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Returns to Scale, Markup and Total Factor Productivity for the Japanese Manufacturing Industry*

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This study utilizes industrial panel data for the Japanese manufacturing industry to decompose the Solow residual into scale economies, markup effects, and technical change. Empirical results show that the economic growth during 1970-1985 was driven mostly by scale economies resulting from large capital investments rather than by pure technological progress. The results also indicate that productivity growth started to decline in 1985 when manufacturers tried to contest eroding price competitiveness with economies of scale, which is much earlier than implied by the original Solow residual. Furthermore, sectoral estimation suggests that productivity grew much faster in the high-growth sector than in the low-growth sector, suggesting that international competition caused the high-growth sector to be more efficient than the low-growth sector.

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1. INTRODUCTION

Researchers generally assume constant returns to scale (CRS), perfect competition, and full employment of factor inputs to estimate the Solow residual. However, the Solow residual fails to provide an accurate measure of changes in total factor productivity (TFP) if one of the assumptions is violated. For instance, previous studies have reported that cyclical factor utilization is the most likely cause of mismeasurement of technology shocks, as measured by the Solow residual (Basu, 1996; Burnside and Eichenbaum, 1994; Paquet and Robidoux, 2001; Sbordone, 1996). Other studies have found that market power and increasing returns to scale (RTS) generate procyclical bias in the Solow residual (Caballero and Lyons, 1992; Hall, 1988, 1989).

The Solow residual, as measured under the given assumptions, usually fluctuates with business cycles, overstating true productivity shocks (e.g., Basu, 1996; Burnside *et al*., 1995; Paquet and Robidoux, 2001; Sbordone, 1996). Nevertheless, studies suggest that the Solow residual with variable capital utilization represents true productivity shocks because it is invariant to demand shocks (e.g., Basu, 1996; Burnside *et al*., 1995).

Recently, however, Kim (2014) shows that the Solow residual with variable capital utilization contains too much bias to yield true productivity shocks, and also that the Solow residual does not necessarily overstate true productivity due to demand shocks. Furthermore, the adjusted Solow residual suggests that true productivity changes can be procyclical even after the restrictive assumptions are relieved.

Following Kim (2014), this study utilizes industrial panel data for the Japanese manufacturing industry to decompose the Solow residual into scale economies, markup effects, and technical change. Thus, this study estimates the influence of scale economies and market competition on the Japanese manufacturing industry, and identifies TFP growth after deleting these factors from the Solow residual.[1)]

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1) This study is in line with previous studies that have tried to estimate the impact of cyclical bias in the Solow residual by controlling for demand shocks to estimate technical shocks better for the Japanese economy (Kawamoto, 2005; Kiyota, 2010; Miyagawa *et al*., 2006).

The Japanese manufacturing industry is far from perfect competition, with many industries characterized by a small number of firms. As a result, markup in the manufacturing industry is likely significantly greater than in the American economy, in which studies show that the impact of markup to productivity is ignorable under variable capital utilization. Regarding RTS, scale economies have been regarded as an important factor in determining productivity change for the Japanese manufacturing industry, because market expansion through increased exports has led to reduction in production costs. This was especially true when the Japanese economy grew fast with heavy capital investment for the period of 1950-1990. Therefore, it seems reasonable to consider RTS and markup along with variable utilization when estimating true technology shocks for the Japanese manufacturing industry.

Previous studies reported a considerable downturn in estimated TFP growth in the aftermath of the bubble in the 1990s and indicated that it was one of the main reasons for lagging Japanese economic growth (e.g., Hayashi and Prescott, 2002; Fukao and Kwon, 2004; Fukao and Saito, 2006; Jorgenson and Nomura, 2005; Nakajima *et al*., 2007; Motonishi, 1999; Okada, 2005; Sato, 2002; Tomohiko *et al*., 2012). The argument is based generally on low estimates of TFP growth, which is usually measured as the Solow residual. Thus, this study will provide additional insights to the literature by investigating the interaction between productivity growth and economies of scale and market competition for the Japanese manufacturing industry.

Empirical results of this study suggest that the measured Solow residual significantly overestimates the total factor productivity growth of the total Japanese manufacturing sector. The results show that the economic growth during 1970-1985 was driven mostly by scale economies resulting from large investments that enabled industries to exploit booming foreign demand, rather than by pure technological progress. The results also indicate that productivity growth started to decline in 1985 when manufacturers tried to contest eroding price competitiveness with economies of scale, which is much earlier than implied by the original Solow residual. Furthermore, sectoral estimation suggests that productivity grew much faster in the high-growth sector than in the low-growth sector, suggesting that international competition caused the high-growth sector to be more efficient than the low-growth sector through the sample years.

This study suggests that the economic growth driven by capital investment to utilize scale economies is subject to decreasing returns if not accompanied by technical progress. Specifically, the study indicates that lacking innovation caused slowdown of the Japanese manufacturing industry despite that the industry had heavily invested to weather severe economic challenges to maintain its productivity growth, especially after the Plaza Accord in 1985. The study also shows that the economy can benefit from enhanced competition as lowered markup boosts productivity growth. Thus, opening the market and promoting its competition will enhance the competitiveness of the economy.

This paper is organized as follows. Section 2 presents the theoretical background of the analysis. Section 3 provides data, empirical applications, and sources of the Solow residual for Japanese manufacturing industries. Section 4 presents our conclusions.

2. THEORETICAL BACKGROUND

This section summarizes the theoretical background for estimating the effects of RTS, markup, and capital utilization along with productivity changes from the Solow residual in realistic economic environments. We begin with the following production function:

$$Y_{it} = A_{it} F(K_{it}, L_{it}), \tag{1}$$

where Y_{it}, K_{it}, and L_{it} represent real output, capital stock, and labor employment for industry *i* at period *t*, respectively; A_{it} is a Hicks-neutral technology index that allows for shifts in the production function. By taking the logarithm on both sides of equation (1), and totally differentiating, we can generate the following growth equation:

$$\Delta y_{it} = \Delta a_{it} + \gamma_{it}(s_{it}^{k}\Delta k_{it} + s_{it}^{l}\Delta l_{it}), \tag{2}$$

where Δx_{it}, as a log-derivative of variable X_{it} with respect to time, represents the growth rate of X_{it}. We use γ_{it}, s_{it}^{l}, and s_{it}^{k} to denote RTS (as represented by average cost divided by marginal cost), the shares of labor, and capital in total cost, respectively. Note that no assumptions of perfect competition are required in equation (2). Because the shares of each factor in the total cost must sum to one, the share of capital in the total cost can be written as $s_{it}^{k} = 1 - s_{it}^{l}$.

RTS multiplied by a factor share in total cost is equivalent to a price markup multiplied by the factor share in total revenue as follows:

$$\gamma_{it}s_{it}^{l} = (\frac{AC}{MC})_{it}(\frac{wL}{ACQ})_{it} = (\frac{P}{MC})_{it}(\frac{wL}{PQ})_{it} = \mu_{it}\phi_{it}^{l}, \tag{3}$$

where AC, MC, P, w, μ, and ϕ^{l} are average cost, marginal cost, output price, wage rate, markup, and labor share in revenue, respectively. Substituting equation (3) into equation (2), we can generate the following growth equation that can simultaneously allow for RTS (γ) and imperfect competition (μ):

$$\Delta y_{it} = \Delta a_{it} + \gamma_{it}\Delta k_{it} + \mu_{it}\phi_{it}^{l}(\Delta l_{it} - \Delta k_{it}). \tag{4}$$

This growth equation was used to estimate RTS and markup by Hall (1988, 1989), and Paquet and Robidoux (2001).

The growth equation can be developed further to consider capital utilization.[2)] Note that the quantity of output produced depends on the effective capital employed when the utilization rate changes over time. Let $E_k = \lambda K$ denote effective capital employed, which determines actual production, instead of nominal capital employed (K), where λ represents a capital-utility ratio. By substituting the effective capital into equation (4), we

[2)] We can also consider underutilization in labor here, but labor is assumed to be paid for by its marginal productivity.

can rewrite the growth equation function as

$$\Delta y_{it} = \Delta a_{it} + \gamma_{it}\Delta k_{it} + \mu_{it}\phi^{l}_{it}(\Delta l_{it} - \Delta k_{it}) + (\gamma_{it} - \mu_{it}\phi^{l}_{it})\Delta\lambda_{it}. \quad (5)$$

This equation shows the relationship between the measure of TFP using the traditional growth accounting framework and the one that takes RTS, imperfect competition, and capacity utilization into account. This can be seen by deleting $\phi^{l}_{it}\Delta l_{it} + \phi^{k}_{it}\Delta k_{it}$ from both sides of the equation and rearranging the equation using $\phi^{k}_{it} = 1 - \phi^{l}_{it}$ to yield the following relationship:

$$SR_{it} = \Delta a_{it} + (\gamma_{it} - 1)\Delta k_{it} + (\mu_{it} - 1)\phi^{l}_{it}(\Delta l_{it} - \Delta k_{it}) + (\gamma_{it} - \mu_{it}\phi^{l}_{it})\Delta\lambda_{it}, \quad (6)$$

where $SR_{it} = \Delta y_{it} - (\phi^{l}_{it}\Delta l_{it} + \phi^{k}_{it}\Delta k_{it})$ is the measured Solow residual under the assumptions of CRS, perfect competition, and full employment of capital. Thus, technical progress (Δa_{it}) differs from the Solow residual (SR_{it}) by three additional terms. The relationship shows that the Solow residual deviates from total factor productivity under conditions of increased RTS in technology, $(\gamma_{it} - 1) > 0$, price markup under imperfect competition, $(\mu_{it} - 1) > 0$, and increased capacity utilization, $\Delta\lambda_{it} > 0$.

Based on equation (6), the measured Solow residual can be decomposed into the effects of RTS, markup, and capital utilization, along with productivity change under realistic economic assumptions. Thus, to estimate true productivity, we must delete the biases arising from RTS, markup, and capacity underutilization, as discussed in the next section.

3. DATA AND EMPIRICAL RESULTS

3.1. Data

We use the Japan Industrial Productivity (JIP) Database 2011, which was compiled in a collaborative effort between the Research Institute of Economy, Trade and Industry (RIETI) and Hitotsubashi University's Global COE Hi-Stat Program. Based on the database, we concentrate our analysis on the manufacturing sector, which is the backbone of the Japanese economy, to obtain a clear picture of productivity fluctuation throughout the sample years. Our final data consist of a panel of 52 Japanese manufacturing industries for the years 1973-2002, from which we can construct all the variables required for estimation.

For estimation, capital stock is given by the real amount of tangible fixed assets, labor inputs are proxied by the number of working hours, and gross value added is used for output. Labor cost consists of employee remuneration, including wages, bonuses, retirement compensation, and other welfare costs, and capital cost is calculated as the sum of interest payments, rents, and depreciation costs. The capital utilization rate is proxied by the capital utility index estimated by the Wharton School method. All variables have been converted into 2000 constant prices to allow for comparison in real terms.

To allow for industry heterogeneity, the sample manufacturing industries are classified into the high-growth sector and the low-growth sector: The high-growth sector is comprised of the industries that have annual growth rates in output greater than the median rate of the total sample industries, whereas the low-growth sector is comprised of the remaining industries. The high-growth sector is comprised of 26 industries in JIPC 8, 9, 11, 13, 18, 19, 20, 22, 24, 25, 26, 28, 37, 39, 42, 43, 44, 46, 50, 53, 54, 55, 56, 57, 58 and 59 (see table A1 for JIP Codes). The high-growth sector contains the chemical industries (22, 24-26 and 28), the iron and steel industries (37 and 39), the machinery industries (42-44), the industrial electronic industries (46, 50 and 53), the automobile industries (54-56), and the precision industries (57 and 58), along with some light industries. This sector represents a core part of Japanese heavy and chemical manufacturing industry that has been perennially competitive in the world market. This suggests that the core sector still carries the growth of the whole manufacturing industry during the sample period. Also included in the high-growth sector are some light industries such as the paper and printing industries (18-20) and the food and beverage industries (8, 9, 11, and 13).

During the sample period, Japanese manufacturing grew by 2.7% per annum. On the other hand, the measured Solow residual increased from 1.2% in the early 1970s, to 2.3% in the late 1970s, and 3.2% in the early 1980s, but decreased thereafter until the late 1990s. The Solow residual fluctuates from year to year over the sampling period: it grew fastest (6.3%) in 1981 and slowest (–2.4%) in 1990 (see table 3).

3.2. Empirical Application

To estimate pure TFP from the measured Solow residual, we must estimate markup and RTS from the dataset because no reported series is available for these, as there is for capital utilization index λ_t. By rearranging and adding an error term, ε_{it}, to equation (5), we can generate the following estimation equation:

$$\Delta y_{it} = \Delta a_{it} + \gamma(\Delta k_{it} + \Delta\lambda_{it}) + \mu\phi_{it}^{l}[\Delta l_{it} - (\Delta k_{it} + \Delta\lambda_{it})] + \varepsilon_{it}, \qquad (7)$$

where technical change can be replaced with a constant. Note that RTS (γ) and markup (μ) are assumed to be constant in estimation. Many researchers have used this equation to estimate RTS and markup (e.g., Basu and Fernald, 1997; Hall, 1988, 1989; Paquet and Robidoux, 2001). When estimating equation (7) by using time-series data, researchers often have to face a multicollinearity problem due to correlations between explanatory variables. However, we do not have this problem because our panel data have enough cross-industry variations, eliminating any correlation between the explanatory variables.[3)]

We adopt instrumental variable (IV) regression for the panel data by utilizing two-stage least-squares (TSLS) estimation. For instruments, we use a

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3) In our data, regressors of $(\Delta k_{it} + \Delta\lambda_{it})$ and $\phi_{it}^{l}[\Delta l_{it} - (\Delta k_{it} + \Delta\lambda_{it})]$ in equation (7) are not correlated with the Pearson correlation coefficient of –0.0178, eliminating multicollinearity when estimating the equation directly.

growth rate of M2 (ΔM_t) and the domestic corporate price index (Δp_t), along with lagged dependent variables ($\Delta k_{it-1} + \Delta\lambda_{it-1}$, $[\Delta l_{it-1} - (\Delta k_{it-1} + \Delta\lambda_{it-1})]$).[4)] To test the validity of the instrumental variables, the null hypothesis that the excluded instruments are uncorrelated with the error term and correctly excluded from the estimated equation is tested. The null hypothesis cannot be rejected at any meaningful significance level for every model, except for Models 1 and 5, which do not have a time variable representing time-varying effects as independent variables (see table 1 and 2). This suggests that the instruments become invalid if the time variable is excluded from the model specifications. Otherwise, the tests show that the instruments are relevant for our estimation.

In estimation, we utilize both fixed effects and random effects models and apply the Hausman test to find a better model.[5)] Table 1 presents coefficient estimates of two-stage instrumental variables estimation for panel data from equation (7). Three different panel data models are estimated including a fixed-effects model with an industry dummy and with both industry and time dummies, and a random effects model. The Hausman test rejects the random effects model (Models 3 and 4) over the fixed effects model (Models 1 and 2) at the 1% statistical significance level. In addition, based on an observation that the growth rate of output decreases over the sample period, we include the time variable to estimate the time-varying effects of the growth (Model 2).

In the fixed effects model without the time variable (Model 1), the markup rate is estimated at 1.031 and is significant at the 1% significance level. The null hypothesis that the markup is equal to 1 cannot be rejected at the 5% significance level, implying the nonexistence of a significantly positive markup in Japanese manufacturing industry during the sample period. The RTS is estimated at 1.726 and significant at the 1% significance level. The null hypothesis of CRS is rejected at the 10% significance level, implying that

4) Finding adequate instruments for a panel of 52 manufacturing industries is limited, even though it is necessary to estimate our growth equation successfully. Our instruments are comparable to those used by Kawamoto (2005) who used the growth rates of oil prices, monetary policy, and banking crisis indicators.

5) In estimation, we also tried the generalized method of moments (GMM) with industry dummies, but failed to have any significant results.

Table 1 Estimates of Markup and Returns to Scale for Japanese Manufacturing

Estimation Equation: $\Delta y_{it} = \beta_0 + \beta_1(\Delta k_{it} + \Delta\lambda_{it}) + \beta_2\phi_{it}^l[\Delta l_{it} - (\Delta k_{it} + \Delta\lambda_{it})] + \varepsilon_{it}$				
Variable	Fixed Effects		Random Effects	
	Model 1	Model 2	Model 3	Model 4
β_0	0.021 (0.015)	10.96 (3.44)*	0.025 (0.016)	7.037 (3.28)**
β_1	1.726 (0.419)*	1.430 (0.397)*	1.643 (0.442)*	1.378 (0.404)*
β_2	1.031 (0.274)*	1.024 (0.259)*	1.060 (0.016)*	0.998 (0.262)*
Time-varying Effect (year)	no	–0.005 (0.002)*	no	–0.003 (0.001)**
Industry Dummy	yes	yes	no	no
R^2	0.231	0.234	0.255	0.260
χ^2	26.28*	33.98*	5.88*	19.97*
Instruments	$P, M, \ \Delta k_{it-1} + \Delta\lambda_{it-1}, \ [\Delta l_{it-1} - (\Delta k_{it-1} + \Delta\lambda_{it-1})]$			
Sargan-Hansen χ^{2} +	10.1*	1.3	4.0	1.2
Hypothesis Test				
Null (H_0)	*p*-value			
CRS: $\hat{\gamma} = 1$	0.083	0.278	0.146	0.349
No Markup: $\hat{\beta}_3 = 1$	0.908	0.927	0.835	0.996

Notes: * Standard errors are in parentheses. Every coefficient estimate is statistically significant at the 1% level of significance. + This is to test the null hypothesis that the instruments are valid or uncorrelated with the error term. Estimation utilizes two-stage instrumental variables estimation for panel data.

the Japanese economy was subject to IRS technology during the sampling period. When the time variable is added to the fixed effects model (Model 2), the coefficients of markup rate and RTS are estimated at 1.024 and 1.430, respectively. The null hypotheses of both no markup and CRS cannot be rejected at the 5% significance level. The test results suggest that Japanese manufacturing industry as a whole is subject to a competitive market and CRS technology.

Table 2 Estimates of Markup and RTS by High-growth and Low-growth Sectors

Variable	High-growth Sector		Low-growth Sector	
	Model 5	Model 6	Model 7	Model 8
β_0	0.014 (0.008)	5.009 (1.69) *	0.0460 (0.027)	17.18 (6.62) *
β_1	1.692 (0.172) *	1.546 (0.176) *	2.367 (1.070) **	1.825 (0.927) **
β_2	2.770 (0.393) *	2.696 (0.388) *	0.973 (0.357) *	0.931 (0.319) **
Time-varying Effect (year)	no	–0.003 (0.001) *	no	–0.009 (0.003) *
Industry Dummy	yes	yes	yes	yes
R^2	0.145	0.157	0.306	0.234
χ^2	126.4*	138.1*	10.09**	14.29*
Instruments	$P, M, \ \Delta k_{it-1} + \Delta\lambda_{it-1}, \ [\Delta l_{it-1} - (\Delta k_{it-1} + \Delta\lambda_{it-1})]$			
Sargan-Hansen χ^2	17.9*	4.1	4.3	1.1
Hypothesis Test				
Null (H_0)	p-value			
CRS: $\hat{\gamma} = 1$	0.0001	0.002	0.201	0.373
No Markup: $\hat{\beta}_3 = 1$	0.000	0.000	0.939	0.828

Notes: Estimation equation is the same with that in table 1. For all others, refer to the notes to table 1.

Noticeably, the coefficient estimate of the time variable is negatively significant at the 1% significance level, which is consistent with the stylized fact that output growth declined steadily over the sample years. This suggests that the growth potential of Japanese manufacturing has gradually declined due to factors other than competitive structure, scale economies, and exogenous technology change. Estimation results also show that coefficient estimates of markup rate and RTS can be exaggerated if the time variable is omitted from the model specification.

Table 2 presents coefficient estimates of the two-stage instrumental variables estimation after dividing the sample industries into high- and low-growth sectors. Again, coefficient estimates of the time variable are negatively significant at the 1% significance level for both sectors. The coefficient estimate of the time-varying effect of the high-growth sector is estimated at –0.003, which is greater than that of the low-growth sector at –0.009.

For the high-growth sector, the coefficients of the markup rate and RTS are estimated at 2.696-2.770 and 1.546-1.692, respectively. The null hypotheses of both no markup and CRS are rejected at the 1% significance level, suggesting that industries in the high-growth sector generally enjoy a positive markup and are subject to IRS technology. On the other hand, those of the markup rate and RTS for the low-growth sector are estimated at 0.931-0.973 and 1.825-2.367, respectively. The null hypotheses of both no-markup and CRS cannot be rejected at any meaningful significance level, suggesting that the industries in the low-growth sector generally operate in a competitive market under CRS technology.

Estimation results indicate that both markup and RTS have significantly positive influences on industry growth for the high-growth sector while they are less significant for the low-growth counterpart. This suggests that industries in the high-growth sector may operate in more profitable markets, making a considerable markup, compared with those in the low-growth sector, which are more likely to maneuver in severely competitive environments without positive markups. However, the RTS are estimated to be much greater in the low-growth sector than in the high-growth sector, suggesting that increasing investment in the latter sector reduces its marginal return. There may be some industries in the low-growth sector that enjoy both great RTS and markup, which must be promising industries, irrespective of their overall low growth rates. They will grow faster in the future with increased investment to exploit greater increasing returns to scale. Rising industries, consisting mostly of venture capital firms, might characterize this industry.[6)]

[6)] Acknowledging the importance of industry-heterogeneity, we tried to estimate industry-specific RTS and markup by interacting industry dummies with slopes but failed to obtain any significant results.

In the next section, we will discuss sources of the Solow residual to estimate TFP after deleting estimated RTS and markup from the residual. Our further analysis will proceed with a fixed effects model with time-varying effects (Models 2, 6, and 8) because the models perform better than other specifications we observed.

3.3. Sources of the Solow Residual

3.3.1.Total manufacturing industry

Based on estimated markup, RTS, and equation (6), we can estimate sources of Solow residual growth. Table 3 presents the sources of the Solow residual over the sample years for all manufacturing industry. In the table, sources of Solow residual growth are divided into the effects of RTS and markup. Then, after eliminating these effects from the residual, we derive the adjusted Solow residual, which should be considered as a better measure for TFP. Decomposition results reveal that RTS has a slightly positive effect on the Solow residual, except during the early 1970s and 2000s, averaging 2% during the sampling period.[7] The effects of RTS, however, change over the period, being largest in the late 1980s, with 3%, when the Japanese economy grew fastest, and then slowing down after that period and becoming negative since the 2000s.

Markup has negligible effects on Solow residual growth, averaging 0.00% overall, as expected from the modest estimate of markup. Thus, markup does not provide any discernable bias in the measured Solow residual growth as productivity shocks for the Japanese manufacturing sector. Note that this does not mean that there is no bias in the Solow residual as a TFP measure because the above non-effects results are derived from the weighted average of the total sample industry, in which biases among industries canceled each other out. This will be clear when we decompose the Solow residual based on sectors more homogenous in growth rate, as reported in tables 4 and A1.

[7] The impact of RTS on the residual is positive because the average estimated RTS is greater than one.

Table 3 Sources of Solow Residual Growth for the Total Japanese Manufacturing

Period	Output	SR	Solow Residual (SR)					
			RTS		Markup		TFP	
1974-1975	–0.040	0.012	–0.022	(–189)	0.000	(1)	0.034	(294)
1976-1980	0.058	0.023	0.019	(85)	0.001	(4)	0.003	(14)
1981-1985	0.057	0.032	0.014	(45)	0.000	(–1)	0.017	(52)
1986-1990	0.049	–0.005	0.030	(–547)	0.000	(7)	–0.035	(643)
1991-1995	0.006	–0.004	0.010	(–271)	0.000	(9)	–0.013	(362)
1996-2000	0.014	0.007	0.007	(103)	0.000	(–3)	0.000	(0)
2001-2002	–0.027	–0.003	–0.009	(330)	0.000	(3)	0.006	(–234)
1974-2002	0.027	0.010	0.012	(120)	0.000	(0)	–0.002	(–20)

Notes: Decomposition is based on coefficients estimates of Model 2 in table 1. Numbers in parentheses represent the shares of determinant sources in the Solow residual growth in per cent. Except simple averaged intervals, all numbers are weighted averages with weight of gross value added.

We can estimate an adjusted Solow residual by eliminating the combined effects of RTS and markup from the measured Solow residual. The adjusted Solow residual representing TFP in table 3 grew fastest, by 3.4% per annum, in the early 1970s, followed by growth rates of 1.7% in the early 1980s and 0.6% in the early 2000s. The adjusted Solow residual was lowest, at –3.5%, in the late 1980s, followed by –1.3% in the early 1990s, and 0.0% in the late 1990s. The adjusted TFP grew by –0.2% per year over the whole period, which is much slower than the original TFP measure, which grew by 1.0% per annum. The gap between the two measures varied greatly across periods: it was greatest (6.5%) in the late 1980s and lowest (0.3%) in the early 1980s. The comparison of the two residuals reveals that the Solow residual significantly overestimates the total factor productivity growth of the Japanese manufacturing sector.

The adjusted Solow residual is estimated at –0.2% per annum during the sample period. According to our new productivity measure, TFP growth accounts for –20% of the original Solow residual growth in Japanese manufacturing that grew by 1.0% per annum, which accounts for about 36% of the growth.

Previously, Kawamoto (2005) adjusted the Solow residual to account for scale effects and markup effects by using the same JIP dataset for the period 1973-1998. The study estimated RTS as 1.06 for the durable manufacturing sector and 0.81 for the nondurable manufacturing sector. After controlling for increasing returns, imperfect competition and cyclical utilization, it reported TFP at 3.6% for durable manufacturing and 2.3% for the nondurable sector, suggesting that technological progress was underestimated due to cyclical utilization and reallocation of inputs from the productive manufacturing sector to the less productive services sector. Kiyota (2010) decomposed the Solow residual into markup effects, scale economies, and productivity by using an extensive survey panel of Japanese firms from 1994-2006. Focusing on the manufacturing sector, the study reported that average markup and scale economies ranged from 0.825-1.104 and 0.782-1.012, respectively. The study rejected the null hypothesis of no-markup and CRS in more than half of the sampled manufacturing industries. It also showed that the adjusted TFP is procyclical, even after adjusting markup and scale effects from the measured Solow residual. Miyagawa *et al*. (2006) estimated the production function by controlling for RTS and capital utilization for 33 Japanese manufacturing industries for the period 1883-2002. The study showed that many industries are subject to CRS with estimated RTS at 1.14 for the durable manufacturing sector and 1.18 for the non-durable manufacturing sector. However, the study suggested that the conventional Solow residual is affected by IRS in some industries. Nakajima *et al*. (2007) estimated technical change, RTS and TFP for Japanese manufacturing firms for the period 1988-1998. The study reported low technological change in many industries in the 1980s, resulting from overinvestment during the bubble. Estimated scale effects in this study are more or less consistent with ours even though it rejected CRS technology in favor of DRS.

In contrast to the literature, this study cannot reject the null hypothesis of CRS even though the RTS estimate is greater than in previous studies. As indicated in previous studies, the study confirms that RTS varies widely across manufacturing industries. The study also finds that the measured Solow residual overestimates the productivity of Japanese manufacturing industry.

The estimated TFP in table 3 reflects Japanese economic trends well during the sample period. In the aftermath of the oil shock in 1973 and the ensuing negative growth, the Japanese economy moved away from huge, heavy and energy-consuming industries towards lean, light and energy-saving industries, successfully building a more efficient manufacturing industry. At the same time, both Japanese management techniques and the total quality management system were utilized widely to enhance efficiency in the production process. With these structural reforms and process innovations, the Japanese economy was able to recover a growth trend similar to that before the shock, even accounting for two-thirds of the total world trade surplus in the late 1970s.

Positive estimates of both the Solow residual and adjusted TFP in those periods reflect the successful restructuring of the economy. However, the Solow residual overstates true productivity by including the impacts of restructuring on economic growth, which remained substantially positive from the late 1970s until the late 1980s. After deleting these impacts, the adjusted TFP becomes much lower than the original Solow residual, better representing true productivity trends. Likewise, before the reforms in 1974-1975, when the economy depended on huge capital investments with decreasing returns, the productivity of the economy as measured by the adjusted TFP is considerably greater than the measured Solow residual if scale diseconomies are eliminated from the residual.

Specifically, the measured Solow residuals are 1.2%, 2.3% and 3.2% during 1974-1975, 1977-1980, and 1981-1985, respectively, whereas the adjusted TFPs are 3.4%, 0.3%, and 1.7%, respectively, for the same periods. This suggests that the economic growth was driven largely by scale economies resulting from successful restructuring and large investments to exploit booming foreign demand rather than by pure technological progress.

The Plaza Accord in 1985 was a turning point for the Japanese economy. Facing rapid appreciation of its currency, Japanese manufacturers tried to automate production processes with massive investments to cope with eroding price competitiveness.[8)] At the same time, many uncompetitive manufacturers migrated to foreign countries, causing the domestic manufacturers to become more capital-oriented. By including this increase in scale economies, the Solow residual underestimates declining productivity when it is measured to grow by –0.5% per annum for the years 1986-1990. Controlling for the scale economies from the residual, the adjusted TFP is measured as growing by –3.5% per annum, which is significantly lower than the Solow residual. Estimation also shows that TFP growth dropped to a negative rate simultaneously with the Plaza Accord of 1985, while the Solow residual became negative only after the burst of the bubble in the early 1990s.[9)]

After the collapse of the bubble in the early 1990s, the Japanese economy plunged into severe depression, and even firms with great technological capabilities went out of business because of short-term liquidity difficulties. The depression that pushed firms to bankruptcy and shrank capital investment persisted throughout the 1990s. The collapse of the economy in both financial and real sectors delayed technical progress as well, as is well shown by the negative estimates of TFP for many years in the 1990s. In turn, lagging technological progress made it difficult for the economy to escape from the recession.

According to our estimation of TFP, technological progress in Japanese manufacturing industry might have been exaggerated. The negative TFP growth, on average, throughout the sample period suggests that firms should have pursued and achieved technology progress to recover from the economic recession, rather than exploit their scale economies. For this, firms should have invested more in R&D, IT, and new technology and improved the quality of workers and managers.

Estimated TFP also implies that the enduring depression of the Japanese

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[8)] For the behavior of Japanese Yen since 1980, see Kim and Kang (1980).

[9)] For a historical perspective on Japanese economic growth, see Fukao and Saito (2006), Lee (2002) and Sato (2002).

economy in the 1990s was deeply rooted in the sharp productivity decline that started in 1985, which is much earlier than the bursting of the financial bubble in the early 1990s, which is often considered the direct cause of the depression. This suggests that the depression in the 1990s was not entirely or directly caused by the financial collapse but, instead, had much to do with productivity decline, which started with the new economic paradigm of the Plaza Accord of 1985. Researchers agree that the depression started with the bursting of the financial bubble, but many of them presume the depression in the real sector also started at the same time along with the sudden productivity drop. However, our estimation shows that productivity began to decline much earlier, with the formation of the financial bubble itself in the middle of the 1980s.[10)] This underscores the importance of productivity growth to sustain economic growth, even for an economy that has rapidly transformed itself towards becoming financially oriented.

In sum, empirical findings show, first, that there exists a significant discrepancy between the Solow residual and the adjusted TFP; the former overstates the latter in 20 out of 28 sample years (see figure 1). Specifically, our estimation shows that scale effects have a significant positive bias on the Solow residual for Japanese manufacturing industry. On the other hand, markup does not have a discernable influence on the Solow residual at the total manufacturing level. Second, the adjusted TFP shows that productivity started to decline much earlier than that of the original Solow residual. Third, the two productivity measures still co-move despite the significant gap between the Solow residual and the estimated TFP. This implies that the adjusted TFP still reflects business cycles, indicating the possibility that productivity shocks move together with business cycles procyclically.[11)]

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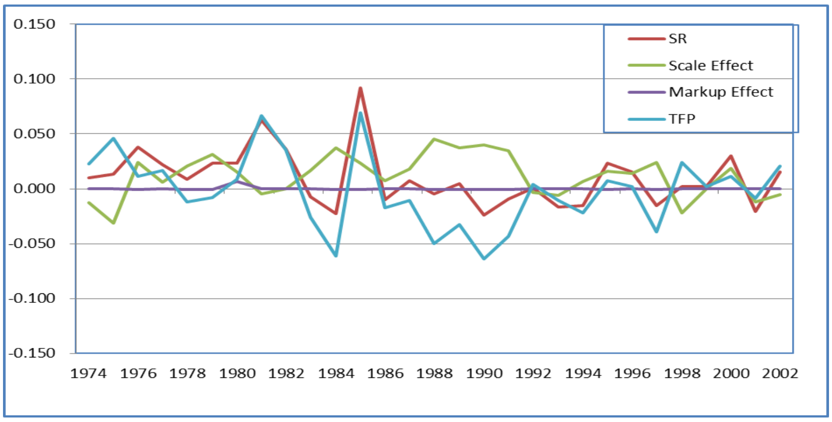
10) Regardless of the timing of the slowdown, our results confirm that the Japanese economic depression is related to its sluggish productivity growth (Fukao and Saito, 2006; Hayashi and Prescott, 2002; Jorgenson and Nomura, 2007), but are more in line with the argument that the depression resulted from excess capacity that started when the bubble was forming prior to its bursting (Nakajima *et al*., 2007).

11) The two productivity series are strongly correlated with the Pearson correlation coefficient of 0.796.

Figure 1 Sources of Solow Residual Growth for the Total Japanese Manufacturing Industry (1974-2002)



3.3.2. High-growth sector vs. low-growth sector

Table 4 presents sources of the Solow residual over the sample years for the high-growth and low-growth manufacturing sectors based on coefficient estimates of Models 6 and 8, respectively. In parentheses are the sources of the low-growth sector.

Table 4 Sources of Solow Residual Growth by High- and Low-growth Sectors

Period	SR		Solow Residual (SR)					
			RTS		Markup		TFP	
1974-1975	0.007	(0.016)	–0.024	(–0.047)	–0.013	(–0.001)	0.044	(0.065)
1976-1980	0.056	(–0.015)	0.039	(0.013)	–0.031	(–0.009)	0.048	(–0.033)
1981-1985	0.025	(0.043)	0.032	(–0.005)	–0.027	(0.000)	0.020	(0.040)
1986-1990	–0.005	(–0.006)	0.043	(0.043)	–0.032	(0.001)	–0.016	(–0.050)
1991-1995	–0.010	(0.008)	0.008	(0.028)	–0.020	(0.001)	0.001	(–0.021)
1996-2000	–0.005	(0.023)	0.010	(0.011)	–0.015	(0.001)	0.001	(0.011)
2001-2002	–0.012	(0.011)	–0.009	(–0.021)	–0.002	(0.001)	0.000	(0.031)
1974-2002	0.010	(0.011)	0.020	(0.011)	–0.023	(–0.001)	0.012	(–0.002)

Notes: Estimates for the low-growth sector are in parentheses, and estimates for the high- and low-growth sectors are based on Model 6 and 8 in table 2, respectively. For all others, refer to the notes to table 3.

The Solow residual grew by 1.0% and 1.1% per annum for the high-growth and low-growth sectors, respectively, surprisingly suggesting that productivity grew faster in the low-growth sector than in the high-growth sector. However, the adjusted TFP grew by 1.2% per annum for the high-growth sector whereas it grew by –0.2% per annum for the low-growth sector, indicating a significant gap in productivity growth that favors the high-growth sector. This again shows that the adjusted TFP better represents the true productivity growth than the Solow residual, which is biased by scale economies and markup effects as productivity measures.

Scale effects are 2.0% for the sample period for the high-growth sector and 1.1% for the low-growth sector, suggesting that the high-growth sector enjoyed scale economies about twice as large as the low-growth sector. This implies that the high-growth sector operated much closer to the optimal scale to produce its output, either through adequate investment or restructuring, as we discussed in the earlier section, while the low-growth sector suffered from lack of investments and reforms.

On the other hand, markup effects are –2.3% for the high-growth sector and –0.1% for the low-growth sector, indicating that the high-growth sector witnessed shrinking markup over the sample period. This implies that the high-growth sector had to lower its price in the international market to compete with products from less developed countries, thus eroding its markup.[12] Consequently, international competition caused the high-growth sector to be more efficient than the low-growth sector throughout the sample years.[13]

Despite enhanced competition, and resulting lowered markup, the high-growth sector experienced about the same growth in the Solow residual as the low-growth sector due to the difference in scale economies. Scale effects are about two times greater in the high-growth sector than in the low-growth sector, suggesting that the high-growth sector invested much more

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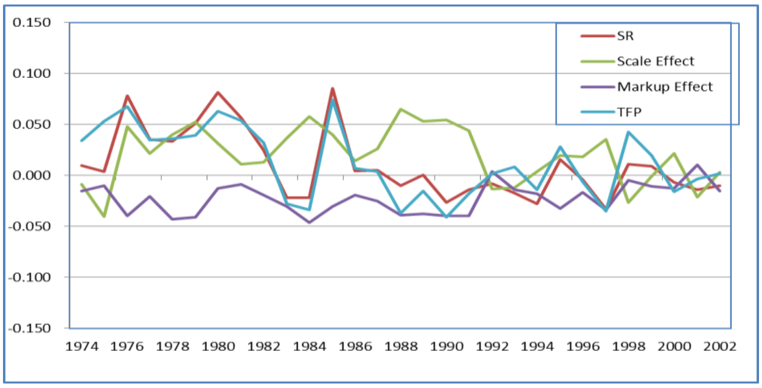
[12] This observation is consistent with Okada (2005) and Tomohiko *et al*. (2012), who reported a positive relationship between market competition and productivity growth.

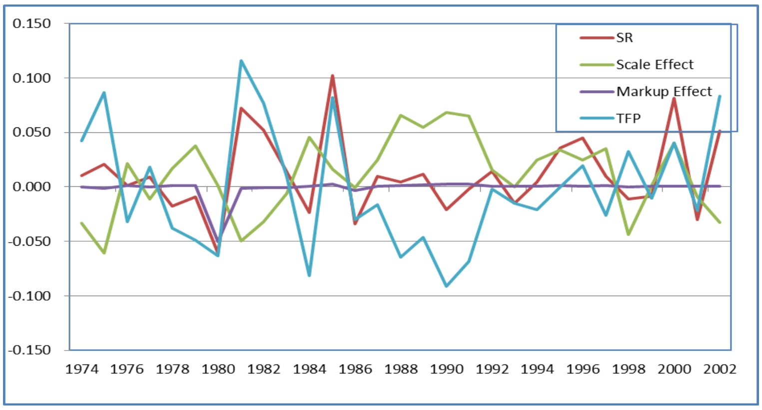
[13] The high-growth sector represents the core of the Japanese manufacturing industry, which drives its growth mostly from foreign exports.

Figure 2 Sources of Solow Residual Growth for the Total Japanese Manufacturing Industry by High-growth and Low-growth Sectors (1974-2002)

(a) High-growth Sector



(b) Low-growth Sector



in new technology and restructured itself more vigorously. After deleting these two effects, the adjusted TFP shows that productivity grew much faster in the high-growth sector than in the low-growth sector. This underscores the importance of market competition in enhancing productivity growth.

Figure 2 shows that the decline of TFP was contained at a much smaller scale for the high-growth sector than for the low-growth sector throughout the depressions. This suggests that the former sector restructured itself continuously to meet economic crises originating from the oil shocks in the 1970s, currency appreciation in the late 1980s, and the bursting of the bubble in the 1990s. This indicates that the high-growth sector owned enough technological and financial resources to execute the necessary reforms to weather mounting challenges while the low-growth sector suffered from a lack of resources.[14)]

Figure 2 also shows that the adjusted TFP co-moved with the Solow residual in the high-growth sector while the co-movement became non-existent in the low-growth sector.[15)] This suggests that productivity growth is influenced more strongly by business cycles in the high-growth sector than the low-growth sector, showing again that the former sector can be more opportunistic in riding or weathering economic cycles. However, the Solow residual is greater than the adjusted TFP in most of the sample years, confirming that the residual overstates the true productivity growth due to demand conditions, as reflected in scale economies and markup effects.

To allow for industry-heterogeneity, we estimate sources of output and Solow residual growth across industries for the entire sampling period and present in table A1.

4. CONCLUSIONS

This paper investigated the sources of Solow residual growth in the Japanese manufacturing sector to estimate productivity growth for the sector by simultaneously considering returns to scale, imperfect competition, and underutilization of factor inputs.

Empirical results reveal that RTS has a slightly positive effect on the Solow residual, except during the early 1970s and 2000s, which averaged 1.2%

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14) This explanation about the gap in TFP growth between the high- and low-growth sectors is consistent with that of Motonishi (1999), who suggested that financial constraints are only significant for small firms during the credit crunch after the bubble burst.

15) Detailed discussion on individual estimation is omitted here to save space.

during the sampling period. The effects of RTS, however, change over the period, being largest in the late 1980s when the Japanese economy grew fastest and then decreasing after that period and becoming negative since the 2000s. Markup has negligible effects on Solow residual growth, averaging at 0.00% overall due to the small estimated markup. When we adjust the Solow residual by eliminating the combined effects of RTS, markup, and capital utilization, the adjusted Solow residual turns out to be smaller than the original. The adjusted Solow residual grew by –0.2% per year over the whole period, which is slower than the original TFP measure, which grew by 1.0% per annum.

This study suggests that the measured Solow residual significantly overestimates the total factor productivity growth of the total Japanese manufacturing sector. The study shows that the economic growth during 1970-1985 was driven mostly by scale economies resulting from successful restructuring and large investments that enabled industries to weather looming crises and exploit booming foreign demand, rather than by pure technological progress. In addition, the study also indicates that productivity growth started to decline in 1985 when manufacturers tried to contest eroding price competitiveness with economies of scale, which is much earlier than implied by the original Solow residual.

Sector-wise estimation shows that the high-growth sector, despite its lowering markup, registered about the same Solow residual growth as the low-growth sector. This was possible because scale effects are about twice as great in the high-growth sector as those in the low-growth sector, indicating that the high-growth sector invested much more in new technology and restructured itself much more vigorously over the years. The high-growth sector had to lower its prices in the international market to compete with products from less developed countries, as observed by the decreasing markup. By deleting these two effects, the adjusted TFP shows that productivity grew much faster in the high-growth sector than in the low-growth sector. This shows that international competition caused the high-growth sector to be more efficient than the low-growth sector through the sample years.

This study suggests that the measured Solow residual contains significant bias in representing the total factor productivity growth of the Japanese manufacturing sector due to scale economies and markup effects. The study also shows that the bias varies across industrial sectors. Therefore, future studies should estimate markup and scale economies at the individual industry level to allow for industry heterogeneity. This requires firm-level data to extend the degree of freedom that is necessary to estimate industry-specific RTS and markup.

APPENDIX

Table A1 Sources of Output and Solow Residual Growth across Industry (1973-2002)

JIPC	Industry	Output	Sources of Output Growth			Sources of Solow Residual		
			Labor	Capital	SR	RTS	Markup	TFP
8	Livestock Products	0.017	0.002	0.024	–0.005	0.015	0.000	–0.020
9	Seafood Products	0.034	–0.003	0.004	0.056	0.003	0.000	0.053
10	Flour and Grain Mill Products	0.006	0.000	0.03	–0.023	0.013	0.000	–0.036
11	Miscellaneous Foods	0.014	0.001	0.03	–0.021	0.017	0.000	–0.038
12	Animal Foods and Fertilizers	–0.006	–0.001	0.045	–0.038	0.022	0.000	–0.060
13	Beverages	0.009	–0.001	0.044	–0.030	0.020	0.000	–0.050
14	Tobacco	–0.008	–0.001	0.037	–0.037	0.016	0.000	–0.053
15	Textile Products	–0.008	–0.015	0.001	0.005	0.000	0.000	0.005
16	Lumber and Wood	–0.013	–0.015	–0.002	0.009	–0.001	0.000	0.010
17	Furniture and Fixtures	–0.014	–0.009	0.011	–0.016	0.007	0.000	–0.023
18	Pulp and Paper	0.009	–0.006	0.033	–0.019	0.020	0.000	–0.038
19	Paper Products	0.013	–0.003	0.024	–0.004	0.014	0.000	–0.018
20	Printing and Bookbinding	0.016	–0.003	0.026	–0.006	0.019	0.000	–0.024
21	Leather and Leather Products	–0.021	–0.008	0.024	–0.037	0.014	0.000	–0.051
22	Rubber Products	0.018	–0.005	0.019	–0.003	0.013	0.000	–0.016
23	Chemical Fertilizers	–0.006	–0.012	0.001	0.025	–0.002	0.000	0.027
24	Basic Inorganic Chemicals	0.019	–0.005	0.013	0.033	0.007	0.000	0.027
25	Basic Organic Chemicals	0.137	–0.024	0.03	0.203	0.017	–0.001	0.190
26	Organic Chemicals	0.028	–0.003	0.022	0.031	0.012	0.000	0.019

27	Chemical Fibers	0.027	–0.033	0.007	0.066	0.000	–0.001	0.069
28	Miscellaneous Chemical	0.044	0.000	0.021	0.030	0.011	0.000	0.019
29	Pharmaceutical Products	0.088	–0.001	0.04	0.058	0.023	0.000	0.035
30	Petroleum Products	–0.018	0.000	0.016	–0.035	0.007	0.000	–0.042
31	Coal Products	–0.029	–0.002	0.005	–0.023	0.003	0.000	–0.025
32	Glass and Its Products	0.078	–0.003	0.016	0.051	0.009	0.000	0.042
33	Cement and Its Products	–0.015	–0.007	0.002	–0.006	0.001	0.000	–0.007
34	Pottery	0.013	–0.012	–0.009	0.032	–0.007	0.000	0.039
35	Miscell Ceramic, Stone, Clay	–0.006	–0.008	–0.002	0.005	–0.002	0.000	0.007
36	Pig Iron and Crude Steel	–0.029	–0.018	–0.016	0.018	–0.017	0.000	0.036
37	Miscellaneous Iron and Steel	0.013	–0.004	0.038	–0.013	0.021	0.000	–0.034
38	Smelting of Non-ferrous Metal	0.078	–0.023	–0.021	0.063	0.009	–0.002	0.055
39	Non-ferrous Metal products	0.02	–0.004	0.024	–0.009	0.013	0.000	–0.022
40	Fabricated Constructional Metal	0.001	–0.006	0.005	0.016	0.005	0.000	0.011
41	Miscellaneous Fabricated Metal	0.011	–0.005	0.015	–0.001	0.010	0.000	–0.010
42	General Industry Machinery	0.036	0.000	0.016	0.016	0.011	0.000	0.006
43	Special Industry Machinery	0.047	–0.003	0.015	0.008	0.008	0.000	0.000
44	Miscellaneous Machinery	0.027	0.001	0.019	0.007	0.011	0.000	–0.004
45	Office Industry Machines	0.098	0.976	–0.092	0.088	0.012	0.034	0.077
46	Electrical Industrial Apparatus	0.028	–0.01	0.036	–0.004	0.024	–0.001	–0.027
47	Household Electric Appliances	0.161	–0.004	–0.04	0.104	0.000	–0.001	0.093
48	Computer Equipment	0.187	0.011	–0.142	0.219	–0.018	–0.001	0.212
49	Communication Equipment	0.153	0.002	0.015	0.155	0.004	0.000	0.152
50	Electronic Equipment	0.075	0.000	0.037	0.046	0.022	0.000	0.024
51	Semiconductor Devices	0.204	0.008	–0.063	0.173	0.016	–0.001	0.144
52	Electronic Parts	0.138	0.010	0.023	0.142	0.027	0.000	0.118
53	Miscell Electrical Machinery	0.041	–0.003	0.041	–0.002	0.025	0.000	–0.026
54	Motor Vehicles	0.078	–0.001	0.024	0.041	0.013	0.000	0.028
55	Motor Vehicle Parts	0.051	0.004	0.033	0.020	0.022	0.000	–0.002
56	Other Transportation Equipment	0.048	–0.009	0.011	0.039	0.009	–0.001	0.030
57	Precision Machinery	0.039	–0.009	0.026	0.014	0.019	–0.001	–0.005
58	Plastic Products	0.029	0.000	0.026	–0.004	0.016	0.000	–0.019
59	Miscellaneous Manufacturing	0.031	–0.010	0.014	0.039	0.009	0.000	0.030

Note: All numbers are weighted averages with yearly weight of gross value added.

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