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Dynamic factor demand in the Japanese manufacturing industry

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Abstract

Purpose – This study investigates the dynamic production structure of the Japanese manufacturing industry by using the adjustment cost approach. The study is to shed some light on the unique dynamic structure of the Japanese manufacturing industry. The study attempts to help design and predict industrial policies that are implemented to enhance domestic investments by the Japanese government.

Design/methodology/approach – This study obtains a system of dynamic factor demand and output supply equations by applying the dual approach to the intertemporal value function as represented by the Hamilton–Jacobi equation. By using industrial panel data for 1973–2012 of the Japanese manufacturing industry, the study estimates the system of the behavioral equations and corresponding elasticities. The study uses hypothesis tests and dynamic elasticities to investigate the dynamic structure of the Japanese manufacturing industry.

Findings – Estimation results show that labor and capital are quasi-fixed variables that adjust about 0.2 percent annually to the long-run optimum levels. Estimated adjustment rates are very slow as often presumed about the Japanese manufacturing industry, which uses lifetime employment practice and slow decision-making process in investment decisions. The results also show that output supply and factor demand elasticities vary greatly depending on time horizon. Factor demand increases when its own price increases in the short run, suggesting that factor adjustment is mostly determined factor prices in the past due to sluggish factor adjustment. However, factor demand becomes a normal downward-sloping curve in the long run as factor adjustment gets completed.

Originality/value – Japanese manufacturing firms hire employees through lifetime contract to exploit the benefits of dynamic learning-by-doing and execute investments carefully considering all the possible impacts. Under the strategy, adjustment costs for changing workers and capital stock are minimized. Dynamic adjustment model is expected to shed some light on the unique dynamic structure of the Japanese manufacturing industry. However, researches regarding the dynamic factor adjustment of the Japanese manufacturing industry are hard to find. This study is expected to fill the research vacuum.

Keywords Adjustment costs, Dynamic duality, Production, Japanese manufacturing

Paper type Research paper

1. Introduction

The Japanese manufacturing industry has endured intense transformation since the 1970s. The manufacturing industry restructured itself successfully toward an energy-saving industry after oil shocks in the 1970s, and it introduced automatic production process to cope with eroding price competitiveness after the Plaza Accord in 1985. It tried to eliminate

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overcapacity after the burst of the bubble in the early 1990s, and it undertook strong investments to utilize information technology (IT) since the 2000s. It plunged into depression after the world economic crisis in 2007, and it has been the focus of government industrial policy to boost its competitiveness.

Considering its active transformation, the problem of resource adjustment in the Japanese manufacturing industry can be adequately investigated within a dynamic adjustment cost framework. In this regard, this paper can shed some light on the production structure of the Japanese manufacturing industry.

Continuity of the Japanese manufacturing industry is well known to the world as Japanese firms continue their businesses over generations through booms and busts. The firms endeavor to make perfect their products over the long haul by improving their practices and processes step by step. They hire employees through lifetime contract to exploit the benefits of dynamic learning-by-doing and execute investments carefully considering all the possible impacts. Under the strategy, adjustment costs for changing workers and capital stock are minimized. On the downside, however, factor adjustments are likely to be lumpy due to the lack of frequent adjustments. Dynamic adjustment model is expected to shed some light on the unique dynamic structure of the Japanese manufacturing industry.

The dynamic model provides a consistent theoretical basis for explaining manufacturing investment patterns based on the dynamic optimization of economic agents. Despite their significant implication, researches regarding the dynamic factor adjustment of the Japanese manufacturing industry are hard to find. This study is expected to fill the research vacuum.

In dynamic factor demand models, behavioral equations can be obtained either primarily from the first-order optimization conditions of the Hamilton–Jacobi equation (Berndt *et al.*, 1981; Mortensen, 1973; Nadiri and Prucha, 1989; Treadway, 1970) or dually by applying the envelop theorem to the equation (Epstein, 1981; Epstein and Denny, 1983; McLaren and Cooper, 1980). This study obtains a system of dynamic factor demand and output supply equations by applying the dual approach to the intertemporal value function as represented by the Hamilton–Jacobi equation. By using industrial panel data for 1973–2012 of the Japanese manufacturing industry, the study estimates the system of the behavioral equations and corresponding elasticities. Previous studies applied dynamic factor demand model to empirically investigate the production structure of various industries. For example, Berndt *et al.* (1981), Epstein and Denny (1983) and Nadiri and Prucha (1996) investigated the US manufacturing industry, and Taylor and Monson (1985), Howard and Chunway (1988) and Vasavada and Chambers (1986) applied the model to the US agricultural industry. These studies used a dynamic factor demand system to test the existence of adjustment costs and dynamic interaction between factor demands. These studies showed that the dynamic factor demand model can deliver factor adjustments responding to changing economic environments. This is very important in accurately analyzing the impacts of industrial policy of the government on factor investment.

Following previous empirical studies, this study will test the hypothesis whether there exists adjustment costs in the Japanese manufacturing industry and whether factor adjustments interact dynamically or not. The study will also investigate what characterizes the structure of the Japanese manufacturing industry, which has not yet been pursued. Currently, the Japanese government applies a set of structural reform and industrial policies to enhance domestic investments. Even though these industrial policies are less heralded than expansionary monetary and fiscal policies, these are a vital part of Abenomics that prepared three arrows to attack economic depression[1]. In particular, the government reduced corporate tax rate from 38 percent to about 30 percent since Prime Minister Abe took office in 2012. The government further reduced it by 5–10 percent for the firms that raised wages by more than 3 percent or invested in selected new technologies in 2018.

In analyzing impacts of industrial policies on investments, the dynamic factor adjustment model can provide an empirical basis for policy analysis in predicting input and output adjustments brought by changing relative prices through industrial policies.

Empirical results of this study show that adjustment coefficients for labor and capital are very low, suggesting the existence of great adjustment costs inherent in the Japanese manufacturing industry. The results also show that elasticities of output supply and factor demand vary greatly depending on time horizon and that there exists disembodied technical change in labor even after the input is adjusted for quality.

The study suggests that policy makers should consider time dimension to assess policy impacts accurately when implementing industrial policies that affect output supply and factor demand. Furthermore, the Japanese government should apply policy measures large enough to overcome sluggish factor adjustment to successfully affect factor investments. In this respect, this study confirms a great corporate tax reduction of 8–18 percent executed by the current government to boost corporate investments.

This study is organized as follows. Section 2 provides a theoretical background for dynamic dual model and gives the functional form of the estimation model. Section 3 discusses the data and estimation results. Section 4 presents the conclusions.

2. The dynamic factor demand

A perfectly competitive firm maximizes the current stream of future profits over the infinite time horizon at a base period t, yielding the intertemporal value function as follows:

$$J(P,\ V,\ C,\ r,\ k,\ t) = \max_{Y,M,\dot{K}} \int_t^{\infty} e^{-\mathrm{rs}}\left\{\mathrm{PF}\left(M,\ K,\ \dot{K}\right) - \mathrm{VM} - C'K\right\}\mathrm{d}s \tag{1}$$
$$\text{subject to } t \le s \le \infty,\ M,\ K > 0,\ \dot{K}_t = I_t - \delta K_{t-1},\ \text{and}\ K(t) = k > 0,$$

where P is the price of output $F(\cdot)$, V is the price of variable input M, C is the rental price vector of the quasi-fixed input K, r is the real discount rate, I is the gross investment in K, δ is the constant depreciation rate, k is the initial endowment of K, $\dot{K}$ is the net change in K and t is the time trend denoting technical change. Time subscript t is dropped for brevity even though all variables are implicit functions of time.

The value function $J(\cdot)$ represents the optimal value of problem (1) when an interior solution exists. The value function is the long-run profit function for a competitive firm, representing the maximized sum of discounted profit flow over the entire planning horizon. Besides the regularity assumptions that production function $F(\cdot)$ is twice continuously differentiable and concave, it should be further assumed that $F_{\dot{K}}<0$, $\lim_{t\to\infty}\dot{K}(t) = 0$ and that $J(\cdot)$ is twice continuously differentiable, convex in prices and concave in quasi-fixed inputs.

A sequence of static optimization problems linked over time can replace the dynamic optimization problem (1), assuming that the firm expects the prices denoting actual market at time t to persist indefinitely. Therefore, decisions made in period t are based on information available in that period containing all relevant information about future prices. Now the static optimization problem can be defined by the Hamilton–Jacobi equation:

$$\mathrm{rJ}(P,\ V,\ C,\ k,\ t) = \max_{Y,M,\dot{K}}\left\{\mathrm{PF}\left(M,\ K,\ \dot{K}\right) - \mathrm{VM} - C'K + J_k\dot{K} + J_t\right\} \tag{2}$$

The Hamilton–Jacobi equation enables us to convert the dynamic problem in (1) into a more manageable form. Especially, the value function is identified as the discounted present value of the current profit plus the marginal value of optimal change in net investment. According to Epstein (1981), the properties of $F(\cdot)$ are fully expressed in the value function $J(\cdot)$ if the regularity conditions on $F(\cdot)$ are satisfied, establishing a dynamic duality between $F(\cdot), J(\cdot)$ and $rJ(\cdot)$. The dynamic factor demand and supply functions can be derived by applying the envelope theorem to the Hamilton–Jacobi Eqn (2) as follows:

$$F(P, V, C, k, t) = rJ_p - J_{kp} - J_{tp}, \tag{3}$$

$$M(P, V, C, k, t) = -rJ_v + J_{kv} + J_{tv}, \tag{4}$$

$$\dot{K}(P, V, C, k, t) = J_{kc}^{-1}(rJ_c + K - J_{tc}). \tag{5}$$

In addition to the regularity properties of the value function, the value function should be affine in capital for consistent aggregation across firms, satisfying $J_{kk} = 0$ (Blackorby and Schworm, 1982). Furthermore, the value function must have a form such that J_{kc} is not a function of prices, which allows us to express the net demand for quasi-fixed inputs in the flexible accelerator form. The restriction on J_{kc} also facilitates determination of the curvature properties on the production technology. However, convexity of J in prices is sufficient for the existence of the curvature properties if J_k is linear in price (Epstein, 1981).

In estimation, a modified general Leontief function is used to specify the value function because the Leontief function satisfies the above requirements and maintains linear homogeneity in prices and concavity in quasi-fixed inputs. The modified generalized Leontief function can be defined as follows:

$$\begin{aligned} J(P, V, C, k, t) = {} & [PV]AK + C'B^{-1}K + \left[P^{1/2}V^{1/2}\right]EC^{1/2} + C^{1/2'}FC^{1/2} \\ & + \left[P^{1/2}V^{1/2}\right]G\left[P^{1/2}V^{1/2}\right]' + tH\left[PVC'\right]', \end{aligned} \tag{6}$$

where P is the output price, V is the material price, K is the (2×1) vector of quasi-fixed factors where k_1 is the number of employees and k_2 is the fixed capital asset, C is the (2×1) vector of corresponding rental prices including the wage rate and the capital rental rate and t represents year. Parameters A, B^{-1}, E, G and F are each a (2×2) matrix, and H is a (1×4) vector denoting disembodied technical change.

The dynamic factor demand for the quasi-fixed inputs (5) can be rewritten as follows:

$$\dot{K} = M(K - \overline{K}^*), \tag{7}$$

where M is an adjustment matrix and $\overline{K}^*$ is the vector of steady-state stocks[2]. In this case,

$$M = (rI + B) \text{ and } \overline{K}^* = -(rI + B)^{-1}[rJ_c - (rI + B)K - J_{tc}]. \tag{8}$$

Thus, the optimal net investment demand vector is consistent with the multivariate flexible accelerator model with constant adjustment coefficient (Nadiri and Rosen, 1969).

3. Data and empirical results

Data and variables

The data used in this paper represent a balanced panel of Japanese manufacturing industries taken from the Japan Industrial Productivity (JIP) database 2015. Based on the database, a panel of 52 manufacturing industries for 1973–2012 is compiled, from which all the variables required for estimation can be constructed. The sample period starts from the early 1970s in which the Japanese manufacturing dominated the world with successful structural reforms after the oil shocks in the 1970s. Thus, the sample encompasses the dynamic adjustment of manufacturing sector of the Japanese economy through booms in 1980s, structural transformation in 1990s after the burst of bubble in the early 1990s, IT innovation in the 2000s and two quantitative easing monetary policies before and after the world economic crisis in 2007.

For the estimations, labor input (k_1) is proxied by the number of employees, capital stock (k_2) is given by the real amount of tangible fixed assets, intermediate material goods (M) are measured by total value of intermediate input and total value of output (Y) is used for output. Both labor and capital are augmented by respective quality indices provided by the database to account for embodied technical change[3]. The quality of employment is estimated as the weighted average composition of employees in gender, education, age and employment status (full time vs part time) with a weight derived from the ratio of compensation paid to each category of employees. Likewise, the quality of capital stock is estimated by the value-augmented capital stock with a value defined by the average share of compensation paid for specified capital stock components[4].

Wage rate (c_1) is constructed to denote labor price by dividing the total labor cost by the number of working hours[5]. The rental price of capital (c_2) is used for capital price, and material price (v) and the output price (p) are represented by an intermediate input deflator and an output deflator, respectively. All nominal variables are converted into 2000 constant prices using deflators obtained from the JIP database 2015. Then, all prices are changed into price indices with their 2000 prices equaling to ones.

Parameter estimation and hypothesis test

Table I presents the parameter estimates of the value function (6) obtained by applying the feasible generalized nonlinear least square (FGNLS) method to the system of Eqs (3), (4) and (5), assuming constant real discount rate of 4 percent. In the full model, the symmetry of the value function is imposed with $F_{12} = F_{21}$ and $G_{12} = G_{21}$[6]. Also reported are two additional models that assume independent adjustment of quasi factors ($B_{12} = B_{21} = 0$) and no dynamic adjustment of the factors ($B_{12} = B_{21} = 0$ and $B_{11} = B_{22} = -1$). For all the models, four-fifths of coefficient estimates are statistically significant at the 1 percent significance level, and all the significant estimates are mostly significant at the 1 percent.

The adjustment rates for labor ($M_{11} = B_{11} + r$) and capital ($M_{22} = B_{22} + r$) are estimated as -0.0023 and -0.0020, respectively. The rates are significantly different from -1.0, indicating that both labor and capital are very slow in changing their stocks toward steady-state levels. The estimates suggest that the number of employees and capital stock adjust 0.23 percent and 0.20 percent annually, respectively, to their long-run optimal levels[7]. This implies not only that both factors are quasi-fixed in their nature but changing them requires large adjustment costs.

The estimations suggest that the Japanese manufacturing industry is very slow in moving the number of employees and capital stock toward the long-run optimal levels. The estimations are consistent with business practices of Japanese manufacturing firms that prefer gradual improvement (Kaizen) to rapid innovation. The firms endeavor to make perfect their products over the long haul by improving their practices and processes step by step. They take time to fully utilize technology embodied in machinery and equipment, and they try to modify or fine-tune them to fit their jobs. Because adapting to new capital is slow and thorough, the firms execute investments carefully considering all the possible impacts. On the other hand, craftsmanship is highly valued; so the firms hire employees through lifetime contract to exploit the benefits of dynamic learning-by-doing. After recruiting new employees, the firms try to train and educate them extensively. Therefore, adjustment costs for changing workers and capital stock are great for Japanese manufacturers, which can be minimized through gradual adjustment[8]. In this respect, the estimations confirm the sluggish investment behavior of the Japanese manufacturing industry.

Table II presents hypothesis tests for dynamic nature of factor demand for the Japanese manufacturing industry, along with tests about its technological progress. All the tests are

Table I. FGNLS estimates for parameters of the value function for dynamic factor demand for Japanese manufacturing

		Model	
Parameter	Full model	Independent adjustment	No dynamic adjustment+
A_{11}	7.2964 (0.3001)	6.1051 (0.2979)	3.1037 (0.2113)
A_{12}	0.4158 (0.0333)	0.4675 (0.0342)	−0.1707 (0.0245)
A_{21}	−4.6188 (0.2122)	−3.7933 (0.2102)	−1.9420 (0.1475)
A_{22}	−0.3292 (0.0236)	−0.3623 (0.0241)	0.1000 (0.0170)
B_{11}	−0.0423 (0.0009)	−0.0465 (0.0009)	−1
B_{12}	−0.0014 (0.0001)	0	0
B_{21}	0.0643 (0.0106)	0	0
B_{22}	−0.0420 (0.0017)	−0.0366 (0.0015)	−1
E_{11}	0.1677 (0.2195)*	0.2987 (0.2211)*	−0.8869 (0.2499)
E_{12}	35.468 (1.0485)	35.655 (1.0530)	30.401 (1.1770)
E_{21}	−0.0383 (0.3530)*	−0.1884 (0.3537)*	1.1431 (0.4319)
E_{22}	−17.977 (1.0277)	−18.036 (1.0275)	−13.228 (1.1862)
F_{11}	−0.6908 (1.7487)*	−7.1286 (1.5821)	−7.8888 (1.8559)
F_{12}	−0.2311 (0.2392)*	−0.3775 (0.2411)*	1.0402 (0.2538)
F_{22}	−6.9543 (20.455)*	−46.7443 (23.911)*	185.157 (11.313)
G_{11}	−13.532 (1.4010)	−13.156 (1.4025)	−18.423 (1.4121)
G_{12}	5.7817 (0.4487)	5.8268 (0.4490)	4.3263 (0.5120)
G_{22}	−5.5390 (1.0085)	−5.3021 (1.0094)	−8.7593 (1.0246)
H_1	0.1641 (0.0178)	0.1595 (0.0178)	0.2300 (0.0179)
H_2	−0.0715 (0.0128)	−0.0686 (0.0128)	−0.1141 (0.0129)
H_3	0.0084 (0.0222)*	0.0905 (0.0201)	0.0936 (0.0236)
H_4	0.0652 (0.2600)*	0.5645 (0.3041)*	−2.3992 (0.1438)

Note(s): *Except those denoted by star, all the variables are statistically significant at the 1 percent significance level. +In the model that has no dynamic adjustment, both independent adjustments, $B_{12} = B_{21} = 0$ and instantaneous adjustment of both capital and labor, $B_{11} = B_{22} = -1$ are assumed. Asymtotic standard errors are in parentheses.

Table II. Hypothesis tests for dynamic factor demand for Japanese manufacturing industry

Null hypotheses	Test statistics	Critical value	Decision
Independent adjustment $B_{12} = B_{21} = 0$	413	$\chi^2_{2,0.01} = 9.210$	Rejected
Instantaneous adjustment of labor $B_{11} = -1$ & $B_{12} = B_{21} = 0$	14.367	$\chi^2_{3,0.01} = 11.34$	Rejected
Instantaneous adjustment of capital $B_{22} = -1$ & $B_{12} = B_{21} = 0$	121.37	$\chi^2_{3,0.01} = 11.34$	Rejected
No technological change $H_i = 0, i = 1, 2, 3, 4$	132.92	$\chi^2_{4,0.01} = 13.27$	Rejected
No disembodied technological change in labor $H_3 = 0$	22.28	$\chi^2_{1,0.01} = 6.634$	Rejected
No disembodied technological change in capital $H_4 = 0$	−73.10	$\chi^2_{1,0.01} = 6.634$	Accepted

Note(s): All tests are based on the full model in which symmetricity of $G_{12} = G_{21}$ and $F_{12} = F_{21}$ is assumed. In addition, independent adjustment of $B_{12} = B_{21}$ is assumed for the tests about instantaneous adjustment.

nested on the full model assuming symmetricity of the value function by using the likelihood-ratio test.

Independent adjustment occurs when each quasi-fixed input adjusts to its optimum level independently with $B_{12} = B_{21} = 0$. The null hypothesis of independent adjustment is rejected at the 1 percent significance level. Instantaneous adjustment of labor and capital is tested to see if quasi-fixed factors move to their desirable level instantaneously. Instantaneous adjustment of labor (capital) arises when not only $B_{11} = -1(B_{22} = -1)$ but $B_{12} = B_{21} = 0$. The null hypothesis of instantaneous adjustment is rejected for both factors, suggesting the existence of dynamic adjustment of the factors. The tests confirm that the factors are not variable inputs.

The null hypothesis of no technical change, $H_i = 0$ for $i = 1, 2, 3$ and 4, is rejected for the sampling period. Also, the null hypothesis of no disembodied technical change in labor, $H_3 = 0$ is rejected significantly, but the null hypothesis in capital, $H_4 = 0$ is accepted. The test results suggest that there exists disembodied technical change in labor even after labor input is adjusted for its quality over time. The disembodied technical change occurs in the form of labor usage for the Japanese manufacturing industry during the sampling period. For capital, however, no disembodied technical change suggests that the quality change of capital stock represents well the technical change occurred in capital for the Japanese manufacturing industry during the sampling period.

Short-run and long-run elasticities

Base on the coefficient estimates of the full model, short-run and long-run elasticities are estimated to summarize the dynamic behavior of output supply and input demands. Table III reports estimated elasticities of output supply and input demands for the Japanese manufacturing industry for selected periods.

Own-price output supply elasticity is about 0.0216 in the short run and 0.1578 in the long run. Own-price elasticity of demand for material input is 0.0039 in the short run and −0.0635 in the long run, whereas the elasticities for labor and capital are 0.0000 and 0.0001, respectively in the short run and −0.0024 and −0.0429 in the long run, respectively.

All the elasticities become much larger in the long run, compared to those in the short run. Especially, the demand for both labor and capital does not respond to own-price changes with almost zero elasticity in the short run. The demand for labor and capital is still inelastic in the long run even though its size is much larger in the long run than in the short run. Noticeably, factor input demand responds positively to its own-price changes for every factor in the short run, but the demand becomes negative in the long run. For dynamic models, profit-maximizing behavior does not require input demand to be negative theoretically (Treadway, 1970; Caputo, 1990)[9].

Factor-price output elasticity is the most responsive to capital and the least responsive to labor both in the short run and long run. All the factor inputs are very weak substitutes in production in the short run, except material input and capital, but all of them become complements in the long run. Relation between any pair of factors becomes much stronger in the long run than in the short run, as any cross-price long-run elasticities are much greater than their short-run counterparts.

Table IV reports estimated short- and long-run elasticities of output supply and input demands for the Japanese manufacturing industry by four technology sectors following OECD (2011) to consider difference in investment owing to technology disparity.

Noticeably, the demand for labor is the least elastic for the high-technology sector in the long run whereas the demand for capital is the most elastic, compared with the other sectors, in the long run. The estimations suggest that a large and growing number of firms in the high-technology sector are venture or IT firms consisting mostly of manpower of technicians,

Quantity	Year	Output	Elasticity with respect to the price of Material	Labor	Capital
Short run					
Output	1973–1990	0.0220	−0.0052	−0.0001	−0.0167
	1991–2000	0.0216	−0.0052	−0.0001	−0.0163
	2001–2012	0.0212	−0.0054	−0.0001	−0.0157
	1973–2012	0.0216	−0.0053	−0.0001	−0.0163
Material	1973–1990	0.0074	0.0041	0.0000	−0.0115
	1991–2000	0.0072	0.0041	0.0000	−0.0112
	2001–2012	0.0068	0.0034	0.0000	−0.0102
	1973–2012	0.0072	0.0039	0.0000	−0.0110
Labor	1973–1990	−0.0002	0.0001	0.0000	0.0001
	1991–2000	−0.0002	0.0001	0.0000	0.0001
	2001–2012	−0.0002	0.0001	0.0000	0.0001
	1973–2012	−0.0002	0.0001	0.0000	0.0001
Capital	1973–1990	−0.0002	0.0001	0.0000	0.0001
	1991–2000	−0.0002	0.0001	0.0000	0.0001
	2001–2012	−0.0002	0.0001	0.0000	0.0001
	1973–2012	−0.0002	0.0001	0.0000	0.0001
Long run					
Output	1973–1990	0.1572	−0.0713	−0.0039	−0.0821
	1991–2000	0.1540	−0.0718	−0.0037	−0.0785
	2001–2012	0.1617	−0.0792	−0.0038	−0.0788
	1973–2012	0.1578	−0.0738	−0.0038	−0.0802
Material	1973–1990	0.1369	−0.0613	−0.0033	−0.0723
	1991–2000	0.1341	−0.0618	−0.0032	−0.0691
	2001–2012	0.1406	−0.0680	−0.0033	−0.0693
	1973–2012	0.1374	−0.0635	−0.0033	−0.0706
Labor	1973–1990	0.0843	−0.0409	−0.0024	−0.0410
	1991–2000	0.0823	−0.0414	−0.0023	−0.0386
	2001–2012	0.0875	−0.0459	−0.0023	−0.0393
	1973–2012	0.0842	−0.0422	−0.0024	−0.0397
Capital	1973–1990	0.0930	−0.0455	−0.0034	−0.0441
	1991–2000	0.0916	−0.0461	−0.0032	−0.0422
	2001–2012	0.0973	−0.0512	−0.0033	−0.0429
	1973–2012	0.0933	−0.0470	−0.0034	−0.0429

Table III.
Elasticity of short- and long-run output supply and input demand for the Japanese manufacturing industry for selected periods

programmers, engineers and researchers. These firms concentrate on research activity in designing new products, outsourcing a large portion of manufacturing process. Because high technology firms become more specialized in R&D than manufacturing, the firms require less capital as technology level increases. Thus, the demand for labor is relatively less inelastic for the high-technology sector than the other sectors because quality labor is necessity for the high-technology sector. However, firms in the high-technology sector are most flexible in investing in capital.

On the other hand, for firms for traditional manufacturing in the medium-technology sectors, their production is capital intensive. The sectors utilize machinery and equipment greatly with large plants and assembly lines, and the demand for capital is more elastic than the other sectors.

Table IV.
Elasticity of short- and long-run output supply and input demand for the Japanese manufacturing industry by technology sectors

Quantity	Year	Output	Elasticity with respect to the price of Material	Labor	Capital
Short run					
Output	Low technology	0.0225	−0.0055	−0.0001	−0.0169
	Medium-low tech	0.0213	−0.0053	−0.0001	−0.0159
	Medium-high tech	0.0217	−0.0052	−0.0001	−0.0164
	High technology	0.0206	−0.0050	−0.0001	−0.0156
Material	Low technology	0.0069	0.0043	0.0000	−0.0111
	Medium-low tech	0.0070	0.0037	0.0000	−0.0107
	Medium-high tech	0.0072	0.0041	0.0000	−0.0113
	High technology	0.0078	0.0032	0.0000	−0.0110
Labor	Low technology	−0.0002	0.0001	0.0000	0.0001
	Medium-low tech	−0.0002	0.0001	0.0000	0.0001
	Medium-high tech	−0.0002	0.0001	0.0000	0.0001
	High technology	−0.0002	0.0001	0.0000	0.0001
Capital	Low technology	−0.0002	0.0001	0.0000	0.0001
	Medium-low tech	−0.0002	0.0001	0.0000	0.0001
	Medium-high tech	−0.0002	0.0001	0.0000	0.0001
	High technology	−0.0002	0.0001	0.0000	0.0001
Long run					
Output	Low technology	0.1522	−0.0734	−0.0039	−0.0748
	Medium-low tech	0.1608	−0.0770	−0.0038	−0.0801
	Medium-high tech	0.1554	−0.0723	−0.0039	−0.0792
	High technology	0.1670	−0.0725	−0.0036	−0.0909
Material	Low technology	0.1325	−0.0631	−0.0034	−0.0660
	Medium-low tech	0.1398	−0.0662	−0.0032	−0.0704
	Medium-high tech	0.1353	−0.0622	−0.0033	−0.0698
	High technology	0.1453	−0.0624	−0.0031	−0.0797
Labor	Low technology	0.0801	−0.0420	−0.0024	−0.0357
	Medium-low tech	0.0865	−0.0444	−0.0023	−0.0398
	Medium-high tech	0.0831	−0.0416	−0.0024	−0.0392
	High technology	0.0928	−0.0422	−0.0022	−0.0484
Capital	Low technology	0.0892	−0.0469	−0.0034	−0.0389
	Medium-low tech	0.0962	−0.0495	−0.0032	−0.0435
	Medium-high tech	0.0925	−0.0464	−0.0034	−0.0428
	High technology	0.1012	−0.0469	−0.0032	−0.0512

4. Conclusions

By applying a dynamic factor demand model to the Japanese manufacturing industry, estimation results show that labor and capital are quasi-fixed variables that adjust about 0.2 percent annually to the long-run optimum levels. Estimated adjustment rates are very slow as often presumed about the Japanese manufacturing industry, which uses lifetime employment practice and slow decision-making process in investment decisions.

Labor and capital factors are augmented with quality indexes to allow for embodied technical progress in estimation, but disembodied technical change still remains to be observed for labor. This suggests that a portion of technical change is disembodied or quality indexes do not fully represent technical change itself.

The results also show that elasticities of output supply and factor demand vary greatly depending on time horizon. Factor demand increases when its own price increases in the short run, suggesting that factor adjustment is mostly determined by factor prices in the past due to sluggish factor adjustment. However, factor demand becomes a normal downward-sloping curve in the long run as factor adjustment is completed. Labor and capital are substitutes in the short run but become complements in the long run.

Policy makers should consider time dimension in implementing policy measures that affect output supply and factor demand to assess their impacts accurately. The Japanese government should apply policy measures large enough to boost factor investments when implementing an industrial policy because manufacturers respond to policy shocks very reluctantly to reduce factor adjustment cost. In this respect, this study positively confirms a great corporate tax reduction of 8–18 percent adopted by the current government to boost corporate investment since 2012.

Finally, output loss that firms should bear during the adjustment process provides another concern for policy makers when trying to boost the economy through investment expansion. For this, an industrial policy should be announced well in advance to provide manufacturing firms with sufficient time to prepare for their future adjustments to policy shocks. This can enhance the speed of factor adjustment and reduce the adjustment costs borne by manufacturers during the transition period.

Notes

1. The two expansionary policies are referred as two arrows, and a package of policies including the industrial policies are called as the third arrow.
2. The long-run demand vector for the quasi-fixed inputs is solved by setting $\dot{K}$ equal to zero.
3. Disembodied technical change is captured by vector H in the value function (6).
4. Refer to the JIP database for detailed explanation of the measurement of variables.
5. In the JIP database, there are two variables representing the total labor costs: compensation to employees and total labor cost. Among the two, the total labor cost is used to calculate wage rate because this paper is interested in dynamic adjustment of labor demand. However, two variables are highly correlated with the correlation coefficient of 0.972. Two variables do not make any difference in estimation either.
6. An unrestricted model was also estimated without restricting the symmetricity, but covariance matrix does not have full rank, failing to produce all the standard errors for coefficient estimates.
7. To check the robustness of estimates, lower future discount rates with 2 percent to reflect low Japanese interest rate is used in estimation, producing very small adjustment rates for labor and capital with -0.003 and 0.008, respectively. Also, estimation is done with restricted period after 1991 when overcapacity problem became serious, and adjustment rates for labor and capital remain very small with -0.007 and 0.002, respectively.
8. Adjustment cost discussed above can be referred as internal difficulties of capital adjustment. Adjustment cost also arises from external obstacles to investment including price pressure on capital supply. For details, see Eisner and Strotz (1963).
9. Adjustment cost of quasi-fixed factors can cause a firm to increase (decrease) the demand for factor input as its price rises (falls) if the demand is determined in the past when the price is low (high).

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