The Generalized Ozaki-McFadden Cost Function and its Application to a Pooled Data on the Japanese Chemical Industry

by

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Abstract

A globally concave version of the generalized Ozaki (GO) cost function (Nakamura (1990)) is derived by replacing its price substitution term by the generalized McFadden cost function, while leaving the nonhomothetic part unchanged. The derived cost function is asymmetric; the form of demand function for one input, that serves as a normalizer, differs from that of the other inputs. Estimation results by GMM for a pooled data set of the Japanese chemical industry yield different results for the concavity condition depending on which input played the asymmetric role. Non-homothetic scale effect was found to be the most important factor of the change over time in the capital labor ratio, whereas the price substitution effect was least important. For a comparison, we also estimated a nonhomothetic translog model. While being inconsistent with concavity, the translog model also found the presence of significant nonhomotheticity robust to size dummies.

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1. Introduction

A cross sectional comparison of production units often shows a positive correlation between the capital labor ratio and the level of production (Lau and Tamura (1972)). If the production function and the factor prices are the same across cross section and adjustments of input levels are complete, this correlation will imply nonhomotheticity of the underlying technology.

Nakamura (1990) introduced a nonhomothetic flexible cost function, the generalized Ozaki (GO) function, and showed an empirical example where the GO was superior to the well known translog and generalized Leontief (GL) cost functions. As a special case, the GO includes the nonlinear factor limitational cost function considered by Komiya (1962) and Ozaki (1969).

Many flexible cost functions including the translog and

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GL cannot satisfy global concavity without losing flexibility in the price space. This applies to the GO as well, since it is a nonhomothetic extension of GL. The generalized Mcfadden (GM) cost function (Diewert and Wales 1987) is an exception to this and can satisfy flexibility and globally concavity simultaneously.

In this paper, we obtain a globally concave version of the GO by replacing its price substitution term by GM while leaving the nonhomothetic part unchanged. The resulting cost function, the generalized Ozaki-McFadden (GOM) cost function, is globally concave in the price space, and includes the nonlinear nonhomothetic model of Komiya and Ozaki.

For an empirical illustration, the proposed GOM cost function is applied to a pooled data set of the Japanese chemical industry. The GOM is asymmetric in the sense that the demand function for one input, which serves the role of normalizer, is different from that for other inputs. One of our major concerns in empirical analysis is to see if parameter estimates are sensitive to a particular choice of the asymmetric input. Another major concern is to assess the importance, if any, of nonhomotheticity in the observed changes in input ratios.

2. The Model

We consider the case where a single output, the quantity of which we denote by y, is produced out of n inputs. Let us denote by uc the unit cost function, by I the set of indices referring to the n inputs, by P the vector of n positive input prices, and by t a time index that we use as a proxy to the disembodied technical change. The generalized Ozaki cost function (Nakamura 1990) is then given by

$$uc(P,y,t)=[\sum_{i\in I} b_i P_i y^{b_{yi}} e^{b_{ti}}+\sum_{i,j\in I;i\neq j} b_{ij}\sqrt{P_i P_j}]\, y_s^{\beta_y} e^{\beta_t t+\frac{1}{2}\beta_{tt}t^2} \qquad (1)$$

Since this cost function, *GO* for short, has $n(n+1)/2+2n+3$ free parameters, it is a flexible functional form according to the definition of Diewert and Wales (1987).

The *GO* is a nonhomothetic extension of the Generalized Leontief (*GL*) cost function due to Diewert (1971). Since the *GL* cannot be flexible and globally concave simultaneously (Diewert and Wales 1987), the same applies to *GO* as well. We can solve this "shortcoming" of *GO* by using a functional form that can be flexible and globally concave simultaneously for its specification of the price substitution part. The Generalized McFadden (GM) cost function has this desirable feature (Diewert and Wales 1987).

Substitution of the GM for GL in that part of (1) referring to price substitution effects yields the following nonhomothetic cost function, the generalized Ozaki-McFadden function (GOM)

$$uc(P,y,t)=[g(P)+\sum_{i\in I} b_i P_i y^{\beta_{yi}} e^{\beta_{ti}t}]\, y^{\beta_y} e^{\beta_t t+\frac{1}{2}\beta_{tt}t^2} \qquad (2)$$

where

$$g(P)=\frac{1}{2}P_k^{-1}\sum_{i\in\bar{I}}\sum_{j\in\bar{I}} C_{ij}P_iP_j\ ,\ C_{ij}\neq C_{ji},\ \ i,j\in\bar{I}$$

and $\bar{I}$ is the set of n-1 indices obtained by deleting from I the index referring to an arbitrary input, say the kth, which is used as a normalizer in $g(p)$ and is treated differently from other inputs. While *GOM* looks ideal because it can satisfy both global concavity and flexibility, some authors find this asymmetry troublesome because using different inputs as the normalizer we "might well yield conflicting results " (Diewert and Wales 1987,

p.53)[2].

We do not regard this asymmetry as a source of troubles, but take a more pragmatic view: different specifications of the underlying technology would result from choosing different inputs to play the asymmetric role. Since different specifications would produce different estimation results for the same set of data, with one of them hopefully being consistent with the data generation process, there would be no "conflicts".

The GOM is globally concave if the matrix $C=[C_{ij}]$ is negative definite. If the estimated C is not negative definite, we can impose it via reparametrization by replacing C by minus the product of a lower triangular matrix of dimension n-1 by n-1, A say, times its transpose A^T (Diewert and Wales 1987, Theorem 9). For example, when $n=3$, this reparametrization is given by

$$C^*=-AA^T=-\begin{vmatrix} a_{11} & 0 \\ a_{12} & a_{22} \end{vmatrix}\begin{vmatrix} a_{11} & a_{12} \\ 0 & a_{22} \end{vmatrix}=-\begin{vmatrix} a_{11}^2 & a_{11}a_{12} \\ a_{11}a_{12} & a_{12}^2+a_{22}^2 \end{vmatrix} \tag{3}$$

The GOM in (2) is flexible in terms of price, output, and trend in the sense of Diewert and Wales (1987). For the sake of simplicity, however, from now on we set $\beta_{tt}=0$. If we further assume neutral technical change, this implies a constant rate of technical change.

Suppose that there are $N>1$ production units the technology of which is represented by (2). These units may differ from each other in terms of product mix and therefore of relevant

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[2] Diewert and Wales (1987) proposed an alternative form of the Generalized McFadden cost function that treats all inputs symmetrically and thus is free from the asymmetric problem. This form, however, has a disadvantage that it cannot be globally flexible. See the above paper for details.

product and factor markets. To allow for these individual specific effects, we introduce an $Nn\times 1$ vector $\alpha=(\alpha_1,\alpha_2,..\alpha_N)$ where $\alpha_i=(\alpha_{i1},\alpha_{i2},...,\alpha_{in}),i=1,..n,$ of fixed effects representing specific factors known to individual units but not observable to the econometrician. We also introduce a dummy variable D to allow for a possible structural change over time. Eq. (2) for the sth production unit, $s=1,..N,$ would now look as follows:

$$uc_s=uc[\alpha_s,D,P_s,y_s,t]$$
$$=\sum_{i\in I}P_{si}(\alpha_{si}+\gamma_i D)+[g(P_s)+\sum_{i\in I}b_iP_{si}y_s^{\beta_{yi}}e^{\beta_{ti}t}]\,y_s^{\beta_y}e^{\beta_t t} \qquad (4)$$

where $\gamma_i,i\in I$ is the input specific parameter of structural change. We normalize the fixed effects by setting $\alpha_s=0$ for an arbitrary single production unit s. Otherwise, a complete multicollinearity would follow in the special case of $\beta_{yi}+\beta_y=\beta_{ti}+\beta_t=0$. Note that the price vector is now attached with the index referring to production units to take account of the difference in relevant product and factor markets among them.

In terms of input coefficients, the system of input demand functions corresponding to the GOM cost function (4) is given by

$$a_{si}=\alpha_{si}+\gamma_i D+[P_{sk}^{-1}(C_{ii}P_{si}+C_{ij}P_{sj})+b_iy_s^{\beta_{yi}}e^{\beta_{ti}t}]\,y_s^{\beta_y}e^{\beta_t t} \qquad (5a)$$

$$a_{sk}=\alpha_{sk}+\gamma_k D+[-\frac{1}{2}P_{si}^{-2}(C_{ii}P_{sk}^2+C_{jj}P_{sj}^2+2C_{ij}P_{si}P_{sj})+b_ky_s^{\beta_{yk}}e^{\beta_{tk}t}]\,y_s^{\beta_y}e^{\beta_t t}$$

(5b)

where $i,j\in\bar{I},\ i\neq j,\ k\in I-\bar{I}.$

We now turn to economic implications of the GOM in terms of elasticities. When technology is nonhomothetic, the scale of production can have different effects among inputs. The partial

scale elasticity represents individual input specific effects of the scale of production. For $i \in I$, this elasticity is given by (for the sake of simplicity, from now on we omit the suffix referring to production units unless confusion might arise otherwise):

$$\frac{\partial \ln a_i}{\partial \ln y} = \beta_y \cdot \frac{a_i - \alpha_i - \gamma_i D}{a_i} + \frac{\beta_{yi} b_i y^{\beta_{yi}+\beta_y} e^{(\beta_{ti}+\beta_t)t}}{a_i} \tag{6}$$

On the other hand, the overall scale elasticity es measuring the effect of a proportional change in each of the inputs is given by

$$es = \left(1 + \frac{\partial \ln uc}{\partial \ln y}\right)^{-1}$$
$$= \left[1 + \beta_y \frac{uc - \sum_{i \in I} P_i(\alpha_i + \gamma_i D)}{uc} + \frac{\left(\sum_{i \in I} P_i \beta_{yi} b_i y^{\beta_{yi}} e^{\beta_{ti} t}\right) y^{\beta_y} e^{\beta_t t}}{uc}\right]^{-1} \tag{7}$$

The growth rate of TFP (total factor productivity) is

$$\frac{\partial \ln TFP}{\partial t} = -\frac{\partial \ln uc}{\partial \ln t}\left(1 + \frac{\partial \ln uc}{\partial \ln y}\right)^{-1} \tag{8}$$

where

$$\frac{\partial \ln uc}{\partial t} = \beta_t \frac{uc - \sum_{i \in I} P_i(\alpha_i + \gamma_i D)}{uc} + \frac{\left(\sum_{i \in I} P_i \beta_{ti} b_i y^{\beta_{yi}} e^{\beta_{ti} t}\right) y^{\beta_y} e^{\beta_t t}}{uc}$$

Biased technical change implies that the price of each input has specific effects on the rate of TFP growth

$$\frac{\partial^2 \ln TFP}{\partial t \partial \ln P_i} =$$
$$\left[-\frac{\partial w_i}{\partial t} + \frac{\partial \ln uc}{\partial t} w_i \left(\frac{\partial \ln a_i}{\partial \ln y} - \frac{\partial \ln uc}{\partial \ln y}\right)\left(1 + \frac{\partial \ln uc}{\partial \ln y}\right)^{-1}\right]\left(1 + \frac{\partial \ln uc}{\partial \ln y}\right)^{-1} \tag{9}$$

where $w_i \equiv p_i a_i$ refer to the share of the ith input in total cost.

In the special case of linear homogeneous technology, the right hand side of (9) reduces to the first term in the square brackets only and becomes identical to the definition of Jorgenson (1986).

Finally, the price elasticity of input coefficients is

$$\epsilon_{ij}=\frac{\partial \ln a_i}{\partial \ln p_j},\ i,j\in I$$

where for $i,j\in\overline{I}$ and $k\in I-\overline{I}$

$$\frac{\partial a_i}{\partial P_i}=C_{ii}y^{\beta_y}e^{\beta_t t}P_k^{-1} \tag{10a}$$

$$\frac{\partial a_k}{\partial P_k}=(C_{ii}P_k^2+C_{jj}P_j^2+2C_{ij}P_iP_j)\,y^{\beta_y}e^{\beta_t t}P_k^{-3} \tag{10b}$$

$$\frac{\partial a_i}{\partial P_j}=C_{ij}y^{\beta_y}e^{\beta_t t}P_k^{-1},\ i\neq j \tag{10c}$$

$$\frac{\partial a_i}{\partial P_k}=-(C_{ii}P_i+C_{ij}P_j)\,y^{\beta_y}e^{\beta_t t}P_k^{-2},\ i\neq j \tag{10d}$$

3. Estimation Methods and Results

We apply the above GOM model to a pooled data set for the Japanese chemical industry on price and real quantity of capital (K), labor (L), and materials (M). The data set consists of annual time series over 1964-82 of a cross section for seven groups of establishments distinguished by seven ranges of the number of employees: (1) 30-49, (2) 50-99, (3) 100-199, (4) 200-299, (5) 300-499, (6) 500-999, (7) 1000 and more. The Census of

Manufacturing (Kogyo Tokei Hyo) by the Ministry of International Trade and Industry provides the basic data source (see Data Appendix for details).

We divided all the input and output quantities by the number of establishments, assuming that this will yield values representative to each range of the number of employees. The number of production units, which we denoted in Section 2 by N, is therefore seven.

The chemical industry was severely hit by the two oil crises, causing them to be declared a "structurally depressive" industry characterized by huge excess productive capacity. We therefore multiplied the data on capital stock by the rate of capacity utilization to adjust for fluctuations in the rate of utilization. [3]

Figure 1 shows the logarithms of capital labor ratio for nine ranges of output size, with range 1 referring to the smallest and range 9 to the largest output size. Since the original data are classified by the number of employees, this rearrangement in terms of output size produced some cells with zero entry. In Figure 1 the points on the horizontal axis refer to these cells. We can make three observations. First, within each cross section the capital labor ratio was positively correlated with output size, especially in the first half of the sample period. Secondly, the capital labor ratio was increasing over time for each output size, except for breaks following the two oil crises. Thirdly, the capital labor ratio of production units with different output levels was converging over time, except the largest output size.

Figure 2 shows the development over time of the loga-

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[3] The rate of utilization was available only at the industry level and not at the individual size group level.

rithms of the price ratio of capital to labor for the nine ranges of output size. Within each cross section, we find a negative correlation between the price ratio and output size. The price ratio was decreasing across cross section until 1977, when this pattern came to a halt and subsequently gave way to the opposite pattern.

Figures 1 and 2 thus indicate that the capital labor ratio was positively correlated with output level and negatively correlated with the relative price. The first feature is consistent with nonhomotheticity, while the second is consistent with factor substitution.

We obtain the system of input demand functions to be estimated by adding to the right hand side of (5) a vector of stochastic error terms with mean zero $u_t=(u_{it},u_{jt},u_{kt})$, t=1964,..1982, which should represent stochastic technology shocks and errors in optimization. Stacking eq. (5) for 9 cross sections and denoting the left hand side of the resulting 27×1 vector by a_t and the right hand side by $f(z_t,\theta)$, the system of estimating equations becomes

$$a_t=f(z_t,\theta)+u_t$$

We assume $E(u_t\ u_t^T)=diag\{\Sigma_{1,t},\Sigma_{2,t},..\Sigma_{7,t})=:\Sigma_j, j=1,..7$, where $\Sigma_{j,t}$ is the 3×3 positive definite covariance matrix of factor demand equations of the jth size group at time i, and that $E(u\ u^T)=diag\{\Sigma_{1964},\Sigma_{1965},..\Sigma_{1982})$, where u is the 399×1 vector obtained by stacking u_ts for t=1964,..82. The error u is assumed to be uncorrelated both over time and across cross section, but can be heteroscedastic. Instead of searching for possible specifications of heteroscedasticity over time and cross section, we use a heteroscedasticity consistent covariance estimator (HCCME).

It is highly unlikely that the factor prices and output

in our model are contemporaneously uncorrelated with the error term u. We therefore use the *GMM* with HCCME to estimate the unknown parameters of (6). Since the model is nonlinear, we should use as instruments besides exogenous and predetermined variables as usual their powers and even cross products (Bowden and Turkington (1984, Chapter 5), Davidson and Mackinnon (1993, p.226)). For each of the three input demand equations we use the following twenty instruments: (i) the price ratio of labor to material, (ii) the price ratio of capital to material, (iii) output, (iv) the mean lending rate of commercial banks, (v) the logarithm of housing investment, (vi) the growth rate of GNP, (vii) the price index of imported energy, (viii) the logarithm of GNP, (ix) the rate of unemployment, (x) the product of (i) and (iii), (xi) the product of (ii) and (iii), a constant, the structural dummy, six size dummies, and the time trend. Each of the variables (i) to (ix) are lagged for one year. The estimates are thus consistent for MA(1) serially correlated error terms, and the estimated covariance matrix is robust to heteroscedasticity.

The asymmetry of GOM implies that different estimation results may follow when different inputs play the asymmetric role because each choice of the asymmetric input represents a different specification. We therefore estimate eq. (6) for three choices of the asymmetric input for the period of 1965-82.

Table 1 shows the estimation results. It turned out that the estimates of parameter are indeed not neutral to the choice of the asymmetric input. This applies in particular to the nonlinear parameters and c_{ij}s. Since the latter refers to concavity of the estimated cost function, it follows that different results for concavity emerge depending on which input plays the asymmetry role. When capital played the asymmetric role concavity was automatically satisfied, whereas it was violated

when either labor or materials played the role.

Furthermore, when capital played the asymmetric role we could obtain mostly precise estimates of the parameters referring to nonhomotheticity and biased technical change. The price of capital is characterized by a large cross sectional variation and a relatively small correlation with time trend. Normalization with it seems to increase the cross sectional variation of the normalized prices, resulting in increased efficiency of nonlinear parameters. We therefore choose to use the specification with capital as the asymmetric input in the following analysis.

We tested the null of no first order serial correlation of residuals by use of a Lagrange multiplier test: the Gauss Newton regression (Davidson and Mackinnon 1993) corresponding to (6) was estimated by GMM for 1966-82, after having augmented it with the estimated residuals lagged for one year. The estimates (asymptotic t-values in parenthesis) of the serial correlation parameter were .11 (.37) for labor, .22 (2.06) for material, and .63 (7.48) for capital, indicating the presence of a significant serial correlation for the capital equation. We could conceive of two standard ways to cope with this result.

First, one could reestimate the model in a more general error correction framework, allowing for slow adjustments of inputs to its long-run levels. High nonlinearity of the model, however, appears to make this approach quite difficult in practice. Furthermore, the fact that the present data set is not a panel and therefore does not possess continuity over time seems to prevent the use of dynamic optimization models. The "size group" whose components change every year cannot be regarded as a subject engaged in dynamic optimization over time.

Secondly, instead of altering the specification, one could use the serial correlation robust estimates of the variance

covariance matrix such that asymptotically valid inferences could be made. Since our sample size is small, however, usefulness of this asymptotic result is questionable (Andrews 1991). Given these limitations, we choose to be satisfied with the fact that the estimates are at least consistent and proceed to analyzing economic implications of the estimated model[4].

For a comparison, we also estimated a nonhomothetic translog model, with biased technical change and dummies, for the same set of data. Table 2 shows parameter estimates of the translog model, obtained by applying GMM to a system of cost share equations. The estimated translog model violates concavity at 51 of the total 126 sample points. While being inconsistent with concavity at more than forty percent of the sample points, the translog model also found the presence of significant nonhomotheticity robust to size dummies.

For the translog model, too, we tested the null of absence of first order serial correlation of residuals. The estimated serial correlation parameters (t values in parenthesis) were .99 (4.3) for capital share equation, .06 (.3) for labor equation and .64 (2.6) for materials equation. These results qualitatively resemble those for the GOM. Quantitatively, however, the translog model showed a higher degree of serial correlation, with the capital equation indicating the presence of a unit root. The GOM thus appears preferable to the translog for the present data.

4. Analysis

Table 4 shows economic implications of the estimated

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[4] Relaxation of cross equation restrictions did not remove serial correlation. The translog model also showed significant serial correlation.

model in terms of various elasticities introduced in Section 2. We obtained the figures by evaluating the model at the mean value across cross section of 1980-82. Own price elasticity ε_{ii} was smaller than unity in absolute value for each of the three inputs. Since the cross price elasticities were positive, none of the inputs were complements to each other. Quantitatively, however, the estimated Allen Uzawa elasticity σ_{ij} was uniformly smaller than 0.3, and indicates that the scope of substitution, if any, was quite limited. In particular, the elasticity of substitution between labor and material was almost zero, implying that they were practically complements to each other.

We next turn to the partial scale elasticity, $\partial lna_L/\partial ln\ y$, which represents nonhomothetic effects of the scale of production on each input. The estimated elasticity was positive for capital, whereas it was negative for both materials and labor. With other things being equal, the capital-labor ratio would rise with the scale of production.

Leaving partial scale effects, we now turn to the overall scale elasticity. Its estimate was slightly less than unity (.98) and indicates that the technology was almost subject to constant returns to scale. Note that non-homotheticity by itself does not imply overall scale economies except in the case when the partial elasticity is negative for all the inputs. In the present case, partial economies in labor and materials are cancelled out with diseconomies in capital, the net effect being overall constant returns. If we compute the scale elasticity in terms of labor and materials alone, the resulting "short run" elasticity was around 1.15.

The TFP growth rate was 4.2 percent, and was increasing in the price of labor and material but decreasing in the price of capital. In the terminology of Jorgenson (1986), technical change was capital using and labor and material saving (see eq.

(9) of Section 2).

In our model the input ratios (relative levels of inputs) depend on the relative prices of inputs (substitution effects), the scale of production (nonhomothetic effects), the time trend (technical change effects), structural dummies (structural change effects), and size dummies (size specific fixed effects). We now investigate relative importance of these factors in the change over time of the input ratios.

Nonhomotheticity implies that we cannot decompose (even if other factors were not present) the change in input ratios between substitution and scale effects in a mutually exclusive way: mixed terms always remain. We therefore compare individual effects of each of these factors on the input ratios when the other factors are kept constant at their initial levels.

In the following, we are concerned with the overall change at the industry level and not at the level of individual size. Rows (a) and (b) of Table 4 show the estimated input coefficients for capital and labor and their ratios, obtained by evaluating the model at the sample mean of cross section over 1965-67 and over 1980-82, respectively. Between these two periods the input requirements for capital and labor decreased by 46 and 62 percent, respectively, and the ratio of the former to the latter increased by 41 percent. In contrast, the input requirements for materials (not reported) decreased by a mere five percent. We therefore concentrate our analysis on the capital labor ratio only.

In Table 4, rows (d) to (j) show the hypothetical input requirements and their ratios at 1980-82, obtained by keeping all but one factor at their 1965-67 levels. Rows (l) to (o) summarize results. We find that the level of production had the largest effect on the capital labor ratio, whereas input prices had the smallest effect: with other things being equal, the former

increased the capital labor ratio by more than 70 percent, whereas the latter increased it by only 5 percent. Nonhomothetic effects induced by production scale thus dominated substitution effects induced by price.

5. Concluding Remarks

We have presented a nonhomothetic cost function, the generalized Ozaki McFadden (GOM) cost function, which can be globally concave and flexible as well, and applied it to a pooled data set of the Japanese chemical industry. The GOM is asymmetric because the functional form of demand function of one input, which serves as a normalizer, differs from that of the other inputs. Since the choice of asymmetric input is arbitrary, we will have n different specifications of the underlying technology for a GOM with n inputs. We do not see any ground to expect that all these n specifications should yield the same result.

It turned out that estimation results were in fact different depending on which input played the asymmetric role. In particular, we obtained different results for the concavity condition. Concavity was automatically satisfied when capital played the asymmetric role, whereas it was violated when either materials or labor was chosen. We do not regard these results as "conflicting" because different specifications will usually produce different results.

While one could in principle impose global concavity without losing flexibility (this is an important property of the Mcfadden class functions), in practice it could be a difficult task to do. This will especially be the case when unrestricted estimates "strongly" violate the condition in that some estimates of C_{ii}s are significantly positive. If concavity is violated for a particular choice of the asymmetric input, it seems a good idea first to check for concavity for other choices

of the asymmetric input, before one embarks on imposing concavity.

Nonhomotheticity is a distinguishing feature of the GOM. Otherwise, it reduces to the GM. We found significant non-homothetic effects. In particular, nonhomothetic scale effect was the most important factor of the change over time in the capital labor ratio. In contrast, the price induced substitution effect was least important.

If nonhomotheticity is a standard feature of technology than an exceptional one, it would have extensive consequences for economic analysis since a considerable portion of it makes use of homotheticity. In this paper, we found significant non-homotheticity within a static framework assuming instantaneous adjustments (except for the ad hoc adjustment of capital by the rate of utilization). It remains to be seen if nonhomotheticity remains significant when we use more general dynamic specifications of the adjustment process. Recall that we rejected the null of no serial correlation of residuals for capital and materials equation for both GOM and the translog model. An important future direction of work will therefore be to test for nonhomotheticity in a dynamic framework using a panel data set.

Data Appendix

The data of manufacturing census on factor inputs and output provide nominal values only, except labor input that is given in both nominal and real (man) terms. It was therefore necessary to obtain real quantities from the nominal figures by using appropriate price indices. Since price indices of output and materials were not available at the level of individual size, we used the corresponding price indexes at the industry level taken from an updated version of Ogawa et al (1992). From this it follows that we assume equality across cross section of the prices of output and materials.

As for labor, we set the number of employees being equal to the real quantity of labor input and obtained wage rates by dividing the labor cost by the number of employees. We neglected any possible difference in labor quality over time and across cross section.

Estimation of real capital input was the most problematic. The census data provide book values of fixed assets, depreciation, and investment expenditures. If the data were a panel, we could estimate a time series of real capital stock by using perpetual inventory methods based on a given benchmark capital stock and a fixed rate of physical depreciation. Since the data is not a panel, however, this standard procedure would not be applicable to the present case. We therefore chose to deflate book values of fixed assets directly by a weighted average over ten preceding years of the price index of private investment expenditure, with weights representing the vintage structure of investment at the industry level. Let $P_{I,t}$ and XK_t be the price indexes of private investment expenditure in year t and real capital stock at the industry level at the end of year t, respectively. The price deflator of fixed assets was computed as follows:

$$q_I(t) = \sum_{j=0}^{9} P_I(t-j) * [XK(t-j) - XK(t-j-1)] / \sum_{j=0}^{9} XK(t-j) - XK(t-j-1)$$

We obtained the data on real capital stock at the industry level from an updated version of Ogawa et al.

Finally, assuming zero excess profit, the user cost of capital was obtained as a residual, by dividing the value of production minus expenditures for materials and labor by the quantity of real capital stock. Recall that the price of output was assumed equal across cross section. Combined with the assumption of zero profit, this implies equality across cross section of unit production costs.

References

Andrews, Donald (1991): Heteroscedasticity and auto-correlation consistent covariance matrix estimation, Econometrica vol.59, no.3, pp. 817-58

Bowden, Roger and Darrell Turkington (1984): Instrumental Variables, Cambridge, Cambridge University Press

Davidson, Russell and James MacKinnon (1993): Estimation and inference in econometrics, New York, Oxford University Press

Diewert, Erwin and Terence Wales (1987): Flexible functional forms and global curvature conditions, Econometrica vol.55, pp. 43-68

Hansen, Lars (1982): Large sample properties of generalized method of moments estimators, Econometrica vol.50, pp.1029-1054

Jorgenson, Dale (1986): Econometric methods for modelling producer behavior, in Z. Griliches and M. Intriligator(eds.), Handbook of Econometrics 3, pp.1841-1915

Komiya, Ryutaro (1962): Technological progress and production function in the United States steam power industry, The Review of Economics and Statistics vol.44, pp.156-166

Lau, Lawrence and Shuichi Tamura (1972): Economies of scale, technical progress and the nonhomothetic Leontief production function, Journal of Political Economy 80, pp.1167-1187

Nakamura, Shinichiro (1990): A nonhomothetic generalized Leontief cost function based on pooled data, The Review of Economics & Statistics vol. 72 no. 4, pp. 649-656

Ozaki, Iwao (1969): Economies of scale and input output coefficients, in Anne Carter and Andrew Brody(eds.), Applications of Input Output Analysis, pp. 280-302

Ogawa, Kazuo et al. (1992): Tabumon keizai model no jissyo kenkyu (Empirical Studies of multisectoral economic models), in Japanese, Sobunsya, Tokyo

Table 1: Estimation results of the GOM model by GMM (continued)

t refers to asymptotoc t values which are robust to heteroscedasticity

	input used as the normalizer					
	Material		Labor		Capital	
parameter	estimate	t	estimate	t	estimate	t
γ_K	0.001717	0.14	0.003221	0.25	0.000142	0.01
α_{K2}	−0.018945	−2.34	−0.012901	−1.27	−0.024359	−2.20
α_{K3}	−0.017377	−1.37	−0.229387	−0.02	−0.031002	−1.87
α_{K4}	−0.054122	−2.64	−0.023995	−1.01	−0.084007	−3.36
α_{K5}	−0.097885	−3.36	−0.059763	−1.86	−0.152367	−4.37
α_{K6}	−0.114215	−3.10	−0.057899	−1.51	−0.207933	−4.38
α_{K7}	−0.175295	−3.16	−0.102066	−1.81	−0.426769	−5.27
β_{KK}	0.847425	13.34	0.798476	12.27	0.906134	11.87
β_{YK}	0.045437	0.66	−0.212009	−2.62	−1.30949	−5.43
β_{TK}	−0.010894	−0.46	−0.102587	−6.41	0.086557	5.84
C_{KK}	−0.06443	−3.17	−0.023854	−3.56		
C_{KL}	0.110063	4.22				
C_{KM}			−0.286864	−0.59		
C_{LL}	−0.07459	−2.50			−0.097864	−5.24
C_{LM}					0.023919	1.05
C_{MM}			0.033265	3.14	−0.237473	−3.14
β_y	0.135243	1.68	0.384857	4.11	1.53018	6.37
β_T	−0.041448	−1.76	0.062742	3.57	−0.132313	−8.90

Table 1: Estimation results of the GOM model by GM (concluded)
t refers to asymptotoc t values which are robust to heteroscedasticity

	input used as the normalizer					
	Material		Labor		Capital	
γ_L	0.040892	10.55	0.041129	8.62	0.025176	11.94
α_{L2}	−0.155809	−0.22	−0.627327	−0.15	0.002192	0.58
α_{L3}	0.004563	0.45	0.005781	1.15	0.011413	3.03
α_{L4}	−0.492	−0.35	−0.145349	−0.27	0.017883	3.82
α_{L5}	−0.01134	−0.76	−0.679029	−1.21	0.018301	3.59
α_{L6}	−0.980924	−0.57	−0.638517	−0.94	0.031296	3.89
α_{L7}	0.029023	1.48	0.033466	4.60	0.118412	4.94
β_{LL}	0.173969	5.48	0.255179	12.43	0.2212	19.14
β_{YL}	−0.347046	−2.77	−0.533056	−5.16	−1.71593	−7.15
β_{TL}	−0.085952	−2.50	−0.184181	−10.22	0.023982	1.61
γ_M	0.074385	7.74	0.092871	10.63	0.105118	9.59
α_{M2}	0.083006	3.65	0.030285	1.65	0.041258	1.69
α_{M3}	0.121685	3.78	0.025589	0.86	0.041083	1.10
α_{M4}	0.133353	3.25	0.0030478	0.08	0.031674	0.65
α_{M5}	0.173829	3.92	0.015464	0.32	0.062192	1.10
α_{M6}	0.219997	4.55	0.027611	0.47	0.134145	2.22
α_{M7}	0.257699	4.91	0.025228	0.35	0.32616	5.17
β_{MM}	0.329515	5.66	0.48571	6.72	0.511129	5.17
β_{YM}	−0.340965	−4.01	−0.495617	−5.27	−1.6336	−6.29
β_{TM}	0.042489	1.93	−0.077035	−3.74	0.118462	7.51

Table 2: Estimation Results of Translog Function

(Estimates of parameters referring to the dummies not shown)

parameters	estimates	t-values*
β_K	0.327339	27.53
β_L	0.081958	18.25
β_M	0.590702	41.13
β_{KK}	0.201827	1.91
β_{KL}	-0.020676	-3.20
β_{KM}	-0.181151	-1.71
β_{LL}	0.043487	5.90
β_{LM}	-0.022811	-2.72
β_{MM}	0.203962	1.90
β_{YK}	0.052005	4.11
β_{YL}	0.012287	5.31
β_{YM}	-0.064293	-5.22
β_{TK}	-0.005448	-0.61
β_{TL}	-0.004943	-3.52
β_{TM}	0.010392	1.09

* Heteroscedasticity consistent asymptotic t values.

Table 3: Elasticities

elasticities	estimates evaluated at the mean of 1980-82
ε_{KK}	-0.09416
ε_{KL}	0.025532
ε_{KM}	0.068627
ε_{LK}	0.0934
ε_{LL}	-0.122459
ε_{LM}	0.029058
ε_{MK}	0.035066
ε_{ML}	0.004059
ε_{MM}	-0.039125
σ_{KL}	0.301725
σ_{KM}	0.113279
σ_{LM}	0.047965
$\partial \ln a_K / \partial \ln y$	0.385781
$\partial \ln a_L / \partial \ln y$	-0.217656
$\partial \ln a_M / \partial \ln y$	-0.125304
es	0.975524
es without capital	1.158242
$\partial \ln uc / \partial \ln y$	0.025089
$\partial \ln TFP / \partial t$	0.042617
$\partial^2 \ln TFP / \partial t \partial P_K$	-0.001845
$\partial^2 \ln TFP / \partial t \partial P_L$	0.010980
$\partial \ln TFP / \partial t \partial P_M$	0.03348

Table 4[1]: Factors of change in capital-labor ratio

	a_K	a_L	a_K/a_L
(a)1965-7 values	0.4897	0.1983	2.4697
(b)1980-2 values	0.2626	0.0753	3.4842
(c)b/a-1	-0.46	-0.62	0.41
(d)output effects	0.6894	0.1617	4.2614
(e)d/a-1	0.41	-0.18	0.73
(f)price effects	0.4950	0.1904	2.6002
(g)f/a-1	0.01	-0.04	0.05
(h)trend effects	0.1760	0.0620	2.8372
(i)h/a-1	-0.64	-0.69	0.15
(j)structural change	0.4898	0.2234	2.1920
(k)j/a-1	0.00	0.13	-0.11
(l)e/c scale	-0.88	0.30	1.77
(m)g/c price	-0.02	0.06	0.13
(n)i/c trend	1.38	1.11	0.36
(o)k/c structure change	0.00	-0.20	-0.27

[1] The figures in (a) and (b) refer to the estimated values obtained by using the mean across 7 size groups over three years, 1965-67 for (a) and 1980-82 for (b).

Figure 1

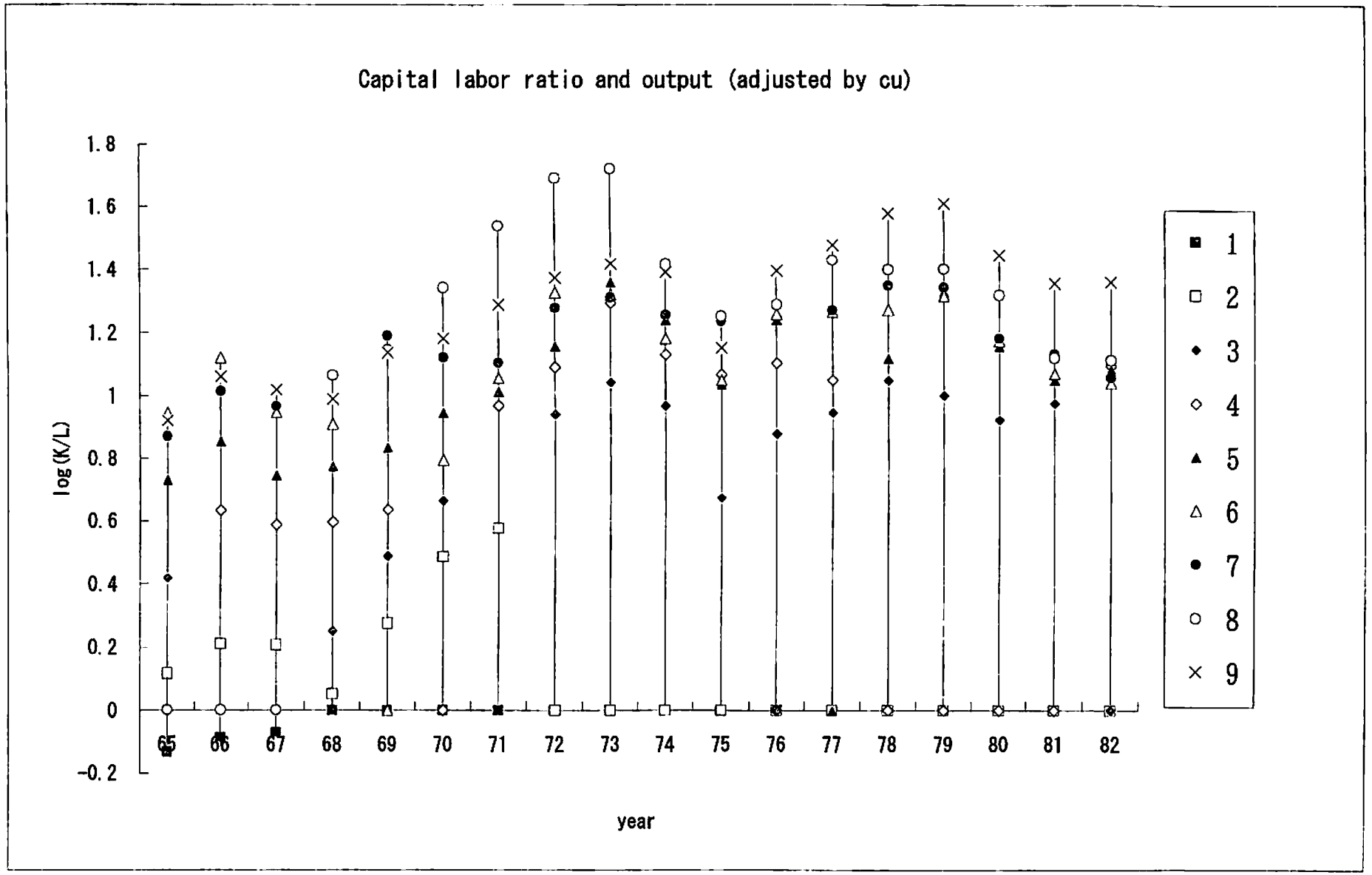
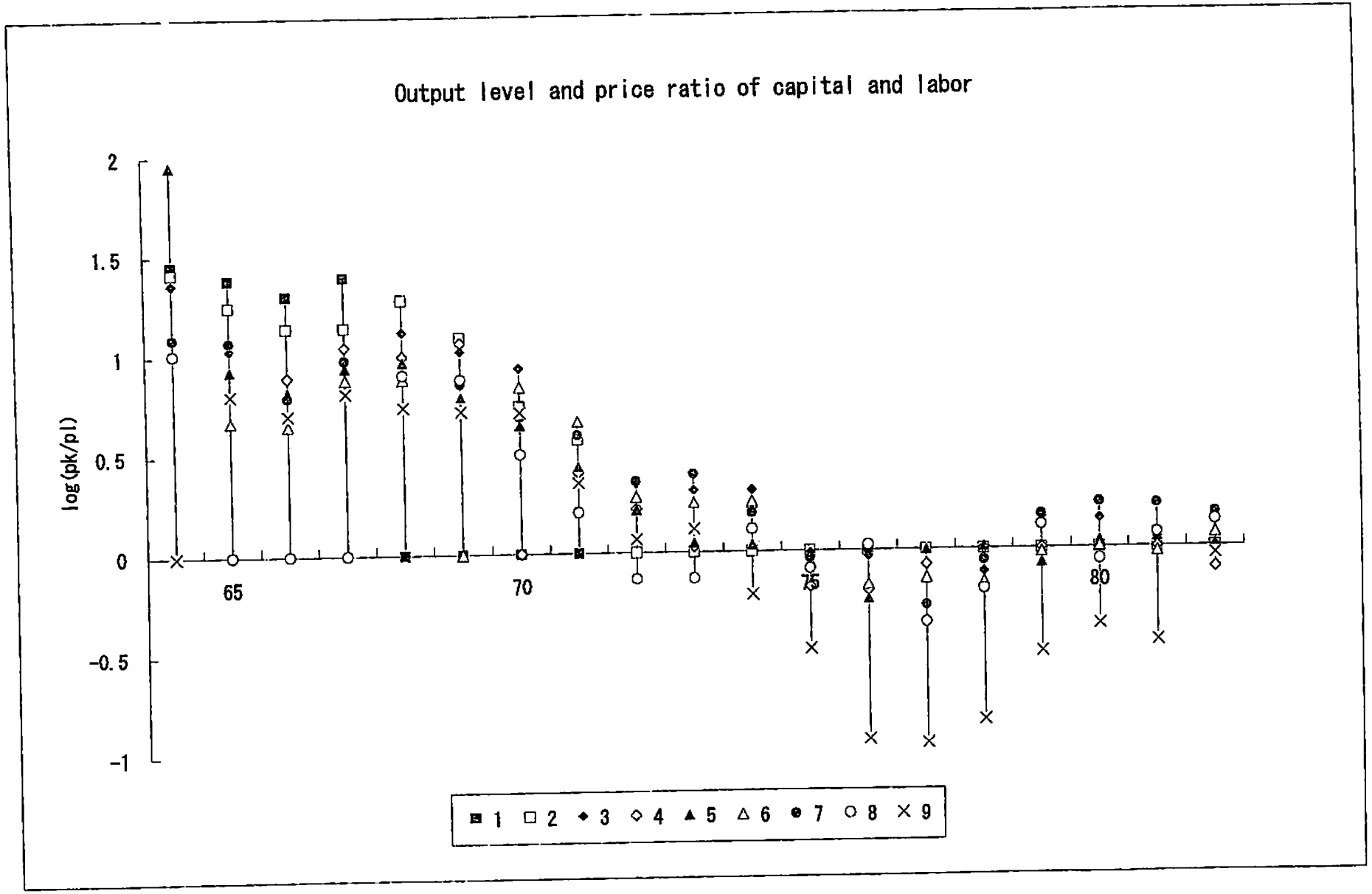

Capital labor ratio and output (adjusted by cu)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
log(K/L)
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
year
1
2
3
4
5
6
7
8
9

Figure 2


Output level and price ratio of capital and labor
log(pk/pl)
2
1.5
1
0.5
0
-0.5
-1
65
70
75
80
1
2
3
4
5
6
7
8
9

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