AN ADJUSTMENT COST MODEL OF LONG TERM EMPLOYMENT IN JAPAN

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Abstract

A dynamic factor demand model is presented which pays special attention to the prevalence of a long-term employment relationship in Japan. The model is based on the representation of technology by a variable cost function with adjustment costs for employment and capital stock, where the variable cost consists of the sum of overtime costs and materials costs. With employment being quasi-fixed and scheduled hours institutionally regulated, short-run adjustments are mostly made by overtime hours. Application to a time series data on the Japanese electrical machinery industry indicates quasi-fixity of capital and employment and reproduces short-run overshooting of overtime hours to compensate for the sluggish adjustment of employment.

1. Introduction

The prevalence of a long-term employment relationship, which means a job tenure of ten to twenty-nine years, has been viewed as a symbol of unique industrial relations in Japan and also as a principal reason for Japan's high labor productivity and low unemployment rate (Hashimoto and Raisian (1985) and Lee (1991)). While its extreme form of lifetime employment may not apply to the majority of employees (Tachibanaki (1984)), it is safe to say that long-term employment is more common in Japan than in the U.S. and Korea (Hashimoto and Raisian (1985) and Lee (1991)). The prevalence of long-term employment implies that it is difficult to adjust employment in response to changes in production. In other words, employment is a quasi-fixed input, the level of which is costly to change. To compensate for this quasi-fixity of employment, short-run adjustments of labor input are known to be mostly done by hours of work and especially by overtime hours in Japan (Tachibanaki (1987)).

In this paper a KLEM factor demand model is presented which explicitly takes into account these specific Japanese features of quasi-fixity of employment and of flexible overtime hours, and is applied to a time series data on the Japanese electrical machinery industry. This particular industry was chosen because of its substantial contribution to the Japanese economy. Its share of employment in manufacturing is fifteen percent in 1985, and, according to Suzuki (1991), more than forty percent of the manufacturing labor productivity growth in the eighties was due to the growth in this industry.

Table 1 shows the growth rates of output, capital stock, employment, materials, overtime hours, and scheduled hours of work for five sub-periods of 1961 - 85 (the growth rate of overtime hours refers to the rate of absolute changes, since it has no trend). Materials change almost proportionally to output, and indicate its highly variable nature. The rate of change in employment is remarkably smaller than that of capital stock for each of the five sub-periods. Of the three components of labor input, the rate of change is the largest for overtime hours, the smallest for scheduled hours, and is of an intermediate level for employment. This reproduces the finding by Tachibanaki (1987) that in Japan working hours were much more flexible than employment, and that the change in working hours was strongly affected by the change in overtime hours. The highly variable nature of overtime hours is further confirmed by the fact that its rate of change even exceeded that of output during the volatile seventies.

Scheduled hours of work change very little over the period, showing a slightly decreasing tendency. In Japan the length of scheduled hours of work depends on institutional regulations and other socio-economic factors which are exogenous to individual firms. Scheduled hours of work are therefore assumed to be exogenous to firms in the following sections. A great advantage of this assumption is that one can then use the model for assessing the effects of several measures for the shortening of working hours. This is an important feature in view of the fact that working hours in Japan are long by international standards, and the urgent necessity of their shortening is widely recognized, with the necessary policy measures currently being discussed in Japan.

The Japanese electrical machinery industry has been the subject of similar studies by Nadiri and Prucha (1990) and Suzuki (1991). These studies are theoretically similar to each other, in that they consider R&D stock besides the conventional inputs of capital, labor, and materials, use a dual restricted cost function to represent the technology, and take account of the quasi-fixity of capital stock and R&D stock by introducing quadratic adjustment cost functions. The data types they used, however, are substantially different: while Nadiri and Prucha used a time series of aggregate industry data for the period 1968-80, Suzuki used a panel data of the twenty largest firms for the period of 1979-88. Another common feature of these studies is that they do not take account of the quasi-fixity of employment but treat employment as a variable input. In the model of Nadiri and Prucha labor input is measured by man-hours, and employment and hours are assumed to have the same marginal productivity, an assumption which appears inconsistent with the findings of Feldstein (1967) and Bils (1987). Suzuki measures labor input by employment alone and does not take account of hours. In short, neither of these two papers explicitly takes into account the above mentioned specific Japanese features. The model in this paper is significantly different from their models in that it explicitly takes account of the quasi-fixity of employment as well as adjustments by overtime hours.

Dynamic factor demand models which explicitly take account of the quasi-fixity of employment have been developed by Shapiro (1986) and Bils (1987), among others, for U.S. manufacturing. Their models are more general than the model in this paper in that they disaggregate employment into production and nonproduction workers, but are less general in that other factors of production such as materials are not considered in the specification of technology. However, the fundamental theoretical difference of the model from those of Shapiro and Bils is that it is based on the dual representation of technology by the cost function, whereas their models use the primary representation of the production function. The resulting cost function has some unique features compared to the standard one used by Nadiri and Prucha, and Suzuki.

This paper is structured as follows. Section 2 presents the theoretical model and its specification for empirical application. Section 3 discusses econometric issues and reports estimation results. Section 4 then analyzes economic implications of the estimated model based on various elasticities. Section 5 reports several simulation results including shortening of working hours. Concluding remarks are given in Section 6.

2. Theoretical Model and Empirical Specification

2.1 Theoretical Model

Consider a representative firm producing a single output, with capital, labor, and materials, and a production function of the type:

$$Y = f(K, N, H+O, M, t, \Delta K, \Delta N), \tag{1}$$

where Y is output, K is capital stock, N is the number of employees, H is scheduled hours of work per employee, O is overtime hours of work per employee, M is materials, t is time, and Δ is the difference operator over two successive periods. Since N is the simple sum of employees, I implicitly assume homogeneity of all employees. Men and hours do not enter multiplicatively into the production function, and are hence allowed to have different marginal productivities. Hours of work consist of scheduled and overtime hours. Since the distinction in hours of work between scheduled hours and overtime hours is institutional rather than technological, it seems natural to assume homogeneity of H and O. Therefore, H and O do not enter into the production function separately, but via a linear aggregator function. The production function f is subject to the usual regularity conditions of production functions with adjustment costs; positive monotone in K, N, H, O, M, and t, quasi concave in K, N, H, O, M, negative monotone and concave in $|\Delta K|$ and $|\Delta N|$.

Corresponding to the distinction in total hours of work between scheduled and overtime hours, total labor costs can also be divided into scheduled payments and nonscheduled overtime payments. Scheduled payments include bonus payments, which constitute a considerable portion of annual labor compensation in Japan. I assume that total labor costs are given as follows:

$$\textit{total labor costs} = c_1\, PH\, N\, H + PO\, N\, O + v, \qquad (2)$$

where c_1 is a parameter, PH is the hourly wage rate for scheduled hours of work, PO is the hourly wage rate for overtime hours, and v is the error term representing measurement errors. The parameter c_1 is supposed to exceed unity, and $c_1 - 1$ represents the mean rate of annual bonus payments. I assume that PH and PO are exogenous to the firm and that overtime hours of work are evenly distributed among workers. This assumption, although it may appear quite strong, is consistent with the assumption of homogeneity of employees[1]. The first term on the right hand side refers to the scheduled labor cost of N employees, and the second term to the non-scheduled overtime cost. Since N is quasi-fixed and O is variable, the first term gives the quasi fixed costs of employing N workers, while the second term gives the variable labor costs arising from changing overtime hours for a given size of employment. The quasi-fixity of employment also implies that the cost associated with a unit change in O is not PO but PO·N.

The overtime wage rate in the labor cost equation (2) is independent of overtime hours of work. This represents a substantial difference from the standard specification used by Shapiro and Bils in which the overtime wage rate is an increasing function of overtime. I chose to use the simple specification (2) instead of the standard one because, for the current data set, the overtime wage rate was not found to be positively related to overtime hours: an OLS regression of PO on PH and O yielded

$$\underset{}{PO}=\underset{(18.2)}{1.5014PH} - \underset{(-1.8)}{0.00075O},$$

with t-values in parentheses, R^2 = .99, and d.w = 2.19. The independence of the overtime wage rate from overtime hours considerably simplifies the structure of the model. In particular, we can apply duality theorems between cost and production functions

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[1] The even distribution of overtime hours among employees is assumed by Shapiro (1986), but not by Bils (1987).

(Diewert (1974)) and represent the technology by the dual cost function instead of the primary production function.

Since marginal costs of overtime are thus unaffected by increasing overtime hours, whereas adjustment costs in employment are increasing, it could be the case that all adjustments in labor input occur through overtime hours with no change in employment[2]. To exclude this strange case from occurring, I assume that the relative marginal products of overtime versus employment are decreasing in overtime hours:

$$\partial\left(\frac{\partial f/\partial O}{MP_N}\right)/\partial O=\left(\frac{\partial^2 f}{\partial O^2}MP_N-\frac{\partial f}{\partial O}\frac{\partial^2 f}{\partial N\partial O}\right)/(MP_N)^2<0, \tag{3}$$

where

$$MP_N=\frac{\partial f}{\partial N}+\frac{\partial f}{\partial \Delta N}\frac{\partial \Delta N}{\partial N}.$$

Sufficient conditions for this are positivity of marginal products of employment net of marginal adjustment costs and substitutability of employment and overtime.

The short-run costs, CV, consist of materials costs and overtime payments. Assume that, in the short-run, the firm minimizes CV for a given set of variable factor prices, quasi-fixed inputs, scheduled hours of work, and output, subject to the production function (1). CV is then given by the restricted cost function g:

[2] I would like to thank a referee for pointing out this point.

$$CV \equiv \min_{M,O}(PM \cdot M + PO \cdot O \cdot N \mid f(K,N,H+O,M,t,\Delta K,\Delta N) \geq Y)$$
$$= g(PM,PO,Y,K,N,H,t,\Delta K,\Delta N), \tag{4}$$

where PM is the price of materials.

Lemma 1 in Appendix 1 shows derivative properties of g. Since (4) is the standard definition of the restricted cost function except for the presence of a quasi-fixed factor in the definition of the short-run cost, g has most of the properties of the standard restricted cost function: it is positive monotone and linear homogeneous in PM and PO, negative monotone in K and H, convex in $|\Delta K|$ and $|\Delta N|$, and positive monotone in Y, $|\Delta K|$ and $|\Delta N|$. Unique to g is the following monotonicity condition with respect to N

$$\frac{\partial g}{\partial N} - PO \cdot O = -PN^{*} < 0, \tag{4b}$$

which is weaker than the standard one. PN^{*} is the shadow price of a unit of employment and the equality follows from (A.5) of Appendix 1.

A unique feature of our model is that while H and O are technologically homogeneous, they are institutionally heterogeneous and their unit prices are also different: whereas O is variable and endogenous to the firm, H is institutionally determined and exogenous to the firm. Lemma 2 in Appendix 1 shows that this feature has a strong implication for the form of g: there exists a function h, which is independent of H, such that g can be written as follows:

$$g(PM, PO, Y, K, N, H, t, \Delta K, \Delta N) = h(PM, PO, Y, K, N, Y, \Delta K, \Delta N) - PO \cdot N \cdot H. \quad (5)$$

This implies that, other things being equal, a unit decrease in H increases the short run cost by PO·N.

Since the term PO·N·H is exogenous in (4), we can alternatively obtain from (4) and (5) the following definition of h:

$$\begin{aligned} CV2 &\equiv CV + PO \cdot H \cdot N \\ &= \min_{M,O}(PM\,M + PO(O + H)N \mid f(K, N, H+O, M, t, \Delta K, \Delta N) \geq Y)) \\ &= h(PM, PO, Y, K, N, t, \Delta K, \Delta N). \end{aligned} \quad (6)$$

The function h thus gives the minimized value with respect to materials and overtime hours of the sum of materials costs and total man-hours evaluated at overtime wage rates. Henceforth, h is called the quasi restricted cost function and CV2 the quasi short run costs. In the following analysis I use h instead of g because it fully embodies the specific features of the model.

The regularity conditions of h are very similar to g except for two cases shown below. From (6) it follows that h is linear homogeneous and concave in PM and PO, negative monotone in K, convex in K, N, ΔK and ΔN. Furthermore, lemma 1 in Appendix 1 combined with (5) implies the following derivatives of h:

$$\frac{\partial h}{\partial PM}=M,\quad \frac{\partial h}{\partial PO}=(H+O)\,N$$

$$\frac{\partial f}{\partial M}=PM\left(\frac{\partial h}{\partial Y}\right)^{-1},\quad \frac{\partial f}{\partial O}=PO\cdot N\left(\frac{\partial h}{\partial Y}\right)^{-1}, \tag{7}$$

$$\frac{\partial f}{\partial K}=-\frac{\partial h}{\partial K}\left(\frac{\partial h}{\partial Y}\right)^{-1},\ \frac{\partial f}{\partial N}=-\left(\frac{\partial h}{\partial N}-PO(H+O)\right)\left(\frac{\partial h}{\partial Y}\right)^{-1}.$$

Two conditions in (7) are unique and seem worth noting. First, the second condition of the first line gives the counterpart of Shephard's lemma, and implies that the partial derivative of h with respect to PO gives total man-hours. Secondly, from the second condition of the last line it follows that the monotonicity condition of h with respect to N is weaker than that of g in (4b) and is given by

$$\frac{\partial h}{\partial N}-PO(H+O)=-PN^{*}<0. \tag{7b}$$

I now turn to the long-run optimization problem of the firm with respect to capital stock and employment. This optimization is intertemporal due to the dynamic nature of the model represented by the adjustment costs. I use the standard assumption that the firm minimizes the expected value of the future stream of total costs for given information on factor prices and output. The total cost at time t, CT_t, is the sum of CV, investment expenditure, and the quasi-fixed labor cost, and is from (2), (4), and (5) given by

$$CT_t = CV2_t-PO_tH_tN_t+PI_t(K_t-(1-\delta)K_{t-1})+c_1PH_tH_tN_t. \tag{8}$$

where PI_t is the acquisition price of capital stock, and δ is the constant rate of depreciation. The intertemporal optimization problem is:

$$\min_{[K_t,\ N_t, K_{t+1},\ N_{t+1}, \ldots]} E_t \sum_{i=0}^{\infty} R^i\ CT_{t+i}, \tag{9}$$

subject to (8) and K_{t-1} and N_{t-1} given, where E_t denotes expectation conditional on information available at time t, and R is the constant rate of discount. The solution of (9) together with the transversality condition would describe the optimum path of K and N over time.

2.2 Specification

For the empirical analysis, I specify the quasi restricted cost function h by the following truncated translog function:

$$\begin{aligned}
&\ln CV2_t = \ln h(PO_t, PM_t, K_t, N_t, Y_t, t, \Delta K_t, \Delta N_t) = \\
&\ln PO_t + a + a_p \ln\left(\frac{PM_t}{PO_t}\right) + a_k \ln K_t + a_n \ln N_t + a_y \ln Y_t + a_t t + \\
&\frac{1}{2}\left(a_{pp} \ln\left(\frac{PM_t}{PO_t}\right)^2 + a_{kk}(\ln K_t)^2 + a_{nn}(\ln N_t)^2 + a_{yy}(\ln Y_t)^2\right) + \\
&a_{kn} \ln K_t \ln N_t + a_{py} \ln\left(\frac{PM_t}{PO_t}\right) \ln Y_t + \\
&\frac{1}{2}\left(b_{kk}(K_t - (1-\delta)K_{t-1})^2 + b_{nn}(N_t - N_{t-1})^2\right).
\end{aligned} \tag{10}$$

Constant returns to scale is not assumed. Technical change is neutral to the restricted variable cost, but not to the long-run cost. This form is flexible within quasi-fixed inputs and within variable inputs, but not across quasi-fixed and variable inputs, and excludes complementarity between quasi-fixed and variable inputs. Since employment and overtime are thus assumed to be substitutes, one of the two sufficient conditions for (3) is automatically satisfied. Still, concavity, convexity as well as monotonicity conditions are not imposed a priori, and its consistency with the data remains to be empirically examined.

The adjustment cost function in (10) is the usual quadratic form and does not include cross terms of ΔK and ΔN, in accord with empirical results of Pindyck and Rotemberg (1983), Morrison (1988) and Shapiro (1986). The quadratic form implies symmetric adjustments: hiring costs and firing costs of a given number of workers are the same, and scrapping costs and investment costs of a given amount of capital are also the same. Since Japanese firms are known to be more reluctant to fire than hire employees, one may doubt the empirical validity of the assumption of symmetric adjustment costs.

In fact, Pfann and Palm (1988) estimated a model of demand for labor with asymmetric adjustment costs using quarterly data on Dutch and UK manufacturing and found significant asymmetry in labor adjustment costs: hiring costs exceeded the firing costs of production workers while firing costs exceeded the hiring costs of nonproduction workers. For the current data set, however, $\Delta K>0$ at all sample points and $\Delta N>0$ at all but two sample points. With only two sample points available to identify the asymmetry parameter of Pfann and Palm, their model cannot be effectively applied to the current data set. The model of Pfann and Palm is more suitable to industries with larger fluctuations in the employment level.

Given (10) the system of short-run share equations for materials and hours of work are from (7) given by

$$\begin{aligned} wm &\equiv \frac{PM \cdot M}{CV2} = a_p + a_{pp}\ln\left(\frac{PM_t}{PO_t}\right) + a_{py}\ln Y, \\ wo &\equiv \frac{PO \cdot N(O+H)}{CV2} = 1 - a_p - a_{pp}\ln\left(\frac{PO_t}{PM_t}\right) - a_{py}\ln Y, \end{aligned} \tag{11}$$

while the first order conditions (Euler equations) of (9) for the capital stock and employment are given by

$$\begin{aligned} &\frac{\partial CT_t}{\partial K_t} + R \cdot E_t\left(\frac{\partial CT_{t+1}}{\partial K_t}\right) = \\ &(a_k + a_{kk}\ln K_t + a_{kn}\ln N_t + b_{kk}(K_t - (1-\delta)K_{t-1})K_t)\left(\frac{h_t}{K_t}\right) + \\ &PI_t - R(1-\delta)E_t((b_{kk}(K_{t+1} - (1-\delta)K_t)h_{t+1} + PI_{t+1})) = 0, \end{aligned} \tag{12a}$$

$$\begin{aligned} &\frac{\partial CT_t}{\partial N_t} + R \cdot E_t\left(\frac{\partial CT_{t+1}}{\partial N_t}\right) = \\ &(a_n + a_{nn}\ln N_t + a_{kn}\ln K_t + b_{nn}(N_t - N_{t-1})N_t)\left(\frac{h_t}{N_t}\right) + \\ &(c_1 PH_t - PO_t)H_t - R \cdot E_t(b_{nn}(N_{t+1} - N_t)h_{t+1}) = 0. \end{aligned} \tag{12b}$$

3. Estimation and Empirical Results

I now turn to an application of the model to time series data for 1960-85 on the Japanese electrical machinery industry. For later references the above model is henceforth called Model 1. Appendix 2 gives a detailed description of the data sources and the variables used in the model. The equations to be estimated consist of the labor cost equation (2), the cost function (10), one of the share equations (11), and the Euler equations (12).

The general method of moments (GMM) estimator of Hansen (1982) provides a suitable estimation procedure for this type of model which includes unobservable conditional expectations. I replace the unobservable conditional expectations in the Euler equations with actual values and the zeros on the right-hand side with a vector of error terms. If the model is correct and expectations are rational, the error terms represent forecast errors and are orthogonal to anything known by the firm in period t. Further, the variable cost function and the share equation are augmented by additive error terms which represent measurement error, optimization error, and/or technological shocks. I use a set of instrumental variables that does not include any current variables appearing in the cost function, share function, and the Euler equations. The instruments are a constant, lagged values of the quantity of output and employment, as well as lagged values of the price of output, materials, and scheduled hourly wage rate.

One could consider a simultaneous GMM estimation of all the equations (2), (10), (11) and (12) subject to cross equation restrictions. On the other hand, since (2) contains only one structural parameter to be estimated, the loss in efficiency of its estimator resulting from estimation by OLS will be negligible, if any. On the other hand, exclusion of this equation from the simultaneous estimation could significantly reduce the computational burden. I therefore chose to estimate (2) by OLS first, and then to use the resulting estimate of c_1 in a simultaneous GMM estimation of the remaining equations. The OLS estimate of c_1 was 1.4695 with t- value 270, $R^2 = .99$, and d.w. = 1.04. This implies an annual bonus payment of about 4.7 months wages, which appears plausible.

If the error terms are i.i.d., GMM in the present context reduces to three stage least squares (3SLS). Since the Euler equations include conditional expectations of one period future variables, their error terms would be MA(1) even if the model is correct and expectations are rational (Cumby, Huizinga and Obstfeld (1983)). To test for serial correlation in the error terms, I first estimated the system with 3SLS, added on the estimated lagged residuals to each equation, then re-estimated the system with 3SLS, and tested if the lagged residuals are significant. It turned out that the hypothesis of no serial correlation was rejected at the 5 percent level but not at the 1 percent level based on the D statistic of Newey and West (1987b) (the statistic was 11.686 with the probability value .98015 for four degrees of freedom).

Table 2 (the left column) shows GMM estimates of Model 1 allowing for MA(1) errors, with the variance covariance matrix of error terms estimated using the method of Newey and West (1987a)[3]. The estimated model satisfies all the regularity conditions of the quasi restricted cost function at all sample points except that the concavity condition is not satisfied at five sample points from the early sixties[4]. The estimate of the adjustment cost parameter is positive and significant for employment but negative and insignificant for the capital stock. Thus, while employment is found to be quasi-fixed as expected, the capital stock turns out to be variable, which is hard to accept since it is not possible to construct plants within a year in this indusrtry.

Note, however, that the insignificance of b_{KK} merely implies that the adjustment cost for the capital stock does not respond to ΔK but not the absence of the adjustment cost itself. Since this industry is characterized by very high growth rates of both the capital stock and output (see Table 1), it is likely that a given level of investment does not cause any significant adjustment costs. A proper response therefore may be to put $\Delta^2 K$ in as the

[3] The estimation was done by 386TSP version 4.2a.

[4] Violation of the concavity condition was not statistically significant. The same applies to estimation results of Models 2 and 3 below.

adjustment cost term [5]: the adjustment costs are associated with a change in the level of investment but not with the level of investment itself. With this modification, the adjustment cost for the capital stock in (10) now becomes:

$$\frac{1}{2}b_{KK}(K_t-(2-\delta)K_{t-1}+(1-\delta)K_{t-2})^2,$$

and the term of b_{KK} in the Euler equation for capital becomes (with the expectation operator omitted for simplicity):

$$\begin{gathered} b_{KK}[(K_t-(2-\delta)K_{t-1}+(1-\delta)K_{t-2})h_t- \\ R(2-\delta)(K_{t+1}-(2-\delta)K_t+(1-\delta)K_{t-1})h_{t+1}+ \\ R^2(1-\delta)(K_{t+2}-(2-\delta)K_{t+1}+(1-\delta)K_t)h_{t+2}]. \end{gathered}$$

I henceforth call the model with Δ^2K Model 2. Estimation results of Model 2 for the period 1962 - 83 are reported in the middle column of Table 2. Since the Euler equation for the capital stock now includes conditional expectations of two period future variables, I allowed for MA(2) errors in the GMM estimation. The estimated Model 2 satisfies all the regularity conditions except the concavity condition at one point from the sixties. The estimate of b_{KK} now has the correct sign and remarkably increases its efficiency, while the estimate of b_{NN} remains positive and significant as in Model 1. On the other hand, the estimates of the second order parameters a_{ij}, i,j = K,N, become insignificant. If these parameters are jointly equal to zero, the model reduces to a

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[5] I owe the Co-Editor for this point.

simple Cobb-Douglas type in terms of the quasi-fixed factors. A D test (Newey and West (1987b)) of the joint hypothesis of $a_{KK} = a_{KN} = a_{NN} = 0$ yielded the statistic of 1.66 with the P value of .645, implying that the hypothesis is not rejected. I henceforth call Model 2 with this zero restriction imposed Model 3.

The right hand column of Table 2 reports the estimated parameters of Model 3. The regularity conditions are satisfied except the concavity condition at two points from the sixties. If all the variables of the model have stationary stochastic processes, the J static (Hansen (1982)) is Chi square distributed and can be used to test for over-identification restrictions of the model. For Model 3, the J statistic is 19.93 with 13 degrees of freedom (6 instrumental variables for each of four equations minus 11 parameters), and the P value is .097. For Model 1 and 2, the P value is 0.0186 and 0.0422, respectively. It follows that, of the three models examined, Model 3 is the only one that cannot be rejected at the five percent level. Model 3 is therefore used in the following analysis. Of course, if some variables of the model have stochastic trends, the above Chi square result no longer holds. Although the present sample size is too small to test for stationarity of the variables, one should be aware of the limit of applicability of the J test in the present context.

Before turning to economic implications of the estimated model, it seems useful to check for its goodness of fit. For this purpose, I solved the model dynamically for the period 1962-83 and computed the percent root mean square error (RMSE). The RMSE is 10.1 percent for the capital stock, 7.8 percent for employment, 3.0 percent for materials, and 5.0 percent for total hours of work. Figure 1 compares the dynamic solution with the actual values for employment. The RMSE may be rather low by the conventional standard, and the level of employment is constantly overestimated throughout the sixties. In view of the rather unique features of this type of dynamic model, it may be more appropriate to evaluate the goodness of fit within the class of Euler equation models. Since empirical Euler equation models are usually not tested for the goodness of fit (see Fair (1992)), such a comparison cannot be made at the moment.

4. Adjustment Costs and Various Elasticities

4.1 Adjustment Costs

I now turn to economic implications of the estimated model, and start from the degree of quasi-fixity of the capital stock and employment. The ratio of the marginal adjustment costs (MAC) of a quasi-fixed input to its unit price measures the degree of quasi-fixity. If the ratio is zero, the factor is perfectly variable, and the higher the ratio the lower the degree of variability. For the capital stock and employment, the ratio is respectively given by:

$$\frac{MAC_K}{PI_t}=\frac{b_{KK}[K_t-(2+\delta)K_{t-1}+(1-\delta)K_{t-2}]CV2_t}{PI_t},$$

$$\frac{MAC_N}{C_1PH_tH_t}=\frac{b_{NN}(N_t-N_{t-1})\,CV2_t}{C_1PH_tH_t}.$$

The upper section of Table 3 shows that, evaluated for 1983, the ratio is .0823 for the capital stock and .0264 for employment. The marginal adjustment cost of an additional unit of investment when the increase in investment is at the 1983 level is about 8.23 percent of the investment cost. Similarly, the marginal adjustment cost of an additional worker when the increase in employment is at the 1983 level is about 2.6 percent of the annual regular labor compensation.

Although the capital stock appears to have a higher degree of quasi-fixity than employment, this result also reflects the difference in the rate of increase besides that in the adjustment parameter. When adjusted for the same rate of increase of 10 percent, the ratio becomes 0.022 for the capital stock and 0.041 for employment, implying that employment has a higher degree of fixity than the capital stock.

A comparison of the above result with empirical results for the U.S. will be of interest, because long-term employment is known to be less prevalent in the U.S. firms. Estimating a labor demand model with quadratic adjustment costs for annual data on U.S.

manufacturing for the period 1957-83, Bils (1987, p.849) found that when employment was 10 percent above the surrounding years the marginal adjustment cost of an additional worker was about 4.1 percent of annual compensation. The degree of employment fixity in the Japanese electrical machinery industry thus turns out to be equal to that of the U.S. manufacturing.

4.2 Input Elasticities, Scale elasticities and TFP Growth Rate

The middle section of Table 3 shows marginal productivities in logarithmic form, or input elasticities of output, obtained by using (7). In Section 2.1, I assumed that the relative marginal products of overtime hours versus employment are decreasing in overtime hours (see equation (3)). Of the two sufficient conditions for this to hold, (10) implies that relating to substitutability. The remaining sufficient condition is the positivity of the marginal productivity of employment net of adjustment costs. Table 3 shows that this condition is also satisfied. The estimated model excludes the unrealistic case of all adjustments in labor input taking place solely through overtime hours with no change in employment.

For the same rate of increase in input, materials have the largest effect on output, followed by employment, scheduled hours, capital, and overtime hours, in a decreasing order. The feature that materials have the largest and overtime the smallest effect merely reflects the fact that the former has the largest cost share while the latter the smallest cost share. Both employment and scheduled hours elasticities are significantly larger than the capital elasticity.

Perhaps the most remarkable finding from the input elasticities is that the employment elasticity is significantly larger than the hours elasticity: the employment elasticity exceeds the sum of regular and overtime hours elasticities by about 12 percent without marginal adjustment costs and by 9 percent with marginal adjustment costs, and the difference is statistically significant with the t-value being above 15. This result is in sharp contrast to U.S. results of Feldstein (1967) and Bils (1987), among others, who found the hours elasticity to be significantly higher than the employment elasticity. This "inconsistency" with U.S. results, however, is quite consistent with Abraham and Houseman (1989), Shinozuka (1989), and Tachibanaki (1987) who found that Japanese industry relies relatively more on adjustment of average hours while U.S. industry relies relatively more on employment adjustment, because the above finding implies that employment responds less than hours to a given change in output.

Addition of the input elasticities of materials and overtime gives the short-run scale elasticity. The estimated elasticity, in the bottom section of Table 3, is 0.82 and significantly smaller than unity at the 5 percent level, and indicates the presence of significant short-run diseconomies of scale. Materials and overtime hours overshoot their long-run equilibrium values in the short-run to compensate for the sluggish adjustment of the capital stock and employment.

Addition of all input elasticities gives long-run scale elasticities. Since the labor input consists of employment and hours per employment, two measures of long-run scale elasticities could be defined depending upon which of the two components of labor is kept constant, although in reality the extent to which hours can be increased is quite limited. In Table 3, LRS measures the effect on output of a proportionate increase in capital, materials, and employment while keeping hours of work constant, whereas LRS2 measures the same effect when employment instead of hours is kept constant. The estimated long-run scale elasticity is 0.999 with hours kept constant but employment changed, and is .981 with employment kept constant but hours changed. Since these estimates are not significantly different from unity at the 5 percent level, the hypothesis of constant-returns to scale in the long-run is not rejected. Note that these LRSs do not include the effects of adjustment costs. When adjustment costs are included, the LRS is slightly reduced to .9518, which is still not significantly different from unity. The finding of constant returns to scale is thus robust to adjustment costs.

The above result for the long-run scale elasticity is consistent with Suzuki(1991) who obtained a scale elasticity of 0.999 for a panel data of 20 firms, but inconsistent with Nadiri and Prucha (1990) who obtained a large scale elasticity of 1.4 for a time series of aggregated industry data. However, the scale elasticity in the studies of Suzuki, and Nadiri and Prucha is not directly comparable with ours since it includes the effects of R&D capital besides the factors considered here. Assuming a homothetic production function which has capital, employment, and materials as factors of production, Yosioka (1989) estimated the scale elasticity for the Japanese electrical machinery industry. Index number methods were used with time series data from 1960 - 1985 and a cross section of nine groups of establishments with different sizes of employees. Neither quasi-fixity of employment nor effects of overtime are considered in his model. Since under homotheticity the scale elasticity depends on the size of output, he reports the upper and lower bounds which are 1.06 and 1.02. The above result is thus almost consistent with his lower bound.

Finally, the TFP (total factor productivity) growth rate was obtained as follows:

$$TFP\ growth\ rate \equiv \frac{\partial \ln f}{\partial t} = -\left(\frac{\partial \ln h}{\partial \ln y}\right)^{-1}\left(\frac{\partial \ln h}{\partial t}\right).$$

The estimated annual TFP growth rate is 4.58, and indicates a very high rate of technical change which is characteristic to this typical high-technology industry. This TFP growth rate is close to the estimate of Yosioka of 5.54, and is almost identical to the estimate of Nadiri and Prucha of 4.74.

4.3 Price Elasticities of Demand

Table 4 shows short-run and long-run price elasticities of demand evaluated for 1983. The short-run refers to the situation where the level of quasi-fixed inputs remain unchanged and the long-run to that where all the adjustments including those involving the level of quasi-fixed inputs have been completed. I start from short-run price elasticities. In the short-run, the demand for materials is practically insensitive to a change in its price, while the demand for overtime is fairly elastic with the elasticity significantly exceeding unity in absolute value. The possibility of factor substitution between materials and overtime in the short run is quite limited with the short run elasticity of substitution being 0.15.

The long-run price elasticities of demand were obtained using the method of Brown and Christensen (1981). Recall that the unit cost of overtime hours is the overtime wage rate times employment, $PO \cdot N$. Therefore, whenever the level of employment changes, the unit price of overtime hours is also changed, and this could cause indirect effects. A change in the overtime wage rate may also have indirect effects because it changes the level of employment, and this in turn the unit price of overtime hours. The presence of these indirect effects is unique to our model. The indirect effects will be particularly important when the initial shock refers to the price of employment $c_1PH\ H$ and/or the overtime wage rate PO. Since overtime- and scheduled wage rates are likely to change simultaneously, however, for practical purposes the direct effects may be more relevant than the indirect effects, for then the indirect effects would be mutually canceled out. Table 4 reports the elasticities without indirect effects[6]. An important exception is the case when the overtime premium only is changed with no accompanying changes in the scheduled wage rate, which will be considered in Section 5.2.

The own price elasticity (in absolute value) exceeds unity for overtime, is around unity for employment and capital, and is significantly below unity for materials. Overtime thus appears to be most price elastic, whereas materials are least price elastic. Statistically, however, the own elasticity for overtime is not significantly different from that of employment and capital. Materials are least price elastic in the short-run and the long-run as well.

The cross price elasticities between capital and labor are

[6] The elasticities including indirect effects can be provided by the author upon request.

positive by the definition of Model 3, and those between a quasi-fixed input and a variable input are also positive by assumption. The cross price elasticity between overtime and materials is the only one that is not subject to any prior restriction, and turns out to be positive but insignificant. The price of materials has the largest cross effects on the factor demand due to its largest cost share.

5. Some Simulation Results

5.1 Dynamic response of inputs to a change in output

Up to now the analyses of the model have been restricted to either its short-run or long-run properties, and no explicit attention was paid to its dynamic properties. I now show results of a dynamic simulation of the response to an unexpected increase in output of the capital stock, employment, materials, and overtime hours of work. Figure 1 shows the simulation result over 9 years of a sudden and permanent change in output of 10 percent in the first year. The control solution for year 0 is the long-run solution of the model for 1983.

The response to the shock is remarkably different between materials, overtime, and the quasi-fixed inputs. While the level of materials is almost immediately adjusted to the new long-run level, for the capital stock and employment the adjustment takes about six years. The slow adjustment of employment first causes a strong overshooting of overtime hours, with its level increased by almost 40 percent. Corresponding to the gradual, if slow, adjustment of employment to the new long-run level, however, the level of overtime hours is gradually reduced, until it finally returns to the initial level. Overtime hours are the only input the level of which returns to the initial level in the long-run.

Figure 1 supports the model in two ways. First, it reproduces findings of Abraham and Houseman (1989), Tachibanaki (1987), and Shinozuka(1989) that, in Japan, working hours are much more flexible than employment. Secondly, it demonstrates that adjustments in labor input are achieved by both overtime hours and employment and not by overtime hours alone, notwithstanding the fact that overtime premiums are independent of overtime hours and that any change in employment involves adjustment costs.

5.2 Effects of a shortening of hours of work

Working hours in Japan are known to be long compared to other advanced countries. The necessity of a significant shortening of working hours seems nowadays widely recognized in Japanese society. Hours of work can be shortened in several different ways, but the resulting economic effects can be quite different depending on which way is used. As an application of the model, this section shows simulation results for a shortening of hours of work.

Table 5 shows long-run effects on the factor demand and the unit cost (CT/Y) of three different cases of shortening of hours of work obtained by solving the model using the same control solution as in Section 5.1. In each of these cases, scheduled hours of work are exogenously shortened by 10 percent, say by regulation. The three cases differ from each other in the way income is compensated. First, (a) considers the case of no increase in hourly wage rates: regular income is reduced by 11 percent. Secondly, (b) considers the case of full income compensation where hourly wage rates are increased by 11 percent for both scheduled and overtime hours. Finally, (c) considers the case when the overtime wage rate only is increased by 11 percent with no increase in wage rates for scheduled hours. This case thus considers the effects of an increase in the overtime premium.

Simulation results indicate that a shortening of scheduled hours combined with a compensating increase in the hourly wage rates (case (b)) can not reduce but actually increase total hours, because the resulting increase in overtime hours more than cancels out the reduced scheduled hours. When the income is not compensated (case (a)), total hours can actually be reduced but only marginally. In contrast to (a) and (b), case (c) indicates that a significant reduction in overtime hours can be achieved by increasing the overtime premium: in our example, overtime hours are reduced to null! While quite effective for reducing total hours, this measure also causes the highest increase in employment and the unit cost. In fact, the effects of an increase in the overtime premium are much larger than what we might expect from the estimates of price elasticities in Table 4. The indirect price effects discussed in Section 4.3 are primary causes of these large effects[7].

A shortening of scheduled hours increases employment and the unit cost in all three cases, but with different magnitudes. (a) is the only case where employment can be increased without increasing the unit cost significantly. In summary, we can say that an effective shortening of working hours can only be realized at the cost of a reduced income and a higher unit cost.

6. Concluding Remarks

A dynamic factor demand model was presented which explicitly takes account of the quasi-fixity of employment and flexible overtime hours which are said to be characteristic of the Japanese practice of long-term employment, and was applied to a time series of data from 1960-1985 on the Japanese electrical machinery industry. The estimated model indicates a significant quasi-fixity of the capital stock and employment, and reproduces the standard finding on Japanese firms, say of Tachibanaki (1987, p.654), that

[7] With the indirect effects included, E_{OO} is -58.96, E_{NO} is 6.78, and E_{MO} is -.11.

working hours are much more flexible than employment, with working hours strongly affected by changes in overtime hours. In particular, a dynamic simulation shows that a sudden increase in output causes a substantial overshooting of overtime hours to compensate for the sluggish adjustments of employment.

As an application, I used the model to assess the effects of three forms of the shortening of working hours on the factor demand and the unit cost. It was found that an effective shortening of working hours can be achieved only at the cost of a lower labor income and higher unit costs. This rather strong conclusion is a tentative one, however, because the current model is still too simple for serious policy analysis. Furthermore, it can only provide partial equilibrium solutions which could be quite different from their general equilibrium counterparts. I close this paper by referring to two possible future directions for improving the model.

First, the assumption of an even distribution of overtime hours among employees is a strong one but is theoretically consistent with the assumption of homogeneous employees. It seems appropriate first to consider relaxation of the latter assumption because it is a more fundamental assumption. The assumption on the distribution of overtime could then be easily relaxed because overtime hours may be significantly different among heterogenous groups of employees.

Once employees are disaggregated into heterogeneous groups, we could easily take account of differences in adjustments among the groups by using group specific adjustment cost functions. As for possible ways of disaggregation, I refer to the fact that male employees work considerably longer overtime than female employees and that female employees adjust more quickly than male employees (Shinozuka(1989), Abraham and Houseman(1989)). Disaggregation of employees by gender thus seems promising.

Secondly, the assumption of symmetric adjustment costs is also a testable one, although for the data set of this study the asymmetric model of Pfann and Palm was found to be not applicable. While the model of Pfann and Palm is a general one, it is highly nonlinear and not easy to estimate. A theoretically simpler and more straightforward approach will be to estimate adjustment cost functions for the accession and separation of employees separately instead of applying a single adjustment function to the net difference of accession and separation, although this approach is more demanding in terms of data requirements.

Appendix 1. Lemmas

Lemma 1.

Let a,b,m,n $\in \mathbb{R}$ and p,q $\in \mathbb{R}^{+}$, respectively. Consider the function

$$y=f(a+b,m,n), \qquad (A.1)$$

that maps elements of $\mathbb{R}^3$ into $\mathbb{R}$. Let m = m(a+b,n,y) be the unique solution of (A.1) for any a,b,n,y, and a = a(p,q,b,n,y) be the unique solution of

$$\frac{\partial(p\ m(a+b,n,y)+q\cdot n\cdot a)}{\partial a}=0, \qquad (A.2)$$

for any p,q,b,n,y. Define

$$g(p,q,b,n,y)=p\ m(a(p,q,b,n,y)+b,n,y)+q\ n\ a(p,q,b,n,y) \qquad (A.3)$$

then

$$\frac{\partial g}{\partial p}=m,\ \frac{\partial g}{\partial q}=n\ a,\ \frac{\partial g}{\partial y}=p\frac{\partial m}{\partial y},\ \frac{\partial g}{\partial n}=p\frac{\partial m}{\partial n}+q\cdot a, \qquad (A.4)$$

$$\frac{\partial f}{\partial m}=p\left(\frac{\partial g}{\partial y}\right)^{-1},\ \frac{\partial f}{\partial a}=\left(\frac{\partial g}{\partial y}\right)^{-1}q\cdot n,\ \frac{\partial f}{\partial n}=-\left(\frac{\partial g}{\partial y}\right)^{-1}\left(\frac{\partial g}{\partial n}-q\cdot a\right). \qquad (A.5)$$

(Note that we have implicitly assumed that m(.), a(.), and g(.) are differentiable.)

Proof. The proof is shown for the last conditions of (A.4) and (A.5) which seem unique to the current model. Since the rest is well known, it is omitted (see the proof of Shepherd's Lemma). Differentiation of g under observation of (A.3) yields

$$\frac{\partial g}{\partial n}=\frac{\partial a}{\partial n}\left(p\frac{\partial m}{\partial a}+q-n\right)+p\frac{\partial m}{\partial n}+q-a=p\frac{\partial m}{\partial n}+q-a, \tag{A.6}$$

$$\frac{\partial g}{\partial y}=\frac{\partial a}{\partial y}\left(p\frac{\partial m}{\partial a}+q-n\right)+p\frac{\partial m}{\partial y}=p\frac{\partial m}{\partial y}. \tag{A.7}$$

By definition

$$y\equiv f\,[\,m(a+b,n,k,y),a+b,n,k\,].$$

Differentiation yields

$$1=\frac{\partial f}{\partial m}\frac{\partial m}{\partial y},\quad o=\frac{\partial f}{\partial m}\frac{\partial m}{\partial n}+\frac{\partial f}{\partial n}. \tag{A.8}$$

From (A.6),(A.7) and (A.8) it then follows that

$$\frac{\partial f}{\partial n}=-\frac{\partial f}{\partial m}\frac{\partial m}{\partial n}=-\left(\frac{\partial m}{\partial y}\right)^{-1}\frac{\partial m}{\partial n}=-\left(\frac{\partial g}{\partial y}\right)^{-1}\left(\frac{\partial g}{\partial n}-q-a\right).\quad \square$$

Lemma 2

Let g be the function defined by (A.3). Then there exists a function h that maps $\mathbb{R}^{2+}\times\mathbb{R}^{2}$ into $\mathbb{R}$ such that

$$g(p,q,b,n,y)=h(p,q,n,y)-q\cdot n\cdot b. \tag{A.9}$$

Proof: From (A.2) and observing $\partial m/\partial a = \partial m/\partial b$, it follows that

$$p\frac{\partial m}{\partial b}=p\frac{\partial m}{\partial a}=-q\cdot n. \tag{A.10}$$

Differentiation of (A.3) with respect to b and observing (A.2) and (A.10) then yields

$$\begin{aligned}\frac{\partial g}{\partial b}&=p\left(\frac{\partial m}{\partial b}+\left(\frac{\partial m}{\partial a}\right)\left(\frac{\partial a}{\partial b}\right)\right)+q\left(\frac{\partial a}{\partial b}\right)n\\&=\left(\frac{\partial a}{\partial b}\right)\left(p\left(\frac{\partial m}{\partial a}\right)+q\cdot n\right)+p\left(\frac{\partial m}{\partial b}\right)\\&=-q\cdot n.\end{aligned} \tag{A.11}$$

Upon integration (A.9) follows.□

Appendix 2: Data

The data on capital stock (K), gross output (Y), material (M), and workers (N), price indices of gross output (PY) and materials (PM) were taken from Saito and Tokutsu (1989), and the rate of depreciation from Kuroda and Yosioka (1985, Table 3).

"Basic Survey on Wage Structure" of Ministry of Labor gives data on monthly scheduled and overtime hours of work, scheduled earnings, overtime earnings, and annual special earnings which include bonuses. Addition of the three types of earnings gives labor costs. I transformed the monthly hours into the yearly figures H and O by multiplying by 12. The scheduled and overtime wage rates were respectively obtained by dividing scheduled earnings by scheduled hours of work, and by dividing overtime earnings by overtime hours of work. The overtime premium thus obtained was rather stable with a mean value of 30 percent, which slightly exceeds the legally determined minimum premium rate of 25 percent.

The acquisition price of capital stock (PI) is the price index of private corporate investment from the National Income Statistics. The rate of discount R was set to 0.96 implying a required annual rate of return of about 4 percent. Estimation results were insensitive to the use of alternative values taken from the range between .92 and .98.

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Table 1

Mean Growth Rates of Output and Inputs (in percentage):

Japanese Electrical Machinery Industry

period	output	capital	employment	materials	overtime hours[1]	scheduled hours
61-65	10.95	14.41	8.91	9.61	12.67	-0.94
66-70	23.82	13.56	9.57	22.62	12.20	-0.97
71-75	2.85	6.59	-1.71	-1.07	19.90	-1.12
76-80	17.35	9.25	1.24	14.75	22.39	0.48
81-85	18.88	14.09	6.45	16.09	7.34	-0.12

1) The figures for overtime refer to the mean absolute rate of change.

Table 2: Estimation Results[1]

	Model-1[2]		Model-2[3]		Model-3[4]	
a	5.5064	1.2091	6.0572	1.5805	6.3907	1.3943
a_P	-0.5856	0.0992	-0.5033	0.1336	- 0.5594	0.1187
a_K	0.1101	0.0818	0.0058	0.1147	-0.0410	0.0061
a_N	-0.2005	0.0597	-0.0598	0.0518	-0.0198	0.0007
a_Y	1.0201	0.2045	0.8807	0.2672	0.8506	0.2346
a_T	-0.0517	0.0057	-0.0470	0.0052	-0.0487	0.0049
a_{PP}	0.1111	0.0066	0.1054	0.0087	0.1092	0.0080
a_{KK}	-0.0113	0.0094	-0.0024	0.0128		
a_{KN}	-0.0081	0.0039	-0.0037	0.0028		
a_{NN}	0.0363	0.0123	0.0104	0.0097		
a_{YY}	-0.0362	0.0197	-0.0229	0.0258	-0.0206	0.0230
a_{PY}	0.0673	0.0055	0.0628	0.0076	0.0658	0.0066
b_{KK}	-3.63E-10	1.30E-09	2.30E-09	1.34E-09	2.61E-09	1.23E-09
b_{NN}	4.22E-08	2.04E-08	2.96E-08	1.23E-08	3.51E-08	1.08E-08

1) The numbers in the second column for each model are standard errors corrected for MA(1) errors for Model-1, and for MA(2) errors for Models-2,3.

2) Model-1: the original model with capital adjustment costs in terms of ΔK.

3) Model-2: the model with capital adjustment costs in terms of $\Delta^2 K$.

4) Model-2 with $a_{KK} = a_{KN} = a_{NN} = 0$.

Table 3

Adjustment Costs and Scale Related Elasticities

(evaluated for 1983)

The degree of quasi -fixity		
MAC_K/PI	.0823	(.0389)
MAC_N/WR	.0264	(.0081)
MAC_K/PI^1	.0224	(.0106)
MAC_N/WR^1	.0408	(.0125)
Input Elasticities of Output		
materials	.8011	(.0444)
scheduled hours	.1262	(.0070)
overtime hours	.0152	(.0008)
capital	.0384	(.0064)
employment	.1600	(.0089)
employment[2]	.1574	(.0082)
Returns to Scale and TFP Growth Rate		
short-run returns to scale	.8162	(.0453)
long-run returns to scale[3]	.9995	(.0557)
long-run returns to scale[4]	.9808	(.0547)
TFP growth rate	.0458	(.0028)

The numbers in parentheses are estimated standard errors.
1. Evaluated for 1983 when the rate of change is 10 percent above the surrounding years.
2. Net of marginal adjustment costs.
3. Hours of work kept constant.
4. Employee kept constant.

Table 4

Price Elasticities of Demand (evaluated for 1983)[1]

Short-run Elasticities

ES_{MM}	-.0232	(.01162)
ES_{OO}	-1.2410	(.42264)
SS_{MO}	.1549	(.07750)

Long-run Elasticities

E_{KK}	-0.9616	(0.0340)
E_{KN}	0.0187	(0.0030)
E_{KM}	0.8015	(0.1271)
E_{KO}	0.1414	(0.0224)
E_{NK}	0.0384	(0.0061)
E_{NN}	-0.9813	(0.1598)
E_{NM}	0.8015	(0.1271)
E_{NO}	0.1414	(0.0224)
E_{MK}	0.0384	(0.0061)
E_{NM}	0.0187	(0.0030)
E_{MM}	-0.0719	(0.0169)
E_{MO}	0.0148	(0.0093)
E_{OK}	0.3585	(0.0569)
E_{ON}	0.1739	(0.0276)
E_{OM}	0.7829	(0.4899)
E_{OO}	-1.3153	(0.4960)

1) The numbers in parentheses are estimated standard errors.
K: capital, N: employment, M: materials, O: overtime hours of work,
ES_{ij}: short-run price elasticity of demand for i with respect to the price of j,
SS_{ij}: short-run elasticity of substitution,
E_{ij}: long-run price elasticity of demand for i with respect to the price of j,

Table 5[1]

Effects of a Shortening of Working Hours

case	a	b	c
capital stock	1.12	1.19	0.63
employment	10.84	1.66	72.98
materials	-0.25	0.21	-0.95
overtime hours	61.20	129.45	-100.00
total hours	-2.36	4.96	-19.65
unit cost	0.92	2.69	9.89

1) The figures refer to the rate of change in percentage caused by:

a: scheduled hours decreased by 10 percent.

b: (a) with scheduled and overtime wage rates increased by 11 percent.

c: (a) with only overtime wage rate increased by 10 percent.

Figure 1: Dynamic Solutions
Employment (millions)

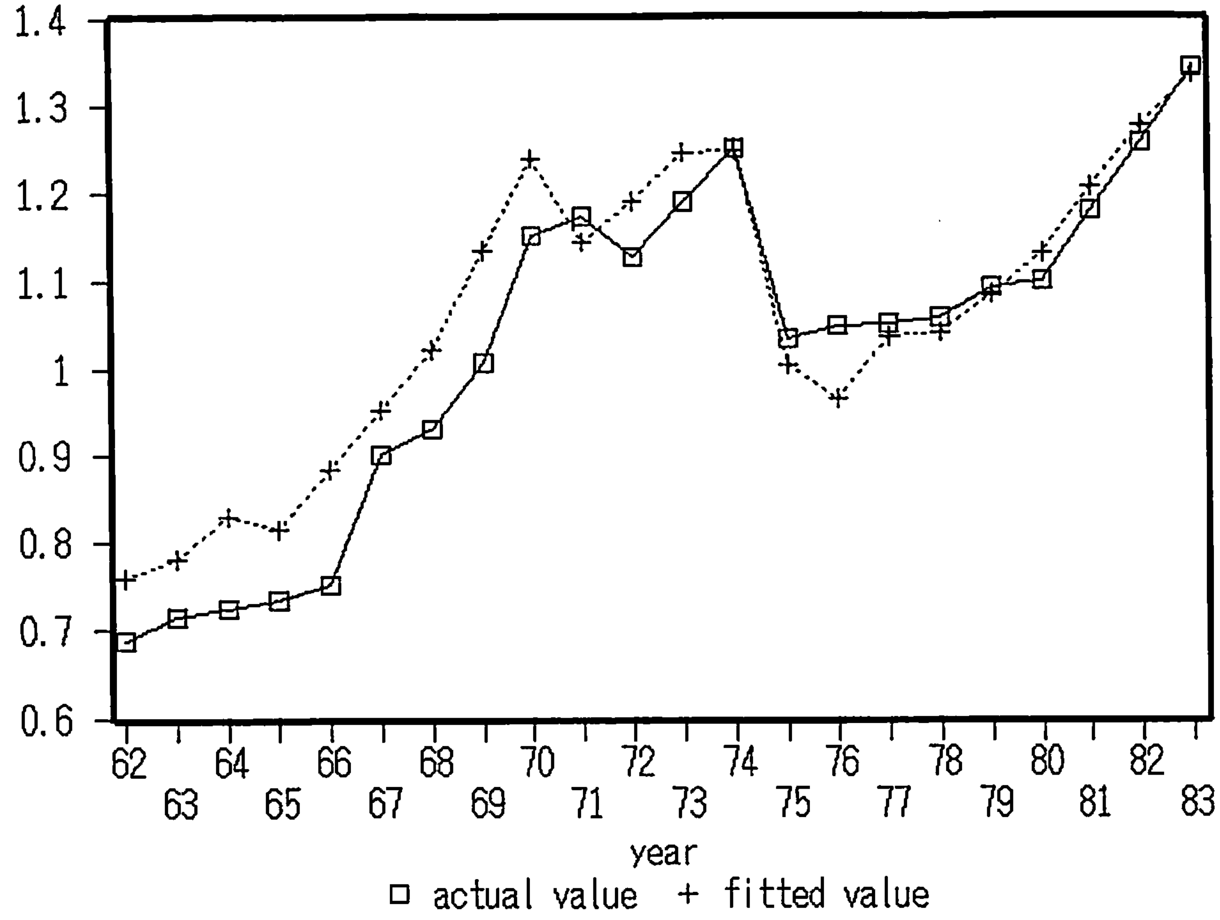
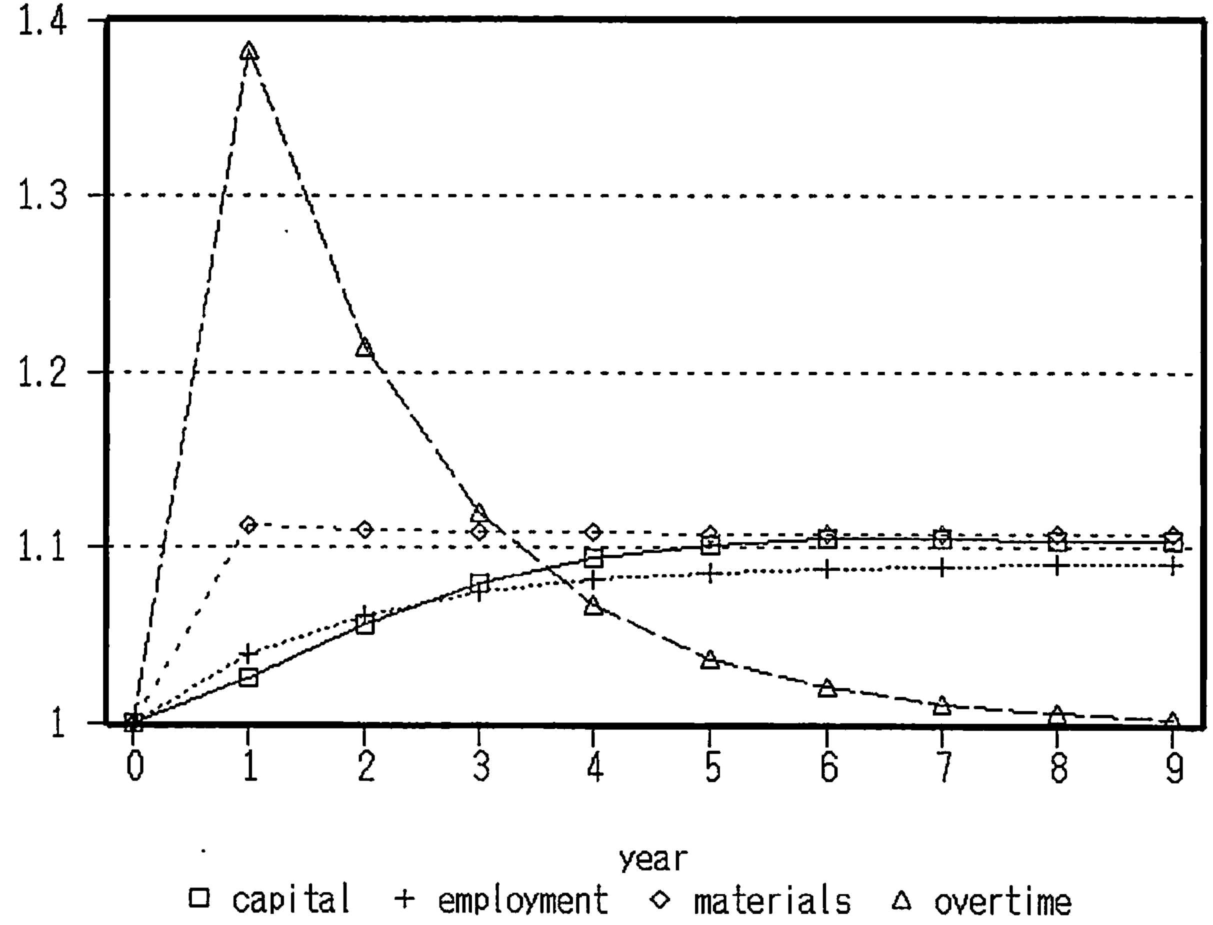


Figure 2
Effects of a 10% increase in output



Number	Author	Title	Date
9201	Shinichiro Nakamura	An Adjustment Cost Model of Long Term Employment in Japan	09/92