ &= 0 \quad \text{if} \quad t = S \end{aligned}$$

and $b_0 \equiv \ln a(S),\ b_1 \equiv r,\ b_2 \equiv k$.

Using data on I establishments pooled over two consecutive years, we can estimate equation (12). The constant term b_0 gives an estimate for $\ln a(S)$ while b_1 and b_2 provide estimates, respectively, for the rate of technical change r and the elasticity of scale k. By repeating this estimation process for $S = 1, 2, \ldots, T-1$, we will obtain estimates for $\ln a(S)$, r and k for each of the consecutive years: years 1 and 2, years 2 and 3, ..., years $T-1$ and T.

There are only three unknown parameters to estimate in our econometric specification (12). This is in contrast to the large number of unknown parameters contained in flexible functional forms that have to be estimated relative to the number of available observations on aggregate time series in some studies.[4] Our hope is that our model with much fewer parameters to estimate relative to the sample size will provide more stable estimates for scale economies and technical progress.

In regression equation (12) year dummy D_{it} and Translog input quantity chain index number q_{it} are not expected to be highly correlated.[5] This will allow us to empirically identify both r and k without the sample problem of multicollinearity. Since we allow the error term u_{it} in (12) to obey a first-order autoregressive process, we estimate b_0, b_1 and b_2 using generalized least squares (GLS).

4.3. Empirical Estimates for Technical Change and Economies of Scale: Japanese Manufacturing Industries 1964-1988

In order to estimate equation (12) using our data pooled over time periods as well as over establishments, it is necessary to deflate (1964 = 100) some of the quantities defined in Section 2. The Bank of Japan output price index by industry is used to deflate our output variable x (sales). In computing the capital stock v^2, new investment in fixed assets is deflated using the investment goods deflator by industry published by the Economic Planning Agency. The input price of capital (p^2) is also adjusted by the investment goods deflator. The input of intermediate goods (v^3) is now deflated by the Bank of Japan input price deflator which is also used as the price of intermediate goods (p^3). Because of the lack of correct industry-specific deflators two manufacturing industries, printing and other, will

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[4] In estimating scale economies and technical change using aggregate time series, Berndt and Khaled (1979) and Chan and Mountain (1983), for example, both had to estimate 22 unknown parameters using 25 annual observations.

[5] For our particular data set used, the correlation coefficients calculated for the 18 manufacturing industries are quite small and range between .009 and .025.

be excluded from our empirical analysis to follow. Thus the following empirical analysis will be done using data for 18 manufacturing industries.

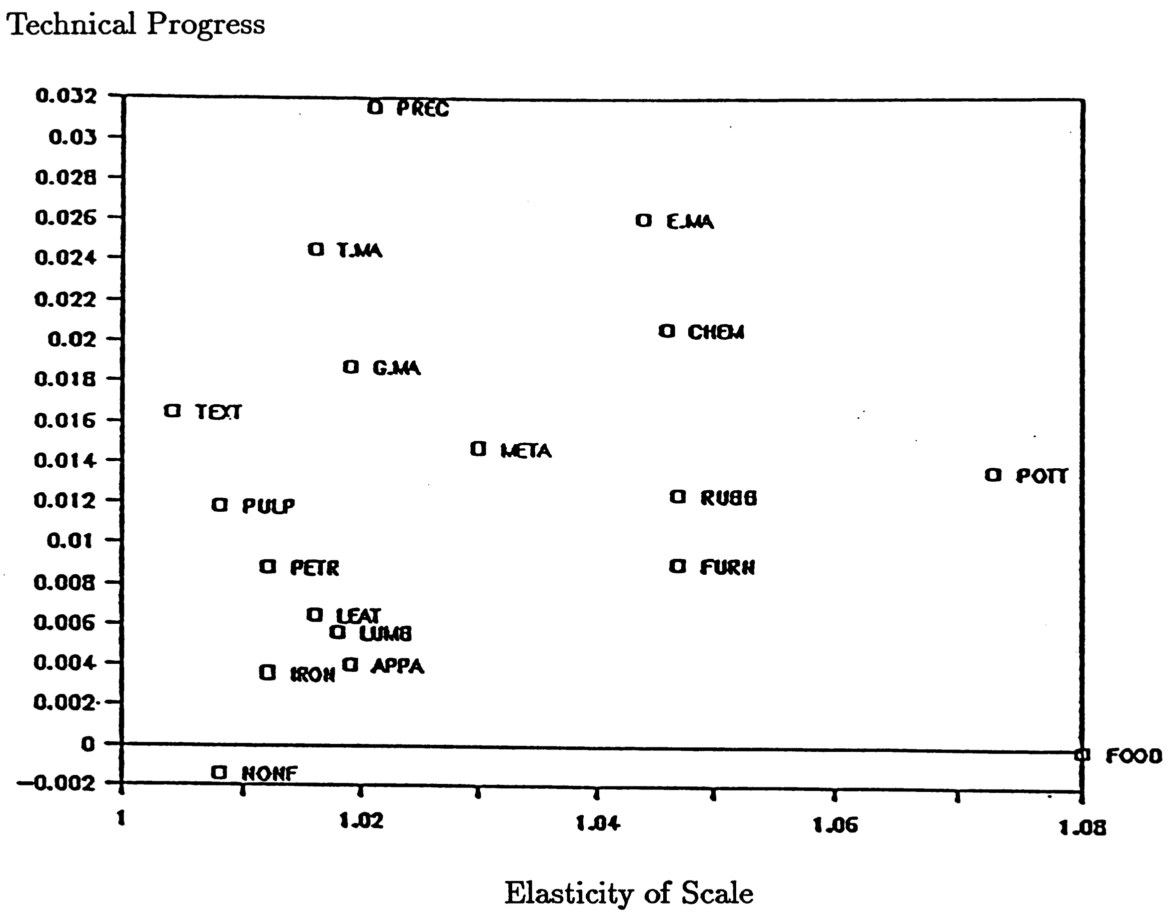
Table 4.1 at the end of the book presents year-to-year GLS estimation results for equation (12) for 1964-1988 for 18 Japanese manufacturing industries included in this study. Industry-specific estimates for $\ln a(S)$, r and k as well as their $t-$ratios averaged over 1964-88 are also given in the last two rows of Table 4.1. Industry-specific estimates for technical progress and the elasticity of scale averaged over 1964–88 are also shown in Figure 4.1.

Estimates for the elasticity of scale, k, are statistically highly significant and relatively stable over time. The null hypothesis $H_0 : k = 1$ is rejected decisively in favor of the alternative $H_1 : k > 1$ for many industries for many time periods, showing the presence of increasing returns to scale. Constant returns to scale (i.e. $k = 1$) cannot be rejected, however, for the textile industry. In addition, Pulp, Non-ferrous Metals as well as Petroleum and Iron and Steel industries show only modest evidence of economies of scale. This does not necessarily imply, however, that there are little increasing returns to scale in these industries. All of these industries contain subindustries which were classified sometime during the sample period as depressed industries by the Ministry of International Trade and Industry and were subject to the Law of Extraordinary Measures for Stabilization of Specific Depressed Industries. It is likely that the excess capacity of large establishments in these depressed industries has tended to lower our estimates for k.[6] It is not possible to control for capacity utilization in depressed subindustries, however, since no published data are available for capacity utilization.

On the other hand, our estimates for r, the rate of technical change, are much smaller

[6] During business downturns it is typical in Japan that small establishments suffer from excess capacity much more than large establishments, resulting in an overestimation of scale elasticity. During 1970s and 1980s when depressed industries were restructured, however, many of the small establishments dropped out of our data sample. When a data sample has a relatively large number of large establishments with idle capacity, scale elasticity is usually underestimated.

FIGURE 4.1[a]. TECHNICAL PROGRESS VS. SCALE ELASTICITY: JAPANESE MANUFACTURING 1964-1988



[a] The 18 manufacturing industries included and their estimated technical progress and scale elasticity coefficients (r and k in Table 4.1) are: FOOD/kindred products ($r = -.0001$, $k = 1.08$), TEXTiles (.0164, 1.004), APPArels (.0040, 1.019), LUMBER/wood products (.0056, 1.018), FURNiture/fixture (.0090, 1.047), PULP/ paper products (.0118, 1.008), CHEMicals (.0206, 1.046), PETROleum/coal products (.0088, 1.012), RUBBer/plastic products (0.124, 1.047), LEATHER/leather products (.0065, 1.016), POTTery/glass products (.0135, 1.073), IRON/steel (.0036, 1.012), NON-Ferrous metals (-.0014, 1.008), METAL products (.0147, 1.030), General MAchinery (.0187, 1.019), Electric MAchinery (.026, 1.044), Transportation MAchinery (.0245, 1.016) and PRECision (.0316, 1.021).

in magnitude, fluctuate more over time and are often not statistically significant.

Figure 4.1 shows that most of the 18 manufacturing industries considered here exhibit scale economies. In particular Pottery and Food/Kindred industries have particularly high estimates (1.07 or higher) for the elasticity of scale. Precision and Transportation Machinery industries, on the other hand, have modest scale elasticities (about 1.02) but very high rates of technical progress (2.5%-3% per year). Electric Machinery industry enjoys both a high rate of technical progress and a large elasticity of scale.

4.4. Contributions of Scale Economies and Technical Change to Aggregate Total Factor Productivity

We found in the previous section that economies of scale, and not technical progress, characterize the production activities of many of the Japanese manufacturing industries at the establishment level. This does not imply, however, that gains in TFP at the aggregate industry level are primarily due to economies of scale rather than technical change.

In order to decompose TFP growth at the aggregate industry level into a scale economy component and technical change component, we first aggregate input indexes and predicted outputs over all establishments in each industry to derive aggregate input and output indexes at the industry level ($D(t)$ and $X(t)$ in Appendix B). The difference between the log ratios of aggregate output and input indexes (B3) is the industry TFP growth, which is then decomposed to show the effects of scale economies and technical change (B7).[7]

[7] A standard way to decompose TFP growth at an aggregate level into scale economy and technical change effects is to use:

$$\underbrace{d\ln TFP/dt}_{\text{TFP growth}} = \underbrace{\{1-(1/k)\}(d\ln X/dt)}_{\text{scale economy}} + \underbrace{\{-(\partial\ln C/\partial T)(\partial\ln T/\partial T\}}_{\text{technical change}}$$

where X is output, $C = C(p_1(t), \ldots, p_n(t),\ X(t),\ T(t))$ is a cost function and T is technology (often approximated by time t). The first term on the right-hand side vanishes under constant returns to scale ($k = 1$). In addition to the potential problem of nonexistence of

Using equation (B7) and our estimates for the elasticity of scale and the rate of technical change we decompose TFP at the industry level. (Further details of this decomposition are explained in Appendix B.) Year-by-year decomposition results for the 18 manufacturing industries are given in Table 4.2 at the end of the book. The estimated effects of scale economies on TFP are generally very small.[8] This is in contrast to the large contribution of technical change. These results are summarized in Table 4.3 in which the change in TFP, the effects on the change in TFP of technical progress and scale economies, and the contributions in percent of these effects averaged over 1964-1988, are presented. More than 90% of the increase in TFP during this period is due to technical change. On the other hand the effects of scale economies are quite small in general. These results support the standard practice in macro econometric modeling (e.g. Solow (1957) and Jorgenson, Gollop and Fraumeni (1987)) that attributes gains in TFP at the aggregate level to technical progress by specifying an aggregate production function which is homogeneous of degree one.

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an aggregate production function when constant returns to scale cannot be assumed, we have a serious multicollinearity problem, as we have argued in this paper, in estimating both scale economy and technical change parameters, k and $(\partial \ln C/\partial T)$, using aggregate data.

[8] Notable exceptions are Chemicals (1972-73), Rubber/Plastics (1987-88), Pottery/Glass Products (1987-88), Iron/Steel (1987-88), Electric Machinery (1983-84) and Transportation Machinery (1987-88) for which TFP gains exceeded 0.01 and the contributions of scale economies to TFP gains exceeded those of technical change. It is of interest to note that many of these TFP gains due to scale economies can be traced back to the (identifiable) addition of new production capacity which became available in these industries in these specific calendar years.

Table 4.3. Decomposition of Average Annual Gains in TFP

1964-1988[a]

Industry	TFP Gains[b]	Technical Change (E_1)[c]	Scale Economies (E_2)[c]	ΔTFP[d]
Food/Kindred Products	0.02167	0.02072 (96%)	0.00095 (4)	0.01879
Textiles	0.02281	0.02279 (100)	0.00002 (0)	0.02152
Apparels	0.05027	0.05058 (101)	-0.00031 (-1)	0.04966
Lumber/Wood Products	0.02313	0.02213 (96)	0.00100 (4)	0.02146
Furniture/Fixture	0.04135	0.04016 (97)	0.00119 (3)	0.03858
Pulp/Paper Products	0.02961	0.02925 (99)	0.00036 (1)	0.01639
Chemicals	0.02956	0.02874 (97)	0.00082 (3)	0.02398
Petroleum/Coal Products	0.05489	0.05478 (100)	0.00011 (0)	0.04516
Rubber/Plastic Products	0.04627	0.04207 (91)	0.00420 (9)	0.03836
Leather/Leather Products	0.03996	0.03836 (96)	0.00160 (4)	0.03810
Pottery/Glass Products	0.03192	0.03292 (103)	-0.00100 (-3)	0.02376
Iron/Steel	0.04480	0.03434 (77)	0.01046 (23)	0.01941
Non-Ferrous Metals	0.03759	0.03691 (98)	0.00068 (2)	0.02581
Metal Products	0.03218	0.03224 (100)	-0.00006 (0)	0.03129
General Machinery	0.02707	0.02479 (92)	0.00228 (8)	0.02009
Electrical Machinery	0.05186	0.04667 (90)	0.00519 (10)	0.04370
Transportation Machinery	0.04332	0.03983 (92)	0.00349 (8)	0.03074
Precision	0.04324	0.04163 (96)	0.01161 (4)	0.03826

[a] Values in this table were calculated using those cases for which the estimated rates of technical change are positive and estimated scale elasticities are greater than one.

[b] These are based on (B3) in text.

[c] These were based on (B7) in text. Numbers in parentheses are percentage contributions.

[d] ΔTFP denotes gains in TFP based on (B1) in text.

4.5. Concluding Remarks

We have presented econometric methods for estimating the elasticity of scale in Chapter 3 and also both the elasticity of scale and the rate of technical change using establishment data grouped by size and pooled over time in this chapter. Our estimation methods are based on index number theory and may be viewed as an extension of the nonparametric approach proposed by Frisch (1965) to deal with serious multicollinearity problems in estimating scale elasticities. Because of the small number of parameters to be estimated, and because of the explanatory variables included in our model which are generally not highly correlated, our estimation results for Japanese manufacturing industries are quite stable and satisfactory. We have found empirical evidence for the presence of substantial scale economies and modest technical progress for the period 1964-1988 at the establishment level. Estimates for the sources of aggregate (macro) TFP were calculated by aggregating estimation results derived at the establishment (micro) level. The change over time in aggregate TFP is explained primarily by technical progress. These findings provide a justification for the standard practice of using a homogeneous production function of degree one (which attributes gains in TFP to technical change) in macro econometric modeling.

Our findings that the effects of scale economies exist at the establishment level but disappear at the aggregate level imply, among other things, that the establishment size does not adjust rapidly within the time period we consider. That is, large establishments do not grow fast at the expense of small establishments. It is the slowly changing technical level that explains most of the gains in aggregate TFP in the Japanese manufacturing sector.

Appendix A. Derivation of Equations (11a-b)

I. Derivation of Equation (11a)

Combining equation (4) for $i = 1$ and $t = S$ with equation (10a) and (9) gives (11a) for $i = 1$:

$$(A1) \qquad \ln x_{1S} = \ln a(S) + k \ln q_{1S} + u_{1S}, \text{ where } \ln q_{1S} \equiv 0.$$

From (6) we obtain:

$$(A2a) \qquad \ln x_{2S} - \ln x_{1S} = k(\ln Q_S^{1,2}) + (u_{2S} - u_{1S})$$

$$(A2b) \qquad \ln x_{3S} - \ln x_{2S} = k(\ln Q_S^{2,3}) + (u_{3S} - u_{2S})$$

$$\ldots$$

$$(A2c) \qquad \ln x_{iS} - \ln x_{i-1,S} = k(\ln Q_S^{i-1,i}) + (u_{iS} - u_{i-1,S}).$$

Adding equation (A2a) to (A1) and using (7), we get

$$(A3) \qquad \ln x_{2S} = \ln a(S) + k \ln q_{2S} + u_{2S}.$$

Adding equation (A2b) to (A3) and using (7), we get

$$(A4) \qquad \ln x_{3S} = \ln a(S) + k \ln q_{3S} + u_{3S}.$$

Continuing in this manner, we obtain (11a) in general.

II. Derivation of Equation (11b)

Using (4) for $i = 1$ and $t = S + 1$, we have

$$(A5) \qquad \ln x_{1,S+1} = \ln f(v_{1,S+1}) + r(S + 1) + u_{1,S+1}.$$

We also have

$$(A6) \qquad v_{1,S+1} = v_{1S} Q^1_{S,S+1}$$

by the definition of input index $Q^1_{S,S+1}$ and

$$(A7) \qquad \ln f(v_{1,S+1}) = \ln f(v_{1S} Q^1_{S,S+1}) = \ln f(v_{1S}) Q(^1_{S,S+1})^k$$

where the second equality in (A7) holds since the production function is homogeneous of degree k ((2)). Substituting (A7) into (A5) and using (10b) and (9), we obtain

$$(A8) \qquad \begin{aligned} \ln x_{1,S+1} &= \ln f(v_{1S}) + r(S+1) + k \ln Q^1_{S,S+1} + u_{1,S+1} \\ &= \ln a(S+1) + k \ln q_{1,S+1} + u_{1,S+1} \end{aligned}$$

which is equation (11b) for $i = 1$.

From (6) we get

$$(A9a) \qquad \ln x_{2,S+1} - \ln x_{1,S+1} = k(\ln Q^{1,2}_{S+1}) + u_{2,S+1} - u_{1,S+1},$$

$$(A9b) \qquad \ln x_{3,S+1} - \ln x_{2,S+1} = k(\ln Q^{2,3}_{S+1}) + u_{3,S+1} - u_{2,S+1},$$

$$\ldots$$

$$(A9c) \qquad \ln x_{i,S+1} - \ln x_{i-1,S+1} = k(\ln Q^{i-1,i}_{S+1}) + u_{i,S+1} - u_{i-1,S+1}.$$

Adding equation (A8) to (A9a), and using (9), we get

$$(A10) \qquad \ln x_{2,S+1} = \ln a(S+1) + k \ln q_{2,S+1} + u_{2,S+1}$$

which is equation (11b) for $i = 2$. Adding equation (A9b) to (A10), and using (9), we get

$$(A11) \qquad \ln x_{3,S+1} = \ln a(S+1) + k \ln q_{3,S+1} + u_{3,S+1}$$

which is equation (10b) for $i = 3$. Continuing in a similar manner equation (11b) is shown to hold for any i $(i = 1, 2, ..., I)$ in general.

Appendix B. Decomposition of the Sources of Total Factor Productivity into the Effects due to Scale Economies and Technical Change

A standard way to measure the change in TFP is

$$(B1) \qquad \ln \frac{TFP(t+1)}{TFP(t)} = \ln \frac{X(t+1)}{X(t)} - \sum_{j=1}^{n} 1/2\{w_j(t) + w_j(t+1)\} \ln \frac{v_j(t+1)}{v_j(t)},$$

where aggregate output X and aggregate production input indices v_j are defined by

$$(B2a) \qquad X(t) = N(t) \int_0^\infty x dF_t(x),$$

and

$$(B2b) \qquad v_j(t) = N(t) \int_0^\infty v_j d\phi_t(v_j),$$

and where $w_j(t)$ denotes the cost share for the j−th aggregate production input. In (B2a-b), $N(t)$ is the total number of establishments in period t, x and v_j are random variables representing, respectively, the output and the j−th production input for a representative establishment, and $F_t(x)$ and $\phi_t(v_j)$ denote the distribution functions for random variables x and v_j in period t. (Strictly speaking, Equation (B1) is a valid measure of TFP growth under the assumption of constant returns to scale. This assumption seems satisfied at the industry level in this study. See Chan and Mountain (1983) for a modification of (B1) when constant returns to scale cannot be assumed.)

Another way to compute the change in TFP which is more consistent with our model for individual establishments is the following:

$$(B3) \qquad \ln \frac{\Phi(t+1)}{\Phi(t)} = \ln \frac{X(t+1)}{X(t)} - \ln \frac{D(t+1)}{D(t)},$$

where $\Phi(t+1)/\Phi(t)$ denotes a new measure for the change in TFP defined by (B3) and

$D(t)$ represents an aggregate production input index defined by

$$D(t) = N(t) \int_0^{\infty} q dG_t(q). \tag{B4}$$

In (B4) q is a random variable representing a production input index for an establishment and $G_t(q)$ is the distribution function for q in period t.

Ignoring the error term in (11a), we can write output x as follows:

$$x = a(t)q^k. \tag{B5}$$

Substituting (B5) and (B4) into (B3), we obtain

$$\begin{aligned} \ln \frac{\Phi(t+1)}{\Phi(t)} = & \ln \frac{N(t+1) \int_0^{\infty} a(t+1) q^k dG_{t+1}(q) |J_{t+1}|}{N(t) \int_0^{\infty} a(t) q^k dG_t(q) |J_t|} \\ & - \ln \frac{N(t+1) \int_0^{\infty} q dG_{t+1}(q)}{N(t) \int_0^{\infty} q dG_t(q)}, \end{aligned} \tag{B6}$$

where $|Jt|$ denotes the Jacobian corresponding to the transformation (B5) such that $J_t = (dx/dq)$ if q is a continuous random variable and $J_t = 1$ if q is a discrete random variable. (In our case q is a discrete random variable and hence $J_t = 1$.) Rewriting (B6), we obtain

$$\ln \frac{\Phi(t+1)}{\Phi(t)} = E_1 + E_2, \tag{B7}$$

where

$$E_1 = \ln \frac{N(t+1) \int_0^{\infty} a(t+1) q^k dG_{t+1}(q) |J_{t+1}|}{N(t) \int_0^{\infty} a(t+1) q^k dG_t(q) |J_t|} - \ln \frac{N(t+1) \int_0^{\infty} q dG_{t+1}(q)}{N(t) \int_0^{\infty} q dG_t(q)}, \tag{B8}$$

and

$$E_2 = \ln \frac{N(t) \int_0^{\infty} a(t+1) q^k dG_t(q) |J_t|}{N(t) \int_0^{\infty} a(t) q^k dG_t(q) |J_t|} - \ln \frac{N(t) \int_0^{\infty} q dG_t(q)}{N(t) \int_0^{\infty} q dG_t(q)}. \tag{B9}$$

E_1 measures the gains in TFP due to the economies of scale while E_2 measures the gains in TFP due to technical progress. Both E_1 and E_2 can be evaluated using establishment data and estimated parameters $a(t)$ and k both of which are statistically highly significant.

Finally it is of interest to compare TFP growth calculated by (B1) and by (B3). The differences in estimated TFP growth using (B1) and (B3) for manufacturing industries averaged over 1964-1988 are presented in Table 4.B1. We see from Table 4.B1 that the estimates we get from (B1) and (B3) for TFP growth are quite close. Absolute deviations between these two types of estimates range from 0.06% to 2.5%. In our present application the calculation based on (B3) leads to a natural decomposition of TFP growth given by (B7). Yet, because our estimates based on (B3) are very close to the estimates based on the standard formula (B1), we conclude that our decomposition results reported in Table 4.3 also hold for the TFP growth measured by (B1).

Table 4.B1. Percentage point differences in measured annual changes in aggregate TFP for manufacturing industries

1964-1988[a]

Industry	% Point Differences
Food/Kindred Products	0.288
Textiles	0.129
Apparels	0.061
Lumber/Wood Products	0.167
Furniture/Fixture	0.277
Pulp/Paper Products	1.322
Chemicals	0.558
Petroleum/Coal Products	0.973
Rubber/Plastic Products	0.791
Leather/Leather Products	0.186
Pottery/Glass Products	0.816
Iron/Steel	2.539
Non-Ferrous Metals	1.178
Metal Products	0.089
General Machinery	0.698
Electrical Machinery	0.816
Transportation Machinery	1.258
Precision	0.498

[a] Calculated as the annual average over 1964–1988 of $(|(\mathrm{TFP}(t+1)/\mathrm{TFP}(t) - \Phi(t+1)/\Phi(t)|)/(|\Phi(t+1)/\Phi(t)|)$ where $\mathrm{TFP}(t+1)/\mathrm{TFP}(t)$ and $\Phi(t+1)/\Phi(t)$ are defined by (B1) and (B3), respectively.

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TABLE 3.1 ESTIMATED SCALE ELASTICITY

FOOD, KINDRED PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0605755	(1.1042)	0.0296818	(1.1032)	0.0296497	(1.1037)	0.0296643	(1.1036)	OK	K>1	OK	8
1965	1.0565416	(1.0820)	0.0209386	(1.0823)	0.0210980	(1.0821)	0.0210178	(1.0819)	OK	K>1	OK	8
1966	1.0629740	(1.0797)	0.0173324	(1.0787)	0.0167287	(1.0792)	0.0170300	(1.0790)	OK	K>1	OK	8
1967	1.0541564	(1.0778)	0.0144659	(1.0769)	0.0141091	(1.0774)	0.0142836	(1.0771)	OK	K>1	OK	8
1968	1.0610571	(1.0784)	0.0163296	(1.0767)	0.0156204	(1.0775)	0.0159717	(1.0774)	OK	K>1	OK	7
1969	1.0779077	(0.0216)	1.0782217	(0.0216)	1.0780649	(0.0216)	1.0780354	(0.0216)	K>1	K>1	OK	7
1970	1.0797722	(0.0160)	1.0798388	(0.0158)	1.0798059	(0.0159)	1.0797698	(0.0159)	K>1	K>1	OK	7
1971	1.0819772	(0.0179)	1.0817108	(0.0176)	1.0818455	(0.0177)	1.0817471	(0.0177)	K>1	K>1	OK	7
1972	1.0981731	(0.0213)	1.0966108	(0.0213)	1.0973947	(0.0213)	1.0971715	(0.0213)	K>1	K>1	OK	7
1973	1.0978077	(0.0182)	1.0973884	(0.0178)	1.0975994	(0.0180)	1.0974891	(0.0180)	K>1	K>1	OK	7
1974	1.0742908	(0.0107)	1.0737901	(0.0101)	1.0740418	(0.0104)	1.0739365	(0.0103)	K>1	K>1	OK	7
1975	1.0612088	(0.0107)	1.0603773	(0.0104)	1.0607944	(0.0106)	1.0606470	(0.0105)	K>1	K>1	OK	7
1976	1.0923076	(0.0199)	1.0903663	(0.0190)	1.0913399	(0.0194)	1.0910457	(0.0194)	K>1	K>1	OK	6
1977	1.0962446	(0.0160)	1.0936534	(0.0153)	1.0949521	(0.0156)	1.0946507	(0.0155)	K>1	K>1	OK	6
1978	1.1081128	(0.0181)	1.1078182	(0.0175)	1.1079696	(0.0178)	1.1077493	(0.0177)	K>1	K>1	OK	6
1979	1.1029289	(0.0210)	1.1026761	(0.0207)	1.1028028	(0.0209)	1.1027547	(0.0208)	K>1	K>1	OK	6
1980	1.1132157	(0.0188)	1.1120022	(0.0182)	1.1126099	(0.0185)	1.1125262	(0.0185)	K>1	K>1	OK	6
1981	1.1026795	(0.0291)	1.1022244	(0.0290)	1.1024525	(0.0291)	1.1023521	(0.0290)	K>1	K>1	OK	6
1982	1.1029491	(0.0385)	1.1014322	(0.0389)	1.1021922	(0.0387)	1.1020081	(0.0387)	K>1	K>1	OK	6
1983	1.1059411	(0.0361)	1.1031794	(0.0364)	1.1045616	(0.0362)	1.1042164	(0.0363)	K>1	K>1	OK	6
1984	1.1042308	(0.0297)	1.1032198	(0.0296)	1.1037255	(0.0297)	1.1036099	(0.0296)	OK	OK	OK	3
1985	1.0819711	(0.0209)	1.0822675	(0.0211)	1.0821194	(0.0210)	1.0818752	(0.0209)	K>1	K>1	OK	4
1986	1.0797186	(0.0173)	1.0786543	(0.0167)	1.0791866	(0.0170)	1.0789989	(0.0170)	K>1	K>1	OK	5
1987	1.0778277	(0.0145)	1.0768979	(0.0141)	1.0773632	(0.0143)	1.0771472	(0.0142)	K>1	K>1	OK	6
1988	1.0783581	(0.0163)	1.0767071	(0.0156)	1.0775329	(0.0160)	1.0773712	(0.0159)	K>1	K>1	OK	6

TEXTILE MILL PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	0.9931887	(1.0082)	0.0085995	(1.0104)	0.0086867	(1.0093)	0.0086413	(1.0093)	OK	OK	OK	8
1965	0.9870106	(1.2753)	0.0590192	(1.2736)	0.0583963	(1.2744)	0.0587064	(1.2741)	OK	K>1	OK	8
1966	0.9884605	(1.2401)	0.0640169	(1.2396)	0.0635268	(1.2398)	0.0637716	(1.2397)	OK	K>1	OK	8
1967	0.9915834	(1.2251)	0.0541727	(1.2256)	0.0534410	(1.2254)	0.0538062	(1.2253)	OK	K>1	OK	8
1968	0.9935692	(1.2498)	0.0459932	(1.2526)	0.0462859	(1.2512)	0.0461373	(1.2511)	OK	K>1	OK	7
1969	0.9857572	(0.0038)	0.9855989	(0.0039)	0.9856781	(0.0038)	0.9857050	(0.0038)	K<1	K<1	OK	7
1970	0.9846552	(0.0049)	0.9846682	(0.0051)	0.9846617	(0.0050)	0.9846732	(0.0050)	K<1	K<1	OK	7
1971	0.9899273	(0.0048)	0.9903448	(0.0049)	0.9901360	(0.0048)	0.9901385	(0.0048)	OK	OK	OK	7
1972	0.9939255	(0.0049)	0.9944444	(0.0049)	0.9941849	(0.0049)	0.9941815	(0.0049)	OK	OK	OK	7
1973	1.0085768	(0.0031)	1.0086556	(0.0031)	1.0086162	(0.0031)	1.0086389	(0.0031)	K>1	K>1	OK	7
1974	1.0008654	(0.0034)	1.0022739	(0.0033)	1.0015693	(0.0034)	1.0015792	(0.0034)	OK	OK	OK	7
1975	0.9711794	(0.0100)	0.9736732	(0.0099)	0.9724249	(0.0100)	0.9723861	(0.0100)	K<1	K<1	OK	7
1976	0.9851736	(0.0083)	0.9874195	(0.0082)	0.9862953	(0.0083)	0.9862723	(0.0083)	OK	OK	OK	6
1977	0.9765434	(0.0069)	0.9796498	(0.0064)	0.9780949	(0.0067)	0.9781376	(0.0066)	K<1	K<1	OK	6
1978	1.0111037	(0.0154)	1.0102315	(0.0145)	1.0106701	(0.0149)	1.0105637	(0.0149)	OK	OK	OK	6
1979	1.0189992	(0.0083)	1.0209760	(0.0080)	1.0199868	(0.0082)	1.0199596	(0.0082)	OK	OK	OK	3
1980	1.0069780	(0.0117)	1.0073776	(0.0109)	1.0071799	(0.0113)	1.0070849	(0.0113)	OK	OK	OK	6
1981	0.9957323	(0.0166)	0.9976442	(0.0170)	0.9966875	(0.0168)	0.9966621	(0.0168)	OK	OK	OK	4
1982	0.9960099	(0.0149)	0.9973862	(0.0152)	0.9966977	(0.0151)	0.9966770	(0.0151)	OK	OK	OK	4
1983	1.0043309	(0.0101)	1.0064893	(0.0102)	1.0054090	(0.0101)	1.0054019	(0.0101)	OK	OK	OK	4
1984	1.0081732	(0.0086)	1.0104130	(0.0087)	1.0092919	(0.0086)	1.0092649	(0.0086)	OK	OK	OK	3
1985	1.2753388	(0.0590)	1.2735603	(0.0584)	1.2744494	(0.0587)	1.2740619	(0.0587)	K>1	K>1	OK	4
1986	1.2400835	(0.0640)	1.2396095	(0.0635)	1.2398466	(0.0638)	1.2397359	(0.0638)	K>1	K>1	OK	5
1987	1.2250985	(0.0542)	1.2256345	(0.0534)	1.2253670	(0.0538)	1.2252894	(0.0538)	K>1	K>1	OK	6
1988	1.2497618	(0.0460)	1.2526321	(0.0463)	1.2511958	(0.0461)	1.2510965	(0.0461)	K>1	K>1	OK	4

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

APPAREL, OTHER TEXTILE PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	0.9938501	(1.1528)	0.0839842	(1.1555)	0.0801021	(1.1542)	0.0820460	(1.1537)	OK	OK	OK	7
1965	0.9991183	(1.0062)	0.0067015	(1.0083)	0.0070839	(1.0072)	0.0068918	(1.0072)	OK	OK	OK	7
1966	0.9992799	(1.0089)	0.0189263	(1.0108)	0.0193024	(1.0099)	0.0191132	(1.0098)	OK	OK	OK	7
1967	0.9972369	(1.0235)	0.0157896	(1.0247)	0.0163930	(1.0241)	0.0160831	(1.0240)	OK	OK	OK	7
1968	1.0050115	(1.0140)	0.0163247	(1.0160)	0.0170000	(1.0150)	0.0166592	(1.0150)	OK	OK	OK	7
1969	0.9977870	(0.0075)	0.9990205	(0.0080)	0.9984038	(0.0078)	0.9984012	(0.0078)	OK	OK	OK	5
1970	1.0029765	(0.0088)	1.0049355	(0.0089)	1.0039552	(0.0088)	1.0039516	(0.0088)	OK	OK	OK	5
1971	0.9917670	(0.0041)	0.9937049	(0.0039)	0.9927352	(0.0040)	0.9927402	(0.0040)	OK	OK	OK	5
1972	1.0203244	(0.0120)	1.0225370	(0.0117)	1.0214298	(0.0118)	1.0214482	(0.0118)	OK	OK	OK	5
1973	1.0450787	(0.0208)	1.0566535	(0.0198)	1.0508621	(0.0202)	1.0502139	(0.0202)	OK	K>1	OK	7
1974	1.0279623	(0.0115)	1.0317933	(0.0116)	1.0298744	(0.0115)	1.0298627	(0.0115)	OK	OK	OK	5
1975	1.0518967	(0.0064)	1.0544141	(0.0066)	1.0531540	(0.0065)	1.0531377	(0.0065)	K>1	K>1	OK	5
1976	1.0158018	(0.0112)	1.0255090	(0.0100)	1.0206354	(0.0106)	1.0206449	(0.0106)	OK	OK	OK	5
1977	1.0202155	(0.0054)	1.0395541	(0.0078)	1.0298104	(0.0063)	1.0293880	(0.0061)	K>1	K>1	NO	4
1978	1.0485730	(0.0105)	1.0536872	(0.0106)	1.0511243	(0.0105)	1.0511734	(0.0105)	K>1	K>1	OK	4
1979	1.0925575	(0.0308)	1.0954812	(0.0295)	1.0940200	(0.0302)	1.0938568	(0.0300)	K>1	K>1	OK	5
1980	1.0999953	(0.0300)	1.1041294	(0.0306)	1.1020588	(0.0303)	1.1021817	(0.0304)	K>1	K>1	OK	5
1981	1.0261147	(0.0106)	1.0294752	(0.0113)	1.0277955	(0.0109)	1.0277636	(0.0109)	OK	OK	OK	5
1982	1.0190661	(0.0039)	1.0340525	(0.0056)	1.0265129	(0.0045)	1.0264739	(0.0045)	K>1	K>1	NO	5
1983	1.1656879	(0.0812)	1.1690858	(0.0793)	1.1673899	(0.0802)	1.1667175	(0.0794)	OK	OK	OK	6
1984	1.1527975	(0.0840)	1.1554928	(0.0801)	1.1541615	(0.0820)	1.1536965	(0.0817)	OK	OK	OK	3
1985	1.0061653	(0.0067)	1.0082890	(0.0071)	1.0072261	(0.0069)	1.0072070	(0.0069)	OK	OK	OK	4
1986	1.0088967	(0.0189)	1.0108168	(0.0193)	1.0098560	(0.0191)	1.0098309	(0.0191)	OK	OK	OK	5
1987	1.0234522	(0.0158)	1.0247389	(0.0164)	1.0240961	(0.0161)	1.0240135	(0.0161)	OK	OK	OK	6
1988	1.0139814	(0.0163)	1.0159552	(0.0170)	1.0149679	(0.0167)	1.0150031	(0.0166)	OK	OK	OK	4

LUMBER, WOOD PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0140681	(1.1060)	0.0420747	(1.0936)	0.0366626	(1.0998)	0.0393319	(1.1001)	OK	K>1	OK	8
1965	1.0176799	(1.0234)	0.0254350	(1.0257)	0.0242410	(1.0245)	0.0248346	(1.0238)	OK	OK	OK	8
1966	1.0155614	(1.1376)	0.0807048	(1.1406)	0.0790133	(1.1391)	0.0798608	(1.1390)	OK	OK	OK	8
1967	0.9997115	(1.1510)	0.0706476	(1.1536)	0.0701199	(1.1523)	0.0703841	(1.1522)	OK	OK	OK	8
1968	1.0050603	(1.1562)	0.0743795	(1.1599)	0.0744248	(1.1581)	0.0744010	(1.1575)	OK	OK	OK	7
1969	1.0136272	(0.0030)	1.0137297	(0.0029)	1.0136785	(0.0029)	1.0136440	(0.0029)	K>1	K>1	OK	7
1970	1.0338961	(0.0049)	1.0349733	(0.0049)	1.0344345	(0.0049)	1.0343911	(0.0049)	K>1	K>1	OK	7
1971	1.0140563	(0.0109)	1.0159826	(0.0112)	1.0150187	(0.0110)	1.0150081	(0.0110)	OK	OK	OK	7
1972	1.0245344	(0.0041)	1.0255136	(0.0041)	1.0250237	(0.0041)	1.0250040	(0.0041)	K>1	K>1	OK	7
1973	1.0521433	(0.0102)	1.0530814	(0.0102)	1.0526122	(0.0102)	1.0525901	(0.0102)	K>1	K>1	OK	5
1974	1.0006021	(0.0043)	1.0024357	(0.0043)	1.0015182	(0.0043)	1.0014487	(0.0043)	OK	OK	OK	5
1975	0.9989040	(0.0029)	1.0000178	(0.0031)	0.9994607	(0.0030)	0.9994040	(0.0030)	OK	OK	OK	5
1976	1.0087184	(0.0123)	1.0102928	(0.0123)	1.0095051	(0.0123)	1.0094822	(0.0123)	OK	OK	OK	4
1977	1.0214162	(0.0121)	1.0228698	(0.0121)	1.0221425	(0.0121)	1.0221500	(0.0121)	OK	OK	OK	4
1978	1.0088187	(0.0122)	1.0123195	(0.0125)	1.0105666	(0.0124)	1.0105114	(0.0124)	OK	OK	OK	5
1979	1.0057823	(0.0066)	1.0080873	(0.0069)	1.0069336	(0.0067)	1.0069040	(0.0067)	OK	OK	OK	5
1980	0.9842207	(0.0114)	0.9864983	(0.0115)	0.9853582	(0.0115)	0.9853515	(0.0115)	OK	OK	OK	5
1981	0.9933589	(0.0181)	0.9958442	(0.0183)	0.9946001	(0.0182)	0.9946503	(0.0182)	OK	OK	OK	5
1982	1.0113789	(0.0172)	1.0149941	(0.0172)	1.0131835	(0.0172)	1.0131904	(0.0172)	OK	OK	OK	5
1983	1.1224616	(0.0367)	1.1114023	(0.0319)	1.1169240	(0.0343)	1.1171323	(0.0344)	K>1	K>1	OK	5
1984	1.1060373	(0.0421)	1.0935696	(0.0367)	1.0997923	(0.0393)	1.1000925	(0.0394)	OK	OK	OK	3
1985	1.0234023	(0.0254)	1.0256835	(0.0242)	1.0245447	(0.0248)	1.0238491	(0.0247)	OK	OK	OK	4
1986	1.1376067	(0.0807)	1.1406209	(0.0790)	1.1391159	(0.0799)	1.1390286	(0.0796)	OK	OK	OK	5
1987	1.1510024	(0.0706)	1.1536154	(0.0701)	1.1523081	(0.0704)	1.1522489	(0.0702)	OK	OK	OK	6
1988	1.1562368	(0.0744)	1.1599150	(0.0744)	1.1580738	(0.0744)	1.1575209	(0.0739)	OK	OK	OK	6

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

FURNITURE, FIXTURES

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0029456	(1.1508)	0.0376564	(1.1571)	0.0367932	(1.1540)	0.0372188	(1.1535)	OK	K>1	OK	7
1965	1.0066709	(1.0367)	0.0170700	(1.0221)	0.0123196	(1.0294)	0.0145381	(1.0290)	OK	OK	OK	7
1966	1.0067326	(1.1567)	0.0341399	(1.1367)	0.0257198	(1.1467)	0.0298491	(1.1455)	OK	K>1	OK	7
1967	1.0097195	(1.1522)	0.0316403	(1.1391)	0.0255994	(1.1457)	0.0285805	(1.1451)	OK	K>1	OK	7
1968	1.0350304	(1.1268)	0.0294149	(1.1155)	0.0243954	(1.1211)	0.0268768	(1.1199)	OK	K>1	OK	5
1969	1.0263838	(0.0059)	1.0264162	(0.0060)	1.0264000	(0.0060)	1.0264417	(0.0060)	K>1	K>1	OK	5
1970	1.0418586	(0.0082)	1.0425378	(0.0084)	1.0421982	(0.0083)	1.0421917	(0.0083)	K>1	K>1	OK	6
1971	1.0180787	(0.0129)	1.0214694	(0.0132)	1.0197725	(0.0130)	1.0197176	(0.0130)	OK	OK	OK	6
1972	1.0487821	(0.0147)	1.0499878	(0.0150)	1.0493847	(0.0148)	1.0493611	(0.0148)	K>1	K>1	OK	6
1973	1.0393989	(0.0106)	1.0412050	(0.0109)	1.0403017	(0.0107)	1.0402694	(0.0107)	K>1	K>1	OK	6
1974	1.0318978	(0.0075)	1.0322701	(0.0075)	1.0320839	(0.0075)	1.0321355	(0.0075)	K>1	K>1	OK	6
1975	1.0203741	(0.0045)	1.0222653	(0.0044)	1.0213189	(0.0045)	1.0213973	(0.0044)	K>1	K>1	OK	6
1976	1.0349203	(0.0083)	1.0377350	(0.0089)	1.0363262	(0.0086)	1.0363706	(0.0086)	K>1	K>1	OK	5
1977	1.0473799	(0.0185)	1.0499957	(0.0184)	1.0486862	(0.0184)	1.0488953	(0.0185)	OK	OK	OK	5
1978	1.0620656	(0.0363)	1.0652434	(0.0361)	1.0636527	(0.0362)	1.0635983	(0.0362)	OK	OK	OK	5
1979	1.0634963	(0.0174)	1.0648505	(0.0175)	1.0641731	(0.0174)	1.0641935	(0.0175)	K>1	K>1	OK	5
1980	1.0638211	(0.0143)	1.0659585	(0.0142)	1.0648889	(0.0142)	1.0648772	(0.0142)	K>1	K>1	OK	5
1981	1.0665539	(0.0065)	1.0693216	(0.0065)	1.0679362	(0.0065)	1.0679036	(0.0065)	K>1	K>1	OK	5
1982	1.0663233	(0.0103)	1.0675458	(0.0101)	1.0669347	(0.0102)	1.0669614	(0.0102)	K>1	K>1	OK	5
1983	1.1337707	(0.0290)	1.1368559	(0.0285)	1.1353169	(0.0287)	1.1351170	(0.0286)	K>1	K>1	OK	4
1984	1.1508263	(0.0377)	1.1571035	(0.0368)	1.1539587	(0.0372)	1.1534626	(0.0372)	OK	OK	OK	3
1985	1.0366546	(0.0171)	1.0220851	(0.0123)	1.0293523	(0.0145)	1.0290330	(0.0145)	OK	OK	OK	4
1986	1.1566834	(0.0341)	1.1367372	(0.0257)	1.1466796	(0.0298)	1.1455235	(0.0295)	K>1	K>1	OK	5
1987	1.1522271	(0.0316)	1.1390967	(0.0256)	1.1456537	(0.0286)	1.1450949	(0.0284)	K>1	K>1	OK	6
1988	1.1267539	(0.0294)	1.1155489	(0.0244)	1.1211442	(0.0269)	1.1199414	(0.0265)	K>1	K>1	OK	5

PULP, PAPER PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0161441	(1.0443)	0.0071026	(1.0341)	0.0046298	(1.0392)	0.0058248	(1.0431)	OK	K>1	OK	8
1965	1.0114437	(1.0841)	0.0298539	(1.0845)	0.0298035	(1.0843)	0.0298009	(1.0847)	OK	K>1	OK	8
1966	1.0125645	(1.1274)	0.0495777	(1.1327)	0.0499468	(1.1300)	0.0497552	(1.1299)	OK	K>1	OK	8
1967	1.0106745	(1.1130)	0.0542309	(1.1172)	0.0540211	(1.1151)	0.0541257	(1.1151)	OK	OK	OK	8
1968	1.0189182	(1.1400)	0.0355911	(1.1475)	0.0342710	(1.1438)	0.0349333	(1.1437)	OK	K>1	OK	7
1969	1.0191111	(0.0032)	1.0219480	(0.0033)	1.0205276	(0.0033)	1.0204378	(0.0033)	K>1	K>1	OK	7
1970	1.0186297	(0.0049)	1.0233258	(0.0050)	1.0209727	(0.0049)	1.0208248	(0.0049)	K>1	K>1	OK	7
1971	1.0093309	(0.0052)	1.0123877	(0.0052)	1.0108571	(0.0052)	1.0107026	(0.0052)	OK	OK	OK	7
1972	1.0089353	(0.0042)	1.0132219	(0.0040)	1.0110742	(0.0041)	1.0108777	(0.0041)	OK	K>1	OK	7
1973	1.0122006	(0.0061)	1.0142424	(0.0061)	1.0132205	(0.0061)	1.0130810	(0.0061)	OK	OK	OK	7
1974	1.0113726	(0.0078)	1.0137550	(0.0077)	1.0125624	(0.0078)	1.0124887	(0.0078)	OK	OK	OK	7
1975	1.0015277	(0.0032)	1.0038457	(0.0033)	1.0026854	(0.0032)	1.0026441	(0.0032)	OK	OK	OK	7
1976	1.0151041	(0.0103)	1.0173616	(0.0103)	1.0162316	(0.0103)	1.0161755	(0.0103)	OK	OK	OK	6
1977	1.0067578	(0.0086)	1.0103159	(0.0088)	1.0085338	(0.0087)	1.0085300	(0.0087)	OK	OK	OK	6
1978	0.9989684	(0.0108)	1.0010463	(0.0108)	1.0000064	(0.0108)	0.9999144	(0.0108)	OK	OK	OK	6
1979	0.9977356	(0.0080)	1.0004271	(0.0080)	0.9990796	(0.0080)	0.9989217	(0.0080)	OK	OK	OK	6
1980	0.9871934	(0.0084)	0.9895253	(0.0085)	0.9883581	(0.0085)	0.9883570	(0.0085)	OK	OK	OK	6
1981	0.9882073	(0.0116)	0.9909883	(0.0117)	0.9895959	(0.0116)	0.9895454	(0.0116)	OK	OK	OK	6
1982	0.9905522	(0.0069)	0.9932431	(0.0071)	0.9918959	(0.0070)	0.9919087	(0.0070)	OK	OK	OK	6
1983	1.0406595	(0.0062)	1.0311805	(0.0049)	1.0359027	(0.0055)	1.0400108	(0.0060)	K>1	K>1	OK	4
1984	1.0443481	(0.0071)	1.0341089	(0.0046)	1.0392085	(0.0058)	1.0430764	(0.0066)	K>1	K>1	OK	3
1985	1.0841039	(0.0299)	1.0844785	(0.0298)	1.0842973	(0.0298)	1.0847422	(0.0297)	OK	OK	OK	4
1986	1.1274126	(0.0496)	1.1326749	(0.0499)	1.1300394	(0.0498)	1.1299104	(0.0494)	OK	OK	OK	5
1987	1.1129710	(0.0542)	1.1171676	(0.0540)	1.1150657	(0.0541)	1.1150612	(0.0538)	OK	OK	OK	6
1988	1.1400450	(0.0356)	1.1475408	(0.0343)	1.1437827	(0.0349)	1.1437025	(0.0346)	K>1	K>1	OK	4

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

PRINTING, PUBLISHING

YEAR	LOWER BOUND OF SCALE ELASTICITY KL		UPPER BOUND OF SCALE ELASTICITY KU		SCALE ELASTICITY BY IDEAL INDEX KI		SCALE ELASTICITY BY DIVISIA INDEX KD		NULL HYPOTHESIS OF CONSTANT RETURN			
	EST	*SD*	*EST*	*SD*	*EST*	*SD*	*EST*	*SD*	HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0459310	(1.0780)	0.0182981	(1.0919)	0.0181882	(1.0849)	0.0180967	(1.0838)	OK	K>1	OK	8
1965	1.0474638	(1.0039)	0.0027802	(0.9902)	0.0025475	(0.9970)	0.0024356	(1.0063)	OK	OK	OK	8
1966	1.0663513	(1.0552)	0.0092067	(1.0444)	0.0070146	(1.0498)	0.0079500	(1.0516)	OK	K>1	OK	8
1967	1.0663257	(1.0586)	0.0159121	(1.0482)	0.0133071	(1.0534)	0.0144920	(1.0539)	OK	K>1	OK	8
1968	1.0690198	(1.0578)	0.0166898	(1.0473)	0.0131121	(1.0525)	0.0147859	(1.0533)	OK	K>1	OK	7
1969	1.0669093	(0.0180)	1.0898928	(0.0156)	1.0783585	(0.0165)	1.0781791	(0.0162)	K>1	K>1	NO	7
1970	1.0585704	(0.0060)	1.0628641	(0.0059)	1.0607132	(0.0059)	1.0606797	(0.0059)	K>1	K>1	OK	7
1971	1.0667123	(0.0078)	1.0705961	(0.0079)	1.0686508	(0.0079)	1.0686749	(0.0079)	K>1	K>1	OK	7
1972	1.0662545	(0.0073)	1.0708654	(0.0072)	1.0685552	(0.0072)	1.0685332	(0.0072)	K>1	K>1	OK	7
1973	1.0678347	(0.0110)	1.0719815	(0.0114)	1.0699045	(0.0112)	1.0698957	(0.0112)	K>1	K>1	OK	7
1974	1.0759700	(0.0085)	1.0804732	(0.0087)	1.0782170	(0.0086)	1.0782089	(0.0086)	K>1	K>1	OK	7
1975	1.0771298	(0.0072)	1.0829880	(0.0076)	1.0800513	(0.0074)	1.0800343	(0.0074)	K>1	K>1	OK	7
1976	1.0788880	(0.0096)	1.0838200	(0.0099)	1.0813486	(0.0098)	1.0813139	(0.0097)	K>1	K>1	OK	6
1977	1.0709803	(0.0091)	1.0765454	(0.0094)	1.0737558	(0.0092)	1.0737295	(0.0092)	K>1	K>1	OK	6
1978	1.0689810	(0.0078)	1.0747359	(0.0077)	1.0718512	(0.0077)	1.0718789	(0.0077)	K>1	K>1	OK	6
1979	1.0819029	(0.0086)	1.0858850	(0.0084)	1.0838907	(0.0085)	1.0840186	(0.0084)	K>1	K>1	OK	6
1980	1.0840566	(0.0056)	1.0888739	(0.0054)	1.0864605	(0.0055)	1.0865007	(0.0054)	K>1	K>1	OK	6
1981	1.0930452	(0.0129)	1.0973737	(0.0121)	1.0952069	(0.0125)	1.0949797	(0.0124)	K>1	K>1	OK	6
1982	1.0976099	(0.0109)	1.1127602	(0.0127)	1.1051381	(0.0117)	1.1052889	(0.0118)	K>1	K>1	OK	6
1983	1.0924120	(0.0255)	1.1074621	(0.0243)	1.0999193	(0.0247)	1.0984789	(0.0247)	K>1	K>1	OK	4
1984	1.0780030	(0.0183)	1.0918816	(0.0182)	1.0849129	(0.0181)	1.0837907	(0.0181)	OK	K>1	OK	3
1985	1.0039228	(0.0028)	0.9902178	(0.0025)	0.9970279	(0.0024)	1.0005194	(0.0023)	OK	K<1	NO	4
1986	1.0551960	(0.0092)	1.0443568	(0.0070)	1.0497585	(0.0079)	1.0516249	(0.0082)	K>1	K>1	OK	5
1987	1.0585912	(0.0159)	1.0482468	(0.0133)	1.0534066	(0.0145)	1.0538672	(0.0146)	K>1	K>1	OK	6
1988	1.0577909	(0.0167)	1.0472775	(0.0131)	1.0525245	(0.0148)	1.0533027	(0.0150)	K>1	K>1	OK	4

CHEMICAL, ALLIED PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL		UPPER BOUND OF SCALE ELASTICITY KU		SCALE ELASTICITY BY IDEAL INDEX KI		SCALE ELASTICITY BY DIVISIA INDEX KD		NULL HYPOTHESIS OF CONSTANT RETURN			
	EST	*SD*	*EST*	*SD*	*EST*	*SD*	*EST*	*SD*	HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0302215	(1.0283)	0.0860015	(1.0309)	0.0908545	(1.0296)	0.0884167	(1.0250)	OK	OK	OK	8
1965	1.0240421	(1.1070)	0.0249263	(1.1149)	0.0219231	(1.1110)	0.0234082	(1.1154)	OK	K>1	OK	8
1966	1.0264125	(1.0498)	0.0305402	(1.0612)	0.0282753	(1.0555)	0.0294119	(1.0551)	OK	OK	OK	8
1967	1.0391450	(1.0243)	0.0353742	(1.0321)	0.0343571	(1.0282)	0.0348596	(1.0285)	OK	OK	OK	8
1968	1.0447256	(1.0258)	0.0420628	(1.0341)	0.0403722	(1.0300)	0.0412215	(1.0301)	OK	OK	OK	7
1969	1.0602833	(0.0058)	1.0603939	(0.0059)	1.0603387	(0.0058)	1.0603124	(0.0058)	K>1	K>1	OK	7
1970	1.0654278	(0.0087)	1.0662002	(0.0085)	1.0658140	(0.0086)	1.0657457	(0.0086)	K>1	K>1	OK	6
1971	1.0518686	(0.0100)	1.0526606	(0.0100)	1.0522645	(0.0100)	1.0521228	(0.0100)	K>1	K>1	OK	7
1972	1.0466922	(0.0114)	1.0469772	(0.0114)	1.0468347	(0.0114)	1.0466638	(0.0114)	K>1	K>1	OK	7
1973	1.0545002	(0.0141)	1.0556226	(0.0139)	1.0550612	(0.0140)	1.0549803	(0.0140)	K>1	K>1	OK	7
1974	1.0275201	(0.0108)	1.0276814	(0.0110)	1.0276008	(0.0109)	1.0275905	(0.0109)	K>1	K>1	OK	7
1975	1.0272493	(0.0146)	1.0273584	(0.0146)	1.0273040	(0.0146)	1.0272940	(0.0146)	OK	OK	OK	7
1976	1.0231244	(0.0177)	1.0234563	(0.0178)	1.0232904	(0.0177)	1.0232248	(0.0177)	OK	OK	OK	6
1977	1.0226071	(0.0092)	1.0227459	(0.0093)	1.0226765	(0.0093)	1.0226152	(0.0093)	OK	OK	OK	6
1978	1.0362150	(0.0113)	1.0359092	(0.0113)	1.0360621	(0.0113)	1.0359865	(0.0113)	K>1	K>1	OK	6
1979	1.0361878	(0.0184)	1.0353300	(0.0185)	1.0357590	(0.0185)	1.0356586	(0.0185)	OK	OK	OK	6
1980	1.0195759	(0.0190)	1.0196733	(0.0190)	1.0196247	(0.0190)	1.0195313	(0.0190)	OK	OK	OK	6
1981	1.0208952	(0.0204)	1.0207473	(0.0202)	1.0208214	(0.0203)	1.0207362	(0.0203)	OK	OK	OK	6
1982	1.0279878	(0.0205)	1.0290699	(0.0199)	1.0285291	(0.0202)	1.0285006	(0.0202)	OK	OK	OK	6
1983	1.0159115	(0.0788)	1.0185531	(0.0850)	1.0172584	(0.0819)	1.0128665	(0.0675)	OK	OK	OK	4
1984	1.0283188	(0.0860)	1.0308696	(0.0909)	1.0296101	(0.0884)	1.0250438	(0.0758)	OK	OK	OK	3
1985	1.1070491	(0.0249)	1.1148668	(0.0219)	1.1109578	(0.0234)	1.1154266	(0.0259)	K>1	K>1	OK	4
1986	1.0497854	(0.0305)	1.0612286	(0.0283)	1.0554822	(0.0294)	1.0551160	(0.0295)	OK	OK	OK	5
1987	1.0242730	(0.0354)	1.0320794	(0.0344)	1.0281647	(0.0349)	1.0284666	(0.0348)	OK	OK	OK	6
1988	1.0258430	(0.0421)	1.0340946	(0.0404)	1.0299560	(0.0412)	1.0301172	(0.0412)	OK	OK	OK	4

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

PETROLEUM, COAL PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0294625	(1.0476)	0.0224599	(1.0476)	0.0224599	(1.0476)	0.0224599	(1.0476)	OK	OK	OK	8
1965	1.0294665	(1.0767)	0.0402809	(1.0765)	0.0422817	(1.0766)	0.0412603	(1.0677)	OK	OK	OK	7
1966	1.0346073	(1.0832)	0.0723750	(1.0890)	0.0783975	(1.0862)	0.0753647	(1.0780)	OK	OK	OK	7
1967	1.0499014	(1.0761)	0.0515906	(1.0823)	0.0569051	(1.0792)	0.0542288	(1.0717)	OK	OK	OK	6
1968	1.0195953	(1.0843)	0.0523909	(1.0903)	0.0560791	(1.0873)	0.0542160	(1.0811)	OK	OK	OK	5
1969	1.0120490	(0.0197)	1.0253911	(0.0187)	1.0186850	(0.0192)	1.0212167	(0.0190)	OK	OK	OK	5
1970	1.0019264	(0.0143)	1.0084029	(0.0136)	1.0051551	(0.0139)	1.0067646	(0.0137)	OK	OK	OK	5
1971	0.9970547	(0.0143)	1.0022815	(0.0143)	0.9996620	(0.0143)	1.0012520	(0.0142)	OK	OK	OK	5
1972	1.0028745	(0.0148)	1.0068593	(0.0147)	1.0048632	(0.0147)	1.0058517	(0.0148)	OK	OK	OK	7
1973	0.9961231	(0.0225)	1.0026686	(0.0224)	0.9993866	(0.0224)	1.0003322	(0.0225)	OK	OK	OK	5
1974	0.9841033	(0.0140)	0.9897460	(0.0142)	0.9869167	(0.0141)	0.9878045	(0.0140)	OK	OK	OK	7
1975	0.9854476	(0.0097)	0.9863284	(0.0093)	0.9858883	(0.0095)	0.9878476	(0.0094)	OK	OK	OK	7
1976	0.9893782	(0.0094)	0.9960792	(0.0094)	0.9927199	(0.0094)	1.0009705	(0.0086)	OK	OK	OK	6
1977	1.0004906	(0.0071)	1.0067736	(0.0064)	1.0036252	(0.0067)	1.0080377	(0.0062)	OK	OK	OK	6
1978	0.9818541	(0.0175)	0.9860020	(0.0174)	0.9839244	(0.0175)	0.9906820	(0.0167)	OK	OK	OK	6
1979	1.0094516	(0.0121)	1.0161649	(0.0122)	1.0127983	(0.0121)	1.0150122	(0.0119)	OK	OK	OK	6
1980	1.0021946	(0.0079)	1.0064567	(0.0078)	1.0043221	(0.0078)	1.0065533	(0.0078)	OK	OK	OK	6
1981	0.9973342	(0.0097)	1.0045543	(0.0097)	1.0009337	(0.0097)	1.0031820	(0.0094)	OK	OK	OK	6
1982	0.9807273	(0.0222)	0.9852560	(0.0221)	0.9829866	(0.0222)	0.9850651	(0.0221)	OK	OK	OK	6
1983	1.0377750	(0.0212)	1.0191997	(0.0186)	1.0284047	(0.0199)	1.0475923	(0.0225)	OK	OK	OK	2
1984	1.0475923	(0.0225)	1.0475923	(0.0225)	1.0475923	(0.0225)	1.0475923	(0.0225)	OK	OK	OK	3
1985	1.0766834	(0.0403)	1.0765195	(0.0423)	1.0766116	(0.0413)	1.0676796	(0.0359)	OK	OK	OK	4
1986	1.0832400	(0.0724)	1.0890301	(0.0784)	1.0861507	(0.0754)	1.0780025	(0.0672)	OK	OK	OK	5
1987	1.0760689	(0.0516)	1.0823372	(0.0569)	1.0792122	(0.0542)	1.0716700	(0.0484)	OK	OK	OK	6
1988	1.0843351	(0.0524)	1.0902510	(0.0561)	1.0872956	(0.0542)	1.0810873	(0.0504)	OK	OK	OK	4

RUBBER, PLASTIC PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0179190	(1.1957)	0.0463005	(1.1841)	0.0401758	(1.1899)	0.0432074	(1.1860)	OK	K>1	OK	8
1965	1.0114883	(1.0185)	0.0004276	(0.9974)	0.0005049	(1.0078)	0.0003820	(1.0170)	OK	K>1	OK	8
1966	1.0234483	(1.0849)	0.0199996	(1.0558)	0.0153875	(1.0701)	0.0176340	(1.0757)	OK	K>1	OK	8
1967	1.0013179	(1.1069)	0.0005859	(1.0722)	0.0046392	(1.0893)	0.0021104	(1.0937)	OK	K>1	OK	7
1968	1.0305599	(1.1148)	0.0049761	(1.0790)	0.0008045	(1.0966)	0.0027530	(1.1001)	OK	K>1	OK	7
1969	1.0247111	(0.0097)	1.0228208	(0.0094)	1.0237662	(0.0096)	1.0236982	(0.0095)	K>1	OK	OK	7
1970	1.0325899	(0.0080)	1.0344843	(0.0078)	1.0335375	(0.0079)	1.0334149	(0.0079)	K>1	K>1	OK	7
1971	1.0358367	(0.0090)	1.0366394	(0.0086)	1.0362396	(0.0088)	1.0360627	(0.0087)	K>1	K>1	OK	7
1972	1.0571318	(0.0076)	1.0653492	(0.0078)	1.0612261	(0.0077)	1.0611924	(0.0076)	K>1	K>1	OK	7
1973	1.0537502	(0.0097)	1.0563883	(0.0088)	1.0550704	(0.0093)	1.0549012	(0.0092)	K>1	K>1	OK	7
1974	1.0386940	(0.0138)	1.0434300	(0.0137)	1.0410573	(0.0137)	1.0411383	(0.0137)	K>1	K>1	OK	7
1975	1.0420088	(0.0085)	1.0440428	(0.0085)	1.0430267	(0.0084)	1.0429614	(0.0084)	K>1	K>1	OK	7
1976	1.0517290	(0.0144)	1.0550640	(0.0136)	1.0533959	(0.0140)	1.0532557	(0.0140)	K>1	K>1	OK	6
1977	1.0366099	(0.0162)	1.0410734	(0.0157)	1.0388395	(0.0159)	1.0385054	(0.0160)	OK	K>1	OK	6
1978	1.0503382	(0.0123)	1.0563492	(0.0115)	1.0533398	(0.0119)	1.0528729	(0.0119)	K>1	K>1	OK	6
1979	1.0495521	(0.0133)	1.0567303	(0.0124)	1.0531310	(0.0128)	1.0529243	(0.0128)	K>1	K>1	OK	6
1980	1.0485478	(0.0055)	1.0523924	(0.0054)	1.0504672	(0.0054)	1.0505307	(0.0054)	K>1	K>1	OK	6
1981	1.0405779	(0.0120)	1.0459504	(0.0119)	1.0432581	(0.0119)	1.0431800	(0.0119)	K>1	K>1	OK	6
1982	1.0400036	(0.0061)	1.0453977	(0.0067)	1.0426941	(0.0064)	1.0425712	(0.0064)	K>1	K>1	OK	6
1983	1.1938235	(0.0456)	1.1818174	(0.0395)	1.1878109	(0.0425)	1.1840274	(0.0413)	K>1	K>1	OK	4
1984	1.1956706	(0.0463)	1.1840892	(0.0402)	1.1898724	(0.0432)	1.1859742	(0.0419)	OK	K>1	OK	3
1985	1.0184763	(0.0004)	0.9973932	(0.0005)	1.0078247	(0.0004)	1.0169816	(0.0003)	K>1	K<1	NO	4
1986	1.0848800	(0.0200)	1.0557606	(0.0154)	1.0701262	(0.0176)	1.0757122	(0.0185)	K>1	K>1	NO	5
1987	1.1069353	(0.0006)	1.0722478	(0.0046)	1.0893219	(0.0021)	1.0936619	(0.0015)	K>1	K>1	NO	6
1988	1.1147601	(0.0050)	1.0790088	(0.0008)	1.0966014	(0.0028)	1.1000891	(0.0032)	K>1	K>1	NO	3

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

LEATHER, LEATHER PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KL=1	HO:KL=KU	S.S
1964	0.9807505	(0.9843)	0.0083104	(0.9843)	0.0083104	(0.9843)	0.0083104	(0.9843)	OK	OK	OK	7
1965	0.9940677	(1.0377)	0.0120730	(1.0286)	0.0124718	(1.0331)	0.0122295	(1.0328)	OK	K>1	OK	7
1966	0.9992205	(1.0573)	0.0221817	(1.0487)	0.0233339	(1.0530)	0.0227564	(1.0524)	OK	K>1	OK	7
1967	1.0291557	(1.0490)	0.0250307	(1.0445)	0.0297348	(1.0467)	0.0273813	(1.0464)	OK	OK	OK	7
1968	1.0168724	(1.0536)	0.0177399	(1.0468)	0.0201704	(1.0502)	0.0189505	(1.0499)	OK	K>1	OK	5
1969	1.0179408	(0.0219)	1.0239993	(0.0234)	1.0209638	(0.0227)	1.0208054	(0.0226)	OK	OK	OK	5
1970	1.0016314	(0.0220)	1.0058644	(0.0229)	1.0037449	(0.0225)	1.0037784	(0.0225)	OK	OK	OK	5
1971	1.0034418	(0.0203)	1.0129716	(0.0243)	1.0082002	(0.0223)	1.0078672	(0.0222)	OK	OK	OK	5
1972	1.0355923	(0.0165)	1.0351725	(0.0167)	1.0353829	(0.0166)	1.0353504	(0.0166)	OK	OK	OK	5
1973	1.0110888	(0.0179)	1.0135753	(0.0176)	1.0123308	(0.0178)	1.0122795	(0.0178)	OK	OK	OK	5
1974	1.0427046	(0.0167)	1.0442238	(0.0172)	1.0434639	(0.0169)	1.0434141	(0.0170)	OK	OK	OK	5
1975	1.0123881	(0.0171)	1.0117092	(0.0168)	1.0120490	(0.0170)	1.0119811	(0.0169)	OK	OK	OK	5
1976	1.1087528	(0.0447)	1.1061482	(0.0440)	1.1074493	(0.0443)	1.1073968	(0.0443)	OK	OK	OK	5
1977	1.0543167	(0.0254)	1.0562183	(0.0254)	1.0552671	(0.0254)	1.0552348	(0.0254)	OK	OK	OK	5
1978	1.0793981	(0.0258)	1.0821156	(0.0266)	1.0807561	(0.0262)	1.0807246	(0.0262)	K>1	K>1	OK	5
1979	1.0049602	(0.0102)	1.0087959	(0.0106)	1.0068745	(0.0104)	1.0068285	(0.0104)	OK	OK	OK	3
1980	1.0347044	(0.0291)	1.0413553	(0.0289)	1.0380200	(0.0290)	1.0376941	(0.0290)	OK	OK	OK	5
1981	1.0427657	(0.0228)	1.0407926	(0.0196)	1.0417902	(0.0212)	1.0404507	(0.0204)	OK	OK	OK	5
1982	0.9800055	(0.0078)	0.9877924	(0.0089)	0.9838872	(0.0082)	0.9843154	(0.0083)	OK	OK	OK	3
1983	*** CAUTION *** : NOT COMPUTED BECAUSE OF D.F.											
1984	0.9843154	(0.0083)	0.9843154	(0.0083)	0.9843154	(0.0083)	0.9843154	(0.0083)	OK	OK	OK	3
1985	1.0377020	(0.0121)	1.0285523	(0.0125)	1.0331114	(0.0122)	1.0327938	(0.0123)	OK	OK	OK	4
1986	1.0573202	(0.0222)	1.0487076	(0.0233)	1.0529984	(0.0228)	1.0523771	(0.0227)	OK	OK	OK	5
1987	1.0489975	(0.0250)	1.0444662	(0.0297)	1.0467453	(0.0274)	1.0464050	(0.0277)	OK	OK	OK	6
1988	1.0535719	(0.0177)	1.0468449	(0.0202)	1.0502017	(0.0190)	1.0498687	(0.0192)	OK	OK	OK	3

STONE, CLAY, GLASS PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0445348	(1.1298)	0.0675161	(1.1240)	0.0622583	(1.1269)	0.0648710	(1.1260)	OK	OK	OK	8
1965	1.0450621	(1.0657)	0.0206010	(1.0527)	0.0195753	(1.0592)	0.0200122	(1.0538)	OK	K>1	OK	8
1966	1.0460326	(1.2139)	0.0444884	(1.2057)	0.0401379	(1.2098)	0.0422971	(1.2027)	OK	K>1	OK	8
1967	1.0599579	(1.2257)	0.0462397	(1.2193)	0.0419315	(1.2225)	0.0440716	(1.2144)	OK	K>1	OK	8
1968	1.0691941	(1.2211)	0.0443297	(1.2133)	0.0385617	(1.2172)	0.0414244	(1.2086)	OK	K>1	OK	7
1969	1.0767298	(0.0110)	1.0874359	(0.0106)	1.0820603	(0.0108)	1.0817378	(0.0108)	K>1	K>1	OK	7
1970	1.0766295	(0.0078)	1.0827354	(0.0075)	1.0796753	(0.0076)	1.0793648	(0.0076)	K>1	K>1	OK	7
1971	1.0732549	(0.0096)	1.0779999	(0.0093)	1.0756234	(0.0095)	1.0754997	(0.0095)	K>1	K>1	OK	7
1972	1.0722055	(0.0089)	1.0783214	(0.0090)	1.0752568	(0.0089)	1.0751618	(0.0089)	K>1	K>1	OK	7
1973	1.0795291	(0.0102)	1.0835578	(0.0099)	1.0815405	(0.0100)	1.0815106	(0.0100)	K>1	K>1	OK	7
1974	1.0558035	(0.0055)	1.0603201	(0.0052)	1.0580576	(0.0053)	1.0580035	(0.0053)	K>1	K>1	OK	7
1975	1.0440558	(0.0038)	1.0495755	(0.0037)	1.0468087	(0.0037)	1.0467477	(0.0037)	K>1	K>1	NO	7
1976	1.0688916	(0.0082)	1.0774430	(0.0087)	1.0731507	(0.0085)	1.0730652	(0.0085)	K>1	K>1	OK	6
1977	1.0698209	(0.0087)	1.0766277	(0.0087)	1.0732137	(0.0087)	1.0730489	(0.0086)	K>1	K>1	OK	6
1978	1.0602357	(0.0181)	1.0665645	(0.0186)	1.0633915	(0.0183)	1.0632056	(0.0183)	K>1	K>1	OK	6
1979	1.0549281	(0.0166)	1.0598657	(0.0170)	1.0573917	(0.0168)	1.0573910	(0.0168)	K>1	K>1	OK	6
1980	1.0502067	(0.0113)	1.0551325	(0.0111)	1.0526645	(0.0112)	1.0526857	(0.0112)	K>1	K>1	OK	6
1981	1.0579656	(0.0113)	1.0624163	(0.0116)	1.0601866	(0.0114)	1.0601424	(0.0114)	K>1	K>1	OK	6
1982	1.0546702	(0.0153)	1.0595357	(0.0154)	1.0570975	(0.0153)	1.0571123	(0.0153)	K>1	K>1	OK	6
1983	1.1340595	(0.0848)	1.1303442	(0.0818)	1.1322023	(0.0833)	1.1308197	(0.0828)	OK	OK	OK	3
1984	1.1298102	(0.0675)	1.1239881	(0.0623)	1.1269029	(0.0649)	1.1259931	(0.0646)	OK	OK	OK	3
1985	1.0656965	(0.0206)	1.0527145	(0.0196)	1.0591770	(0.0200)	1.0537631	(0.0197)	K>1	OK	OK	4
1986	1.2138798	(0.0445)	1.2057148	(0.0401)	1.2097940	(0.0423)	1.2026618	(0.0401)	K>1	K>1	OK	5
1987	1.2257238	(0.0462)	1.2193127	(0.0419)	1.2225206	(0.0441)	1.2143557	(0.0416)	K>1	K>1	OK	6
1988	1.2211369	(0.0443)	1.2133222	(0.0386)	1.2172298	(0.0414)	1.2085737	(0.0392)	K>1	K>1	OK	3

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

IRON, STEEL

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	0.9959361	(1.0389)	0.0048521	(1.0365)	0.0049158	(1.0377)	0.0048599	(1.0361)	OK	K>1	OK	8
1965	0.9954375	(0.9856)	0.0239937	(0.9877)	0.0241612	(0.9867)	0.0240753	(0.9878)	OK	OK	OK	8
1966	0.9955073	(0.9878)	0.0241981	(0.9878)	0.0241981	(0.9878)	0.0241981	(0.9878)	OK	OK	OK	8
1967	0.9999919	(0.9878)	0.0241981	(0.9878)	0.0241981	(0.9878)	0.0241981	(0.9878)	OK	OK	OK	8
1968	0.9909586	(0.9878)	0.0241981	(0.9878)	0.0241981	(0.9878)	0.0241981	(0.9878)	OK	OK	OK	7
1969	0.9999146	(0.0044)	1.0011857	(0.0043)	1.0005498	(0.0044)	1.0003748	(0.0044)	OK	OK	OK	7
1970	0.9937952	(0.0035)	0.9960998	(0.0031)	0.9949469	(0.0033)	0.9947143	(0.0034)	OK	OK	OK	7
1971	0.9964572	(0.0050)	1.0031943	(0.0049)	0.9998189	(0.0049)	0.9995402	(0.0049)	OK	OK	NO	7
1972	1.0019215	(0.0029)	1.0041479	(0.0029)	1.0030335	(0.0029)	1.0026649	(0.0029)	OK	OK	OK	7
1973	0.9975567	(0.0035)	0.9992601	(0.0038)	0.9984079	(0.0037)	0.9979039	(0.0035)	OK	OK	OK	7
1974	0.9928825	(0.0044)	0.9947998	(0.0044)	0.9938404	(0.0044)	0.9935633	(0.0044)	OK	OK	OK	7
1975	1.0043819	(0.0030)	1.0061388	(0.0030)	1.0052596	(0.0030)	1.0050461	(0.0030)	OK	OK	OK	7
1976	1.0106449	(0.0059)	1.0101295	(0.0057)	1.0103874	(0.0058)	1.0100281	(0.0057)	OK	OK	OK	6
1977	1.0052659	(0.0023)	1.0058485	(0.0023)	1.0055571	(0.0023)	1.0048193	(0.0022)	OK	OK	OK	6
1978	1.0090790	(0.0050)	1.0152772	(0.0053)	1.0121701	(0.0051)	1.0113316	(0.0051)	OK	K>1	OK	6
1979	1.0344406	(0.0071)	1.0368172	(0.0070)	1.0356283	(0.0070)	1.0343765	(0.0070)	K>1	K>1	OK	6
1980	1.0260732	(0.0036)	1.0290019	(0.0034)	1.0275357	(0.0035)	1.0264711	(0.0036)	K>1	K>1	OK	6
1981	1.0264013	(0.0047)	1.0280016	(0.0047)	1.0272010	(0.0047)	1.0264583	(0.0046)	K>1	K>1	OK	6
1982	1.0262112	(0.0107)	1.0272184	(0.0107)	1.0267145	(0.0107)	1.0260654	(0.0106)	OK	OK	OK	6
1983	1.0273104	(0.0095)	1.0250720	(0.0085)	1.0261906	(0.0090)	1.0245923	(0.0087)	OK	OK	OK	3
1984	1.0388866	(0.0049)	1.0364959	(0.0049)	1.0376903	(0.0049)	1.0361412	(0.0048)	K>1	K>1	OK	5
1985	0.9855622	(0.0240)	0.9877435	(0.0242)	0.9866521	(0.0241)	0.9878202	(0.0242)	OK	OK	OK	9
1986	*** CAUTION *** : NOT COMPUTED BECAUSE OF D.F.											
1987	*** CAUTION *** : NOT COMPUTED BECAUSE OF D.F.											
1988	*** CAUTION *** : NOT COMPUTED BECAUSE OF D.F.											

NONFERROUS METAL

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0028726	(1.0920)	0.0074246	(1.0814)	0.0059630	(1.0867)	0.0066600	(1.0869)	OK	K>1	OK	8
1965	1.0014138	(1.0903)	0.0215744	(1.0814)	0.0193060	(1.0858)	0.0204253	(1.0851)	OK	K>1	OK	8
1966	0.9990101	(1.0951)	0.0797324	(1.0916)	0.0764765	(1.0934)	0.0780985	(1.0929)	OK	OK	OK	8
1967	0.9988813	(1.1083)	0.0845882	(1.1006)	0.0777148	(1.1044)	0.0811256	(1.1041)	OK	OK	OK	8
1968	1.0038085	(1.1045)	0.0484824	(1.0985)	0.0459680	(1.1015)	0.0472166	(1.1002)	OK	OK	OK	7
1969	1.0010311	(0.0044)	1.0018904	(0.0043)	1.0014606	(0.0043)	1.0015493	(0.0043)	OK	OK	OK	7
1970	0.9931626	(0.0050)	0.9946867	(0.0048)	0.9939244	(0.0049)	0.9939769	(0.0048)	OK	OK	OK	5
1971	0.9994009	(0.0044)	1.0001543	(0.0044)	0.9997775	(0.0044)	0.9997649	(0.0044)	OK	OK	OK	7
1972	1.0134679	(0.0032)	1.0136508	(0.0031)	1.0135595	(0.0031)	1.0135223	(0.0031)	K>1	K>1	OK	7
1973	1.0127053	(0.0059)	1.0144334	(0.0057)	1.0135687	(0.0058)	1.0135553	(0.0058)	OK	K>1	OK	7
1974	1.0044212	(0.0052)	1.0077578	(0.0053)	1.0060871	(0.0052)	1.0060534	(0.0052)	OK	OK	OK	7
1975	1.0023031	(0.0059)	1.0055346	(0.0059)	1.0039172	(0.0059)	1.0038554	(0.0059)	OK	OK	OK	7
1976	1.0068560	(0.0136)	1.0082515	(0.0137)	1.0075534	(0.0136)	1.0074712	(0.0136)	OK	OK	OK	6
1977	1.0062549	(0.0081)	1.0111108	(0.0081)	1.0086783	(0.0081)	1.0086537	(0.0081)	OK	OK	OK	6
1978	1.0151426	(0.0124)	1.0168593	(0.0123)	1.0160008	(0.0124)	1.0158173	(0.0123)	OK	OK	OK	6
1979	1.0215485	(0.0098)	1.0240122	(0.0102)	1.0227796	(0.0100)	1.0226592	(0.0100)	OK	OK	OK	6
1980	1.0206455	(0.0093)	1.0237369	(0.0091)	1.0221899	(0.0092)	1.0220362	(0.0092)	OK	K>1	OK	6
1981	1.0210967	(0.0044)	1.0265244	(0.0049)	1.0238049	(0.0047)	1.0237250	(0.0047)	K>1	K>1	OK	6
1982	1.0168343	(0.0136)	1.0217471	(0.0136)	1.0192851	(0.0136)	1.0192192	(0.0136)	OK	OK	OK	6
1983	1.0933073	(0.0066)	1.0807951	(0.0068)	1.0870170	(0.0066)	1.0872365	(0.0066)	K>1	K>1	OK	3
1984	1.0920282	(0.0074)	1.0813586	(0.0060)	1.0866688	(0.0067)	1.0868630	(0.0067)	K>1	K>1	OK	3
1985	1.0902612	(0.0216)	1.0813633	(0.0193)	1.0857989	(0.0204)	1.0851362	(0.0203)	K>1	K>1	OK	4
1986	1.0951366	(0.0797)	1.0915734	(0.0765)	1.0933563	(0.0781)	1.0928753	(0.0779)	OK	OK	OK	5
1987	1.1082527	(0.0846)	1.1005928	(0.0777)	1.1044278	(0.0811)	1.1040693	(0.0810)	OK	OK	OK	9
1988	1.1045214	(0.0485)	1.0984974	(0.0460)	1.1015038	(0.0472)	1.1002333	(0.0470)	OK	OK	OK	3

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

FABRICATED METAL PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0156156	(1.0787)	0.0102071	(1.0751)	0.0095597	(1.0769)	0.0096633	(1.0767)	OK	K>1	OK	8
1965	1.0085703	(1.0336)	0.0064690	(1.0250)	0.0060758	(1.0293)	0.0061412	(1.0289)	OK	K>1	OK	8
1966	1.0083253	(1.0427)	0.0117670	(1.0386)	0.0099089	(1.0406)	0.0107951	(1.0393)	OK	K>1	OK	8
1967	1.0087007	(1.0511)	0.0149057	(1.0461)	0.0142037	(1.0486)	0.0144365	(1.0471)	OK	K>1	OK	8
1968	1.0074028	(1.0655)	0.0062439	(1.0621)	0.0049927	(1.0638)	0.0055848	(1.0619)	OK	K>1	OK	7
1969	1.0160567	(0.0044)	1.0174687	(0.0046)	1.0167624	(0.0045)	1.0167800	(0.0045)	K>1	K>1	OK	7
1970	1.0125175	(0.0040)	1.0136850	(0.0041)	1.0131010	(0.0041)	1.0130856	(0.0041)	K>1	K>1	OK	7
1971	1.0337326	(0.0061)	1.0343310	(0.0072)	1.0340367	(0.0066)	1.0340812	(0.0066)	K>1	K>1	OK	7
1972	1.0518952	(0.0188)	1.0548573	(0.0194)	1.0533747	(0.0191)	1.0532594	(0.0190)	K>1	K>1	OK	7
1973	1.0400390	(0.0103)	1.0421840	(0.0109)	1.0411111	(0.0106)	1.0410526	(0.0106)	K>1	K>1	OK	7
1974	1.0254059	(0.0058)	1.0283015	(0.0054)	1.0268531	(0.0056)	1.0268921	(0.0056)	K>1	K>1	OK	7
1975	1.0326889	(0.0087)	1.0341591	(0.0088)	1.0334237	(0.0088)	1.0334056	(0.0088)	K>1	K>1	OK	7
1976	1.0381785	(0.0085)	1.0389856	(0.0085)	1.0385822	(0.0085)	1.0387128	(0.0085)	K>1	K>1	OK	6
1977	1.0505366	(0.0178)	1.0520194	(0.0179)	1.0512775	(0.0179)	1.0512685	(0.0179)	OK	OK	OK	4
1978	1.0708768	(0.0164)	1.0730599	(0.0163)	1.0719673	(0.0163)	1.0718577	(0.0163)	K>1	K>1	OK	6
1979	1.0507151	(0.0063)	1.0532035	(0.0063)	1.0519580	(0.0063)	1.0519188	(0.0063)	K>1	K>1	OK	6
1980	1.0123694	(0.0207)	1.0148301	(0.0196)	1.0136001	(0.0201)	1.0134573	(0.0202)	OK	OK	OK	6
1981	1.0363043	(0.0089)	1.0391944	(0.0089)	1.0377477	(0.0089)	1.0377797	(0.0089)	K>1	K>1	OK	6
1982	1.0577460	(0.0122)	1.0601378	(0.0122)	1.0589407	(0.0122)	1.0589094	(0.0122)	K>1	K>1	OK	6
1983	1.0670264	(0.0122)	1.0645557	(0.0096)	1.0657977	(0.0108)	1.0657299	(0.0107)	K>1	K>1	OK	3
1984	1.0787062	(0.0102)	1.0750602	(0.0094)	1.0768847	(0.0097)	1.0766595	(0.0096)	K>1	K>1	OK	3
1985	1.0336264	(0.0065)	1.0249749	(0.0061)	1.0292888	(0.0061)	1.0289239	(0.0061)	K>1	K>1	OK	4
1986	1.0427016	(0.0118)	1.0385671	(0.0099)	1.0406335	(0.0108)	1.0393390	(0.0108)	K>1	K>1	OK	5
1987	1.0510707	(0.0149)	1.0460733	(0.0142)	1.0485727	(0.0144)	1.0470858	(0.0144)	K>1	K>1	OK	9
1988	1.0655299	(0.0062)	1.0621276	(0.0050)	1.0638274	(0.0056)	1.0619253	(0.0059)	K>1	K>1	OK	3

MACHINERY, EXCEPT ELECTRICAL

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0100346	(1.0336)	0.0098846	(1.0226)	0.0079171	(1.0281)	0.0086213	(1.0277)	OK	K>1	OK	8
1965	1.0071817	(1.0091)	0.0091994	(0.9954)	0.0100202	(1.0022)	0.0096073	(1.0024)	OK	OK	OK	8
1966	1.0166044	(1.0927)	0.0034871	(1.0799)	0.0055349	(1.0863)	0.0044004	(1.0858)	OK	K>1	OK	8
1967	1.0085265	(1.0943)	0.0096307	(1.0797)	0.0078246	(1.0869)	0.0086915	(1.0861)	OK	K>1	OK	8
1968	1.0097923	(1.0551)	0.0409482	(1.0434)	0.0415983	(1.0492)	0.0412782	(1.0480)	OK	OK	OK	7
1969	1.0119723	(0.0056)	1.0132966	(0.0056)	1.0126541	(0.0056)	1.0126401	(0.0056)	OK	OK	OK	7
1970	1.0095238	(0.0035)	1.0107077	(0.0037)	1.0101155	(0.0036)	1.0101242	(0.0036)	K>1	K>1	OK	7
1971	1.0173352	(0.0038)	1.0184093	(0.0039)	1.0178720	(0.0039)	1.0178824	(0.0039)	K>1	K>1	OK	7
1972	1.0182574	(0.0052)	1.0195947	(0.0051)	1.0189257	(0.0051)	1.0189498	(0.0051)	K>1	K>1	OK	7
1973	1.0142287	(0.0057)	1.0152016	(0.0057)	1.0147149	(0.0057)	1.0147143	(0.0057)	K>1	K>1	OK	7
1974	1.0162610	(0.0044)	1.0175126	(0.0046)	1.0168864	(0.0045)	1.0168756	(0.0045)	K>1	K>1	OK	7
1975	1.0300637	(0.0055)	1.0318073	(0.0056)	1.0309348	(0.0055)	1.0309328	(0.0055)	K>1	K>1	OK	7
1976	1.0380440	(0.0060)	1.0400348	(0.0060)	1.0390385	(0.0060)	1.0390290	(0.0060)	K>1	K>1	OK	6
1977	1.0237767	(0.0028)	1.0258220	(0.0029)	1.0247984	(0.0028)	1.0247990	(0.0028)	K>1	K>1	OK	6
1978	1.0186314	(0.0038)	1.0211658	(0.0040)	1.0198971	(0.0039)	1.0198945	(0.0039)	K>1	K>1	OK	6
1979	1.0181688	(0.0033)	1.0196729	(0.0034)	1.0189203	(0.0034)	1.0189121	(0.0034)	K>1	K>1	OK	6
1980	1.0221837	(0.0019)	1.0238931	(0.0020)	1.0230377	(0.0020)	1.0230358	(0.0020)	K>1	K>1	OK	6
1981	1.0177244	(0.0036)	1.0197757	(0.0036)	1.0187490	(0.0036)	1.0187538	(0.0036)	K>1	K>1	OK	6
1982	1.0271628	(0.0062)	1.0287870	(0.0062)	1.0279743	(0.0062)	1.0279908	(0.0062)	K>1	K>1	OK	6
1983	1.0354323	(0.0063)	1.0244853	(0.0085)	1.0299388	(0.0072)	1.0294610	(0.0073)	K>1	OK	OK	3
1984	1.0336303	(0.0099)	1.0225887	(0.0079)	1.0280908	(0.0086)	1.0276624	(0.0086)	OK	OK	OK	3
1985	1.0091403	(0.0092)	0.9954138	(0.0100)	1.0022316	(0.0096)	1.0023943	(0.0096)	OK	OK	OK	4
1986	1.0926902	(0.0035)	1.0799261	(0.0053)	1.0862726	(0.0044)	1.0858212	(0.0044)	K>1	K>1	NO	5
1987	1.0942897	(0.0096)	1.0796712	(0.0078)	1.0869334	(0.0087)	1.0861299	(0.0086)	K>1	K>1	NO	9
1988	1.0551024	(0.0409)	1.0434100	(0.0416)	1.0492242	(0.0413)	1.0479670	(0.0413)	OK	OK	OK	3

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

ELECTRICAL EQUIPMENT AND SUPPLIES

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0206942	(1.0565)	0.0029661	(1.0557)	0.0066581	(1.0561)	0.0048047	(1.0561)	OK	K>1	OK	8
1965	1.0207988	(1.0247)	0.0018843	(1.0222)	0.0029301	(1.0235)	0.0023204	(1.0231)	OK	K>1	OK	8
1966	1.0220199	(1.0638)	0.0173136	(1.0654)	0.0158401	(1.0646)	0.0165738	(1.0638)	OK	K>1	OK	8
1967	1.0245624	(1.0603)	0.0374258	(1.0643)	0.0386761	(1.0623)	0.0380474	(1.0613)	OK	OK	OK	8
1968	1.0327501	(1.0491)	0.0268786	(1.0510)	0.0278759	(1.0501)	0.0273762	(1.0493)	OK	OK	OK	7
1969	1.0385135	(0.0082)	1.0404084	(0.0084)	1.0394603	(0.0083)	1.0394328	(0.0083)	K>1	K>1	OK	7
1970	1.0323145	(0.0083)	1.0346430	(0.0086)	1.0334776	(0.0084)	1.0334475	(0.0084)	K>1	K>1	OK	7
1971	1.0351625	(0.0073)	1.0369889	(0.0076)	1.0360750	(0.0075)	1.0360563	(0.0075)	K>1	K>1	OK	7
1972	1.0461568	(0.0109)	1.0484025	(0.0111)	1.0472786	(0.0110)	1.0472497	(0.0110)	K>1	K>1	OK	7
1973	1.0407603	(0.0082)	1.0434919	(0.0085)	1.0421244	(0.0083)	1.0420888	(0.0083)	K>1	K>1	OK	7
1974	1.0363665	(0.0073)	1.0386599	(0.0073)	1.0375120	(0.0073)	1.0374938	(0.0073)	K>1	K>1	OK	7
1975	1.0483794	(0.0086)	1.0522596	(0.0089)	1.0503161	(0.0087)	1.0502800	(0.0087)	K>1	K>1	OK	7
1976	1.0575634	(0.0059)	1.0612377	(0.0060)	1.0593974	(0.0059)	1.0593578	(0.0059)	K>1	K>1	OK	6
1977	1.0559774	(0.0043)	1.0606320	(0.0045)	1.0582998	(0.0044)	1.0582562	(0.0044)	K>1	K>1	OK	6
1978	1.0618356	(0.0057)	1.0658599	(0.0057)	1.0638440	(0.0057)	1.0638011	(0.0057)	K>1	K>1	OK	6
1979	1.0677048	(0.0069)	1.0714144	(0.0069)	1.0695564	(0.0069)	1.0695170	(0.0069)	K>1	K>1	OK	6
1980	1.0597823	(0.0069)	1.0637423	(0.0070)	1.0617587	(0.0069)	1.0617092	(0.0069)	K>1	K>1	OK	6
1981	1.0525629	(0.0053)	1.0570792	(0.0055)	1.0548163	(0.0054)	1.0547593	(0.0053)	K>1	K>1	OK	6
1982	1.0565362	(0.0065)	1.0610614	(0.0067)	1.0587941	(0.0066)	1.0587311	(0.0066)	K>1	K>1	OK	6
1983	1.0565882	(0.0119)	1.0571273	(0.0140)	1.0568597	(0.0129)	1.0568522	(0.0129)	K>1	OK	OK	3
1984	1.0565215	(0.0030)	1.0557156	(0.0067)	1.0561250	(0.0048)	1.0561049	(0.0047)	K>1	K>1	OK	3
1985	1.0247321	(0.0019)	1.0222137	(0.0029)	1.0234740	(0.0023)	1.0230921	(0.0022)	K>1	K>1	OK	4
1986	1.0637881	(0.0173)	1.0654477	(0.0158)	1.0646186	(0.0166)	1.0638010	(0.0165)	K>1	K>1	OK	5
1987	1.0603254	(0.0374)	1.0643044	(0.0387)	1.0623120	(0.0380)	1.0612842	(0.0380)	OK	OK	OK	9
1988	1.0491367	(0.0269)	1.0509974	(0.0279)	1.0500667	(0.0274)	1.0493495	(0.0273)	OK	OK	OK	3

TRANSPORTATION EQUIPMENT

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0113729	(1.0452)	0.0081468	(1.0275)	0.0042730	(1.0363)	0.0049510	(1.0366)	OK	K>1	OK	8
1965	1.0124116	(1.0674)	0.0126039	(1.0405)	0.0079969	(1.0538)	0.0101336	(1.0539)	OK	K>1	OK	8
1966	1.0094764	(1.0408)	0.0075757	(1.0285)	0.0071605	(1.0346)	0.0068882	(1.0340)	OK	K>1	OK	8
1967	1.0057967	(1.0318)	0.0050878	(1.0222)	0.0022262	(1.0270)	0.0032330	(1.0266)	OK	K>1	OK	8
1968	1.0087713	(1.0608)	0.0165605	(1.0426)	0.0108185	(1.0517)	0.0136349	(1.0511)	OK	K>1	OK	7
1969	1.0084872	(0.0056)	1.0108426	(0.0063)	1.0096645	(0.0060)	1.0096502	(0.0060)	OK	OK	OK	7
1970	1.0090872	(0.0071)	1.0117812	(0.0078)	1.0104331	(0.0075)	1.0104251	(0.0074)	OK	OK	OK	7
1971	1.0054329	(0.0042)	1.0080668	(0.0046)	1.0067484	(0.0044)	1.0067618	(0.0044)	OK	OK	OK	7
1972	1.0135838	(0.0055)	1.0159187	(0.0057)	1.0147502	(0.0056)	1.0147511	(0.0056)	K>1	K>1	OK	7
1973	1.0157098	(0.0052)	1.0176811	(0.0055)	1.0166946	(0.0054)	1.0166760	(0.0054)	K>1	K>1	OK	7
1974	1.0021465	(0.0058)	1.0040762	(0.0059)	1.0031104	(0.0058)	1.0031217	(0.0058)	OK	OK	OK	7
1975	1.0111373	(0.0020)	1.0135050	(0.0021)	1.0123199	(0.0020)	1.0123352	(0.0020)	K>1	K>1	OK	7
1976	1.0236966	(0.0061)	1.0259599	(0.0058)	1.0248272	(0.0060)	1.0248279	(0.0060)	K>1	K>1	OK	6
1977	1.0249660	(0.0040)	1.0273023	(0.0040)	1.0261329	(0.0040)	1.0261328	(0.0040)	K>1	K>1	OK	6
1978	1.0176342	(0.0032)	1.0205856	(0.0034)	1.0191081	(0.0033)	1.0191350	(0.0033)	K>1	K>1	OK	6
1979	1.0196345	(0.0042)	1.0229990	(0.0045)	1.0213144	(0.0044)	1.0213224	(0.0044)	K>1	K>1	OK	6
1980	1.0173526	(0.0033)	1.0195039	(0.0033)	1.0184272	(0.0033)	1.0184557	(0.0033)	K>1	K>1	OK	6
1981	1.0132902	(0.0062)	1.0163753	(0.0064)	1.0148307	(0.0063)	1.0148414	(0.0063)	OK	K>1	OK	6
1982	1.0195819	(0.0110)	1.0223016	(0.0111)	1.0209401	(0.0110)	1.0209987	(0.0110)	OK	OK	OK	6
1983	1.0470381	(0.0052)	1.0280931	(0.0068)	1.0375167	(0.0042)	1.0379641	(0.0041)	K>1	OK	NO	3
1984	1.0452007	(0.0081)	1.0274768	(0.0043)	1.0362962	(0.0050)	1.0366373	(0.0050)	K>1	K>1	NO	3
1985	1.0673654	(0.0126)	1.0404513	(0.0080)	1.0537629	(0.0101)	1.0538576	(0.0103)	K>1	K>1	NO	4
1986	1.0407970	(0.0076)	1.0284518	(0.0072)	1.0346008	(0.0069)	1.0340212	(0.0069)	K>1	K>1	NO	5
1987	1.0318323	(0.0051)	1.0221972	(0.0022)	1.0270015	(0.0032)	1.0265709	(0.0031)	K>1	K>1	NO	9
1988	1.0608332	(0.0166)	1.0425971	(0.0108)	1.0516508	(0.0136)	1.0511154	(0.0136)	OK	OK	OK	3

TABLE 3.1 ESTIMATED SCALE ELASTICITY (CONT'D)

INSTRUMENT, RELATED PRODUCTS

YEAR	LOWER BOUND OF SCALE ELASTICITY KL *EST*	*SD*	UPPER BOUND OF SCALE ELASTICITY KU *EST*	*SD*	SCALE ELASTICITY BY IDEAL INDEX KI *EST*	*SD*	SCALE ELASTICITY BY DIVISIA INDEX KD *EST*	*SD*	NULL HYPOTHESIS OF CONSTANT RETURN HO:KL=1	HO:KU=1	HO:KL=KU	S.S
1964	1.0079241	(1.0424)	0.0252026	(1.0350)	0.0197750	(1.0387)	0.0224076	(1.0389)	OK	OK	OK	8
1965	1.0052188	(1.0640)	0.0089550	(1.0395)	0.0067013	(1.0517)	0.0069875	(1.0539)	OK	K>1	OK	8
1966	1.0122714	(1.0538)	0.0111228	(1.0547)	0.0129577	(1.0543)	0.0120376	(1.0542)	OK	K>1	OK	8
1967	1.0166422	(1.0515)	0.0177704	(1.0521)	0.0199619	(1.0518)	0.0188586	(1.0518)	OK	K>1	OK	8
1968	1.0172693	(1.0514)	0.0076295	(1.0445)	0.0086519	(1.0480)	0.0077716	(1.0482)	OK	K>1	OK	7
1969	1.0163384	(0.0053)	1.0191003	(0.0059)	1.0177193	(0.0056)	1.0176824	(0.0056)	K>1	K>1	OK	7
1970	1.0135508	(0.0052)	1.0157165	(0.0058)	1.0146334	(0.0055)	1.0145959	(0.0055)	K>1	K>1	OK	7
1971	1.0068660	(0.0085)	1.0101913	(0.0088)	1.0085263	(0.0086)	1.0085076	(0.0086)	OK	OK	OK	7
1972	1.0264280	(0.0070)	1.0287695	(0.0073)	1.0275980	(0.0071)	1.0275463	(0.0072)	K>1	K>1	OK	6
1973	1.0130127	(0.0087)	1.0149032	(0.0086)	1.0139575	(0.0086)	1.0139128	(0.0086)	OK	OK	OK	7
1974	1.0311144	(0.0103)	1.0336621	(0.0106)	1.0323868	(0.0104)	1.0323756	(0.0104)	K>1	K>1	OK	7
1975	1.0364167	(0.0077)	1.0402710	(0.0080)	1.0383407	(0.0078)	1.0383144	(0.0078)	K>1	K>1	OK	7
1976	1.0154910	(0.0087)	1.0208958	(0.0081)	1.0181872	(0.0084)	1.0182399	(0.0084)	OK	K>1	OK	6
1977	1.0239716	(0.0097)	1.0276932	(0.0097)	1.0258296	(0.0097)	1.0259263	(0.0097)	OK	K>1	OK	6
1978	1.0179647	(0.0064)	1.0213998	(0.0060)	1.0196797	(0.0062)	1.0198469	(0.0062)	K>1	K>1	OK	6
1979	1.0150891	(0.0092)	1.0206394	(0.0086)	1.0178577	(0.0089)	1.0178683	(0.0089)	OK	OK	OK	6
1980	1.0171226	(0.0106)	1.0202911	(0.0103)	1.0187047	(0.0104)	1.0187835	(0.0104)	OK	OK	OK	6
1981	1.0057037	(0.0112)	1.0107958	(0.0109)	1.0082438	(0.0110)	1.0082280	(0.0110)	OK	OK	OK	6
1982	1.0224314	(0.0099)	1.0275150	(0.0092)	1.0249677	(0.0096)	1.0249072	(0.0096)	OK	K>1	OK	6
1983	1.0695129	(0.0319)	1.0618841	(0.0244)	1.0657107	(0.0281)	1.0655004	(0.0280)	OK	OK	OK	3
1984	1.0424379	(0.0252)	1.0350375	(0.0198)	1.0387432	(0.0224)	1.0389090	(0.0225)	OK	OK	OK	3
1985	1.0640207	(0.0090)	1.0395317	(0.0067)	1.0516836	(0.0070)	1.0538729	(0.0072)	K>1	K>1	NO	4
1986	1.0538434	(0.0111)	1.0547142	(0.0130)	1.0542803	(0.0120)	1.0542339	(0.0120)	K>1	K>1	OK	5
1987	1.0514738	(0.0178)	1.0520873	(0.0200)	1.0517832	(0.0189)	1.0517666	(0.0188)	K>1	K>1	OK	9
1988	1.0514117	(0.0076)	1.0444943	(0.0087)	1.0479534	(0.0078)	1.0482473	(0.0077)	K>1	K>1	OK	3

TABLE 4.1. EMPIRICAL ESTIMATES FOR THE RATE OF TECHNICAL CHANGE AND THE ELASTICITY OF SCALE: MANUFACTURING INDUSTRIES 1964–1988

	FOOD/KINDRED PRODUCTS						TEXTILES						APPARELS					
Years	lna(s)	r	k	F^b	R^2	Sample size	lna(s)	r	k	F^b	R^2	Sample size	lna(s)	r	k	F^b	R^2	Sample size
64-65	3.33	0.0074	1.047	5.0	0.9966	18	3.08	0.0097	0.989	34.6	0.9999	18	2.89	0.0338	0.994	3.0	0.9997	16
	40.3[a]	0.60	44.2				329.6	1.28	459.7				254.0	2.77	239.7			
65-66	3.34	0.0253	1.056	6.5	0.9967	18	3.08	0.0364	0.990	33.2	1.0000	18	2.81	0.0430	1.001	0.0	0.9995	16
	40.7	1.74	43.3				464.7	6.90	490.3				110.2	8.09	110.7			
66-67	3.51	-0.0045	1.042	15.7	0.9977	18	3.20	0.0390	0.991	19.3	0.9999	18	2.95	0.0219	0.997	0.2	0.9995	16
	59.8	-0.20	87.2				440.9	7.61	427.2				117.9	2.14	124.4			
67-68	4.33	-0.0195	1.064	13.0	0.9980	16	4.16	0.0298	0.992	4.9	0.9999	16	3.90	-0.0275	1.002	0.2	0.9996	14
	73.6	-1.48	53.7				362.3	5.65	226.3				303.5	-3.01	198.1			
68-69	4.51	0.0214	1.060	9.4	0.9977	16	4.34	0.0259	0.974	110.8	0.9998	16	4.01	-0.0152	0.980	73.1	0.9994	12
	71.6	1.94	47.8				255.4	3.67	341.8				143.9	-1.13	342.4			
69-70	4.58	0.0401	1.092	35.2	0.9981	16	4.43	0.0472	0.982	88.3	0.9999	16	4.07	-0.0301	0.995	0.4	0.9997	12
	82.9	2.45	61.6				568.0	11.06	439.5				258.8	-5.28	111.3			
70-71	4.71	-0.0064	1.082	25.9	0.9985	16	4.59	0.0198	0.989	5.7	0.9998	16	4.17	-0.0066	0.995	3.6	0.9998	12
	91.1	-0.52	58.8				330.6	3.91	191.2				329.1	-0.42	335.1			
71-72	4.87	0.0164	1.056	14.1	0.9979	16	4.63	0.0348	0.991	4.1	0.9998	16	4.28	0.0295	0.974	538.1	0.9994	12
	93.0	0.86	62.3				356.7	3.92	191.3				362.2	1.39	718.1			
72-73	4.94	0.0442	1.094	31.6	0.9980	16	4.76	0.0360	1.006	3.5	0.9999	16	4.31	0.0731	1.012	14.4	0.9997	12
	87.9	2.06	57.4				384.2	3.51	293.7				256.5	5.95	263.1			
73-74	5.23	-0.0256	1.070	51.0	0.9989	16	5.04	0.0204	1.008	11.0	0.9999	16	4.58	-0.0777	1.017	26.4	0.9996	12
	129.4	-1.47	95.9				690.9	2.57	377.1				614.3	-4.27	244.4			
74-75	5.41	0.0121	1.060	40.2	0.9993	16	5.15	-0.0266	1.004	1.3	0.9994	16	4.63	0.0246	1.058	102.7	0.9995	12
	166.4	0.75	97.6				470.9	-1.18	233.0				191.1	1.48	150.8			
75-76	6.22	0.0220	1.063	43.3	0.9987	14	5.69	0.0789	0.985	3.2	0.9993	14	5.08	0.0716	1.044	31.6	0.9997	10
	230.8	0.95	94.5				215.1	4.62	102.5				285.7	6.49	99.8			
76-77	6.37	-0.0097	1.082	42.5	0.9987	14	5.91	-0.0343	0.978	11.5	0.99967	14	5.17	-0.0749	1.033	33.9	0.9998	10
	164.5	-0.95	73.1				318.2	-3.21	131.6				337.3	-5.72	136.4			
77-78	6.49	0.0114	1.074	30.8	0.9988	14	5.91	0.0452	0.986	8.3	0.9990	14	5.26	0.0429	1.022	14.8	0.9997	10
	176.9	0.79	69.7				393.1	1.42	177.7				357.0	2.99	138.0			
78-79	6.49	0.0108	1.114	43.0	0.9984	14	5.94	0.0151	1.018	8.5	0.9998	8	5.22	0.0336	1.055	209.4	0.9998	10
	145.8	0.90	55.0				381.7	2.43	105.7				353.8	3.55	210.0			
79-80	6.49	-0.0044	1.119	43.7	0.9984	14	6.00	0.0263	1.031	189.0	0.9999	8	5.34	-0.0162	1.069	6.6	0.9970	12
	132.5	-0.33	53.1				455.3	4.81	285.1				80.9	-1.81	32.6			
80-81	6.67	-0.0315	1.118	45.4	0.9976	14	6.10	-0.0132	1.023	10.9	0.9994	10	5.43	-0.1073	1.039	17.7	0.9970	12
	150.3	-1.28	54.3				312.5	-1.11	111.7				97.3	-1.79	92.6			
81-82	6.74	0.0223	1.097	19.3	0.9953	14	6.14	0.0121	1.003	0.1	0.9992	10	5.43	-0.0016	1.027	44.6	0.9998	12
	114.0	1.29	42.2				212.3	3.40	63.0				355.2	-0.12	209.3			
82-83	6.82	-0.0108	1.084	13.8	0.9946	14	6.16	0.0210	1.003	0.1	0.9994	10	5.45	0.0909	1.026	44.5	0.9996	12
	100.7	-1.06	40.6				242.8	3.25	74.3				592.0	5.55	211.6			
83-84	6.81	-0.0094	1.108	14.6	0.9959	14	6.14	0.0168	1.022	12.6	0.9996	10	5.57	-0.0144	1.024	9.3	0.9994	12
	96.5	-0.54	33.3				274.3	2.08	125.4				242.7	-0.71	104.8			
84-85	6.89	-0.1115	1.087	38.4	0.9972	14	6.24	-0.0236	1.018	20.0	0.999	8	5.55	-0.0189	1.017	3.6	0.9988	12
	146.1	-2.27	65.8				341.9	-7.00	156.4				271.8	-0.63	93.2			
85-86	6.64	-0.0090	1.089	29.9	0.9985	14	6.23	-0.0403	1.013	7.8	0.9998	8	5.57	-0.0006	1.009	1.0	0.9989	12
	156.8	-1.47	56.8				478.2	-2.77	142.4				169.0	-0.02	88.4			
86-87	6.65	-0.0076	1.076	36.4	0.9989	14	6.17	0.0346	1.040	11.0	0.9991	10	5.55	0.0250	1.028	92.6	0.9995	12
	196.8	-0.39	73.1				170.1	3.20	64.9				319.2	0.86	289.6			
87-88	6.64	0.0153	1.075	33.9	0.9990	14	6.18	-0.0176	1.063	178.2	0.9999	8	5.53	-0.0017	1.042	27.3	0.9993	12
	212.8	1.06	70.9				333.9	-4.58	142.0				282.6	-0.09	105.7			
Average	5.61	-0.0001	1.080				5.22	0.0164	1.004				4.70	0.0040	1.019			
	114.0	.45	64.0				385.7	3.40	258.2				267.2	.63	208.7			

[a] Numbers under regression coefficients estimates denote t-statistics for these estimates.

[b] The F denotes the F-Statistic for testing the null hypothesis H_0:k=1.

TABLE 4.1. (Continued)

	LUMBER/WOOD PRODUCTS						FURNITURE/FIXTURES						PULP/PAPER PRODUCTS					
Years	lna(s)	r	k	F[b]	R^2	Sample size	lna(s)	r	k	F[b]	R^2	Sample size	lna(s)	r	k	F[b]	R^2	Sample size
64-65	3.28	0.0045	1.018	60.1	0.9998	18	3.00	0.0113	1.004	1.4	0.9999	16	3.13	0.0021	1.018	13.7	0.9997	16
	255.6[a]	0.24	393.9				274.7	2.92	258.5				147.5	0.15	184.5			
65-66	3.28	0.0385	1.021	39.7	0.9999	18	3.03	0.0255	1.006	1.6	0.9995	16	3.14	0.0528	1.016	10.7	0.9997	18
	240.5	5.06	271.2				192.3	1.69	171.3				160.2	3.25	185.1			
66-67	3.45	-0.0049	1.013	18.5	0.9998	18	3.14	0.0465	1.010	1.8	0.9993	16	3.25	0.0018	1.013	11.3	0.9998	18
	299.2	-0.29	304.0				124.7	1.81	124.6				166.5	0.13	240.3			
67-68	4.31	0.0165	1.000	0.0	0.9997	16	3.97	0.0438	1.040	39.0	0.9994	12	4.23	0.0478	1.027	85.7	0.9998	16
	240.2	1.57	144.7				149.6	2.12	131.7				321.7	2.76	313.6			
68-69	4.42	0.0054	1.013	21.2	0.9998	16	4.11	0.0240	1.029	29.1	0.9998	12	4.44	0.0114	1.022	53.1	0.9999	16
	341.7	0.50	321.3				277.7	2.66	154.4				380.7	1.39	297.5			
69-70	4.54	0.0006	1.014	24.4	0.9998	16	4.28	0.0354	1.024	19.1	0.9997	12	4.59	0.0576	1.017	31.0	0.9998	16
	562.6	0.04	317.1				317.9	2.69	153.7				449.2	4.39	297.3			
70-71	4.66	-0.0304	1.034	40.7	0.9995	16	4.46	-0.0869	1.037	25.7	0.9993	14	4.84	-0.0259	1.020	33.4	0.9997	16
	298.3	-1.45	171.8				220.8	-3.51	120.1				321.9	-1.23	263.1			
71-72	4.70	-0.0284	1.029	50.7	0.9995	16	4.40	0.0604	1.034	15.0	0.9989	14	4.83	0.0384	1.023	83.0	0.9998	16
	218.8	-1.36	225.2				158.2	1.69	99.4				317.8	2.14	360.4			
72-73	4.92	0.0101	1.012	49.5	0.9996	12	4.66	0.0225	1.033	10.7	0.9992	14	4.97	-0.0072	1.022	32.6	0.9998	16
	603.7	0.53	476.0				145.2	1.79	87.9				385.9	-0.56	228.1			
73-74	5.33	0.0004	1.015	23.4	0.9993	12	4.91	-0.0888	1.036	26.9	0.9996	14	5.29	-0.0075	1.013	5.8	0.9997	16
	201.9	0.01	273.5				225.9	-8.71	126.2				292.8	-0.46	165.7			
74-75	5.41	-0.0088	0.998	0.7	0.9999	12	5.13	-0.0701	1.024	79.5	0.9998	14	5.66	-0.0245	0.987	16.4	0.9997	16
	733.9	-1.21	339.3				394.4	-4.14	330.1				205.6	-1.24	277.9			
75-76	5.84	0.0414	1.001	0.1	0.9997	10	5.62	0.0787	1.027	56.1	0.9997	12	6.06	0.0450	0.993	3.2	0.9995	14
	729.6	2.46	202.1				489.1	4.26	235.3				441.0	2.04	206.9			
76-77	6.01	-0.0006	0.999	0.0	0.9995	10	5.71	0.0219	1.035	21.8	0.9992	12	6.19	-0.0633	1.007	0.9	0.9995	14
	253.0	-0.07	74.7				311.3	1.12	112.3				222.6	-2.97	112.1			
77-78	6.07	0.0241	1.028	130.1	0.9997	10	5.82	0.0299	1.049	8.6	0.9970	12	6.33	0.0085	0.998	0.2	0.9995	14
	386.8	1.40	316.1				142.2	0.89	51.1				316.2	1.35	154.7			
78-79	6.15	0.0723	1.007	1.7	0.9996	12	5.89	0.1224	1.058	25.4	0.9971	12	6.39	0.0183	0.994	0.6	0.9994	14
	327.5	8.49	149.5				116.5	4.72	74.4				237.6	1.00	115.4			
79-80	6.32	-0.0345	1.017	10.1	0.9995	12	6.00	-0.0390	1.066	27.0	0.9991	12	6.47	0.0157	0.993	0.9	0.9997	14
	394.6	-1.74	151.2				175.5	-1.82	68.5				288.4	2.04	117.2			
80-81	6.51	-0.0080	0.980	4.0	0.9990	12	6.12	-0.0589	1.065	142.7	0.9996	12	6.68	-0.0295	0.995	0.5	0.9994	14
	233.4	-0.52	79.2				284.2	-3.84	160.1				261.5	-2.33	105.4			
81-82	6.35	0.0166	1.009	0.3	0.9987	12	6.13	0.0332	1.066	154.4	0.9998	12	6.62	0.0464	1.004	0.6	0.9995	14
	145.0	1.33	50.2				462.3	2.42	163.9				239.7	3.52	150.9			
82-83	6.36	-0.0135	1.027	19.5	0.9992	12	6.17	-0.0040	1.061	100.7	0.9989	12	6.71	0.0044	0.996	0.4	0.9997	14
	217.4	-1.07	136.6				332.3	-0.20	143.0				322.1	0.52	128.7			
83-84	6.39	-0.0159	1.036	15.9	0.9991	12	6.27	0.0216	1.042	6.2	0.9972	12	6.68	0.0427	1.009	2.7	0.9997	14
	243.1	-0.68	92.7				123.8	1.22	50.7				322.4	3.43	163.5			
84-85	6.41	0.0220	1.011	1.0	0.9992	12	6.21	-0.0104	1.106	19.3	0.9957	12	6.75	-0.0013	0.994	2.1	0.9998	14
	186.9	1.73	77.6				97.5	-0.80	37.4				386.6	-0.12	215.4			
85-86	6.39	0.0386	1.047	50.2	0.9991	12	6.30	-0.0207	1.082	5.1	0.9947	12	6.70	0.0010	1.002	0.5	0.9997	14
	172.1	1.15	127.9				71.6	-0.90	24.3				552.3	0.05	247.5			
86-87	6.40	0.0131	1.056	163.2	0.9999	12	6.30	0.0254	1.088	5.4	0.9944	12	6.65	0.0057	1.019	11.3	0.9997	14
	449.5	1.28	198.2				69.9	2.06	23.5				346.5	0.34	151.4			
87-88	6.49	-0.0238	1.050	574.1	0.9998	12	6.31	-0.0090	1.096	10.4	0.9954	12	6.66	0.0434	1.021	6.2	0.9996	14
	738.0	-1.17	408.9				78.7	-0.29	30.2				244.5	3.84	101.6			
Average	5.42	0.0056	1.018				5.17	0.0090	1.047				5.55	0.0118	1.008			
	359.2	.83	236.7				247.9	.49	145.8				286.5	.85	209.8			

[a] Numbers under regression coefficients estimates denote t-statistics for these estimates.

[b] The F denotes the F-Statistic for testing the null hypothesis H_0:k=1.

TABLE 4.1. (Continued)

	CHEMICALS						PETROLEUM/COAL PRODUCTS						RUBBER/PLASTIC PRODUCTS					
Years	lna(s)	r	k	F^b	R^2	Sample size	lna(s)	r	k	F^b	R^2	Sample size	lna(s)	r	k	F^b	R^2	Sample size
64-65	3.74	-0.0131	1.037	43.3	0.9996	18	3.58	0.0394	1.028	5.5	0.9989	16	3.11	0.0150	1.022	22.7	0.9997	18
	184.3[a]	-0.71	163.5				67.5	1.30	75.2				206.3	1.18	199.8			
65-66	3.76	0.0577	1.037	30.3	0.9995	18	3.72	0.0292	1.038	6.8	0.9983	16	3.12	0.0415	1.029	25.5	0.9996	18
	139.6	2.97	138.8				57.5	0.89	63.0				123.0	2.45	162.5			
66-67	3.87	0.0409	1.038	55.7	0.9998	18	4.74	0.0267	1.058	8.2	0.9978	14	3.23	0.0223	1.016	34.5	0.9989	16
	196.2	4.87	181.8				57.1	1.70	44.7				382.1	0.68	333.2			
67-68	4.77	0.0517	1.056	147.7	0.9998	16	4.97	0.0260	1.047	26.0	0.9981	12	4.08	0.0475	1.026	22.8	0.9980	14
	272.0	3.4	199.5				82.0	0.87	91.8				100.8	1.03	161.3			
68-69	4.91	0.0226	1.057	219.5	0.9998	16	5.03	-0.0254	1.026	4.6	0.9989	12	4.20	0.0328	1.031	77.3	0.9996	16
	363.8	1.67	241.2				114.6	-0.64	68.5				335.8	1.48	254.0			
69-70	5.66	0.0271	1.072	281.1	0.9996	14	5.22	-0.0325	1.010	0.6	0.9990	12	4.48	0.0445	1.036	27.4	0.9995	16
	339.6	1.03	213.4				99.5	-1.23	67.4				196.6	2.27	133.8			
70-71	5.83	-0.0145	1.069	129.3	0.9994	14	5.63	-0.0110	1.006	0.3	0.9992	12	4.48	-0.0257	1.037	26.2	0.9996	16
	316.2	-0.55	150.1				138.6	-0.51	66.8				212.0	-2.09	127.5			
71-72	5.33	0.0343	1.053	30.3	0.9993	16	5.68	-0.0090	0.994	0.3	0.9993	12	4.53	0.0594	1.066	79.2	0.9993	16
	182.2	2.25	95.3				133.7	-0.34	72.4				149.2	2.21	125.8			
72-73	5.46	0.0002	1.059	31.4	0.9991	16	5.78	0.0173	1.014	0.6	0.9981	12	4.72	0.0507	1.066	100.3	0.9996	16
	174.7	0.02	88.7				85.2	0.66	44.0				257.0	3.65	142.1			
73-74	5.72	-0.0084	1.037	13.1	0.9990	16	5.99	0.3268	0.973	2.8	0.9982	12	5.01	-0.0863	1.052	35.2	0.9992	16
	166.1	-0.36	90.1				79.4	14.72	49.5				206.2	-4.85	104.4			
74-75	6.04	-0.0439	1.038	17.9	0.9990	16	6.25	-0.0832	0.984	3.8	0.9991	16	5.24	-0.0461	1.039	27.0	0.9993	16
	213.2	-4.32	101.1				134.6	-4.32	107.8				187.7	-1.92	121.4			
75-76	6.61	0.0309	1.026	2.6	0.9984	14	7.32	0.0768	1.002	0.2	0.9997	14	5.73	0.1285	1.051	44.7	0.9994	14
	142.7	1.76	53.0				323.6	3.36	157.0				278.3	5.66	116.8			
76-77	6.86	0.0062	1.016	3.5	0.9990	14	7.57	-0.1210	1.002	0.1	0.9997	14	5.88	-0.0347	1.045	14.8	0.9988	14
	214.3	0.29	99.3				271.2	-5.91	142.8				170.7	-1.14	76.1			
77-78	6.92	0.0490	1.023	7.4	0.9994	14	7.54	-0.0052	1.007	1.5	0.9991	14	5.90	0.0504	1.063	29.9	0.9990	14
	306.3	2.67	103.7				309.7	-0.13	141.0				150.5	3.00	78.5			
78-79	6.97	0.0333	1.048	29.2	0.9989	14	7.48	0.0631	1.008	0.4	0.9988	14	5.92	0.0398	1.050	20.9	0.9993	14
	274.3	2.71	101.2				137.8	1.73	75.4				184.7	4.36	81.3			
79-80	7.11	0.0618	1.029	2.8	0.9983	14	7.70	0.0158	1.006	0.6	0.9995	14	6.01	0.0206	1.052	132.1	0.9996	14
	152.7	4.46	50.7				212.6	0.80	112.2				280.9	1.63	199.0			
80-81	7.28	0.0046	1.017	0.9	0.9982	14	8.22	-0.0138	1.006	0.6	0.9997	14	6.09	-0.0391	1.058	392.5	0.9996	14
	146.6	0.43	47.7				278.2	-1.33	113.9				514.2	-2.76	310.4			
81-82	7.34	0.0304	1.020	1.2	0.9980	14	8.12	0.0468	1.004	0.2	0.9985	14	6.14	0.0141	1.048	61.6	0.9995	14
	147.8	2.44	46.6				248.4	0.96	105.3				246.7	0.88	146.1			
82-83	7.43	0.0232	1.034	3.8	0.9982	14	8.41	-0.0838	1.000	0.0	0.9984	14	6.27	0.0290	1.042	67.7	0.9998	14
	158.8	1.25	50.3				142.4	-1.59	81.5				409.7	2.89	174.1			
83-84	7.51	0.0263	1.018	1.6	0.9981	14	8.27	0.0371	1.005	5.8	0.9999	8	6.30	-0.0053	1.043	59.7	0.9998	14
	174.5	3.44	59.0				284.6	1.00	302.4				395.5	-0.73	160.5			
84-85	7.41	0.0036	1.062	12.8	0.9974	14	8.28	0.0557	1.005	9.0	0.9996	8	6.25	-0.1267	1.049	67.5	0.9807	14
	150.9	0.35	52.2				829.7	1.30	360.5				347.6	-0.82	150.6			
85-86	7.42	0.0248	1.085	16.1	0.9970	14	7.97	-0.2106	1.012	0.6	0.9987	8	6.30	-0.0114	1.065	49.5	0.9995	12
	116.7	0.87	43.7				121.3	-2.58	40.7				277.4	-1.38	93.8			
86-87	7.40	0.0080	1.081	17.1	0.9980	14	7.42	0.2234	1.021	0.8	0.9975	10	6.21	0.0283	1.064	64.8	0.9995	12
	145.2	0.88	46.8				84.2	4.96	33.2				261.2	1.21	108.5			
87-88	7.35	0.0383	1.082	17.3	0.9980	14	7.39	-0.1780	1.041	90.6	0.9978	10	6.23	0.0486	1.070	42.5	0.9994	12
	143.1	2.45	46.7				93.1	-1.73	182.7				232.2	2.19	81.4			
Average	6.20	0.0206	1.046				6.59	0.0088	1.012				5.23	0.0124	1.047			
	218.5	1.39	120.3				153.7	.70	88.8				232.8	.98	159.7			

[a] Numbers under regression coefficients estimates denote t-statistics for these estimates.

[b] The F denotes the F-Statistic for testing the null hypothesis $H_0{:}k=1$.

TABLE 4.1. (Continued)

	LEATHER/LEATHER PRODUCTS						POTTERY/GLASS PRODUCTS						IRON/STEEL					
Years	lna(s)	r	k	F^b	R^2	Sample size	lna(s)	r	k	F^b	R^2	Sample size	lna(s)	r	k	F^b	R^2	Sample size
64-65	3.61	0.0213	0.989	2.5	0.9994	16	2.77	-0.0331	1.071	53.3	0.9990	18	3.59	-0.0061	0.993	10.4	0.9999	18
	177.6[a]	1.14	126.9				75.5	-2.46	98.9				243.9	-0.67	427.0			
65-66	3.52	0.0054	1.004	0.2	0.9995	16	2.79	0.0766	1.076	120.5	0.9991	16	3.57	0.0473	0.995	5.6	0.9999	18
	145.0	0.50	107.5				72.4	3.03	138.9				377.4	6.14	381.5			
66-67	3.68	0.0497	1.000	0.0	0.9980	16	3.09	0.0299	1.063	75.2	0.9996	18	3.71	0.0579	1.000	0.0	0.9999	18
	160.8	1.55	111.9				121.8	3.53	130.5				343.0	9.75	386.5			
67-68	4.44	0.0356	1.023	2.8	0.9988	12	4.33	0.0683	1.093	439.6	0.9996	16	4.60	0.0250	1.002	0.7	1.0000	16
	146.2	1.91	60.9				197.3	3.22	215.2				609.8	3.71	444.5			
68-69	4.59	0.0291	1.024	3.2	0.9986	12	4.53	-0.0216	1.089	456.2	0.9996	16	4.69	0.0362	0.998	0.9	0.9999	16
	196.1	1.60	62.4				411.7	-1.43	230.2				529.6	7.60	365.9			
69-70	4.80	0.0405	1.016	0.7	0.9980	12	4.59	0.0469	1.106	1092.3	0.9996	16	4.86	0.0379	1.008	15.0	0.9999	16
	134.8	2.20	41.6				191.7	2.55	302.4				396.3	6.55	426.1			
70-71	4.85	-0.0301	1.009	0.2	0.9981	12	4.81	-0.0477	1.101	643.9	0.9996	16	5.08	-0.0359	1.001	0.3	0.9999	16
	129.6	-1.89	42.4				401.1	-2.89	242.6				597.5	-4.47	366.1			
71-72	4.86	0.1155	1.057	13.8	0.9983	12	4.85	0.0624	1.091	135.7	0.9994	16	5.04	0.0223	1.009	13.0	0.9998	16
	121.3	5.96	56.6				194.2	3.02	122.2				347.6	1.08	367.2			
72-73	5.04	-0.0871	1.029	3.5	0.9987	12	4.99	-0.0053	1.086	133.1	0.9995	16	5.24	0.0817	0.997	0.9	0,9999	16
	178.1	-5.21	53.9				248.8	-0.29	128.2				351.9	5.47	311.0			
73-74	5.20	-0.0416	1.033	4.8	0.9987	12	5.21	0.0175	1.069	399.7	0.9996	16	5.67	0.0460	0.995	3.7	0.9999	16
	167.6	-1.99	56.0				276.5	1.42	272.1				600.9	5.74	311.2			
74-75	5.33	-0.0208	1.026	6.0	0.9987	12	5.45	-0.0636	1.051	179.2	0.9997	16	5.94	-0.1069	0.999	0.1	0.9999	16
	203.6	-0.67	78.3				406.1	-3.47	241.1				521.9	-14.65	308.1			
75-76	5.86	0.0421	1.015	0.6	0.9943	10	5.78	0.0683	1.056	98.5	0.9995	14	6.45	0.0307	1.004	1.4	0.9998	14
	165.2	0.64	39.4				341.9	2.81	160.2				616.3	1.68	266.9			
76-77	6.04	-0.0572	1.058	5.8	0.9950	12	5.89	-0.0013	1.074	158.8	0.9997	14	6.62	-0.0287	1.002	2.2	0.9998	14
	92.2	-1.20	36.0				360.6	-0.09	155.5				447.1	-1.60	526.0			
77-78	6.01	0.0351	1.068	14.8	0.9976	12	5.98	0.0097	1.071	60.0	0.9990	14	6.81	0.0113	1.003	1.7	0.9998	14
	143.7	0.84	49.2				239.4	0.41	100.3				961.8	0.68	379.7			
78-79	6.10	0.0667	0.966	57.2	0.9997	8	6.26	-0.0176	1.006	0.2	0.9986	14	6.93	0.0326	1.017	13.1	0.9998	14
	174.3	21.71	135.5				109.0	-1.74	57.4				501.8	3.61	181.7			
79-80	6.26	-0.0931	0.986	13.8	0.9996	8	6.23	0.0358	1.056	29.1	0.9991	14	7.08	0.0725	1.032	92.9	0.9998	14
	326.7	-3.20	170.3				186.4	2.14	86.8				480.2	6.73	262.2			
80-81	6.27	-0.0142	1.049	6.6	0.9977	12	6.35	0.0036	1.055	33.4	0.9994	14	7.22	-0.0424	1.027	101.4	0.9999	14
	130.1	-0.58	45.2				234.6	0.23	95.0				780.6	-2.84	321.0			
81-82	6.32	0.0220	1.034	579.5	0.9998	8	6.38	0.0183	1.058	27.8	0.9991	14	7.21	0.0487	1.017	14.2	0.9996	14
	227.4	1.54	468.4				208.9	1.35	82.7				542.2	3.01	196.5			
82-83	6.37	0.0230	0.973	22.4	0.9996	8	6.40	-0.0139	1.057	17.9	0.9986	14	7.26	-0.0461	1.006	1.4	0.9995	14
	418.5	1.26	106.1				162.5	-1.82	66.7				262.5	-2.01	166.6			
83-84	6.36	0.0111	0.992	0.4	0.9991	8	6.37	0.0309	1.073	24.2	0.9986	14	7.19	0.0188	1.020	27.6	0.9997	14
	233.9	0.29	52.4				138.9	2.59	61.4				501.1	0.94	231.9			
84-85	6.40	-0.0296	1.012	1.3	0.9989	8	6.39	0.0027	1.084	43.9	0.9955	14	7.23	-0.2075	1.033	43.2	0.9200	14
	151.0	-0.60	63.3				162.6	0.03	72.9				513.7	-0.74	177.2			
85-86	6.42	-0.0305	1.005	0.6	0.9996	8	6.40	0.0105	1.087	84.3	0.9990	12	7.41	-0.0330	1.021	3.7	0.9993	12
	314.9	-1.23	105.9				225.8	0.29	93.8				312.3	-3.34	76.6			
86-87	6.45	0.0426	0.986	15.8	0.9978	8	6.46	0.0149	1.082	24.6	0.9989	12	7.35	-0.0201	1.040	12.0	0.9990	12
	418.2	0.75	174.1				156.0	2.53	53.3				288.8	-2.69	73.2			
87-88	6.39	0.0199	1.021	0.5	0.9955	6	6.47	0.0305	1.099	33.9	0.9966	12	7.33	0.0436	1.062	18.8	0.9987	12
	220.1	0.51	34.9				156.4	0.59	52.9				199.0	1.27	60.9			
Average	5.47	0.0065	1.016				5.37	0.0135	1.073				6.01	0.0036	1.012			
	167.8	1.38	96.8				237.7	0.63	158.9				513.9	2.08	346.1			

[a] Numbers under regression coefficients estimates denote t-statistics for these estimates.

[b] The F denotes the F-Statistic for testing the null hypothesis $H_0{:}k=1$.

TABLE 4.1. (Continued)

	NON-FERROUS METALS						METAL PRODUCTS						GENERAL MACHINERY					
Years	lna(s)	r	k	F^b	R^2	Sample size	lna(s)	r	k	F^b	R^2	Sample size	lna(s)	r	k	F^b	R^2	Sample size
64-65	3.85	-0.0169	1.010	34.2	0.9999	18	3.14	-0.0002	1.013	18.8	0.9998	18	3.03	0.0178	1.009	27.4	1.0000	18
	625.6[a]	-2.00	542.0				232.0	-0.01	303.6				367.5	2.17	512.9			
65-66	3.89	0.0433	1.004	1.0	0.9998	18	3.14	0.0370	1.010	7.5	0.9998	18	3.05	0.0313	1.010	19.9	0.9999	18
	265.0	3.62	236.6				234.4	3.92	243.5				370.7	2.62	412.3			
66-67	4.05	0.0165	1.001	0.0	0.9998	18	3.26	0.05000	1.009	6.2	0.9999	18	3.22	0.0713	1.007	5.6	0.9999	18
	252.1	1.85	228.0				215.7	6.93	244.2				221.8	9.06	322.5			
67-68	5.10	0.0034	1.005	2.3	0.9999	16	4.20	-0.0017	1.010	15.6	0.9999	16	4.12	0.0185	1.012	38.5	1.0000	16
	540.4	0.65	293.2				402.5	-0.18	335.4				578.2	3.71	446.6			
68-69	5.19	0.0523	1.006	3.0	0.9999	16	4.35	0.0632	1.010	10.9	0.9999	16	4.31	0.0538	1.009	17.1	0.9999	16
	480.4	6.59	267.8				456.8	6.80	297.1				611.5	6.79	426.8			
69-70	5.32	-0.0128	1.000	0.0	0.9998	12	4.50	0.0495	1.018	20.3	0.9999	16	4.48	0.0260	1.014	14.3	0.9999	16
	361.5	-1.53	169.1				356.4	10.43	222.3				320.8	3.13	246.5			
70-71	5.43	-0.0303	0.995	2.1	0.9999	12	4.66	0.0021	1.018	24.6	0.9997	16	4.64	0.0128	1.014	14.7	0.9999	16
	531.4	-3.35	214.5				394.3	0.12	246.7				371.3	1.81	248.4			
71-72	5.39	0.0234	1.019	31.0	0.9998	16	4.72	0.0578	1.021	48.0	0.9987	16	4.65	0.0184	1.019	32.5	0.9999	16
	304.3	1.26	267.9				298.9	2.19	293.4				411.5	1.75	266.2			
72-73	5.49	0.0127	1.017	40.9	0.9999	16	4.83	0.0340	1.030	12.7	0.9986	16	4.75	0.0151	1.017	14.3	0.9998	16
	599.9	0.96	332.6				119.4	1.66	107.3				322.6	1.36	204.2			
73-74	5.83	0.0008	1.012	7.8	0.9998	16	5.14	-0.0905	1.034	125.7	0.9996	16	5.04	0.0247	1.019	20.7	0.9999	16
	398.8	0.07	210.7				273.3	-3.77	296.1				335.3	4.77	210.2			
74-75	6.05	-0.0917	1.004	0.9	0.9998	16	5.38	-0.0178	1.027	26.3	0.9997	16	5.26	0.0072	1.019	19.8	0.9998	16
	406.7	-7.28	197.4				344.8	-1.43	168.0				388.2	0.60	213.3			
75-76	6.54	0.0861	1.001	0.0	0.9994	14	5.76	0.0901	1.043	52.5	0.9995	14	5.67	0.0507	1.038	44.6	0.9998	14
	324.5	4.96	115.4				267.5	14.50	151.0				302.0	5.28	153.9			
76-77	6.71	-0.0270	1.000	0.0	0.9994	14	5.92	0.0297	1.042	10.3	0.9994	10	5.77	0.0341	1.026	85.5	0.9999	14
	242.9	-2.52	105.9				203.0	4.88	60.6				381.3	2.54	315.2			
77-78	6.82	-0.0071	1.010	1.4	0.9994	14	6.04	0.0089	1.048	11.6	0.9993	10	5.91	0.0214	1.026	98.8	0.9999	14
	285.2	-0.37	102.8				185.4	0.83	55.8				736.1	4.28	332.7			
78-79	6.86	0.0677	1.019	8.1	0.9994	14	6.14	0.0084	1.053	78.9	0.9992	14	6.02	0.0172	1.019	33.3	0.9999	14
	303.9	2.77	132.6				209.1	0.34	150.0				591.2	5.29	270.7			
79-80	7.01	0.0116	1.022	12.8	0.9996	14	6.23	-0.0072	1.055	90.4	0.9987	14	6.14	0.0445	1.022	278.3	1.0000	14
	332.5	0.56	139.2				390.5	-0.21	154.6				895.1	5.38	667.8			
80-81	7.30	-0.0283	1.021	23.9	0.9998	14	6.39	-0.0017	1.034	17.0	0.9989	14	6.27	0.0122	1.022	139.9	1.0000	14
	443.5	-2.06	205.3				188.5	-0.06	105.7				1081.5	1.76	477.2			
81-82	7.29	0.0138	1.021	26.0	0.9996	14	6.37	0.0430	1.045	35.9	0.9994	14	6.31	0.0005	1.021	37.6	0.9998	14
	668.9	0.74	212.5				278.2	1.70	118.3				605.9	0.04	259.8			
82-83	7.36	-0.0456	0.985	3.0	0.9992	14	6.42	0.0025	1.042	47.2	0.9995	14	6.33	0.0007	1.019	18.9	0.9998	14
	208.7	-3.66	96.1				253.4	0.11	147.0				382.9	0.05	196.2			
83-84	7.41	-0.0006	1.013	1.7	0.9994	14	6.30	0.0063	1.053	27.8	0.9996	14	6.31	0.0138	1.021	78.8	0.9999	14
	292.5	-0.05	89.6				336.6	0.51	133.2				625.2	1.06	372.9			
84-85	7.53	-0.1877	1.017	3.0	0.9630	14	6.45	0.0012	1.058	123.1	0.9985	14	6.39	-0.0611	1.025	41.5	0.9907	14
	306.5	-1.03	89.9				336.6	0.02	171.5				513.4	-0.56	225.8			
85-86	7.36	-0.0661	0.997	0.1	0.9994	12	6.49	-0.0128	1.040	66.5	0.9997	12	6.47	-0.0020	1.019	71.5	0.9999	12
	297.5	-6.35	78.7				513.7	-1.22	174.3				878.6	-0.16	361.6			
86-87	7.23	0.0419	1.000	0.0	0.9995	12	6.60	0.0161	0.968	28.6	0.9994	12	6.45	-0.0080	1.016	10.3	0.9998	12
	396.8	1.88	137.2				124.9	1.53	131.1				457.5	-0.63	164.0			
87-88	7.21	0.1064	1.015	68.7	0.9987	12	6.50	-0.0143	1.056	82.5	0.9991	12	6.42	0.0288	1.029	31.3	0.9998	12
	503.3	2.34	452.0				300.4	-0.35	140.2				348.6	1.69	159.6			
Average	6.18	-0.0014	1.008				5.38	0.0147	1.030				5.29	0.0187	1.019			
	409.3	.27	220.8				280.6	2.70	197.4				494.1	3.46	332.6			

[a] Numbers under regression coefficients estimates denote t-statistics for these estimates.

[b] The F denotes the F-Statistic for testing the null hypothesis $H_0{:}k=1$.

TABLE 4.1. (Continued)

	ELECTRIC MACHINERY						TRANSPORTATION MACHINERY						PRECISION					
Years	ln a(s)	r	k	F^b	R^2	Sample size	ln a(s)	r	k	F^b	R^2	Sample size	ln a(s)	r	k	F^b	R^2	Sample size
64-65	2.99	0.0230	1.021	8.8	0.9995	18	2.96	0.0283	1.014	4.2	0.9996	18	2.95	0.0143	1.008	0.9	0.9993	18
	106.4[a]	2.20	127.9				108.8	3.26	136.6				95.6	1.05	101.2			
65-66	2.97	0.0208	1.017	7.7	0.9995	18	2.98	0.0259	1.013	4.3	0.9997	18	2.98	0.0586	1.015	3.0	0.9993	18
	124.3	3.00	147.6				116.4	6.04	143.0				94.4	4.33	103.1			
66-67	3.04	0.0590	1.025	10.8	0.9995	18	3.08	0.0549	1.009	2.2	0.9997	18	3.11	0.0494	1.018	5.3	0.9995	18
	101.7	6.05	119.0				121.3	8.22	141.7				112.4	4.80	116.3			
67-68	3.94	0.0293	1.034	22.9	0.9996	16	4.05	0.0544	1.012	2.9	0.9996	16	3.88	0.0248	1.020	44.0	0.9997	16
	169.3	3.58	127.9				156.5	6.95	121.2				220.6	1.75	292.8			
68-69	4.04	0.0388	1.044	35.5	0.9996	16	4.26	0.0622	1.009	2.7	0.9997	16	4.11	0.0524	1.018	40.3	0.9999	16
	150.0	7.17	123.9				188.7	6.92	157.8				495.1	6.21	320.4			
69-70	4.26	0.0466	1.039	24.5	0.9996	16	4.38	0.0671	1.003	0.4	0.9997	16	4.25	-0.0167	1.018	13.6	0.9998	16
	171.5	4.71	116.6				228.2	8.94	176.9				288.1	-2.63	186.4			
70-71	4.34	-0.0052	1.035	25.3	0.9996	16	4.60	0.0239	1.003	1.1	0.9998	16	4.37	0.0249	1.015	8.8	0.9997	16
	177.7	-0.76	131.5				249.6	2.76	278.1				298.4	2.06	179.7			
71-72	4.37	0.0419	1.029	20.3	0.9994	16	4.61	0.0257	1.009	5.5	0.9998	16	4.94	0.0157	1.029	21.4	0.9994	14
	191.6	2.84	138.9				313.0	2.14	219.5				180.9	0.69	139.1			
72-73	4.43	0.1140	1.038	26.2	0.9994	16	4.73	0.1123	1.015	11.9	0.9998	16	5.03	0.0996	1.024	53.2	0.9996	14
	148.0	9.64	121.2				286.6	9.25	204.3				399.0	4.02	265.2			
73-74	4.71	0.1108	1.043	39.5	0.9997	16	4.93	0.0883	1.030	39.4	0.9998	16	4.66	0.0556	1.011	2.1	0.9994	16
	201.0	27.20	132.4				254.0	9.40	191.6				188.7	3.10	110.8			
74-75	4.92	-0.0492	1.039	31.6	0.9996	16	5.14	-0.0133	1.010	28.6	0.9999	16	4.90	0.0003	1.035	22.2	0.9995	16
	218.2	-4.08	131.5				359.2	-1.06	483.9				188.2	0.02	121.6			
75-76	5.29	0.0729	1.060	110.6	0.9998	14	5.75	0.0514	1.015	38.3	0.9999	14	5.37	0.0554	1.031	36.7	0.9995	14
	285.1	11.57	158.4				708.1	3.31	364.6				256.0	1.91	173.7			
76-77	5.48	0.0426	1.057	183.8	0.9999	14	5.89	0.0354	1.025	50.8	0.9999	14	5.46	0.0647	1.021	7.3	0.9996	14
	366.6	5.11	215.0				400.5	2.92	245.3				231.2	4.34	113.1			
77-78	5.64	0.0366	1.051	174.6	0.9999	14	6.03	0.0212	1.022	51.0	0.9999	14	5.62	0.0259	1.016	9.8	0.9997	14
	421.3	5.81	233.2				513.3	2.58	287.1				261.1	2.82	168.3			
78-79	5.65	0.0545	1.064	146.6	0.9998	14	6.04	0.0073	1.019	36.0	0.9999	14	5.65	0.0511	1.019	9.8	0.9997	14
	338.6	6.86	170.8				585.2	1.30	280.8				304.6	4.86	143.7			
79-80	5.74	0.0978	1.066	101.7	0.9998	14	6.16	0.0710	1.018	32.2	0.9999	14	5.73	0.0996	1.018	5.3	0.9996	14
	274.6	16.58	138.3				500.1	11.33	278.0				235.0	14.72	112.3			
80-81	5.89	-0.0426	1.051	112.4	0.9998	14	6.32	0.0072	1.019	51.2	0.9999	14	5.89	0.0406	1.015	2.2	0.9994	14
	305.0	-4.81	186.5				676.1	0.91	325.6				192.0	3.13	86.9			
81-82	5.85	0.0134	1.054	117.5	0.9998	14	6.39	-0.0349	1.014	5.7	0.9996	14	5.90	0.0374	1.021	5.3	0.9994	14
	359.9	1.49	180.6				329.8	-2.39	150.1				193.9	1.97	96.3			
82-83	5.89	0.0446	1.057	110.5	0.9998	14	6.35	0.0265	1.023	13.4	0.9996	14	5.89	0.0170	1.033	15.2	0.9995	14
	314.5	7.88	167.4				236.6	2.13	136.7				214.5	1.08	105.5			
83-84	5.89	0.0077	1.055	151.5	0.9999	14	6.41	0.0052	1.021	20.4	0.9998	14	5.91	0.0175	1.034	18.9	0.9996	14
	356.1	1.12	202.6				343.8	0.76	186.3				234.8	1.30	114.0			
84-85	5.91	-0.2115	1.061	1496.2	0.9527	14	6.46	-0.2004	1.026	39.8	0.9251	14	6.00	-0.0836	1.030	12.7	0.9824	14
	535.0	-0.77	571.8				431.2	-0.63	214.1				228.0	-0.58	104.6			
85-86	5.95	0.0069	1.047	53.4	0.9998	12	6.50	0.0294	1.013	28.2	0.9999	12	6.09	0.0127	1.019	1.0	0.9983	12
	301.5	1.25	132.5				599.5	2.60	328.2				117.0	0.85	43.3			
86-87	5.96	0.0110	1.036	224.5	0.9999	12	6.47	0.0190	1.012	19.0	1.0000	12	6.09	-0.0163	1.021	1.7	0.9985	12
	450.7	1.18	354.9				806.7	3.57	289.2				132.0	-2.86	51.6			
87-88	5.94	0.0615	1.042	298.5	0.9997	12	6.48	0.0198	1.026	79.3	0.9999	12	6.11	0.0571	1.023	4.6	0.9989	12
	758.3	2.27	348.9				606.6	1.29	286.6				175.1	1.38	77.3			
Average	4.96	0.0260	1.044				5.29	0.0245	1.016				5.04	0.0316	1.021			
	228.4	5.79	150.1				338.6	4.60	232.6				235.3	3.28	157.3			

[a] Numbers under regression coefficients estimates denote t-statistics for these estimates.

[b] The F denotes the F-Statistic for testing the null hypothesis H_0:k=1.

TABLE 4.2. DECOMPOSITION OF THE SOURCES OF
TOTAL FACTOR PRODUCTIVITY GAINS BY INDUSTRY 1964-1988

	FOOD/KINDRED PRODUCTS				TEXTILES				APPARELS				LUMBER/WOOD PRODUCTS			
Years	TFP Gains[a]	Technical Charge	Scale Economies	ΔTFP[b]	TFP Gains	Technical Charge	Scale Economies	ΔTFP	TFP Gains	Technical Charge	Scale Economies	ΔTFP	TFP Gains	Technical Charge	Scale Economies	ΔTFP
64/65	0.0084	0.0074	0.0010	0.0017	0.0101	0.0097	0.0003	0.0074	0.0339	0.0338	0.0001	0.0285	0.0058	0.0045	0.0012	0.0066
65/66	0.0277	0.0253	0.0024	0.0192	0.0361	0.0364	-0.0002	-0.0233	0.0431	0.0430	0.0000	0.0395	0.0414	0.0385	0.0029	0.0387
66/67	0.0037	-0.0045	0.0081	-0.0038	0.0384	0.0390	-0.0006	0.0322	0.0218	0.0219	-0.0001	0.0147	-0.0028	-0.0049	0.0021	-0.0054
67/68	-0.0175	-0.0195	0.0020	-0.0252	0.0293	0.0298	-0.0005	0.0191	-0.0276	-0.0275	-0.0001	-0.0281	0.0165	0.0165	-0.0000	0.0150
68/69	0.0237	0.0214	0.0023	0.0222	0.0237	0.0259	-0.0022	0.0243	-0.0161	0.0152	-0.0009	-0.0176	0.0071	0.0054	0.0017	0.0079
69/70	0.0468	0.0401	0.0067	0.0394	0.0460	0.0472	-0.0012	0.0384	-0.0303	-0.0301	-0.0001	-0.0278	0.0029	0.0006	0.0022	0.0028
70/71	-0.0004	-0.0064	0.0060	-0.0054	0.0191	0.0198	-0.0007	0.0243	-0.0068	-0.0066	-0.0002	-0.0039	-0.0273	-0.0304	0.0030	-0.0272
71/72	0.0168	0.0164	0.0003	0.0095	0.0350	0.0348	0.0003	0.0275	0.0281	0.0295	-0.0014	0.0271	-0.0287	-0.0284	-0.0003	-0.0252
72/73	0.0431	0.0442	-0.0011	0.0427	0.0358	0.0360	-0.0002	0.0324	0.0725	0.0731	-0.0007	0.0669	0.0105	0.0101	0.0004	0.0025
73/74	-0.0266	-0.0256	-0.0010	-0.0331	0.0203	0.0204	-0.0002	0.0138	-0.0763	-0.0777	0.0044	-0.0713	0.0015	0.0004	0.0011	0.0010
74/75	0.0114	0.0121	-0.0007	0.0112	-0.0267	-0.0266	-0.0001	-0.0206	0.0242	0.0246	-0.0004	0.0275	-0.0085	-0.0088	0.0003	0.0025
75/76	0.0210	0.0220	-0.0010	0.0176	0.0788	0.0789	-0.0000	0.0683	0.0736	0.0716	0.0020	0.0701	0.0415	0.0414	0.0001	0.0340
76/77	-0.0052	-0.0097	0.0045	-0.0030	-0.0351	-0.0343	-0.0008	-0.0325	-0.0722	-0.0749	0.0027	-0.0772	-0.0007	-0.0006	-0.0002	-0.0001
77/78	0.0112	0.0114	-0.0002	0.0085	0.0465	0.0452	0.0012	0.0435	0.0428	0.0429	-0.0001	0.0479	0.0255	0.0241	0.0014	0.0271
78/79	0.0130	0.0108	0.0022	0.0174	0.0156	0.0151	0.0005	0.0126	0.0304	0.0336	-0.0032	0.0280	0.0725	0.0723	0.0003	0.0678
79/80	-0.0044	-0.0044	0.0000	-0.0052	0.0273	0.0263	0.0009	0.0261	-0.0179	-0.0162	-0.0017	-0.0132	-0.0326	-0.0345	0.0020	-0.0333
80/81	-0.0295	-0.0315	0.0021	-0.0255	-0.0121	-0.0132	0.0011	-0.0119	-0.1043	-0.1073	0.0030	-0.1079	-0.0067	-0.0080	0.0014	-0.0058
81/82	0.0216	0.0223	-0.0007	0.0208	0.0122	0.0121	0.0001	0.0136	-0.0016	-0.0016	-0.0000	0.0007	0.0171	0.0166	0.0005	0.0218
82/83	-0.0114	-0.0108	-0.0006	-0.0077	0.0211	0.0210	0.0001	0.0210	0.0898	0.0909	-0.0011	0.0917	-0.0135	-0.0135	0.0001	-0.0142
83/84	-0.0094	-0.0094	0.0001	-0.0117	0.0161	0.0168	-0.0007	0.0168	-0.0134	-0.0144	0.0011	-0.0130	-0.0136	-0.0159	0.0022	-0.0134
84/85	-0.1182	-0.1115	-0.0067	-0.1197	-0.0212	-0.0236	0.0024	-0.0232	-0.0176	-0.0189	0.0013	-0.0180	0.0218	0.0220	-0.0003	0.0193
85/86	-0.0111	-0.0090	-0.0021	-0.0101	-0.0400	-0.0403	0.0002	-0.0362	0.0003	-0.0006	0.0010	0.0009	0.0383	0.0386	-0.0004	0.0397
86/87	-0.0078	-0.0076	-0.0002	-0.0048	0.0343	0.0346	-0.0003	0.0359	0.0259	0.0250	0.0009	0.0257	0.0149	0.0131	0.0018	0.0098
87/88	0.0155	0.0153	0.0003	0.0153	-0.0132	-0.0176	0.0044	-0.0138	-0.0012	-0.0017	0.0005	0.0018	-0.0235	-0.0238	0.0003	-0.0201
Average	0.0009	-0.0001	0.0010	-0.0012	0.0166	0.0164	0.0002	0.0143	0.0042	0.0040	0.0002	0.0039	0.0066	0.0056	0.0010	0.0063

[a] These are measured based on (B7) in text.
[b] ΔTFP denotes gains in TFP measured based on (B1) in text.

TABLE 4.2. (Continued)

	FURNITURE/FIXTURE				PULP/PAPER PRODUCTS				CHEMICALS				PETROLEUM/COAL PRODUCTS			
Years	TFP Gains[a]	Technical Charge	Scale Economies	ΔTFP[b]	TFP Gains	Technical Charge	Scale Economies	ΔTFP	TFP Gains	Technical Charge	Scale Economies	ΔTFP	TFP Gains	Technical Charge	Scale Economies	ΔTFP
64/65	0.0111	0.0113	-0.0002	0.0090	0.0024	0.0021	0.0002	0.0123	-0.0082	-0.0131	0.0049	0.0270	0.0446	0.0394	0.0053	0.0292
65/66	0.0265	0.0255	0.0009	0.0219	0.0526	0.0528	-0.0002	0.0127	0.0555	0.0577	-0.0022	-0.0004	0.0320	0.0292	0.0028	-0.0331
66/67	0.0483	0.0465	0.0018	0.0415	0.0039	0.0018	0.0021	0.0127	0.0455	0.0409	0.0046	0.0698	0.0326	0.0267	0.0059	-0.0167
67/68	0.0486	0.0438	0.0047	0.0424	0.0470	0.0478	-0.0008	0.0093	0.0527	0.0517	0.0010	0.0075	0.0136	0.0260	-0.0124	-0.0007
68/69	0.0285	0.0240	0.0045	0.0201	0.0144	0.0114	0.0029	0.0262	0.0302	0.0226	0.0076	0.0552	-0.0137	-0.0254	0.0117	-0.0077
69/70	0.0381	0.0354	0.0027	0.0305	0.0577	0.0576	0.0001	0.0272	0.0282	0.0271	0.0011	-0.0114	-0.0296	-0.0325	0.0029	-0.0480
70/71	-0.0833	-0.0869	0.0036	-0.0889	-0.0237	-0.0259	0.0022	-0.0040	-0.0073	-0.0145	0.0072	0.0321	-0.0080	-0.0110	0.0030	0.0098
71/72	0.0606	0.0604	0.0002	0.0567	0.0378	0.0384	-0.0006	0.0043	0.0269	0.0343	-0.0073	-0.0167	-0.0087	-0.0090	0.0003	-0.0543
72/73	0.0193	0.0225	-0.0032	0.0214	-0.0059	-0.0072	0.0012	0.0089	0.0123	0.0002	0.0121	0.0270	0.0201	0.0173	0.0028	0.0435
73/74	-0.0878	-0.0888	0.0009	-0.0915	-0.0076	-0.0075	-0.0001	-0.0478	0.0049	-0.0084	0.0133	-0.0397	0.3296	0.3268	0.0029	0.3311
74/75	-0.0694	-0.0701	0.0007	-0.0673	-0.0249	-0.0245	-0.0004	0.0040	-0.0415	-0.0439	0.0024	-0.0283	-0.0831	-0.0832	0.0000	-0.0891
75/76	0.0785	0.0787	-0.0002	0.0758	0.0447	0.0450	-0.0003	0.0209	0.0315	0.0309	0.0006	0.0157	0.0769	0.0768	0.0001	0.0251
76/77	0.0231	0.0219	0.0013	0.0237	-0.0630	-0.0633	0.0003	-0.0439	0.0065	0.0062	0.0003	0.0236	-0.1208	-0.1210	0.0002	-0.0664
77/78	0.0299	0.0299	-0.0000	0.0284	0.0084	0.0085	-0.0000	-0.0105	0.0486	0.0490	-0.0004	0.0440	-0.0052	-0.0052	-0.0000	-0.0516
78/79	0.1236	0.1224	0.0012	0.1231	0.0178	0.0183	-0.0005	0.0312	0.0347	0.3333	0.0015	0.0323	0.0632	0.0631	0.0002	0.1190
79/80	-0.0366	-0.0390	0.0025	-0.0348	0.0157	0.0157	-0.0000	-0.0065	0.0601	0.0618	-0.0017	0.0318	0.0156	0.0158	-0.0003	0.0045
80/81	-0.0595	-0.0589	-0.0006	-0.0585	-0.0296	-0.0295	-0.0001	-0.0041	0.0643	0.0046	-0.0003	0.0140	-0.0142	-0.0138	-0.0004	0.0017
81/82	0.0360	0.0332	0.0028	0.0329	0.0465	0.0464	0.0001	0.0281	0.0297	0.0304	-0.0007	0.0303	0.0464	0.0468	-0.0004	0.0409
82/83	-0.0033	-0.0040	0.0007	-0.0016	0.0044	0.0044	-0.0000	0.0143	0.0244	0.0232	0.0011	-0.0326	0.9838	-0.0838	0.0000	-0.0966
83/84	0.0212	0.0216	-0.0005	0.0225	0.0423	0.0427	-0.0004	0.0261	0.0269	0.0263	0.0006	0.0235	0.0373	0.0371	0.0003	0.0396
84/85	-0.0026	-0.0104	0.0078	-0.0022	-0.0017	-0.0013	-0.0003	0.0140	0.0043	0.0036	0.0007	0.0137	0.0552	0.0557	-0.0005	0.0471
85/86	-0.0156	-0.0207	0.0051	-0.0168	0.0010	0.0010	-0.0000	-0.0136	0.0160	0.0248	-0.0088	0.0281	-0.2128	-0.2106	-0.0022	-0.0241
86/87	0.0271	0.0254	0.0018	0.0290	0.0066	0.0057	0.0010	0.0233	0.0124	0.0080	0.0044	0.0291	0.2211	0.2234	-0.0024	0.2437
86/88	0.0066	-0.0090	0.0156	0.0357	0.0432	0.0434	-0.0001	0.0283	0.0404	0.0383	0.0022	-0.0298	-0.1672	-0.1780	0.0108	-0.2007
Average	0.0112	0.0090	0.0023	0.0093	0.0121	0.0118	0.0003	0.0072	0.0225	0.0206	0.0018	0.0196	0.0101	0.0088	0.0013	0.0013

[a] These are measured based on (B7) in text.
[b] ΔTFP denotes gains in TFP measured based on (B1) in text.

TABLE 4.2. (Continued)

	RUBBER/PLASTIC PRODUCTS				LEATHER/LEATHER PRODUCTS				POTTERY/GLASS PRODUCTS				IRON/STEEL			
Years	TFP Gains[a]	Technical Charge	Scale Economies	ΔTFP[b]	TFP Gains	Technical Charge	Scale Economies	ΔTFP	TFP Gains	Technical Charge	Scale Economies	ΔTFP	TFP Gains	Technical Charge	Scale Economies	ΔTFP
64/65	0.0130	0.0150	-0.0020	0.0179	0.0206	0.0213	-0.0007	0.0243	-0.0330	-0.0331	0.0001	-0.0104	-0.0067	-0.0061	-0.0006	0.0117
65/66	0.0403	0.0415	-0.0012	0.0137	0.0057	0.0054	0.0002	0.0006	0.0664	0.0766	-0.0102	0.0324	0.0474	0.0473	0.0001	0.0097
66/67	0.0227	0.0223	0.0003	0.0804	0.0491	0.0491	0.0001	0.0551	0.0363	0.0299	0.0064	0.0447	0.0579	0.0579	-0.0001	0.0636
67/68	0.0470	0.0475	-0.0004	-0.0287	0.0372	0.0356	0.0017	0.0330	0.0668	0.0683	-0.0015	0.0400	0.0250	0.0250	-0.0000	-0.0166
68/69	0.0370	0.0328	0.0042	0.0475	0.0315	0.0291	0.0024	0.0350	-0.0098	-0.0216	0.0118	0.0213	0.0358	0.0362	-0.0004	0.0463
69/70	0.0500	0.0445	0.0055	0.0296	0.0424	0.0405	0.0019	0.0425	0.0507	0.0469	0.0038	0.0298	0.0390	0.0379	0.0011	-0.0006
70/71	-0.0241	-0.0257	0.0016	0.0005	-0.0302	-0.0301	-0.0001	-0.0250	-0.0345	-0.0477	0.0133	0.0009	-0.0358	-0.0359	0.0001	-0.0014
71/72	0.0535	0.0594	-0.0059	0.0239	0.1115	0.1155	-0.0040	0.1070	0.0514	0.0624	-0.0110	0.0312	0.0211	0.0223	-0.0012	-0.0248
72/73	0.0587	0.0507	0.0080	0.0646	0.0850	-0.0871	0.0022	-0.0853	0.0043	-0.0053	0.0095	0.0160	0.0813	0.0817	-0.0004	0.1097
73/74	-0.0839	-0.0863	0.0024	-0.1338	-0.0405	-0.0416	0.0011	-0.0408	0.0126	0.0175	-0.0049	-0.0313	0.0459	0.0460	-0.0000	-0.0168
74/75	-0.0458	-0.0461	0.0003	-0.0223	-0.0198	-0.0208	0.0010	-0.0139	-0.0614	-0.0636	0.0022	-0.0322	-0.1071	-0.1069	-0.0002	-0.0728
75/76	0.1249	0.1285	-0.0035	0.1076	0.0426	0.0421	0.0005	0.0371	0.0689	0.0633	0.0006	0.0468	0.0302	0.0307	-0.0005	-0.0076
76/77	-0.0313	-0.0347	0.0034	-0.0137	-0.0537	-0.0572	0.0035	-0.0527	-0.0037	-0.0013	0.0050	0.0126	-0.0284	-0.0287	0.0002	0.0093
77/78	0.0516	0.0504	0.0012	0.0417	0.0362	0.0351	0.0010	0.0363	0.0046	0.0097	-0.0051	-0.0098	0.0107	0.0113	-0.0006	-0.0096
78/79	0.0412	0.0398	0.0013	0.0448	0.0672	0.0667	0.0005	0.0613	-0.0173	-0.0176	0.0003	-0.0059	0.0351	0.0326	0.0025	0.0787
79/80	0.0241	0.0206	0.0036	0.0142	-0.0946	-0.0931	-0.0014	-0.0913	0.0381	0.0358	0.0024	0.0149	0.0700	0.0725	-0.0026	0.0119
80/81	-0.0385	-0.0391	0.0006	-0.0236	-0.0150	-0.0142	-0.0007	-0.0105	0.0030	0.0036	-0.0005	0.0183	-0.0399	-0.0424	0.0025	-0.0031
81/82	0.0083	0.0141	-0.0059	-0.0004	0.0222	0.0220	0.0003	0.0221	0.0176	0.0183	-0.0007	0.0154	0.0477	0.0487	-0.0010	0.0085
82/83	0.0311	0.0290	0.0021	0.0384	0.0223	0.0230	-0.0007	0.0214	-0.0102	-0.0139	0.0038	0.0086	-0.0459	-0.0461	0.0002	-0.0040
83/84	-0.0042	-0.0053	0.0011	-0.0117	0.0108	0.0111	-0.0003	0.0143	0.0350	0.0309	0.0040	0.0208	0.0182	0.0188	-0.0007	-0.0088
84/85	-0.1823	-0.1267	-0.0557	-0.0525	-0.0364	-0.0296	-0.0067	-0.0282	-0.0506	0.0027	-0.0533	0.0252	-0.2701	-0.2075	-0.0626	-0.0148
85/86	-0.0117	-0.0114	-0.0003	-0.0129	-0.0305	-0.0305	-0.0001	-0.0270	0.0103	0.0105	-0.0003	0.0088	-0.0339	-0.0330	-0.0010	-0.0290
86/87	0.0294	0.0283	0.0012	0.0386	0.0422	0.0426	-0.0004	0.0410	0.0152	0.0149	0.0003	0.0327	-0.0191	-0.0201	0.0010	-0.0002
87/88	0.1075	0.0486	0.0589	0.0799	0.0305	0.0199	0.0105	0.0293	0.0845	0.0305	0.0540	0.0605	0.1512	0.0436	0.1075	0.1630
Average	0.0133	0.0124	0.0009	0.0143	0.0069	0.0065	0.0005	0.0077	0.0147	0.0135	0.0012	0.0163	0.0054	0.0036	0.0018	0.0126

[a] These are measured based on (B7) in text.

[b] ΔTFP denotes gains in TFP measured based on (B1) in text.

TABLE 4.2. (Continued)

	NON-FERROUS METALS				METAL PRODUCTS				GENERAL MACHINERY			
Years	TFP Gains[a]	Technical Charge	Scale Economies	ΔTFP[b]	TFP Gains	Technical Charge	Scale Economies	ΔTFP	TFP Gains	Technical Charge	Scale Economies	ΔTFP
64/65	-0.0155	-0.0169	0.0014	-0.0047	0.0005	-0.0002	0.0006	-0.0001	0.0172	0.0178	-0.0006	0.0036
65/66	0.0440	0.0433	0.0008	0.0146	0.0373	0.0370	0.0003	0.0246	0.0316	0.0313	0.0002	0.0299
66/67	0.0165	0.0165	0.0001	0.0216	0.0511	0.0500	0.0011	0.0406	0.0722	0.0713	0.0010	0.0394
67/68	0.0041	0.0034	0.0007	-0.0243	0.0004	-0.0017	0.0020	-0.0127	0.0210	0.0185	0.0025	0.0013
68/69	0.0527	0.0523	0.0004	0.0610	0.0636	0.0632	0.0004	0.0600	0.0557	0.0538	0.0018	0.0361
69/70	-0.0128	-0.0128	-0.0000	-0.0212	0.0510	0.0495	0.0015	0.0465	0.0278	0.0260	0.0019	0.0190
70/71	-0.0309	-0.0303	-0.0005	-0.0258	0.0032	0.0021	0.0011	-0.0088	0.0120	0.0128	-0.0008	0.0017
71/72	0.0239	0.0234	0.0005	0.0011	0.0570	0.0578	-0.0009	0.0659	0.0161	0.0184	-0.0023	0.0131
72/73	0.0144	0.0127	0.0017	0.0202	0.0347	0.0340	0.0035	0.0311	0.0175	0.0151	0.0024	0.0003
73/74	-0.0005	0.0008	-0.0013	-0.0281	-0.0921	-0.0905	-0.0016	-0.0974	0.0247	0.0247	0.0001	0.0240
74/75	-0.0916	-0.0917	0.0001	-0.0559	-0.0190	-0.0178	-0.0012	-0.0124	0.0051	0.0072	-0.0022	0.0033
75/76	0.0861	0.0861	0.0001	0.0562	0.0916	0.0901	0.0014	0.0912	0.0538	0.0507	0.0032	0.0577
76/77	-0.0270	-0.0270	0.0000	-0.0036	0.0130	0.0297	0.0013	0.0273	0.0362	0.0341	0.0021	0.0266
77/78	-0.0069	-0.0071	0.0002	-0.0260	0.0141	0.0089	0.0052	0.0137	0.0225	0.0214	0.0010	0.0262
78/79	0.0668	0.0677	-0.0009	0.0714	0.0084	0.0084	-0.0000	0.0053	0.0187	0.0172	0.0015	0.0126
79/80	0.0122	0.0116	0.0006	-0.0146	-0.0097	-0.0072	-0.0025	-0.0065	0.0457	0.0445	0.0012	0.0480
80/81	-0.0282	-0.0283	0.0001	-0.0046	0.0002	-0.0017	0.0019	0.0008	0.0136	0.0122	0.0014	0.0084
81/82	0.0117	0.0138	-0.0022	0.0017	0.0458	0.0430	0.0028	0.0478	-0.0003	0.0005	-0.0008	0.0053
82/83	-0.0458	-0.0456	-0.0002	-0.0354	0.0016	0.0025	-0.0009	0.0047	0.0006	0.0007	-0.0001	-0.0032
83/84	-0.0003	-0.0006	0.0003	-0.0112	0.0081	0.0063	0.0018	0.0083	0.0152	0.0138	0.0014	0.0187
84/85	-0.1995	-0.1877	-0.0118	-0.1026	-0.0183	0.0012	-0.0195	0.0111	-0.0910	-0.0611	-0.0299	-0.0345
85/86	-0.0660	-0.0661	0.0001	-0.0642	-0.0083	-0.0128	0.0045	-0.0082	-0.0024	-0.0020	-0.0004	0.0063
86/87	0.0419	0.0419	0.0000	0.0570	0.0139	0.0161	-0.0022	0.0118	-0.0074	-0.0080	0.0006	-0.0098
87/88	0.1149	0.1064	0.0085	0.0979	0.0087	-0.0143	0.0230	0.0073	0.0620	0.0288	0.0332	0.0501
Average	-0.0015	-0.0014	-0.0001	-0.0008	0.0157	0.0147	0.0010	0.0147	0.0195	0.0187	0.0008	0.0160

[a] These are measured based on (B7) in text.
[b] ΔTFP denotes gains in TFP measured based on (B1) in text.

TABLE 4.2. (Continued)

	ELECTRIC MACHINERY				TRANSPORTATION MACHINERY				PRECISION			
Years	TFP Gains[a]	Technical Charge	Scale Economies	ΔTFP[b]	TFP Gains	Technical Charge	Scale Economies	ΔTFP	TFP Gains	Technical Charge	Scale Economies	ΔTFP
64/65	0.0207	0.0230	-0.0023	0.0159	0.0297	0.0283	0.0014	0.0005	0.0148	0.0143	0.0005	0.0109
65/66	0.0210	0.0208	0.0002	0.0061	0.0262	0.0259	0.0004	0.0152	0.0575	0.0586	-0.0010	0.0385
66/67	0.0650	0.0590	0.0059	0.0473	0.0560	0.0549	0.0011	0.0214	0.0514	0.0494	0.0021	0.0389
67/68	0.0351	0.0293	0.0058	0.0129	0.0557	0.0544	0.0013	0.0211	0.0274	0.0248	0.0026	0.0160
68/69	0.0408	0.0388	0.0021	0.0341	0.0628	0.0622	0.0006	0.0430	0.0543	0.0524	0.0019	0.0448
69/70	0.0480	0.0466	0.0015	0.0243	0.0673	0.0671	0.0002	0.0458	-0.0151	-0.0167	0.0016	-0.0212
70/71	-0.0049	-0.0052	0.0004	-0.0138	0.0245	0.0239	0.0006	0.0075	0.0273	0.0249	0.0024	0.0200
71/72	0.0408	0.0419	-0.0012	0.0314	0.0255	0.0257	-0.0002	0.0060	0.0133	0.0157	-0.0024	0.0050
72/73	0.1145	0.1140	0.0006	0.1075	0.1117	0.1123	-0.0006	0.1002	0.1029	0.0996	0.0033	0.1033
73/74	0.1057	0.1108	-0.0050	0.0891	0.0877	0.0883	-0.0006	0.0814	0.0558	0.0556	0.0002	0.0517
74/75	-0.0534	-0.0492	-0.0042	-0.0548	-0.0126	-0.0133	0.0006	-0.0235	-0.0045	0.0003	-0.0048	-0.0093
75/76	0.0797	0.0729	0.0069	0.0792	0.0512	0.0514	-0.0002	0.0501	0.0578	0.0554	0.0024	0.0558
76/77	0.0484	0.0426	0.0058	0.0462	0.0375	0.0354	0.0021	0.0293	0.0670	0.0647	0.0023	0.0596
77/78	0.0392	0.0366	0.0027	0.0312	0.0228	0.0212	0.0016	0.0179	0.0284	0.0259	0.0026	0.0274
78/79	0.0575	0.0545	0.0030	0.0608	0.0082	0.0073	0.0009	0.0050	0.0516	0.0511	0.0005	0.0492
79/80	0.1001	0.0978	0.0023	0.1069	0.0719	0.0710	0.0010	0.0813	0.1006	0.0996	0.0011	0.1148
80/81	-0.0342	-0.0426	0.0084	-0.0373	0.0085	0.0072	0.0012	-0.0002	0.0421	0.0406	0.0014	0.0413
81/82	0.0141	0.0134	0.0008	0.0078	-0.0346	-0.0349	0.0003	-0.0330	0.0357	0.0374	-0.0016	0.0347
82/83	0.0498	0.0446	0.0052	0.0558	0.0270	0.0265	0.0005	0.0273	0.0153	0.0170	-0.0017	0.0199
83/84	0.0178	0.0077	0.0100	0.0126	0.0065	0.0052	0.0013	0.0067	0.0219	0.0175	0.0044	0.0157
84/85	-0.3047	-0.2115	-0.0931	-0.1374	-0.2632	-0.2004	-0.0628	-0.0822	-0.1108	-0.0836	-0.0266	-0.0462
85/86	0.0077	0.0069	0.0008	0.0045	0.0295	0.0294	0.0001	0.0294	0.0130	0.0127	0.0002	0.0071
86/87	0.0145	0.0110	0.0036	0.0158	0.0194	0.0190	0.0004	0.0228	-0.0155	-0.0163	0.0008	-0.0143
87/88	0.1169	0.0615	0.0553	0.0846	0.0800	0.0198	0.0602	0.0336	0.0745	0.0571	0.0174	0.0584
Average	0.0267	0.0260	0.0006	0.0263	0.0250	0.0245	0.0005	0.0211	0.0320	0.0316	0.0004	0.0301

[a] These are measured based on (B7) in text.
[b] ΔTFP is gains in TFP measured based on (B1) in text.

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