Fixed Costs, Imperfect Competition, and Bias in Technology Measurement: Japan and the United States

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1   Introduction

The phenomenal success of East Asian economies has centered attention on the source of their economic growth. Recent studies based on neoclassical theory have produced controversial results: the most important source of economic growth of the East Asian countries (except Japan) is capital accumulation, and the estimated rate of technological progress is very small and, in some cases, substantially negative (see Tsao [24], Kim and Lau [12], Young [25], and Park and Kwon [20]). Based on these results, it is often argued that economic growth in this area cannot be sustained for a long period of time (see Krugman [13]).

Here, Japan is an interesting exception. A series of studies has shown that technological progress contributes substantially to her economic growth (see Kuroda and Jorgenson [14]). Thus, it is an interesting research agenda to investigate the difference between the Japanese and other East Asian economies.

There are, however, theoretical and resulting measurement problems in the above-mentioned analyses of productivity growth which must be solved before pursuing this agenda. Most of the studies in this field assume perfect competition and constant returns to scale, although many sectors in East Asian economies are considered to be imperfectly competitive and their production entails large fixed costs. Presence of imperfect competition and fixed costs may bias the measurement of technological progress, and the results reported in the previous studies may be misleading.

The first purpose of this paper is to examine the direction and the magnitude of bias in the technological progress measurement due to imperfect competition and fixed costs. We show that imperfect competition coupled with short-run fixed costs is likely to make the traditional measurement of technological progress biased. The direction of bias depends, firstly, on the relative

magnitude of growth between the capital stocks and non-capital inputs, and secondly, on whether firms enjoy a pure profit in the "long run". Here we use the word "long run" for a period long enough to cover at least one business cycle but not long enough to allow entry and exit to drive pure profit to zero.[1] Thus, if capital growth exceeds non-capital input growth (which is the case in many industries in Japan), then the traditional measure underestimates true technological growth if pure profit is on the average positive. On the other hand, however, if pure profit is negative on the average, then the traditional measure overstates the true rate. Since the Japanese (and other East Asian countries') economic growth in the high growth era was accompanied by rapid capital stock accumulation and positive pure profits, this result suggests that the traditional measurement may understate the true productivity growth if the market is imperfectly competitive and there are fixed costs.

The second purpose of this paper is to measure the actual magnitude of this bias by re-estimating sectoral technological progress in Japan and the United States. We base our work on the oft-mentioned studies of Jorgenson (U. S.) and Kuroda (Japan) on sectoral technological progress, which have been focal in the discussion of growth accounting (Jorgenson [8] and Kuroda and Jorgenson [14]). These data sets are particularly suited for our purpose, since (a) they have information about material and energy inputs in addition to labor and capital (which avoids nagging problems plaguing analysis based on value-added production functions), and (b) they meticulously exclude the effect of quality change in capital and non-capital inputs from the calculation of technological progress. Thus, these data sets are relatively free from the quality-change problem which might undermine productivity-growth measurement. Comparing our results assuming imperfect competition and fixed costs with their results assuming perfect competition and constant returns to scale, we immediately gain insights about the possible direction and magnitude of biases.

The plan of this paper is as follows. In section 2, we specify a production technology with fixed costs and examine the representative firm's profit maximization problem under imperfect competition. We derive the formula that relates the "true" rate of technological progress to its traditional measure that assumes perfect competition and constant returns to scale. We examine the direction and magnitude of bias in the traditional measurement of technological bias. In Section 3, we first estimate the mark-up and the magnitude of short-run fixed costs, and then use these to re-estimate technological progress both in Japan and the United States. In Section 4, we discuss implications of the results and present remarks on the debate over Asian productivity growth.

2 Bias in Technology Measurement

For expository self-consistency, we briefly explain the properties of the traditional (neoclassical) measurement of technological progress, which has been a

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[1]In this sense, the "medium run" might be more appropriate, but we stick to this popular word just for convenience.

building block of the recent attempts to analyze Asian economic growth mentioned in the Introduction. We then discuss the combined effect of fixed costs and imperfect competition on its measurement.

2.1 Traditional Approach

The Rate of Technological Progress   In the traditional approach, production technology is assumed to be represented by a production function:

$$y_t = f\left(x_{1t}, ..., x_{nt}, k_t; A_t\right), \tag{1}$$

where y_t is the output, x_{it} is the ith input, k_t is the capital stock,[2] and A_t is the shift parameter representing the level of technology, all of which are evaluated at time t. We hereafter denote the partial derivative of a variable z with respect to time t as $\dot{z}$.

The *rate of technological progress*, θ_t, at time t is then defined as the rate of output growth for given inputs, x_{it} and k_t, which is

$$\theta_t = \frac{\partial f}{\partial A_t} \frac{\dot{A}_t}{y_t} \tag{2}$$

Perfect competition and constant returns to scale.   In the traditional approach, the production technology is assumed to exhibit constant returns to scale (f is homogeneous of degree one in x_{it} and k_t), and the market is perfectly competitive. The firm maximizes profits such that

$$\underset{y_t}{Max} \; p_t y_t - C(y_t; q_{1t}, ..., q_{nt}, r_t).$$

where the cost function is determined by:

$$C(y_t; q_{1t}, ..., q_{nt}, r_t) \equiv \underset{x_{it}, k_t}{Min} \left(\sum_{i=1}^{n} q_{it} x_{it} + r_t k_t\right) \; \text{s.t. (1).}$$

Then, equilibrium conditions are

$$\frac{q_{it}}{\lambda_t} = \frac{\partial f}{\partial x_{it}}; \; \frac{r_t}{\lambda_t} = \frac{\partial f}{\partial k_t}; \tag{3}$$

and

$$p_t = \lambda_t \tag{4}$$

where λ_t is the marginal cost: $\lambda_t = \partial C / \partial y_t$.

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[2] Here we treat capital stocks as a scaler variable, but it may be a vector of many kinds of capital goods. Extension to the multi-capital-good case is straightforward. By the same token, it is also straightforward (though cumbersome) to extend our analysis to the multi-output case.

Measuring technological progress. From (3), we have

$$\frac{\dot{y}_t}{y_t} = \frac{1}{y_t}\left(\sum_{i=1}^{n}\frac{\partial f}{\partial x_{it}}\dot{x}_{it} + \frac{\partial f}{\partial k_t}\dot{k}_t\right) + \frac{\partial f}{\partial A_t}\frac{\dot{A}_t}{y_t} = \left(\sum_{i=1}^{n}\frac{q_{it}x_{it}}{\lambda_t y_t}\frac{\dot{x}_{it}}{x_{it}} + \frac{r_t k_t}{\lambda_t y_t}\frac{\dot{k}_t}{k_t}\right) + \theta_t.$$

Accordingly, we get

$$\theta_t = \frac{\dot{y}_t}{y_t} - \left(\sum_{i=1}^{n}\frac{q_{it}x_{it}}{p_t y_t}\frac{\dot{x}_{it}}{x_{it}} + \frac{r_t k_t}{p_t y_t}\frac{\dot{k}_t}{k_t}\right) \tag{5}$$

where (4) is utilized.

Measurement in practice. In practice, the rate of technological progress is measured from a convenient formula based of perfect competition and constant returns to scale. Since perfect competition and constant returns imply $p_t y_t = \sum_{i=1}^{n} q_{it}x_{it} + r_t k_t$, we have

$$\frac{r_t k_t}{\sum_{j=1}^{n} q_{jt}x_{jt} + r_t k_t} = \frac{r_t k_t}{p_t y_t} = 1 - \frac{\sum_{j=1}^{n} q_{jt}x_{jt}}{p_t y_t}.$$

Thus, the share of capital in total factor payments is derived from the shares of the other factors. This property is almost always used in the literature. The estimated rate of growth in the total factor productivity is then

$$\theta_t^{est} = \frac{\dot{y}_t}{y_t} - \left(\sum_{i=1}^{n}\frac{q_{it}x_{it}}{p_t y_t}\frac{\dot{x}_{it}}{x_{it}} + \left(1 - \frac{\sum_{j=1}^{n} q_{jt}x_{jt}}{p_t y_t}\right)\frac{\dot{k}_t}{k_t}\right). \tag{6}$$

2.2 Production Capacity, Fixed Costs, and Imperfect Competition

There are two problems in this simple framework. First, production facilities and corresponding worker organization are usually designed for a specific range of output, and they are not readily adjustable in the short run. This suggests that there may be non-negligible fixed costs in the short run (see Hall [6]). Second, many industries are not perfectly competitive. This seems particularly important in Japan and other Asian countries where various entry barriers in the form of government regulations and trading practices sustain monopoly power of incumbent firms (see Nishimura et al. [18])[3]

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[3] The observation of the existence of non-negligible fixed costs leads some economists to an approach in which capital stocks are assumed to be a quasi-fixed factor: that is, an approach where all capital stocks are fixed in the short run though they change through investment (see, for example, Morrison [17]).

Empirical studies of plants show that the average-cost curve goes down with increasing output up to a certain level of output, which is often called the Minimum Efficiency Scale, and then becomes virtually flat beyond that point until output hits production capacity. Thus, average cost is decreasing up to the Minimum Efficiency Scale, and beyond that point marginal cost is constant. The formulation of the production function in this paper is based on this stylized fact.

Let $Q_{t-1,t}^{\max}$ be the production capacity in period t determined in the previous period $t-1$, and $Q_{t-1,t}^{MES}$ be the corresponding Minimum Efficiency Scale. For each level of production capacity, the firm has a particular production organization of buildings, equipment, general management, maintenance, procurement, and so on, which is optimized for this production capacity. We assume that to maintain the production capacity, the firm requires a certain level of inputs $\left(x_{1t}^R, ..., x_{nt}^R, k_t^R\right)$ even though its production level falls short of the Minimum Efficiency Scale $Q_{t-1,t}^{MES}$.

Assumption 1. Fixed costs and the Minimum Efficiency Scale. If the firm's output is smaller than the Minimum Efficiency Scale, $y_t < Q_{t-1,t}^{MES}$, then the firm's cost is fixed such that

$$
C^F\left(q_{1t}, ..., q_{nt}, r_t, Q_{t-1,t}^{MES}; A_t\right)
$$
$$
= \underset{\left(x_{1t}^R, ..., x_{nt}^R, k_t^R\right)}{Min} \left(\sum_{i=1}^n q_{it} x_{it}^R + r_t k_t^R\right) \text{ s. t. } h\left(x_{1t}^R, ..., x_{nt}^R, k_t^R; A_t\right) = Q_{t-1,t}^{MES} \quad (7)
$$

where h is the *Minimum-Efficiency-Scale input-output relation*, and A_t denotes the state of technology as in the previous section.

Assumption 2. Constant Marginal Cost beyond the Minimum Efficiency Scale. If the firm's output is no smaller than the Minimum Efficiency Scale and no greater than the capacity, *i.e.*, $Q_{t-1,t}^{MES} \leq y_t \leq Q_{t-1,t}^{\max}$, then the

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These studies, however, ignore the fact that *not all capital inputs are literally fixed* in the short run, and that *not all labor inputs are perfectly flexible* in the short run. On the one hand, firms can purchase machine tools to produce output in the present period, and they customarily do so if possible. On the other hand, they cannot get rid of some of managerial labor in the short run, even if they decide not to produce output temporarily. Thus, both capital and labor are *partially sticky* in the sense that it is difficult to adjust them completely in a single period, but *neither is completely rigid* even in the short run. Because of this partially sticky adjustment, these inputs are often described as being under-utilized, compared with full utilization.

Based on the discussion above, we depart from the neoclassical framework in a different way than the quasi-fixed capital approach. Our approach can be considered as one of *quasi-fixed production organization*, since we assume production organization (including the production facility and the corresponding worker organization) is fixed in the short run. This leads to short-run fixed costs.

firm's cost is such that

$$C\left(y_t; q_{1t}, ..., q_{nt}, r_t; Q_{t-1,t}^{\max}, Q_{t-1,t}^{MES}, A_t\right)$$

$$= \underset{(x_{1t}, ..., x_{nt}, k_t)}{Min} \left[\begin{array}{c} \left(\sum_{i=1}^n q_{it}\left(x_{it} - x_{it}^{R*}\right) + r_t\left(k_t - k_t^{R*}\right)\right) + C^F \\ \text{s. t.} \\ y_t = g\left(\left(x_{1t} - x_{1t}^{R*}\right), ..., \left(x_{nt} - x_{nt}^{R*}\right), \left(k_t - k_t^{R*}\right); A_t \right) + Q_{t-1,t}^{MES} \end{array} \right]$$

$$(8)$$

where x_{it}^{R*} and k_t^{R*} are the optimum required inputs in Assumption 1, and g is the *incremental-production input-output relation*, which is homogeneous of degree one in $\left(\left(x_{1t} - x_{1t}^{R*}\right), ..., \left(x_{nt} - x_{nt}^{R*}\right), \left(k_t - k_t^{R*}\right)\right)$ and defined for the normal range of output, $Q_{t-1,t}^{MES} \le y_t \le Q_{t-1,t}^{\max}$.

Assumption 2 implies the marginal cost of production is constant for the normal range of output, since g is homogeneous of degree one. Thus, the above formulation of fixed cost and production coincides with the stylized fact mentioned earlier.

The Minimum-Efficiency-Scale input-output relation h is determined by the efficiency of management as well as technological conditions. To see this, consider two firms having a plant of the same production technology. They have the same machines with the same number of operators and the same material requirement to produce output beyond the Minimum Efficiency Scale. However, the firms may be different in flexibility of worker orgainzation. In one firm, the worker may operate a machine and at the same time do maintenance when the machine is idle. In the other firm, work rules are rigid, and operation and maintenance are different jobs filled by different workers. It is likely that the former has smaller required inputs to maintain the Minimum-Efficiency-Scale production than the latter, although inputs used for production beyond the Minimum Efficiency Scale is the same in two firms. Similarly, one firm may have a more efficient layout of machines to reduce in-plant inventory costs than the other. Work rules and machine layouts are important managerial decision. Thus, even though two firms have the same production technology (represented by the same incremental-production input-output relation g), their required inputs to maintain the Minimum Efficiency Scale (the function h) may be different because of the difference in managerial efficiency.

If there were no role of management in firms' production process so that fixed costs were negligible, inputs $(x_1, ..., x_n, k)$ would produce output $g(x_1, ..., x_n, k; A)$. However, since there is a fixed cost and the efficiency of management determines the maginitude of the fixed cost, inputs $(x_1, ..., x_n, k)$ is required for the Minimum-Efficiency-Scale $h(x_1, ..., x_n, k; A)$. The more efficient the management is, the same inputs are sufficient for a larger Minimum Efficiency Scale production. Thus, the efficiency of management (in terms of incremental-production techonology) can be measured by (h/g), where h is divided by g in order to make this measure scale-independent. For subsequent discussions, it

turns out to be more conveninent to define the degree of managerial *in*efficiency, instead of that of efficiency, in the following way.

Definition 1 *The degree of managerial* in*efficinecy ϕ is*

$$\phi = \left[\frac{h\left(x_1, ..., x_n, k; A\right)}{g\left(x_1, ..., x_n, k; A\right)} \right]^{-1} \tag{9}$$

Since $Q_{t-1,t}^{MES}$, $x_{1t}^{R*}, ..., x_{nt}^{R*}$ and k_t^{R*} are generally not observable in aggregate data, it is not possible to estimate directly the Minimum-Efficiency-Scale input-output relation h and the incremental-production input-output relation g. To circumvent this problem we assume that the Minimum Efficiency Scale of a given production capacity is proportional to the capacity, and that the degree of managerial inefficiency is constant.

Assumption 3. The Minimum Efficiency Scale is Proportional to Production Capacity.

$$Q_{t-1,t}^{MES} = \eta Q_{t-1,t}^{\max}.$$

Assumption 4. The Degree of Managerial Inefficiency is a Constant and Independent of $(x_1, ..., x_n, k)$. Under Assumptions 1 to 4, it is straightforward to show that the firm's two-tier cost minimization, (7) and (8), is equivalent to the following single-tier cost minimization (see Appendix A.1).

$$C\left(y_t; q_{1t}, ..., q_{nt}, r_t; Q_{t-1,t}^{\max}, A_t\right) \quad \text{where } \eta Q_{t-1,t}^{\max} \le y_t \le Q_{t-1,t}^{\max}$$

$$= \underset{(x_{1t}, ..., x_{nt}, k_t)}{Min} \left[\begin{array}{c} \left(\sum_{i=1}^n q_{it} x_{it} + r_t k_t\right) \\ \text{s. t.} \\ y_t = g\left(x_{1t}, ..., x_{nt}, k_t; A_t\right) - (\phi - 1)\eta Q_{t-1,t}^{\max} \end{array} \right] \tag{10}$$

Let us now consider the determination of output y_t and production capacity $Q_{t-1,t}^{\max}$. We assume that the firm is imperfectly competitive, and faces the (inverse-)demand function $p\left(y_t, d_t\right)$, where d_t represents demand conditions. Taking as given the production capacity $Q_{t-1,t}^{\max}$ determined in the previous period, the firm maximizes its profit with respect to output y_t in the current period such that

$$\underset{y_t}{Max} \left[\begin{array}{c} p\left(y_t, d_t\right) y_t - C\left(y_t; q_{1t}, ..., q_{nt}, r_t, Q_{t-1,t}^{\max}; A_t\right) \\ \\ \text{s. t. } \eta Q_{t-1,t}^{\max} \le y_t \le Q_{t-1,t}^{\max} \end{array} \right] \tag{11}$$

This maximization determines the firm's output as a function of production capacity and product market conditions in addition to cost conditions such that

$$y_t^* = y\left(Q_{t-1,t}^{\max}, d_t; q_{1t}, ..., q_{nt}, r_t; A_t\right). \tag{12}$$

Finally, consider the production capacity determination. The firm has to determine in the current period the production capacity of the next period,

without knowing next-period's market conditions. Thus, the firm's capacity optimization is such that

$$\underset{Q_{t-1,t}^{\max}}{Max} \quad E_{t-1} \sum_{t=0}^{\infty} \beta^t \left\{ p\left(y_t^*, d_t\right) y_t - C\left(y_t^*, q_{1t}, ..., q_{nt}, r_t, Q_{t-1,t}^{\max}; A_t\right) - \Gamma\left(\theta_{t-1}, \Theta_{t-2}\right) \right\}$$

where y_t^* is defined in (12), and expectations are taken based on information available in the $t-1$ period. The function Γ is the capacity adjustment cost, which depends on the capacity growth θ_{t-1}

$$\theta_{t-1} = \frac{Q_{t-1,t}^{\max} - Q_{t-2,t-1}^{\max}}{Q_{t-2,t-1}^{\max}}$$

as well as other factors affecting the capacity adjustment, which are represented by Θ_{t-2}. If the firm's capacity is small, the firm can sell all of what it produces, but it may have to give up possible profit opportunity when demand is strong. If the firm's capacity is large, the firm can satisfy all demand but it may have idle capacity when demand is weak. The firm determines the optimum capacity $Q_{t-1,t}^{\max}$ by balancing the opportunity cost of lost sales and that of idle capacity, as well as the capacity adjustment cost Γ[4].

Let y_t^N be the normal output, which is the expected value of the period t output formed in period $t-1$, $y_t^N = E_{t-1} y_t^*$. Since $Q_{t-1,t}^{\max} \geq y_t$, we have $Q_{t-1,t}^{\max} > y_t^N$. For simplicity, we further assume

Assumption 5. The production capacity is proportional to normal output.

$$Q_{t-1,t}^{\max} = \zeta y_t^N; \zeta > 1 \tag{13}$$

Combining (10) and (13), we have the following *short-run input-output relation* f

$$\begin{aligned} y_t &= f\left(x_{1t}, ..., x_{nt}, k_t; y_t^N, A_t\right) \\ &\equiv g\left(x_{1t}, ..., x_{nt}, k_t; A_t\right) - \gamma y_t^N, \text{ where } \gamma = (\phi - 1)\eta\zeta, \end{aligned} \tag{14}$$

which is, of course, defined only for y_t such that $\eta\zeta y_t^N \leq y_t \leq \zeta y_t^N$ (or equivalently, $Q_{t-1,t}^{MES} \leq y_t \leq Q_{t-1,t}^{\max}$).[5]

We hereafter call γ in (14) the *managerial-inefficiency effect*. If general management is inefficient compared with production management, then we have

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[4] Nishimura et al. [18] incorporate adjustment costs in the form of firm-specific managerial efficiency loss due to the insufficient accumulation of managerial ability in the firm level production function, and show that firms in many Japanese industries, including the Electrical Machinery and Motor Vehicles industry, have this kind of efficiency loss.

[5] A similar form is used in Rotemberg and Woodford [22] in their study of cyclical mark-ups.

$\phi > 1$ in (9), implying positive γ. If, in contrast, general management is more efficient than production management, we have negative γ since $\phi < 1$. If $\phi = 1$ (that is, the general management has the same efficiency as production management), then the short-run input-output relation is homogeneous of degree one since g is homogeneous of degree one. In this case, the short-run input-output relation has the same form as the neoclassical production function in the previous period.

From this short-run input-output relation, we define *input-normal-output relation f^N, which shows the amount of inputs which are needed to produce the normal output under the assumed technology and market structure.* From (14), in order to produce normal output (that is, in order that the actual output is equal to normal output), the firm needs inputs satisfying the following relationship.

$$y_t^N = f\left(x_{1t}, ..., x_{nt}, k_t; y_t^N, A_t\right) = g\left(x_{1t}, ..., x_{nt}, k_t; A_t\right) - \gamma y_t^N.$$

This implicitly defines the *input-normal-output relation*, such that

$$y_t^N = f^N\left(x_{1t}, ..., x_{nt}, k_t; A_t\right) \equiv \frac{1}{1+\gamma} g\left(x_{1t}, ..., x_{nt}, k_t; A_t\right). \qquad (15)$$

Since g is homogeneous of degree one, the input-normal-output relation exhibits constant returns to scale.[6] While the short-run input-output relation is defined only for y_t between a particular production capacity and its corresponding Minimum Efficiency Scale, the input-normal-output relation is defined for all output levels by construction.

2.3 Technological-Progress Measurement under Fixed Costs and Imperfect Competition

Let us now consider the implications of including fixed costs and imperfect competition on production technology measurement. Firstly, the "production function" in the usual sense is the relationship between inputs and the output whose production is sustained by these inputs. In the short-run input-output relation (14), output depends not only on inputs but also on the production capacity, or the normal output as its stand-in, under Assumption 5. Thus, output is dependent on production capacity, which is in turn depends on expected output in the future. In contrast, the input-normal-output relation (15) shows the relationship between inputs and output which is equal to normal, sustainable output. Thus, an appropriate choice of production function is not the short-run input-output relation but the input-normal-output one.

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[6] In response to the apparent deviation from the constant returns to scale, a non-constant-returns property is often incorporated in the quasi-fixed capital approach (see, for example, Morrison [17]).

However, recent studies (see, for example, Basu [1]) show that if *short-run adjustment of production organization is completed,* then the production function exhibits constant returns to scale, as in the neoclassical framework. This suggests that apparent non-constant returns are short-run phenomenon. The formulation in the text is consistent with this observation.

In the long run, capacity and normal output grow on average by the same rate as actual output. With this property in mind, we define the *long-run* rate of technological progress as the long-run average rate of normal output growth not attributable to input growth. Thus, we define

Definition 2 *Long-run rate of technological progress over T periods is*

$$\theta_{LR} = \frac{1}{T} \sum_{t=1}^{T} \frac{\partial f^N}{\partial A_t} \frac{\dot{A}_t}{y_t^N} = \frac{1}{T} \sum_{t=1}^{T} \frac{\dot{y}_t^N}{y_t^N} - \frac{1}{T} \sum_{t=1}^{T} \left(\sum_{i=1}^{n} \frac{\partial f^N}{\partial x_{it}} \frac{\dot{x}_{it}}{y_t^N} + \frac{\partial f^N}{\partial k_t} \frac{\dot{k}_t}{y_t^N} \right) \quad (16)$$

The long-run rate of technological progress can be estimated from observed data. Comparing (14) and (15), we have

$$\frac{\partial f^N}{\partial x_{it}} = \frac{1}{1+\gamma} \frac{\partial f}{\partial x_{it}}; \quad \frac{\partial f^N}{\partial k_t} = \frac{1}{1+\gamma} \frac{\partial f}{\partial k_t}.$$

Thus, we have the following approximate relation in the long run:

$$\frac{1}{T} \sum_{t=1}^{T} \left(\sum_{i=1}^{n} \frac{\partial f^N}{\partial x_{it}} \frac{\dot{x}_{it}}{y_t^N} + \frac{\partial f^N}{\partial k_t} \frac{\dot{k}_t}{y_t^N} \right) \approx \left(\frac{1}{1+\gamma} \right) \frac{1}{T} \sum_{t=1}^{T} \left[\sum_{i=1}^{n} \frac{\partial f}{\partial x_{it}} \frac{\dot{x}_{it}}{y_t} + \frac{\partial f}{\partial k_t} \frac{\dot{k}_t}{y_t} \right].$$
$$(17)$$

Similarly, we have approximately

$$\frac{1}{T} \sum_{t=1}^{T} \frac{\dot{y}_t}{y_t} \approx \frac{1}{T} \sum_{t=1}^{T} \frac{\dot{y}_t^N}{y_t^N} \quad (18)$$

Substituting (17) and (18) into the definition (16), we have

$$\theta_{LR} \approx \frac{1}{T} \sum_{t=1}^{T} \frac{\dot{y}_t}{y_t} - \left(\frac{1}{1+\gamma} \right) \frac{1}{T} \sum_{t=1}^{T} \left(\sum_{i=1}^{n} \frac{\partial f}{\partial x_{it}} \frac{\dot{x}_{it}}{y_t} + \frac{\partial f}{\partial k_t} \frac{\dot{k}_t}{y_t} \right). \quad (19)$$

The short-run cost minimization (10) yields the following relations.

$$\frac{q_{it}}{\lambda_t} = \frac{\partial f}{\partial x_{it}}; \quad \frac{r_t}{\lambda_t} = \frac{\partial f}{\partial k_t} \quad (20)$$

where λ_t is the marginal cost. The output market may be imperfectly competitive, and we have

$$p_t = \mu \lambda_t. \quad (21)$$

Here μ is the mark-up rate over the marginal cost λ_t. We treat the mark up rate as a *parameter* to be estimated from the data, and do not make any specific assumptions on its determination.

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Substituting (20) and (21) into (19), we have [7]

$$\theta_{\text{LR}} \approx \frac{1}{T} \sum_{t=1}^{T} \frac{\dot{y}_t}{y_t} - \frac{1}{T} \sum_{t=1}^{T} \left[\frac{\mu}{1+\gamma} \left(\sum_{i=1}^{n} \frac{q_{it} x_{it}}{p_t y_t} \frac{\dot{x}_{it}}{x_{it}} + \frac{r_t k_t}{p_t y_t} \frac{\dot{k}_t}{k_t} \right) \right] \qquad (22)$$

which is utilized in the measurement of technological progress in this paper.

2.4 Direction and Magnitude of Bias in the Traditional Measurement

Comparing (6) and (22), we have the following relation under reasonable conditions (see Appendix A.2).

$$\theta_{\text{LR}} - \frac{1}{T} \sum_{t=1}^{T} \theta_t^{est} \approx \frac{1}{T} \sum_{t=1}^{T} \left(\frac{\mu}{1+\gamma} - 1 \right) \left\{ \left(\sum_{i=1}^{n} w_{it} \right) \frac{\dot{k}_t}{k_t} - \sum_{i=1}^{n} w_{it} \frac{\dot{x}_{it}}{x_{it}} \right\}. \qquad (23)$$

where w_{it} is the factor share such that

$$w_{it} = \frac{q_{it} x_{it}}{p_t y_t}.$$

Equation (23) shows that if there is no pure profit so as to have $\mu = 1 + \gamma$, then the traditional technological-growth measurement is *not* biased. In other words, *if there are no barriers to entry and if free entry leads to zero pure profit, then the traditional approach, which assumes perfect competition and constant returns, produces the correct measure of technological progress even if competition is imperfect and there are fixed costs.* However, pure profits are not always equal to zero. Then, the traditional approach entails bias, and (23) determines the direction and magnitude of the bias in the estimated technological progress.

The direction and the magnitude of bias depend on (1) whether the market is competitive or not (μ), (2) whether there are substantial fixed costs (γ), and (3) whether capital growth exceeds non-capital input growth.

Suppose that $\mu > 1 + \gamma$, which ensures non-negative profits in the long run. Then, if capital input growth exceeds non-capital input growth ($(\sum w_{it}) \left(\dot{k}_t / k_t \right) > \sum w_{ij} \left(\dot{x}_{it} / x_{it} \right)$), which is often found in the process of actual economic growth, the traditional measure *underestimates* the true technological progress. The magnitude of the bias is greater if the price-marginal-cost margin μ is greater, while it is smaller when the magnitude of fixed costs γ is greater. If, on the contrary, the non-capital input growth is greater than capital growth, the conclusion is reversed.

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[7] This immediately follows the transformation of (19) below:

$$\theta_{\text{LR}} = \frac{1}{T} \sum_{t=0}^{T} \left[\frac{\dot{y}_t}{y_t} - \frac{1}{1+\gamma} \left(\sum_{i=1}^{n} \frac{q_{it}}{\lambda_t} \frac{\dot{x}_{it}}{y_t} + \frac{r_t}{\lambda_t} \frac{\dot{k}_t}{y_t} \right) \right]$$

In reality, the firm may not earn a positive profit for a long period. Then, the conclusion of the bias just presented may be reversed in such a case. Thus, the direction of the bias and its magnitude are empirical questions.

It should be noted here that we have not made any specific assumption with respect to the firm's pricing behavior. Imperfect competition may be Cournot quantity competition, differentiated-product Bertrand, bilateral monopoly, or a repeated-game implicit-cartel. What we have assumed are only (1) firms are input-price takers minimizing cost, and (2) the production function incorporates fixed costs in the form of (14). In this sense, this formulation is quite general.

3   Re-Assessment of Technology Measurement: Japan and the United States

3.1   Data

In order to measure the magnitude of the bias due to fixed costs and imperfect competition, we take the oft-cited work on the sectoral technological progress for the United States by Jorgenson (Jorgenson [9] and Jorgenson et al [10]), and that for Japan by Kuroda (Kuroda et al.[15]).[8]. The sample period of the U. S. data base is 1948-1991, while that of the Japanese data base is 1960-1992. The U. S. data set has 35 sectors at roughly the 2-digit SIC level. The Japanese data set has 43 industries. In both data sets, the government sector is excluded. In order to make both countries' sectors comparable, we aggregate them into 30 industries   Table 1 reports our industry classification. The distinctive characteristics of these data sets are their adjustment of quality change in inputs under the same methodology.[9] Thus, we are relatively free from confusing quality change as technology improves. Also, we postulate a production function whose inputs include materials and energy, as well as labor and capital services. In this way, we avoid problems in using the industry-wide value-added production function.

These data sets are derived from the assumption of perfect competition and constant returns to scale. However, it can easily be seen that the Divisia price and quantity indexes for inputs other than capital service calculated in these data sets are still valid in our approach, because of our specific formulation (14). See Appendix A.4.

The traditional estimates of technological progress based these data sets are obtained from formula (6) under the assumption of perfect competition and constant returns to scale. In particular, they assume that the capital service's share in value-added is equal to the rental payments to capital in order to get the rental price of capital service as in (6).

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[8] We are very grateful to Professors Jorgenson and Kuroda who kindly permitted us to use their data sets in this study.

[9] In each industry, the nominal output and its Divisia price index, and the nominal input and the Divisia price index of labor, capital service, energy and material as well as the nominal capital stock and its Dvisia price index are reported.

Since we do not impose perfect competition, we have to estimate the rental price of capital stocks independently. We follow the standard procedure of constructing the cost of capital and assume that the rental price is equal to the cost of capital.[10]

3.2 Estimating Marginal-Cost Mark-up and Managerial-Inefficiency Effect

Methodology. In estimating the mark up μ and managerial-inefficiency effect γ, we utilize the method developed in Nishimura et al [18]. We hereafter briefly discuss the procedure.

We use the framework of the previous section. The short-run input-output relation f is a function of K_t, L_t, E_t, and M_t, which are, respectively, capital service input, labor input, energy input, and material input in the t-th period. A_t represents the state of technology such that

$$y_t = f(K_t, L_t, E_t, M_t; y_t^N, A_t) = g(K_t, L_t, E_t, M_t; A_t) - \gamma y_t^N.$$

Let us define the elasticity of output with respect to inputs (capital, labor, material and energy) such that

---

[10]The rental price of capital goods r_t is constructed by the following standard formula which corrects for corporate tax and depreciation

$$r_t = (\rho_t + \delta) \times \frac{1 - ITC - \tau d}{1 - \tau} p_t^K$$

where ρ_t is the required rate of return on capital, δ the economic rate of depreciation, ITC the effective rate of investment tax credits, τ the effective rate of the corporate income tax, d the present discounted value of tax deductions for depreciation, and p_t^K the real price of capital goods.

Following Hall [6] , Basu and Fernald [2], and Basu and Fernald [3], we use for ρ_t the dividend yield of S&P500 for the United States and that of Tokyo Stock Exchange for Japan. δ, ITC, and d are estimated for each subcategory of capital stocks (see Jorgenson and Yun[11] and Kuroda et al [15]). We get industry-wide values by first estimating the composition of the capital stock through Fixed Capital Formation Matrixes, and then by taking the weighted average of them using the estimated composition as its weight.

As for the effective corporate tax rate τ in the United States, we use the weighted average of the effective tax rate for incorporated and non-incorporated enterprises reported in the U..S. data set, where the weights are those of incorporated and non-incorporated in the total capital stocks. The Japanese effective corporate tax rate is computed in the usual way in which

$$\tau = \frac{(u + v)(1 + i)}{1 + i + v} \text{ where } u = u_c(1 + u^{\cdot})$$

where u is the overall corporate income tax rate, u_c the national corporate income tax rate, $u^{\cdot}$ the local corporate tax surcharge rate, v the enterprise tax rate (ignoring the progressive part), i the interest rate of Telephone and Telegraph Bonds. Here $u_c, u^{\cdot}$ and v are common to all industries and taken from various tax publications.

It should be noted here that the Japanese capital stock data *exclude* land and inventory, while the United States capital stock data *include* land and inventory.

$$\varepsilon_Q \equiv \frac{K_t}{y_t}[f_K]_t + \frac{L_t}{y_t}[f_L]_t + \frac{E_t}{y_t}[f_E]_t + \frac{M_t}{y_t}[f_M]_t$$

where $[x]_t$ is the value of function x evaluated at t. Then, we have (see Appendix A.3 for the derivation of (24) and (26))

$$\varepsilon_Q = \mu([\alpha_K]_t + [\alpha_L]_t + [\alpha_E]_t + [\alpha_M]_t) \tag{24}$$

where α_K is the capital's share, α_L the labor's share, α_E the energy's share and α_M the material's share in total sales such that

$$[\alpha_K] = \frac{r_t K_t}{p_t y_t}, \quad [\alpha_L]_t = \frac{w_t L_t}{p_t y_t}, \quad [\alpha_E]_t = \frac{p_t^E E_t}{p_t y_t}, \quad [\alpha_M]_t = \frac{p_t^M M_t}{p_t y_t}. \tag{25}$$

Using the above relations, we obtain

$$([\alpha_K]_t + [\alpha_L]_t + [\alpha_E]_t + [\alpha_M]_t) = \frac{1}{\mu}\left(1 + \gamma\frac{y_t^N}{y_t}\right). \tag{26}$$

Taking log of both sides of (26), and then applying the first-order Taylor expansion of $\log(1 + x)$ around $x = 0$ on $\log\left[1 + \gamma\left(y_t^N/y_t\right)\right]$,[11] we get

$$\log([\alpha_K]_t + [\alpha_L]_t + [\alpha_E]_t + [\alpha_M]_t) = -\log\mu + \gamma\frac{y_t^N}{y_t} \tag{27}$$

Procedure The sample period of the U. S. estimation is 1950-1991, while that of Japan is 1962-1992. In our sample period, the World economy experienced two oil crises (1973-74 and 1978-79), which might have significant effects on the sectoral mark-up μ and the sectoral normal output y_t^N, the latter of which is approximated by the time-trend of output in our analysis.[12] Thus, we postulate the following regression equation

$$\begin{aligned}
\log([\alpha_K]_t &+ [\alpha_L]_t + [\alpha_E]_t + [\alpha_M]_t) \\
= - (\log\mu &+ d_1 MarkupDUMMY1 + d_2 MarkupDUMMY2) \\
&+ \gamma\frac{y_t^N}{y_t} + u_{1t}
\end{aligned} \tag{28}$$

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[11] This procedure is justified if γ is sufficiently small. It is in fact shown to be small in empirical analysis.

[12] We also considered possible changes in γ between periods. Qualitative results of the variable γ case on the measurement bias is the same as the constant γ case reported in the text, though the bias is generally larger in the variable γ case.

where $MarkupDUMMY1$ is the dummy for structural change at the first oil crisis, $MarkupDUMMY2$ for that at the second crisis, and u_{1t} is the markup disturbance. Moreover, for the auxiliary trend-output estimation, we have

$$
\begin{aligned}
y_t = &(y_0 + m_2 TrendDUMMY1 + m_2 TrendDUMMY2) \\
&+ (h_1 + h_2 TrendDUMMY1 + h_2 TrendDUMMY2)\, t + u_{2t},
\end{aligned}
\tag{29}
$$

where y_0 is the constant, $TrendDUMMY1$ is the dummy for the structural change at the first oil crisis, $TrendDUMMY2$ for that at the second crisis and u_{2t} is the trend disturbance. Here we consider a structural change altering not only the slope but also the intercept. Consequently, there are four possible trend specifications: no change, one change in 1973, one change in 1979, and two changes in 1973 and 1979.

We proceed with the following two-step method. First, we estimate (28) for each of the four possible trend specifications, and determine whether there is a structural change in the mark up in 1973, in 1979, or in both years by evaluating the t value of $MarkupDUMMY$. We then pick up, for each trend specification, an equation in which only statistically significant dummies are retained. Since there is no guarantee that the markup disturbance (which may stem from measurement errors in constructing the variables) is not correlated with the explanatory variables, we use the instrumental variable method in which the instruments are the constant, dummies, the lag of y_t^N/y_t, and the growth rate of GDP[13]. Finally, among the four trend specifications, we choose the best specification according to the AIC criterion[14].

Result: Managerial Efficiency and International Competitiveness. The result of the estimation of the mark-up μ and the managerial-inefficiency effect γ is summarized in Table 2, of which the underlying industry-specific information is found in Tables A.1 (Japan) and A.2 (United States). Tables A.1 and A.2 report (a) the mark-up rate μ of each sub-period with its confidence interval [15], and (b) the estimate of the managerial-inefficiency effect γ, as well as (c)

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[13] In order to assess the appropriateness of the instruments, we performed Sargan's test for mis-specification (see Godfrey [5]). Table A.5 reports the result for regression specification obtained by use of the two-step method described in the text. Under the null hypothesis that they are appropriate instruments, the test statistics reported in the table are asymptotically distributed as chi-squared distribution (see appendix A.5 for details of the test statistics). The test statistics in Table A.5 show that the null hypothesis cannot be rejected in any of the industries, so that our choice of instrument is appropriate.

[14] We also attempt using only the AIC criterion to select the best specification among all sixteen-regression equations. This yields six industries in Japan and eight industries in the U.S. that have statistically insignificant markup dummy coefficients, though there does not exist a large difference in comparison with the estimate results obtained using the two-step method described in the text.

[15] If γ is statistically significant, then the markup is computed from the result of the estimation of (28). If γ is not statistically significant, (28) implies that

$$
\mu = \frac{1}{[\alpha_K]_t + [\alpha_L]_t + [\alpha_E]_t + [\alpha_M]_t} + u'_{1t}.
$$

Thus, μ is the average of the reciprocal of the sum of factor shares in this case. We use this relation to estimate μ reported in Tables A.1 and A.2.

information of the structural change in the industry-output trend.[16] Figure 1 illustrates the result.

In both countries, there are several industries showing problematic results of extremely large $|\gamma|$ and/or extremely small μ. They are heavily regulated industries at least for some time in our sample period, including Transportation, Communications, Electric Utilities, Gas Utilities, and Finance, Insurance and Real Estate. Because of their technological conditions and regulations, our framework of Section 2.2 (especially cost minimization and constant returns to scale in incremental production) may not be applicable[17]. In addition, Coal Mining, Other Mining, and Trade also show problematic results of extremely large $|\gamma|$ and/or extremely small μ in Japan. However, this strange result is of no surprise because it is likely an artifact of governmental support of Mining industries[18], and the dualistic structure in Wholesale and Retail Trades[19]. In the United States, Food shows a problematic result of extremely large $|\gamma|$ and/or extremely small μ.[20] In order to make figures comparable between Japan and the United States, we exclude these 9 problematic industries from our calculation of the weighted average among industries throughout this paper.

Table 2 shows the aggregate picture of industry competition both in Japan and the United States. Industry-wide mark-up figures are aggregated with each industries' value-added weight. We use two weights: the beginning of the sample period, 1962, and the end year, 1990. The two figures tell almost the same story. The mark-up rate is slightly larger in Japan, while it is slightly smaller in the United States. However, the change is not pronounced.

Table 2 also shows that the mark-up rate μ is higher in Japan than in the United States, suggesting that Japanese firms in general have more market power over their customers than their U. S. counterparts. Moreover, this table also shows that γ on the average is negative in the United States while it is positive in Japan. This means that the general management of U. S. firms is more efficient relative to their production management, than its Japanese counterpart. Japanese firms have generally larger fixed costs, which must be covered by a higher mark-up. This is especially pronounced in the industries supplying non-tradable goods and services, such as Construction and Services. U. S.

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[16] If gamma is not statistically sufficient, we do not use the estimated value of the industry-output trend to estimate the markup rate. For clarity, the word "Yes" or "No" (in "Output Trend Change" in table A.1-2) is put in parentheses if managerial inefficiency is "Neutral".

[17] In addition, there is a conceptual problem in the Japanese data. The Japanese data follows the SNA procedure, and the Real Estate industry is not really the real estate industry in the usual sense. It is constructed under the assumption that home-owners are landlords renting their home to themselves, and the imputed rents are included as output in this "industry".

[18] Mining was once an important industry in Japan, but its share in GDP dwindled quite sharply. The government adopted a slow-death policy in which the industry was gradaually fading away. Meanwhile the government supported the industry directly, which distorted price and marginal cost figures in this industry.

[19] There have been a very large number of small retailers in Japan, coexisting alongside with large-scale retailers, and the number of small retailers has been steadily declining during our sample period. This compositional change may invalidate our assumption of the representative firm.

[20] Unfortunately we do not have a good explanation of this result.

Services have a negative γ, while Japanese Services have a zero γ. Japanese Construction's γ is positive and substantially higher than the U. S. Construction's γ.

This general picture, however, is somewhat misleading on an industry-specific level since not all Japanese industries share these characteristics. Table 3 picks up several important industries from Manufacturing (along with non-manufacturing industries such as Agriculture, Construction and Services), and compare them between Japan and the United States. This table shows that two industries in which Japan shows her international competitiveness, namely Electric Machinery (TV etc.) and Motor Vehicles, have efficient general management and thus a negative γ, while their U. S. counterparts do not. In fact, what is amazing is a stark contrast in Japan between these internationally competitive industries and non-competitive industries such as Lumber, Paper and Pulp, Chemical (including Pharmaceutical), and Transportation Equipment excluding Motor Vehicles (Airplanes etc.), which have substantially large, positive γ, compared to their U. S. counterparts.

A suggestive correlation between international competitiveness and negative γ is also found in the United States. U. S. firms in Chemicals (including Pharmaceutical) and Instruments are internationally competitive, and have a negative γ. Transportation Equipment (Airplanes etc.) has a positive γ, but this is substantially smaller than the Japanese counterpart. Thus, the correlation found in both countries suggests the importance of streamlined general management, which enables a substantial reduction in fixed costs.

3.3   The Revised Rate of Technological Progress

Using the results obtained in the previous section, we estimate the "revised" rate of technological progress based on (22) and compare it with the "traditional" estimate based on (6). In order to make U. S. and Japanese figures comparable, we restrict our attention to the period from 1962 to 1990. The revised annual rate is shown alongside the traditional one in Table 4 in aggregates for the entire sample period and for three subperiods, of which the underlying industry-specific information is found in Tables A.3 (Japan) and A.4 (United States). Figure 2 illustrates the result.

Table 4 shows that the revised aggregate estimate is greater than the traditional one in Japan. The value-added-weighted average of technological progress of the relevant twenty-one industries is slightly greater in the revised estimate than in the traditional estimate (by approximately 7% of the traditional estimate). This is the case regardless of the choice of reference year (1962 or 1990). In contrast, the same table shows that the U. S. revised estimate is smaller than the traditional estimate by approximately the same magnitude (by approximately 7% of the traditional estimate). Thus, this result shows that failure to account for imperfect competition and fixed costs biases downward by about 15% the traditional estimate of the Japan-U. S. technological progress difference.

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Although we found significant deviation from perfect competition and constant returns to scale, as shown in Table 2, both in Japan and the United States, the result reported in Table 4 shows that the resulting bias is not large. This is because, in the long run, pure profits or losses tend to vanish through entry and exit. Relation (23) shows that if pure profit is zero then the traditional measurement is unbiased even though markets are imperfectly competitive and there are substantial fixed costs. The result obtained in Table 4 reveals that such "competitive pressure" is strong enough to keep the bias small both in Japan and the United States.

Finally, let us consider the correlation between market power and technological progress. There are two conflicting views with respect to the effect of market power on productivity growth. In the Schumpeterian perspective, profits from market power make a firm able to afford investment in technological advancement, so that there might be a positive correlation between markup and productivity growth. In contrast, one may argue that high market power implies low competitive pressure to cut costs so that productivity growth is lower in noncompetitive industries than in competitive ones.

For Japan, we calculated the correlation between the mark-up [21] and the revised estimate of technological progress for all twenty-one industries for the entire sample period, and found that the correlation coefficient is -0.079, showing no clear relationship. We also examined the correlation between "pure profit" such that $\mu - (1 + \gamma)$ and the rate of technological progress, and generated a correlation coefficient of -0.078. Thus, there is no clear-cut systematic relation between market power and technological progress in Japan.

In contrast, the U. S. correlation coefficient between the mark-up and the revised estimate of technological progress is -0.44, and that between pure profit and the revised estimate is also -0.44. Thus, the U. S. data suggest a negative relationship between market power and productivity growth, though it is still inconclusive.

4   Concluding Remarks

In this paper, we have examined the measurement of technological progress under imperfect competition and fixed costs.

First, we find that mark-up over marginal cost varies substantially among industries, and differs from unity, suggesting ubiquitous imperfect competition in Japan, while the market seems more competitive in the United States. However, the deviation from perfect competition is small. Second, we also found a substantial number of industries which highlight the importance of fixed costs in their production.

Although one might expect that widespread deviation from perfect competition and constant returns to scale in both countries leads to a significant effect

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[21] Since the mark-up changes over sub-periods in some industries, we use its weighted average over the relevant period in which the ratio of the sub-period length to the sample-period length is used as the weight of the corresponding mark-up.

on productivity-growth measurement, this is actually not the case. The measurement incorporating imperfect competition and fixed costs reveals that the average rate of technological progress between 1962 and 1990 is higher than the traditional measurement by 7% in Japan, and lower by 7% in the United States. Thus, the traditional measurement understates the Japan-U. S. technological change difference by approximately 15%. The reason we obtain only a small bias in the measurement is that Japanese and U. S. industries are essentially "competitive" through entry and exit.

Although the result is still sketchy, it has several implications for East Asian economic growth. First, rapid capital accumulation coupled with imperfect competition in these countries may lead to substantial downward bias in the traditional measurement of productivity growth if sizable pure profit is maintained. If this is the case, then very low productivity growth found in earlier studies may in fact distort the true picture and be misleading.

Second, however, difference between Japan and other East Asian countries properly should be taken into account. Electric Machinery and Motor Vehicle industries show smaller fixed costs and efficient general management compared with production government, and they have been engines of strong economic growth in Japan during our sample period (1962-1990). The low mark-up and small fixed costs found in these industries is in sharp contrast to these industries in other East Asian countries. For example, Park and Kwon [20] found them having substantial fixed costs and significant market power.

As revealed in Table A.3, the growth engine of the Japanese economy between 1962 and 1973 was the "heavy/chemical" industries with large fixed costs, which seriously limited effective competition within industries. Relatively light competitive pressure in these industries resulted in a substantial slowdown after the high growth phase ended at the time of the first oil crisis when migration from rural to urban areas virtually halted. As Krugman [13] indicates, high economic growth solely based on an increase in factor inputs (made possible by, for example, migration from rural to urban areas) is not likely to be sustained for a long period of time.

However, after the 1973 oil crisis, the leading block of the Japanese economy was shifted toward machinery and "assembly" industries. Although these industries are generally considered "heavy" industries with large fixed costs, Japanese firms succeeded in developing production methods in which the burden of fixed costs was mitigated[22], and competitive pressure further strengthened this tendency. In this way, the Japanese economy sustained her growth until 1990 (the end year of our sample period).

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[22] The So-called "flexible production method" can be considered one manifestation of this effort. Also, "multi-functioned" labor within a firm helps to reduce rigidity in the production process.

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Appendix

A.1 Equivalence of (7) and (8) to (10).

Let $x_{it}^P = x_{1t} - x_{1t}^R$ and $k_t^P = k_t - k_t^R$. Under equation (9), The cost minimization problems of (7) and (8) can be rewritten as

$$Min\left(\sum_{i=1}^n q_{it}x_{it}^R + r_t k_t^R\right) \text{ s. t. } g\left(x_{1t}^R, ..., x_{nt}^R, k_t^R; A_t\right) = \phi\eta Q_{t-1,t}^{\max} \qquad (A.1)$$

and

$$Min\left(\sum_{i=1}^n q_{it}x_{it}^P + r_t k_t^P\right) \text{ s. t. } y_t = g\left(x_{1t}^P, ..., x_{nt}^P, k_t^P; A_t\right) = y_t - \eta Q_{t-1,t}^{\max}.$$
$$(A.2)$$

Let $\left(\overline{x_1}, ..., \overline{x_{nt}}, \overline{k}\right)$ be the solution of the following normalized cost-minimization problem

$$Min\left(\sum_{i=1}^n q_{it}\overline{x_i} + r_t\overline{k}\right) \text{ s.t. } g\left(\overline{x_1}, ..., \overline{x_{nt}}, \overline{k}; A_t\right) = 1. \qquad (A.3)$$

They are functions of $(q_{1t}, ..., q_{nt}, r_t, A_t)$.

Let us now consider the solution of the minimization problems (A.1) and (A.2), and let superscript $*$ denote the optimum value. Since g is homogeneous of degree one in $(x_1, ..., x_n, k)$, we immediately get

$$x_{it}^{R*} = (\overline{x_i})\left\{\phi\eta Q_{t-1,t}^{\max}\right\}; \ k_t^{R*} = (\overline{k})\left\{\phi\eta Q_{t-1,t}^{\max}\right\}$$

$$x_{it}^{P*} = (\overline{x_i})\left\{y_t - \eta Q_{t-1,t}^{\max}\right\}; \ k_t^{R*} = (\overline{k})\left\{y_t - \eta Q_{t-1,t}^{\max}\right\}$$

which imply

$$x_{it}^* = x_{it}^{R*} + x_{it}^{P*} = (\overline{x_i})\left\{y_t - (\phi - 1)\eta Q_{t-1,t}^{\max}\right\}; \qquad (A.4)$$

$$k_t^* = k_t^{R*} + k_t^{P*} = (\overline{k})\left\{y_t - (\phi - 1)\eta Q_{t-1,t}^{\max}\right\}. \qquad (A.5)$$

Next, consider the following cost-minimization problem

$$Min\left(\sum_{i=1}^n q_{it}x_{it} + r_t k_t\right) \text{ s. t. } g\left(x_{1t}, ..., x_{nt}, k_t; A_t\right) = y_t - (\phi - 1)\eta Q_{t-1,t}^{\max}.$$
$$(A.6)$$

Since g is homogeneous of degree one, it is evident that the optimum $(x_{1t}^*, ..., x_{nt}^*, k_t^*)$ of the above problem (A.6) is the same as (A.4) and (A.5). Consequently, the problem (A.6) is equivalent to the two-tier problem of (A.1) and (A.2), as claimed in the text.

A.2 Derivation of (23)

Taking the T-period average of (6), subtracting the result from (22), and rearranging terms, we have

$$
\theta_{\text{LR}} - \frac{1}{T}\sum_{t=1}^{T}\theta_t^{est} \approx \frac{1}{T}\sum_{t=1}^{T}\left(1 - \frac{\mu}{1+\gamma}\right)\left(\sum_{i=1}^{n}\frac{q_{it}x_{it}}{p_t y_t}\frac{\dot{x}_{it}}{x_{it}}\right)
$$
$$
+ \frac{1}{T}\sum_{t=1}^{T}\left\{\left(1 - \frac{\sum_{j=1}^{n}q_{jt}x_{jt}}{p_t y_t}\right) - \frac{\mu}{1+\gamma}\frac{r_t k_t}{p_t y_t}\right\}\frac{\dot{k}_t}{k_t}
$$

(A.7)

which is transformed into

$$
\theta_{\text{LR}} - \frac{1}{T}\sum_{t=1}^{T}\theta_t^{est} \approx \frac{1}{T}\sum_{t=1}^{T}\left[\left(1 - \frac{\mu}{1+\gamma}\right)\left(\sum_{i=1}^{n}\frac{q_{it}x_{it}}{p_t y_t}\left(\frac{\dot{x}_{it}}{x_{it}} - \frac{\dot{k}_t}{k_t}\right)\right)\right]
$$
$$
+ \frac{1}{T}\sum_{t=1}^{T}\left(1 - \frac{\mu}{1+\gamma}\left(\sum_{i=1}^{n}\frac{q_{it}x_{it}}{p_t y_t} + \frac{r_t k_t}{p_t y_t}\right)\right)\frac{\dot{k}_t}{k_t}
$$

(A.8)

Consider the second term in the right-hand side of (A.8). Using (20) and (21), we have

$$
\frac{1}{T}\sum_{t=1}^{T}\left(1 - \frac{\mu}{1+\gamma}\left(\sum_{i=1}^{n}\frac{q_{it}x_{it}}{p_t y_t} + \frac{r_t k_t}{p_t y_t}\right)\right)\frac{\dot{k}_t}{k_t}
$$
$$
= \frac{1}{T}\sum_{t=1}^{T}\left[1 - \frac{1}{1+\gamma}\left\{\frac{1}{y_t}\left(\sum_{i=1}^{n}\frac{\partial f}{\partial x_{it}}x_{it} + \frac{\partial f}{\partial k_t}k_t\right)\right\}\right]\frac{\dot{k}_t}{k_t}
$$

(A.9)

Note that $y_t = g - \gamma y_t^N$, and g is homogeneous of degree one. Thus we have

$$
\frac{1}{T}\sum_{t=1}^{T}\left[\frac{1}{y_t}\left\{\sum_{i=1}^{n}\frac{\partial f}{\partial x_{it}}x_{it} + \frac{\partial f}{\partial k_t}k_t\right\}\right] = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{y_t}\left[\sum_{i=1}^{n}\frac{\partial g}{\partial x_{it}}x_{it} + \frac{\partial g}{\partial k_t}k_t\right]
$$
$$
= \frac{1}{T}\sum_{t=1}^{T}\frac{g}{y_t} = \frac{1}{T}\sum_{t=1}^{T}\frac{y_t + \gamma y_t^N}{y_t}.
$$

(A.10)

Substituting (A.10) into (A.9), we have

$$
\frac{1}{T}\sum_{t=1}^{T}\left(1 - \frac{\mu}{1+\gamma}\left(\sum_{i=1}^{n}\frac{q_{it}x_{it}}{p_t y_t} + \frac{r_t k_t}{p_t y_t}\right)\right)\frac{\dot{k}_t}{k_t} = \frac{1}{T}\sum_{t=1}^{T}\left[\frac{\gamma\left(y_t - y_t^N\right)}{(1+\gamma)y_t}\right]\frac{\dot{k}_t}{k_t} \approx 0,
$$

(A.11)

if the current deviation from normal output is not correlated with the change from the current capital stock to next period's capital stock.

Substituting (A.11) into (A.8), we get

$$\theta \,|_{\text{Long Run}} -\frac{1}{T}\sum_{t=1}^{T}\theta_t^{est} \approx \frac{1}{T}\sum_{t=1}^{T}\left[\left(1-\frac{\mu_t}{1+\gamma}\right)\left\{\sum_{i=1}^{n}\frac{q_{it}x_{it}}{p_t y_t}\left(\frac{\dot{x}_{it}}{x_{it}}-\frac{\dot{k}_t}{k_t}\right)\right\}\right]$$

which is (23).

A.3 Derivation of (24) and (26)

First, g is homogeneous of degree one, so that we have

$$\frac{K_t}{[g]_t}[g_K]_t + \frac{L_t}{[g]_t}[g_L]_t + \frac{E_t}{[g]_t}[g_E]_t + \frac{M_t}{[g]_t}[g_M]_t = 1.$$

Second, using the above result and the relation $y_t = g - \gamma y_t^N$, we have

$$\varepsilon_Q = \frac{[g]_t}{y_t}\left(\frac{K_t}{[g]_t}[g_K]_t + \frac{L_t}{[g]_t}[g_L]_t + \frac{E_t}{[g]_t}[g_E]_t + \frac{M_t}{[g]_t}[g_M]_t\right) = 1 + \gamma\frac{y_t^N}{y_t} \quad \text{(A.12)}$$

Since $[f_L]_t = [g_L]_t$ etc., the definition of ε_Q and the marginal conditions $[f_K]_t = r_t/\lambda_t$, $[f_L]_t = w_t/\lambda_t$, $[f_E]_t = p_t^E/\lambda_t$, and $[f_M]_t = p_t^M/\lambda_t$ imply

$$\varepsilon_Q = \frac{K_t}{y_t}[f_K]_t + \frac{L_t}{y_t}[f_L]_t + \frac{E_t}{y_t}[f_E]_t + \frac{M_t}{y_t}[f_M]_t$$
$$= \frac{r_t K_t}{\lambda_t y_t} + \frac{w_t L_t}{\lambda_t y_t} + \frac{p_t^E E_t}{\lambda_t y_t} + \frac{p_t^M M_t}{\lambda_t y_t} = \mu([\alpha_K]_t + [\alpha_L]_t + [\alpha_E]_t + [\alpha_M]_t)$$
$$\text{(A.13)}$$

where (25) and the relation $p_t = \mu\lambda_t$ are used. Combining (A.13) and (A.12), we have (24) and (26) in the text.

A.4 Heterogeneous Inputs and the Divisia Indexes

In the following discussion, we use labor as an example. Consider a generalized short-run input-output relation incorporating heterogeneous labor inputs, which has the form:

$$y_t = f\left\{L\left(L_{1t},...,L_{nt}\right),k\right\} = g\left\{L\left(L_{1t},...,L_{nt}\right),k\right\} - \gamma y_t^N$$

where g is homogeneous of degree one in both L and k. Here $L\left(L_{1t},...,L_{nt}\right)$ is the labor-aggregator function which depends on n kinds of labor inputs $L_{1t},...,L_{nt}$, where L is homogeneous of degree one in the labor inputs. We show that, despite our assumption of imperfect competition in the product market, the Divisia formula used by the KEO group,

$$\frac{\dot{L}_t}{L_t} = \sum_{i=1}^{n}\left(\frac{w_{it}L_{it}}{\sum_j w_{jt}L_{jt}}\right)\frac{\dot{L}_{it}}{L_{it}}$$

where w_{it} is the wage rate of the ith labor input, is still an appropriate input index..

Let us consider L_{it}. Cost minimization implies

$$w_{it} = \lambda_t \frac{\partial g}{\partial L} \frac{\partial L}{\partial L_{it}} \Rightarrow \frac{\partial L}{\partial L_{it}} = \frac{w_{it}}{\lambda_t \frac{\partial g}{\partial L}}$$

where λ_t is the marginal cost. This implies

$$\sum_{i=1}^n w_{it} L_{it} = \lambda_t \frac{\partial g}{\partial L} \sum_{i=1}^n \frac{\partial L}{\partial L_{it}} L_{it} = \lambda_t \frac{\partial g}{\partial L} L_t$$

since we have from the linear homogeneity of L

$$L_t = \sum_{i=1}^n \frac{\partial L}{\partial L_{it}} L_{it}.$$

Then, we have ꝑ

$$\frac{\dot{L}_t}{L_t} = \frac{1}{L_t} \sum_{i=1}^n \frac{\partial L}{\partial L_{it}} \dot{L}_{it} = \sum_{i=1}^n \frac{w_{it} L_{it}}{\lambda_t \frac{\partial g}{\partial L} L_t} \frac{\dot{L}_{it}}{L_{it}} = \sum_{i=1}^n \left(\frac{w_{it} L_{it}}{\sum_j w_{jt} L_{jt}} \right) \frac{\dot{L}_{it}}{L_{it}}.$$

Thus, the Divisia quantity index is still appropriate aggregator in our framework. In the same vein, the corresponding Divisia price index is also an appropriate one.

A.5 Sargan's Test of Appropriateness of Instrument Choice

It is shown (see Godfrey [5] pp.174-176) that the statistic $\frac{\hat{u}Q\hat{\Delta}^{-1}Q\hat{u}}{n}$ is asymptotically distributed as χ^2 (rank of Q) where

$$\hat{\Delta} = \hat{\sigma}^2 n^{-1} \left[QQ - QX \left(\hat{X}\hat{X} \right)^{-1} \hat{X}Q - Q\hat{X} \left(\hat{X}\hat{X} \right)^{-1} XQ + QX \left(\hat{X}\hat{X} \right)^{-1} XQ \right]$$

in which Q is the matrix of instrumental variables, $\hat{X}$ is the projection of X on Q, n is number of observation, and $\hat{u}$ is residual vector. In our case, rank of Q for the regression specification obtained using the two-step method is

$$rank\ of\ Q \ = \ 3 + the\ Number\ of\ Markup DUMMY\ coefficient$$
$$that\ is\ statistically\ significant.$$

Table 1:
Industry Classification

	Sector Name	Abbreviation
1	Agriculture	Agri.
2	Coal Mining	Coal Mining
3	Other Mining	Other Mining
4	Construction	Construc.
5	Food and Kindred Products	Food
6	Textile Mill Products	Textile
7	Apparel	Apparel
8	Lumber and Wood	Lumber
9	Furniture and Fixtures	Furniture
10	Paper and Allied Products	Paper & Pulp
11	Printing, Publishing and Allied Products	Printing
12	Chemicals	Chemicals
13	Petroleum and Coal Products	Petro. & Coal
14	Leather	Leather
15	Stone, Clay, Glass	Stone & Clay
16	Primary Metal	Pri. Metal
17	Fabricated Metal	Fab. Metal
18	Machinery, Non-electrical	Gen. Machinery
19	Electrical Machinery	Elec. Machinery
20	Motor Vehicles	Motor Vehicles
21	Transportation Equipment and Ordnance	Trans. Equipment
22	Instruments	Instruments
23	Miscellaneous Manufacturing	Misc. Manufac.
24	Transportation	Transportation
25	Communications	Communica.
26	Electric Utilities	Electric Utilities
27	Gas Utilities	Gas Utilities
28	Trade	Trade
29	Finance Insurance and Real Estate	Finance & Re. Es.
30	Services	Services

Table 2:
Marginal-Cost Mark-Up and Managerial-Inefficiency Effect: Summary

	Total		Agri.	Construc.	Manufacturing		Services
	1962 weight	**1990 weight**			**1962 weight**	**1990 weight**	
Mark-Up (myu)							
Japan							
1962-73	**1.101**	**1.112**	**1.040**	**1.431**	**1.098**	**1.094**	**0.981**
1974-79	**1.098**	**1.125**	**1.034**	**1.456**	**1.057**	**1.056**	**1.053**
1980-92	**1.113**	**1.155**	**0.968**	**1.548**	**1.094**	**1.095**	**1.053**
US							
1950-73	**1.027**	**1.038**	**0.862**	**1.069**	**1.028**	**1.025**	**1.059**
1974-79	**0.973**	**0.982**	**0.741**	**1.059**	**0.984**	**0.982**	**0.986**
1980-91	**0.976**	**0.984**	**0.741**	**1.086**	**0.981**	**0.978**	**0.986**
Managerial-Inefficiency Effect (gamma)							
Japan	**0.156**	**0.165**	**zero**	**0.308**	**0.090**	**0.069**	**zero**
	(Inefficient)	(Inefficient)	(Neutral)	(Inefficient)	(Inefficient)	(Inefficient)	(Neutral)
US	**-0.052**	**-0.086**	**zero**	**0.096**	**-0.055**	**-0.075**	**-0.138**
	(Efficient)	(Efficient)	(Neutral)	(Inefficient)	(Efficient)	(Efficient)	(Efficient)
Share in GDP excluding Government (%)							
1962							
Japan	**59.91**		**12.24**	**6.93**	**28.55**		**12.20**
US	**52.94**		**4.78**	**7.63**	**27.71**		**12.82**
1990							
Japan		**59.01**	**2.52**	**10.47**		**25.38**	**20.65**
US		**54.68**	**2.58**	**6.77**		**20.55**	**24.78**

Notes: "Total" = 21 industries excluding 9 problematic industries. "Manufacturing" = 18 industries. Food is excluded since it is
   "problematic" in the United States. See the text. "zero" = statistically not different from zero

Table 3:
Mark-up, Managerial Inefficiency, and Rate of Technological Progress: Selected Industries

	Managerial Inefficiency Effect (gamma)		Mark-Up		Revised Rate of Technological Progress (%)		Traditional Rate of Technological Progress (%)	
	Japan	US	Japan	US	Japan	US	Japan	US
Lumber	0.091	zero	1.109	0.995	1.036	0.607	1.032	0.582
Paper & Pulp	0.158	zero	1.189	1.028	1.515	0.395	1.506	0.399
Printing	zero	zero	1.047	1.051	-0.755	-0.325	-0.942	-0.395
Chemicals	0.216	-0.173	1.276	0.899	2.268	0.426	2.368	0.416
Stone & Clay	0.188	zero	1.229	1.010	1.073	0.469	1.143	0.456
Pri. Metal	0.105	zero	1.115	0.987	1.112	0.168	1.286	0.223
Gen. Machinery	zero	zero	1.058	1.022	1.770	1.153	1.492	1.121
Elec. Machinery	-0.022	zero	1.049	1.018	3.818	1.877	3.744	1.801
Motor Vehicles	-0.030	zero	0.990	1.054	2.703	-0.176	2.719	-0.329
Trans. Equipment	0.113	0.034	1.133	1.019	0.575	0.412	0.440	0.385
Instruments	zero	-0.061	1.020	1.001	3.296	1.356	3.112	1.157
Agri.	zero	zero	1.009	0.813	-0.783	1.598	-0.808	1.432
Construc.	0.308	0.096	1.485	1.072	0.251	-0.305	0.300	-0.297
Services	zero	-0.138	1.025	1.030	-0.032	-0.185	-0.138	0.096

Notes: The mark-up rate is the weighted average of sub-period mark-up rates. The rate of technological progress is for 1962-1990.

Table 4:
Annual Rate of Technological Progress (%) 1962-90: Summary

	Total		Agri.	Construc.	Manufacturing		Services
	1962 Weight	**1990 Weight**			**1962 Weight**	**1990 Weight**	
Japan							
1962-1990							
Revised	0.661	0.839	-0.783	0.251	1.674	1.951	-0.032
Traditional	0.616	0.784	-0.808	0.300	1.626	1.891	-0.138
62-73							
Revised	0.860	1.181	-1.338	0.074	2.243	2.624	0.275
Traditional	0.830	1.184	-1.436	0.153	2.170	2.548	0.350
74-79							
Revised	0.756	1.378	-1.592	-0.031	1.510	1.914	1.795
Traditional	0.706	1.316	-1.677	-0.088	1.538	1.960	1.601
80-90							
Revised	0.402	0.185	0.273	0.600	1.156	1.250	-1.344
Traditional	0.347	0.071	0.363	0.672	1.093	1.153	-1.598
US							
1962-1990							
Revised	0.390	0.216	1.598	-0.305	0.639	0.698	-0.185
Traditional	0.421	0.318	1.432	-0.297	0.596	0.649	0.096
62-73							
Revised	0.555	0.640	0.772	-0.516	0.675	0.746	0.854
Traditional	0.605	0.802	0.678	-0.511	0.569	0.628	1.318
74-79							
Revised	0.033	-0.091	0.892	-0.328	0.137	0.110	-0.297
Traditional	0.104	0.010	1.199	-0.359	0.134	0.104	-0.090
80-90							
Revised	0.411	-0.070	2.897	-0.061	0.879	0.973	-1.247
Traditional	0.402	-0.031	2.390	-0.030	0.882	0.976	-1.119
Share in GDP excluding Government (%)							
1962							
Japan	59.91		12.24	6.93	28.55		12.20
US	52.94		4.78	7.63	27.71		12.82
1990							
Japan		59.01	2.52	10.47		25.38	20.65
US		54.68	2.58	6.77		20.55	24.78

Note: "Total" = 21 industries excluding 9 problematic industries.
"Manufacturing" = 18 industries. Food is exluded since it is "problematic." See the text for explanation.

Figure 1 Mark-Up in Japan and US

Mark-Up in Japan (1962-92)

Legend: ☐ 62-73 ☐ 74-79 ☐ 80-92
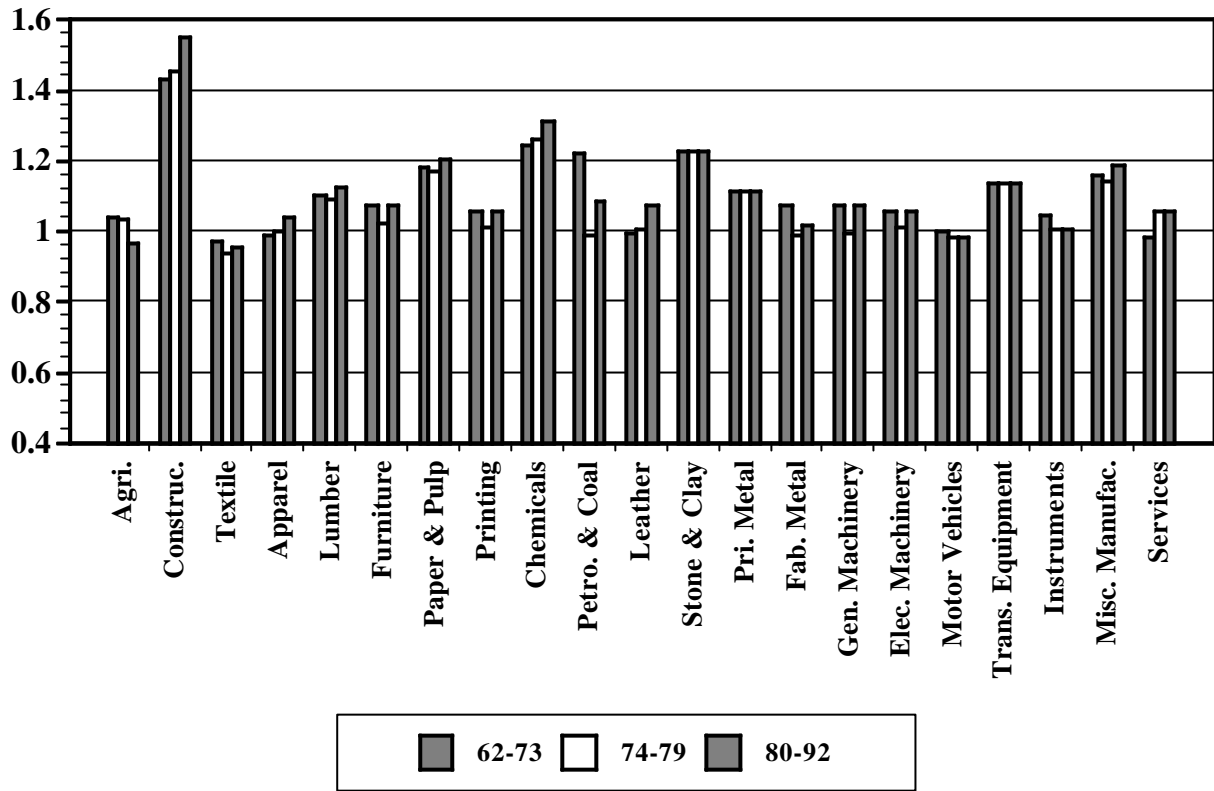
Mark-Up in US (1950-91)

Legend: ☐ 50-73 ☐ 74-79 ☐ 80-91
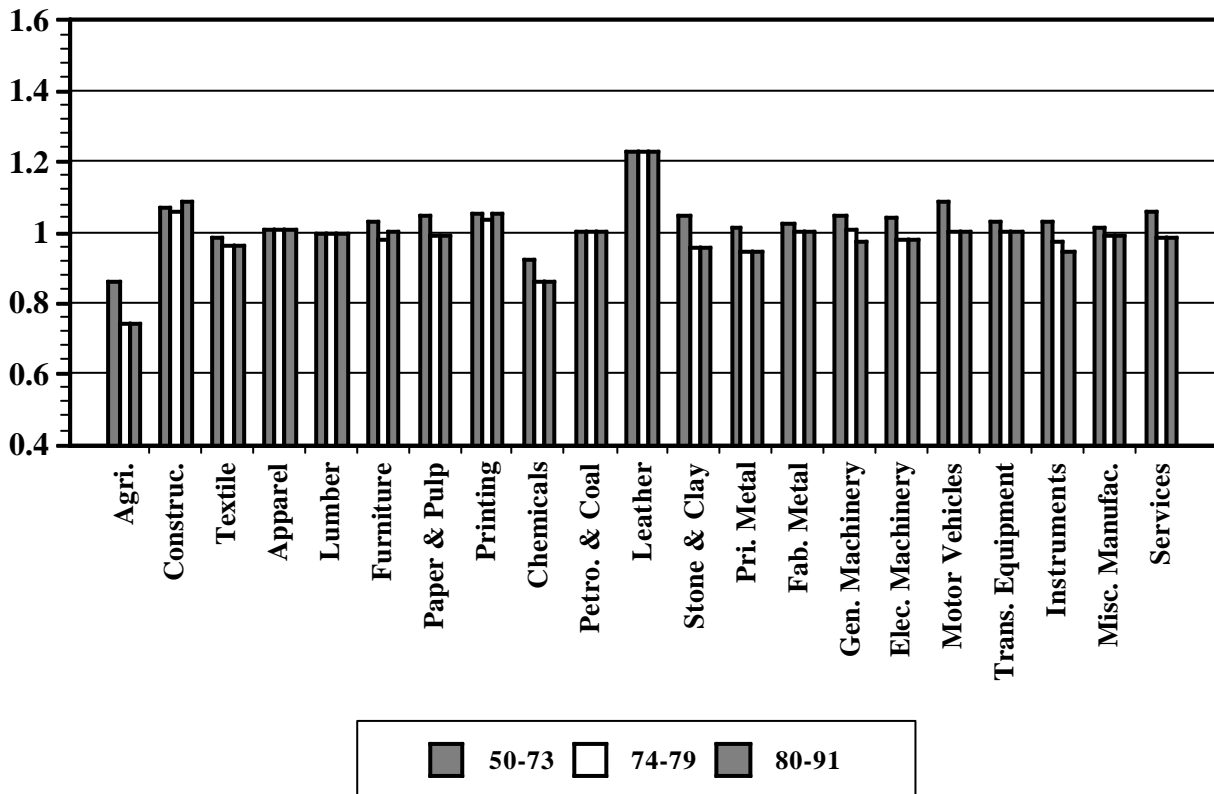
Figure 2 Rate of Technological Progress:
Sample Period 1962-90 in Japan and US

Japan (1962-90)

| | Revised | | Traditional | - - 1962 Share | — 1990 Share |

US (1962-90)

| | Revised | | Traditional | - - - 1962 Share | — 1990 Share |
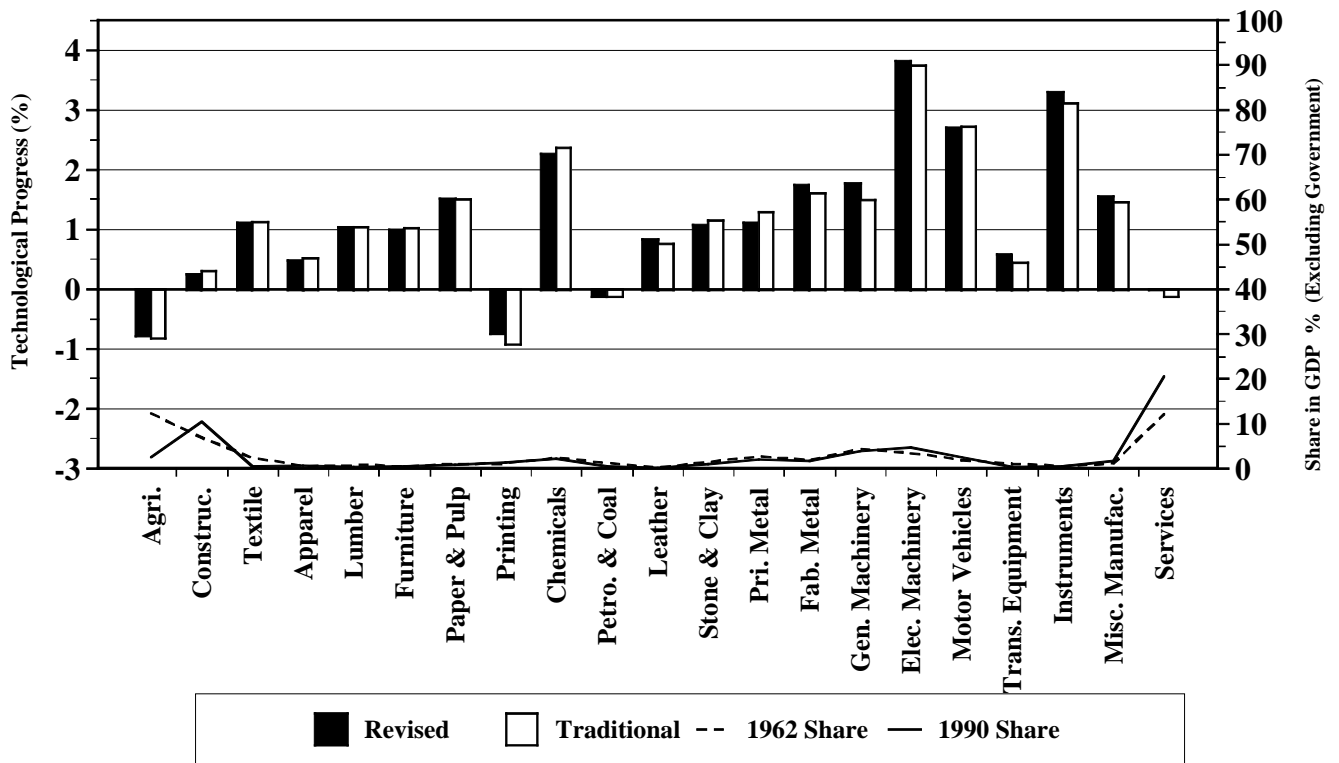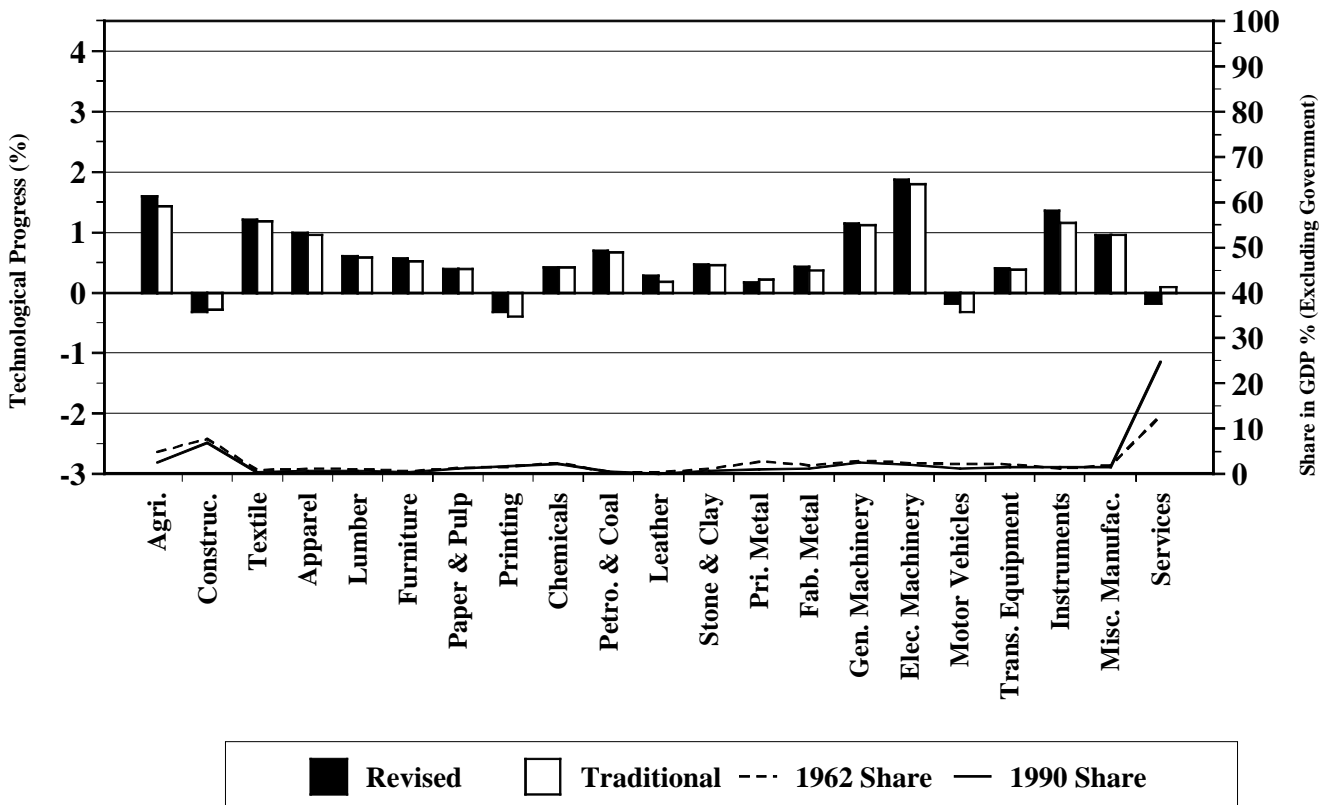
Table A.1: Mark-Up and Managerial-Efficiency Effect by Industry: Japan (1962-92)

	1 Agri.	2 Coal Mining	3 Other Mining	4 Construc.	5 Food	6 Textile	7 Apparel	8 Lumber	9 Furniture	10 Paper & Pulp
INDUSTRY										
Problematic or not		Problematic	Problematic							
Mark-Up (myu)										
62-73	1.040	1.768	1.754	1.431	1.080	0.970	0.990	1.099	1.073	1.184
Upper bound (5%)	1.056	1.859	1.781	1.452	1.085	0.980	0.998	1.107	1.084	1.199
Lower bound (5%)	1.025	1.676	1.727	1.411	1.074	0.961	0.981	1.090	1.062	1.169
74-79	1.034	1.909	1.624	1.456	1.080	0.935	1.001	1.092	1.021	1.172
Upper bound (5%)	1.047	2.011	1.646	1.476	1.085	0.943	1.015	1.099	1.043	1.187
Lower bound (5%)	1.021	1.808	1.602	1.436	1.074	0.928	0.988	1.084	0.998	1.157
80-92	0.968	1.674	1.754	1.548	1.080	0.954	1.037	1.126	1.073	1.203
Upper bound (5%)	0.974	1.762	1.781	1.570	1.085	0.958	1.046	1.136	1.084	1.218
Lower bound (5%)	0.961	1.586	1.727	1.525	1.074	0.950	1.028	1.117	1.062	1.187
Managerial-Inefficiency (gamma)	Neutral	NA	NA	Inefficient	Neutral	Neutral	Neutral	Inefficient	Neutral	Inefficient
estimate	zero	0.785	0.357	0.308	zero	zero	zero	0.091	zero	0.158
t-value	zero	5.397	9.285	7.635	zero	zero	zero	4.135	zero	4.362
Output Trend Change										
Change at 74-79	(Yes)	Yes	No	No	(No)	(Yes)	(No)	No	(Yes)	No
Change at 80-92	(Yes)	No	No	No	(No)	(No)	(No)	No	(No)	No

	11 Printing	12 Chemicals	13 Petro. & Coal	14 Leather	15 Stone & Clay	16 Pri. Metal	17 Fab. Metal	18 Gen. Machinery	19 Elec. Machinery	20 Motor Vehicles
INDUSTRY										
Problematic or not										
Mark-Up (myu)										
62-73	1.056	1.245	1.223	0.997	1.229	1.115	1.073	1.074	1.058	0.999
Upper bound (5%)	1.065	1.276	1.250	1.004	1.255	1.125	1.078	1.085	1.061	1.001
Lower bound (5%)	1.047	1.213	1.195	0.991	1.202	1.105	1.067	1.062	1.056	0.997
74-79	1.009	1.261	0.989	1.005	1.229	1.115	0.989	0.993	1.009	0.984
Upper bound (5%)	1.019	1.293	1.041	1.010	1.255	1.125	1.015	1.001	1.014	0.987
Lower bound (5%)	0.998	1.228	0.937	0.999	1.202	1.105	0.963	0.984	1.004	0.982
80-92	1.056	1.312	1.082	1.074	1.229	1.115	1.016	1.074	1.058	0.984
Upper bound (5%)	1.065	1.346	1.113	1.095	1.255	1.125	1.035	1.085	1.061	0.987
Lower bound (5%)	1.047	1.279	1.052	1.053	1.202	1.105	0.997	1.062	1.056	0.982
Managerial-Inefficiency (gamma)	Neutral	Inefficient	Neutral	Neutral	Inefficient	Inefficient	Neutral	Neutral	Efficient	Efficient
estimate	zero	0.216	zero	zero	0.188	0.105	zero	zero	-0.022	-0.030
t-value	zero	3.041	zero	zero	3.128	4.438	zero	zero	-4.468	-4.778
Output Trend Change										
Change at 74-79	(No)	No	(No)	(No)	No	No	(Yes)	(No)	No	No
Change at 80-92	(Yes)	No	(Yes)	(Yes)	Yes	No	(No)	(No)	No	No

	21 Trans. Equipment	22 Instruments	23 Misc. Manufac.	24 Transportation	25 Communica.	26 Electric Utilities	27 Gas Utilities	28 Trade	29 Finance & Re. Es.	30 Services
INDUSTRY										
Problematic or not				Problematic	Problematic	Problematic	Problematic	Problematic	Problematic	
Mark-Up (myu)										
62-73	1.133	1.047	1.157	1.875	0.657	0.602	NA	1.903	0.156	0.981
Upper bound (5%)	1.143	1.067	1.174	2.013	0.677	0.664		2.057	0.178	1.022
Lower bound (5%)	1.123	1.027	1.140	1.738	0.637	0.540		1.749	0.133	0.940
74-79	1.133	1.003	1.145	2.326	0.808	0.839		1.990	0.243	1.053
Upper bound (5%)	1.143	1.014	1.167	2.495	0.909	0.904		2.149	0.281	1.060
Lower bound (5%)	1.123	0.992	1.123	2.158	0.706	0.773		1.831	0.205	1.047
80-92	1.133	1.003	1.188	2.696	0.943	1.053		1.990	0.335	1.053
Upper bound (5%)	1.143	1.014	1.207	2.896	0.972	1.090		2.149	0.385	1.060
Lower bound (5%)	1.123	0.992	1.168	2.495	0.914	1.016		1.831	0.284	1.047
Managerial-Inefficiency (gamma)	Inefficient	Neutral	Inefficient	NA	NA	NA	NA	NA	NA	Neutral
estimate	0.113	zero	0.110	1.123	zero	zero		0.591	-1.339	zero
t-value	4.648	zero	2.401	5.397	zero	zero		2.619	-3.188	zero
Output Trend Change										
Change at 74-79	No	(No)	No	No	Yes	No	NA	No	No	(No)
Change at 80-92	No	(No)	No	No	No	No		Yes	No	(No)

NA = Not Applicable

See the Text for explanation of the "Problematic" category.

The word "Yes" or "No" in "Output Trend Change" is put in parentheses if we do not use the estimated value of the industry-output trend to estimate the markup rate.

Table A.2: Mark-Up and Managerial Inefficiency Effect by Industry: United States (1950-91)

	1 Agri.	2 Coal Mining	3 Other Mining	4 Construc.	5 Food	6 Textile	7 Apparel	8 Lumber	9 Furniture	10 Paper & Pulp
INDUSTRY										
Problematic or not					Problematic					
Mark-Up (myu)										
50-73	0.862	0.878	1.104	1.069	0.349	0.987	1.009	0.995	1.029	1.052
Upper bound (5%)	0.876	0.899	1.118	1.083	0.400	0.994	1.012	1.003	1.034	1.059
Lower bound (5%)	0.849	0.858	1.091	1.054	0.299	0.980	1.005	0.987	1.024	1.045
74-79	0.741	0.936	1.073	1.059	0.349	0.963	1.009	0.995	0.983	0.994
Upper bound (5%)	0.766	0.958	1.095	1.074	0.400	0.969	1.012	1.003	0.989	1.006
Lower bound (5%)	0.715	0.914	1.050	1.045	0.299	0.957	1.005	0.987	0.976	0.982
80-91	0.741	0.830	1.073	1.086	0.349	0.963	1.009	0.995	1.004	0.994
Upper bound (5%)	0.766	0.847	1.095	1.101	0.400	0.969	1.012	1.003	1.016	1.006
Lower bound (5%)	0.715	0.813	1.050	1.071	0.299	0.957	1.005	0.987	0.991	0.982
Managerial-										
Inefficiency (gamma)	Neutral	Efficient	Neutral	Inefficient	NA	Neutral	Neutral	Neutral	Neutral	Neutral
estimate	zero	-0.153	zero	0.096	-1.066	zero	zero	zero	zero	zero
t-value	zero	-2.133	zero	2.086	-2.193	zero	zero	zero	zero	zero
Output Trend Change										
Change at 74-79	(Yes)	No	(No)	No	No	(No)	(No)	(Yes)	(No)	(No)
Change at 80-91	(Yes)	No	(No)	No	Yes	(No)	(No)	(No)	(No)	(No)

	11 Printing	12 Chemicals	13 Petro. & Coal	14 Leather	15 Stone & Clay	16 Pri. Metal	17 Fab. Metal	18 Gen. Machinery	19 Elec. Machinery	20 Motor Vehicles
INDUSTRY										
Problematic or not										
Mark-Up (myu)										
50-73	1.053	0.924	1.005	1.231	1.047	1.013	1.029	1.046	1.042	1.089
Upper bound (5%)	1.058	0.947	1.008	1.259	1.057	1.021	1.035	1.051	1.049	1.102
Lower bound (5%)	1.049	0.901	1.002	1.202	1.038	1.005	1.022	1.041	1.036	1.076
74-79	1.036	0.864	1.005	1.231	0.956	0.949	1.004	1.006	0.981	1.002
Upper bound (5%)	1.047	0.885	1.008	1.259	0.970	0.957	1.012	1.020	0.992	1.016
Lower bound (5%)	1.026	0.843	1.002	1.202	0.943	0.940	0.995	0.992	0.971	0.988
80-91	1.053	0.864	1.005	1.231	0.956	0.949	1.004	0.976	0.981	1.002
Upper bound (5%)	1.058	0.885	1.008	1.259	0.970	0.957	1.012	0.985	0.992	1.016
Lower bound (5%)	1.049	0.843	1.002	1.202	0.943	0.940	0.995	0.966	0.971	0.988
Managerial-										
Inefficiency (gamma)	Neutral	Efficient	Neutral	Inefficient	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
estimate	zero	-0.173	zero	0.193	zero	zero	zero	zero	zero	zero
t-value	zero	-2.118	zero	2.510	zero	zero	zero	zero	zero	zero
Output Trend Change										
Change at 74-79	(No)	No	(Yes)	Yes	(Yes)	(Yes)	(Yes)	(No)	(No)	(No)
Change at 80-91	(No)	Yes	(Yes)	No	(No)	(No)	(Yes)	(No)	(No)	(No)

	21 Trans. Equipment	22 Instruments	23 Misc. Manufac.	24 Transportation	25 Communica.	26 Electric Utilities	27 Gas Utilities	28 Trade	29 Finance & Re. Es.	30 Services
INDUSTRY										
Problematic or not				Problematic	Problematic	Problematic	Problematic		Problematic	
Mark-Up (myu)										
50-73	1.030	1.031	1.017	0.575	0.678	0.370	1.169	1.202	0.611	1.059
Upper bound (5%)	1.035	1.035	1.020	0.595	0.690	0.384	1.179	1.215	0.626	1.076
Lower bound (5%)	1.025	1.026	1.013	0.555	0.666	0.355	1.159	1.190	0.596	1.042
74-79	1.004	0.973	0.989	0.600	0.659	0.370	1.129	1.131	0.523	0.986
Upper bound (5%)	1.009	0.979	0.996	0.620	0.670	0.384	1.138	1.143	0.536	1.002
Lower bound (5%)	0.999	0.968	0.983	0.579	0.648	0.355	1.120	1.119	0.509	0.971
80-91	1.004	0.948	0.989	0.645	0.711	0.370	1.255	1.131	0.584	0.986
Upper bound (5%)	1.009	0.952	0.996	0.667	0.723	0.384	1.267	1.143	0.597	1.002
Lower bound (5%)	0.999	0.944	0.983	0.623	0.698	0.355	1.243	1.119	0.571	0.971
Managerial-										
Inefficiency (gamma)	Inefficient	Efficient	Neutral	NA	NA	NA	NA	Inefficient	NA	Efficient
estimate	0.034	-0.061	zero	-0.370	-0.414	-0.927	0.147	0.106	-0.460	-0.138
t-value	2.095	-4.495	zero	-3.283	-7.244	-7.261	5.857	3.000	-5.842	-2.601
Output Trend Change										
Change at 74-79	No	No	(No)	No	No	No	No	No	No	Yes
Change at 80-91	No	No	(Yes)	No	Yes	No	No	No	No	Yes

NA = Not Applicable

See the Text for explanation of the "Problematic" category.

The word "Yes" or "No" in "Output Trend Change" is put in parentheses if we do not use the estimated value of the industry-output trend to estimate the markup rate.

Table A.3:

Rate of Technological Progress by Industry: Japan (1962-90)

INDUSTRY	1 Agri.	2 Coal Mining	3 Other Mining	4 Construc.	5 Food	6 Textile	7 Apparel	8 Lumber	9 Furniture	10 Paper & Pulp
Managerial Inefficiency	Neutral	Problematic	Problematic	Inefficient	Neutral	Neutral	Neutral	Inefficient	Neutral	Inefficient
1962-1990										
Revised	-0.783	0.945	3.400	0.251	0.233	1.112	0.473	1.036	0.992	1.515
Traditional	-0.808	0.681	3.579	0.300	-0.049	1.123	0.519	1.032	1.021	1.506
62-73										
Revised	-1.338	5.588	5.855	0.074	0.536	1.347	0.830	1.807	0.923	1.816
Traditional	-1.436	4.396	6.299	0.153	-0.023	1.309	0.952	1.819	1.118	1.810
74-79										
Revised	-1.592	-5.578	4.148	-0.031	1.404	1.632	1.116	-1.627	0.854	0.533
Traditional	-1.677	-4.184	4.270	-0.088	1.381	1.408	1.141	-1.587	0.723	0.463
80-90										
Revised	0.273	-0.319	0.390	0.600	-0.728	0.574	-0.262	1.672	1.142	1.726
Traditional	0.363	-0.571	0.325	0.672	-0.847	0.765	-0.287	1.625	1.078	1.746

INDUSTRY	11 Printing	12 Chemicals	13 Petro. & Coal	14 Leather	15 Stone & Clay	16 Pri. Metal	17 Fab. Metal	18 Gen. Machinery	19 Elec. Machinery	20 Motor Vehicles
Managerial Inefficiency	Neutral	Inefficient	Neutral	Neutral	Inefficient	Inefficient	Neutral	Neutral	Efficient	Efficient
1962-1990										
Revised	-0.755	2.268	-0.137	0.830	1.073	1.112	1.738	1.770	3.818	2.703
Traditional	-0.942	2.368	-0.111	0.758	1.143	1.286	1.603	1.492	3.744	2.719
62-73										
Revised	-1.872	3.741	-1.321	1.323	1.804	1.788	2.645	1.765	4.778	4.369
Traditional	-2.241	3.925	-1.084	1.330	1.950	2.063	2.297	1.208	4.905	4.396
74-79										
Revised	-0.631	0.416	-0.511	-0.611	-0.403	1.210	1.051	3.041	4.240	3.277
Traditional	-0.597	0.543	-0.419	-0.625	-0.313	1.345	1.049	3.041	4.312	3.323
80-90										
Revised	0.410	1.692	1.379	1.086	1.089	0.327	1.131	1.089	2.553	0.608
Traditional	0.304	1.688	1.133	0.895	1.067	0.413	1.152	0.967	2.186	0.599

INDUSTRY	21 Trans. Equipment	22 Instruments	23 Misc. Manufac	24 Transportation	25 Communica.	26 Electric Utilities	27 Gas Utilities	28 Trade	29 Finance & Re. Es	30 Services
Managerial Inefficiency	Inefficient	Neutral	Inefficient	Problematic	Problematic	Problematic	Problematic	Problematic	Problematic	Neutral
1962-1990										
Revised	0.575	3.296	1.554	-0.005	2.990	3.423	NA	2.626	7.718	-0.032
Traditional	0.440	3.112	1.450	1.212	3.406	2.867		3.173	3.341	-0.138
62-73										
Revised	1.532	5.192	2.343	-0.107	3.025	6.614	NA	3.681	8.962	0.275
Traditional	1.231	4.828	2.108	1.440	3.651	5.180		4.702	4.586	0.350
74-79										
Revised	-2.123	4.090	0.933	1.549	-0.430	-0.622	NA	2.679	4.584	1.795
Traditional	-2.126	4.089	1.048	1.551	0.333	-0.553		2.903	3.389	1.601
80-90										
Revised	1.029	0.844	1.039	-0.731	4.867	2.250	NA	1.457	8.104	-1.344
Traditional	1.001	0.751	0.954	0.781	4.851	2.271		1.675	1.973	-1.598

NA = Not Applicable

See the text for the explanation of the "Problematic" category.

Table A.4:
Rate of Technological Progress by Industry: US (1962-90)

	1 Agri.	2 Coal Mining	3 Other Mining	4 Construc.	5 Food	6 Textile	7 Apparel	8 Lumber	9 Furniture	10 Paper & Pulp
Managerial Inefficiency	Neutral	Efficient	Neutral	Inefficient	Problematic	Neutral	Neutral	Neutral	Neutral	Neutral
1962-1990										
Revised	1.598	0.009	-0.680	-0.305	9.005	1.204	1.000	0.607	0.575	0.395
Traditional	1.432	-0.162	-0.786	-0.297	0.467	1.191	0.954	0.582	0.520	0.399
62-73										
Revised	0.772	-2.240	0.228	-0.516	14.133	0.722	0.822	0.606	0.628	0.611
Traditional	0.678	-2.302	0.270	-0.511	0.111	0.666	0.742	0.603	0.521	0.629
74-79										
Revised	0.892	-0.017	-6.258	-0.328	4.042	2.590	1.699	0.288	1.495	-0.081
Traditional	1.199	-0.747	-6.050	-0.359	1.225	2.615	1.681	0.293	1.498	-0.067
80-90										
Revised	2.897	2.536	1.488	-0.061	6.342	0.980	0.815	0.783	0.020	0.420
Traditional	2.390	2.554	1.034	-0.030	0.445	0.992	0.790	0.717	-0.009	0.403

	11 Printing	12 Chemicals	13 Petro. & Coal	14 Leather	15 Stone & Clay	16 Pri. Metal	17 Fab. Metal	18 Gen. Machinery	19 Elec. Machinery	20 Motor Vehicles
Managerial Inefficiency	Neutral	Efficient	Neutral	Inefficient	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
1962-1990										
Revised	-0.325	0.426	0.696	0.286	0.469	0.168	0.439	1.153	1.877	-0.176
Traditional	-0.395	0.416	0.676	0.187	0.456	0.223	0.375	1.121	1.801	-0.329
62-73										
Revised	0.426	0.899	0.194	0.184	0.628	0.163	0.630	0.273	1.632	-0.060
Traditional	0.254	0.910	0.195	0.134	0.634	0.158	0.499	0.175	1.428	-0.330
74-79										
Revised	-1.384	-1.783	-1.602	0.847	-0.725	-0.218	0.511	0.465	2.453	-0.550
Traditional	-1.314	-1.731	-1.563	0.743	-0.720	-0.082	0.491	0.402	2.416	-0.678
80-90										
Revised	-0.561	1.132	2.530	0.094	0.952	0.386	0.192	2.502	1.833	-0.099
Traditional	-0.597	1.066	2.452	-0.059	0.908	0.461	0.178	2.561	1.874	-0.136

	21 Trans. Equipment	22 Instruments	23 Misc. Manufac	24 Transportation	25 Communica.	26 Electric Utilities	27 Gas Utilities	28 Trade	29 Finance & Re. Es	30 Services
Managerial Inefficiency	Inefficient	Efficient	Neutral	Problematic	Problematic	Problematic	Problematic	Inefficient	Problematic	Efficient
1962-1990										
Revised	0.412	1.356	0.965	1.447	1.608	-14.316	-0.078	1.067	0.049	-0.185
Traditional	0.385	1.157	0.956	1.333	2.001	0.475	-0.404	1.082	0.502	0.096
62-73										
Revised	0.760	1.630	1.178	2.384	1.578	-14.945	1.370	1.078	0.865	0.854
Traditional	0.655	1.118	1.160	2.168	1.736	1.386	1.188	1.124	1.218	1.318
74-79										
Revised	-1.298	1.737	0.360	1.334	3.343	-25.223	-1.952	0.463	0.732	-0.297
Traditional	-1.315	1.669	0.365	1.194	4.071	-1.130	-2.122	0.477	0.955	-0.090
80-90										
Revised	0.976	0.851	1.063	0.495	0.706	-6.965	-0.612	1.386	-1.201	-1.247
Traditional	1.029	0.920	1.057	0.506	1.176	0.370	-1.177	1.367	-0.517	-1.119

NA = Not Applicable
See the text for the explanation of the "Problematic" category.

Table A.5:
Sargan's Test for Appropriateness of Instrument Choice

Industry	Japan		United States	
	Probability of Test Statistics under Null Hypothesis (%)	**Degrees of freedom**	**Probability of Test Statistics under Null Hypothesis (%)**	**Degrees of freedom**
Agri.	71.94	5	99.95	4
Coal Mining	100.00	5	100.00	5
Other Mining	94.10	4	99.87	4
Construc.	86.99	5	99.99	5
Food	97.95	3	97.67	3
Textile	99.86	5	100.00	4
Apparel	98.23	5	99.93	3
Lumber	89.60	5	93.81	3
Furniture	99.97	4	99.87	5
Paper & Pulp	100.00	5	100.00	4
Printing	60.47	4	99.82	4
Chemicals	98.06	5	74.95	4
Petro. & Coal	91.55	5	90.23	3
Leather	88.12	5	24.68	3
Stone & Clay	82.66	3	95.57	4
Pri. Metal	99.90	3	94.63	4
Fab. Metal	98.76	5	99.20	4
Gen. Machinery	100.00	4	100.00	5
Elec. Machinery	56.31	4	99.36	4
Motor Vehicles	96.04	4	85.82	4
Trans. Equipment	53.30	3	72.53	4
Instruments	88.76	4	100.00	5
Misc. Manufac.	91.76	5	99.96	4
Transportation	58.00	5	96.98	5
Communica.	90.56	5	99.88	5
Electric Utilities	63.70	5	74.05	3
Gas Utilities	95.01	4	99.74	5
Trade	97.12	4	46.67	4
Finance & Re. Es.	15.74	5	99.30	5
Services	99.96	4	99.80	4

Note:

Null hypothesis is that instruments are appropriate.

Any of test statistics in the table are reported for the regression specification obtained by use of the two-step method described in the main text.