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Determinants of Price Markups at Japanese Firms and Implications for Productivity*

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Abstract

In this paper, we analyze determinants of price markups and their relationship with aggregate productivity based on long-term estimates of price markups and wage markdowns for Japanese firms. The main results are summarized as follows. First, we find that, in order to maintain profitability, Japanese firms have raised their wage markdowns while their price markups have declined since the late 1990s. Both the U.S. and Japanese firms experienced rising wage markdowns, but Japanese firms differ in that they experienced declining price markups. Second, regarding determinants of price markups for Japanese firms, we find that firms' investment in intangible assets has significantly contributed to raising price markups across industries. Meanwhile, in manufacturing, a decline in Japan's share of global exports due to changes in the international competitive environment has worked as a force for exerting downward pressure on price markups. In non-manufacturing, the number of stores per capita increased which worked as a force for enhancing the severity of price competition and exerted downward pressure on price markups. Third, we find that TFP growth in Japan was mainly driven by (1) the efficiency improvements from declining price markups, and (2) contributions from technological progress was much smaller than those of the United States. We also show that Japan's technological frontier, as measured by actual output and price markups, did not expand as much as in the United States.

JEL Classifications：E24, E31, J30, J42, L12

Keywords: price markup; wage markdown; competition; productivity; resource allocation

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1 Introduction

Fluctuations of firms' price markups (the gap between sales price and marginal cost) reflect changes in the competitive environment and pricing stance in the product market. Measuring long-term trend of price markups and their determinants can provide useful insights into Japan's economy and prices over the past 25 years. Price markups of Japanese firms appear to have declined moderately in the long run, which contrasts with those in the United States and Europe, where price markups have risen due to the activities of "superstar firms" with strong price bargaining power (De Loecker, Eeckout, and Unger [2020], Kouvavas et al. [2021], Nakamura and Ohashi [2019]). In Aoki, Hogen, and Takatomi [2023], we jointly estimated price markups and wage markdowns using a big dataset -- covering about 80 percent of the "Economic Census" in terms of sales volume -- and showed that Japanese firms have experienced declining price markups but have secured their profits by raising wage markdowns -- the gap between their marginal revenue product of labor (MRPL) and nominal wages --.[1] In this paper, we provide additional analysis on the following three issues.

The first issue is to measure long-term trends of price markups and wage markdowns in Japan. In Aoki, Hogen, and Takatomi [2023], the sample period started only in 2005 due to data limitations. In this regard, given that the Bank of Japan's "Broad Perspective Review" is conducted with the scope of this past quarter century, backcasting these estimates is a necessary process because Japan experienced various fluctuations in the economy in the 1990s, including the bursting of the Heisei asset price bubble and a domestic financial crisis in the late 1990s. Therefore, in this paper, we conduct long-term estimation of price markups and wage markdowns using financial data for Japanese listed firms since the 1970s. We find that Japanese firms have raised their wage markdowns while their price markups have declined since the late 1990s. Compared to the U.S., Japanese firms share the same trend of rising wage markdowns, but differ in that Japanese firms experienced declining price markups. These differences in markup trends may reflect differences in the competitive environment (e.g., intensifying competition from overseas) and investment activities (intangible assets, research and development [R&D]).

The second issue is to examine determinants of price markups in Japan. Theoretically, price markups could fluctuate with changes in the competitive environment and firms'

[1] Wage markdowns are expected to reflect strength of firm's wage bargaining power in the labor market.

market shares.[2] In addition, the driving mechanism could also be industry-specific. For example, in manufacturing, changes in the global competitive environment could be a primary factor (Weinberger [2020], Obstfeld [2010]). For non-manufacturing, the number of firms in a given region may also determine the degree of price competition (Kiyota, Nakajima, and Nishimura [2009]). There may also be an investment channel through which firms' R&D and investment in intangible assets may affect their competitiveness or market share (Bloom, Van Reenen, and Williams [2019], Oikawa and Ueda [2019], Crouzet and Eberly [2018], De Ridder [2024]). With the above channels in mind, this paper examines determinants of Japanese firms' price markups using firm-level panel data. We find that, regardless of industry, investment in intangible assets has been a significant force in increasing price markups. Industry-specific mechanisms also appear to have been significant. That is, for manufacturing, a decline in Japan's share of world exports due to changes in the international competitive environment has worked as a force for putting downward pressure on price markups. In the non-manufacturing sector, the number of stores per capita was elevated, which acted as a force for increasing the severity of price competition and exerted downward pressure on price markups. In sum, even in the face of intense price competition, some firms were able to offset downward pressure on price markups by investing in intangible assets or R&D.

The third issue concerns the relationship between price markups and aggregate productivity. In theory, a price markup results from a monopolistic environment in which output is lower than the efficient level of output (derived under perfect competition). In this environment, changes in the markup have an impact on aggregate productivity. On this point, Baqaee and Farhi [2020], using a general equilibrium model with industrial linkages, show that fluctuations in total factor productivity (TFP) growth can be decomposed into two parts: (1) one related to price markups (including fluctuations in wage markups and the spillovers between firms through production networks), and (2) the other due to pure technological growth. In other words, this method can be viewed as a means of extracting pure technological growth by removing monopoly distortions from TFP fluctuations (e.g., the Solow residual). The paper shows that TFP growth in the United States has been driven by both (1) efficiency improvements in high-margin firms (both reductions in price markups and expansions of scale) and (2) pure technological progress. In this paper, we perform the same type of exercise for Japan and find that (1) TFP growth has been driven mainly by the efficiency improvements from the reduction of price markups, and (2) the

[2] In oligopolistic competition models, as the market share declines due to increased competition or other factors, the markup declines due to an increase in demand elasticity (Atkeson and Burstein [2008], Edmond, Midrigan, and Xu [2015], Syverson [2019], Fujiwara and Matsuyama [2022]).

contributions from pure technological progress have been much smaller than those of the United States. This suggests that, compared to the United States, the improvement in Japan's productivity has been driven by the efficiency of production processes rather than by demand creating innovations from R&D. We also show that Japan's technological frontier, as measured by actual output and markups, has not expanded as much as that of the United States.

The remainder of this paper is organized as follows: Section 2 presents the methodology and results of the measurement of price markups and wage markdowns; Section 3 describes the methodology and results of the analysis of determinants of price markups; Section 4 discusses the relationship between price markups and aggregate productivity; Section 5 concludes.

2 Long-run Trend in Price Markups and Wage Markdowns in Japan

2.1 Model

When measuring price markups using production functions, estimates could vary depending on the underlying structure of the model. In the literature, there are currently two strands of market structure assumptions: (A) a case where perfect competition is assumed for all factor markets and (B) a case where firms have monopsony power in the labor market and perfect competition for other factors. In case (B), price markups can be measured by distinguishing wage markdowns (Yeh, Macaluso, and Hershbein [2022], Aoki, Hogen, and Takatomi [2023], Mertens [2022]). On the other hand, in the case of (A), estimates of price markups include the impact of wage markdowns, so the markup is conceptually equivalent to a mirror image of the labor share (De Loecker, Eeckhout, and Mongey [2021], Nakamura and Ohashi [2019], Cabinet Office of Japan [2023]).

In this paper, we assume the market structure as in case (B), and estimate price markups and wage markdowns using the production function approach as follows. We denote the production function for firm i as,

$$Y_{it} = A_{it} L_{it}^{\theta^L} X_{it}^{\theta^X} K_{it}^{\theta^K}, \quad (1)$$

where Y_{it} is the level of output, A_{it} is TFP, L_{it} is labor input, X_{it} is intermediate input, K_{it} is capital stock, and θ^k is the output elasticity of production factor k $(k = L, X, K)$. Output and factors of production are in real terms. The product market is assumed to be monopoly, firms have monopsony power in the labor market, and other factors of production is assumed to be under perfect competition. In this setup, as a result of firms' profit maximization and cost minimization, the price markup (μ_{it}) and the wage markdown (ν_{it}) can be expressed as,

$$\mu_{it} = \theta^X \frac{P_{it}Y_{it}}{P_{it}^X X_{it}}, \ \nu_{it} = \left(\theta^L \frac{P_{it}Y_{it}}{w_{it}L_{it}}\right)/\mu_{it}, \tag{2}$$

where P_{it} is the sales price of the good, P_{it}^X is the price of the intermediate good, and w_{it} is the nominal wage.

2.2 Data

In the literature, it is common to use listed firms' financial data with a relatively long time series to measure long-term trends in price markups (De Loecker, Eeckout, and Unger [2020], Kouvavas *et al.* [2021]). In this paper, we use the "Corporate Financial Databank" of the Development Bank of Japan, which contains financial statements of listed firms in Japan since the 1970s. The coverage of this database in terms of sales is about 20 percent of that of the "Economic Census" (as of 2016), but the industry composition within large firms is similar to that obtained from the annual report of the *Financial Statements Statistics of Corporations by Industry* (see Appendix 1). In addition, according to the estimation results of Aoki, Hogen, and Takatomi [2023], the time-series trends in price markups and in wage markdowns showed a high correlation across firm sizes. Given this observation, we believe that long-term trends in the corporate sector can be captured to some extent by using data from listed firms.

With regard to estimating price markups using the production function approach, Bond *et al.* [2021] point out a possibility that price markups are not estimated accurately when the elasticity of the production function is calculated using firms' financial data instead of quantity data. In contrast, De Ridder, Grassi, and Morzenti [2024] note that, although the level of price markups may be distorted by deflating the sales volume with a deflator, doing so is not an issue in terms of trends in price markups and in the distribution among firms. Taking these discussions into account, Sections 2 and 3 of this paper focus on changes in price markups. In addition, Yeh, Macaluso, and Hershbein [2022] show that wage markdowns can be measured without bias using firms' financial data.

2.3 Estimation of the Production Function

Estimation of the production function was conducted using the two-step approach as in De Loecker, Eeckout, and Unger [2020]. Step 1 corresponds to the cleansing of the micro data, where the observed real sales y_{it} (lower case letters are logarithmic values) of the firm i are regressed on the third-order polynomial $\hat{y}_{it}(x_{it}, l_{it}, k_{it})$ to remove the measurement error ε_{it}, which is assumed to be white noise. That is, real sales can be written as,

$$y_{it} = \hat{y}_{it}(x_{it}, l_{it}, k_{it}) + \varepsilon_{it}, \tag{3}$$

where x_{it}, l_{it}, k_{it} denote intermediate input, labor input, and capital stock.

Step 2 is the estimation of the production function using the fitted value $\hat{y}_{it}$ in equation (3). Specifically, we assume that $\hat{y}_{it}$ can be written as,

$$\hat{y}_{it} = \theta^j X_{it} + \omega_{it}, \tag{4}$$

where θ^j is a vector of parameters including the elasticity of the production function in industry j, X_{it} is a vector of explanatory variables including the logarithm of the production factors and various constant terms, and ω_{it} denotes productivity (the Solow residual). We assume that firms select production factors after observing ω_{it} or after predicting ω_{it} based on the information set as of time *t-1*; I_{t-1}. In this set up, when equation (4) is estimated by ordinary least squares (OLS), the consistent estimator cannot be obtained due to endogeniety. For this reason, we assume that productivity ω_{it} follows the following AR(1) process, with reference to Blundell and Bond [2000] and Bauer and Boussard [2020],

$$\omega_{it} = \rho^j \omega_{it-1} + \eta_j + \mu_j t + \epsilon_{it}, \tag{5}$$

where ρ^j is the AR(1) coefficient of productivity in sector j, η_j is the long-run level of productivity in sector j, μ_j is the coefficient on the deterministic trend, and $\epsilon_{it} \sim N(0, \sigma^2)$ represents idiosyncratic shock to productivity. Combining equations (4) and (5), real sales can be written as,

$$\hat{y}_{it} - \rho^j \hat{y}_{it-1} = \theta^j [X_{it} - \rho^j X_{it-1}] + \eta_j + \mu_j t + \epsilon_{it}. \tag{6}$$

We estimate equation (6) using the general method of moments (GMM). The moment restriction for identification is given in equation (7), which states that the information set I_{t-1} is orthogonal to the productivity shock ϵ_{it}. We estimate the production function for firms in manufacturing and non-manufacturing seperately, and conduct a 25-year rolling estimation to capture long-term trends in the elasticity;

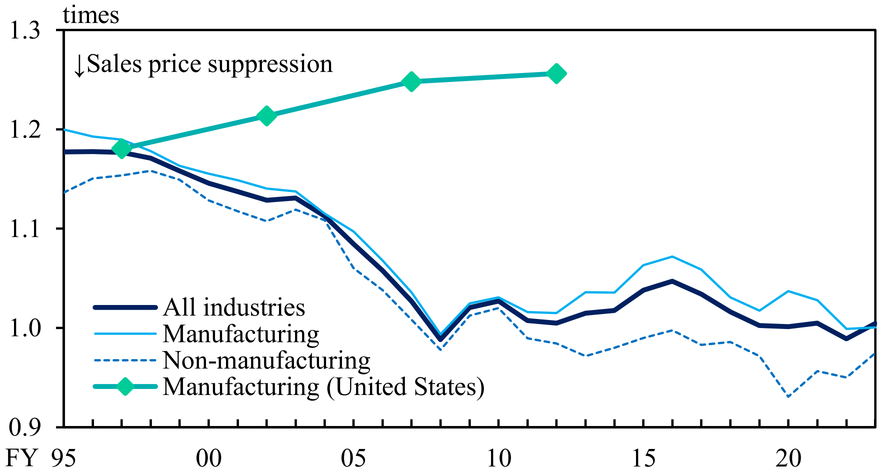
$$\mathrm{E}[\epsilon_{it} | I_{t-1}] = 0. \tag{7}$$

2.4 Estimation Results of Price Markups and Wage Markdowns

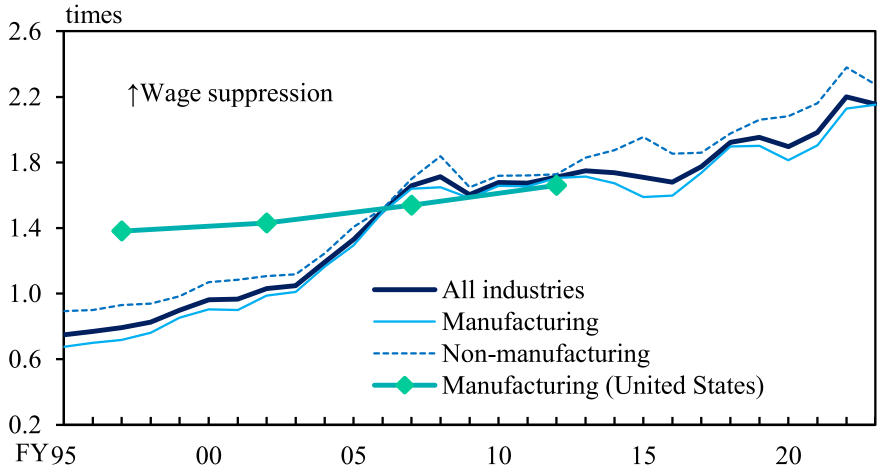
In this subsection, we review estimation results of price markups and wage markdowns in Japan (Figure 1). For reference, Figure 1 also shows the results of Yeh, Macaluso, and Hershbein [2022], who conducted measurements for the U.S. manufacturing sector.[3] The figure shows that in the United States, both price markups and wage markdowns have been rising over the long run, but the trend in price markups is different in Japan, where they have been declining from the late 1990s to the 2010s.

(Figure 1) Price Markups and Wage Markdowns

(1) Price Markups



(2) Wage Markdowns



Note: Figures for U.S. manufacturing are calculated by taking the backward moving average (25 years) of Figures 5 and 6 of the appendix in Yeh, Macaluso, and Hershbein [2022]. The most recent figure for fiscal 2023 is for April to December 2023.

Sources: Cabinet Office of Japan; Development Bank of Japan; Ministry of Finance; Research Institute of Economy, Trade and Industry (RIETI); Yeh, Macaluso, and Hershbein [2022].

[3] The weights used for aggregation are nominal intermediate cost weights for price markups and labor cost weights for wage markdowns (Yeh, Macaluso, and Hershbein [2022]).

It is also worth noting that rising wage markdowns are more or less a common phenomenon for Japan and the United States which indicates that firms' wage bargaining power has strengthened in the labor market. The background of this trend may include (1) a decline in unionization rates (Akcigit *et al.* [2021]), (2) less demand for domestic employment due to effects from globalization, and (3) the wage-setting behavior of "superstar firms," where wages have been suppressed significantly relative to productivity gains (Autor *et al.* [2020]). Globalization may have increased the substitutability of jobs at home and abroad, making domestic employees who want to keep their jobs are more likely to accept unfavorable conditions, which in turn may have strengthened firms' wage bargaining power (Rodrick [1998], Stiglitz [2017], Forbes [2019]). In Japan, it has also been noted that multinational firms have also increased their wage bargaining power, and the recent increase in foreign direct investment may also have contributed to this trend (Dobbelaere and Kiyota [2018]). Another feature of the Japanese labor market is summarized in Goodhart and Pradhan [2020], who point to two main reasons why wages did not rise in Japan despite severe labor shortages. First, firms continued to reduce working hours without laying off workers, even during recessions. Second, the reallocation of labor from manufacturing to services strengthened firms' wage bargaining power. These reasons are also said to have deepened the dual structure of the Japanese labor market and are the underlying factors for the rise in wage markdowns in Japan (Genda [2017], Fukunaga *et al.* [2023], Fukao and Perugini [2021]).

With respect to price markups, there are several possible explanations for the different trends between Japan and the United States. The first reason could be differences in the intensity of competition. As we show in the next section, Japanese firms' price markups have continued to decline since the late 1990s as a result of severe price competition (intensifying global competition in the manufacturing sector and increasing per capita stores in the non-manufacturing sector). It may be that the changes in Japan's competitive environment during the past quarter century have been much more severe than in the United States. The second reason may be due to differences in investment behavior. Studies on the United States have pointed out that R&D and investment in intangible assets have led to rising price markups (Crouzet and Eberly [2019], De Ridder [2024]). Meanwhile, compared with the United States, Japanese firms have tended to focus more on improving production efficiency by purchasing cheap goods from abroad rather than pursuing R&D and related investments (Hogen *et al.* [2024]).

Finally, the variable cost price markup can be written as a composite of the price markup and the wage markdown (as shown later in equation [11]). This expression is conceptually equivalent to the operating margin (value added) or inverse of the labor share. Therefore, it is necessary to evaluate price markups and wage markdowns in a comprehensive manner in order to consider their macroeconomic implications (Mertens [2022]).[4] Based on the results of this paper, it can be said that, in the case of Japan, while price markups have been declining due to intensifying competition and other factors, firms have secured operating revenues through wage markdowns, hence the labor share has been fairly stable over the long run. Mertens [2022] points out that the theoretical background of this phenomenon is consistent with the so-called rent sharing model. In other words, firms with declining price markups tend to face difficulties in rent-sharing their business surplus with their employees, and as a result tend to have raise wage markdowns, and it is possible that a similar mechanism has been at work in Japan during the past quarter century.

3 Determinants of Price Markups

In this section, we analyze how investments and changes in the competitive environment affect price markups through a series of firm-level panel analyses. In particular, we shed light on how firms' investments in R&D and intangible assets affect price markups, which has recently received attention in the literature (Bloom, Van Reenen, and Williams [2019], Oikawa and Ueda [2019]). Furthermore, we analyze manufacturing and non-manufacturing industries separately, as the underlying mechanism of the competitive environment may differ across industries. In the following, we work with a firm-level panel dataset that includes variables such as firm-level price markups and investment-related variables. Firm-level price markups are calculated from the parameters of the production function estimates obtained in Section 2 and the ratio of sales to intermediate input costs obtained from the "Basic Survey of Japanese Business Structure and Activities."[5] Investment variables are also taken from the same survey, which documents firm-level information on R&D, investment in intangible assets, and FDI.

3.1 Manufacturing

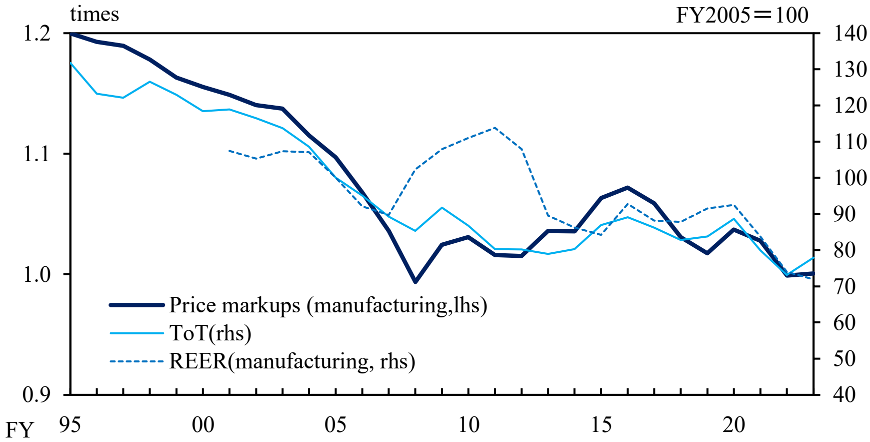
In international economics, it is often discussed that the terms of trade (ToT) and the real exchange rate (RER) can be considered as proxies for the competitive environment faced by manufacturing firms (Obstfeld [2010], Weinberger [2020]). In this regard, Sato *et*

[4] Even if the level of the price markup (excluding the effect of the wage markdown) is less than 1, the total price markup of variable costs (equal to the reciprocal of the labor share) exceeds 1 due to the effect of the wage markdown.

[5] Some production function parameters for each industry are taken from Aoki, Takatomi, and Hogen [2023].

al. [2020] point out that the industry-specific real effective exchange rate (REER) reflects differences in production, sales structures, and industry competitiveness.[6] Indeed, the REER and ToT[7] show similar patterns of fluctuations with price markup estimates of manufacturing (Figure 2). This suggests that price markups may have been declining as the competitive environment surrounding Japan's manufacturing sector intensified.

(Figure 2) Relationship between Price Markups, REER, and Terms of Trade



Note: "Terms of trade (ToT)" is calculated as the export price index divided by import price index (total average). For fiscal 2023, price markups and terms of trade are values from April to December 2023. Real effective exchange rates are values from April 2023 to February 2024.
Sources: Cabinet Office of Japan; Development Bank of Japan; RIETI; Bank of Japan.

Another possible indicator to measure the competitive environment surrounding manufacturing firms is the share of exports of each country's industry in total world exports. In this context, it has been pointed out that some Japanese firms, which have faced stiff competition from imports from China, were forced to switch products and adjust employment to avoid competition (Ito and Matsuura [2022], Bellone, Hazir, and Matsuura [2021]). To capture this profile, we calculated the share of exports in global exports by country and industry[8] using trade micro data (BACI) and match this with the firm-level data from the "Basic Survey of Japanese Business Structure and Activities."[9] The constructed series show that most shares of exports in manufacturing industries in Japan declined over the past quarter century, especially in electrical machinery, while those of

[6] The real effective exchange rates by industry were calculated by the RIETI using producer price indices (PPIs), trade shares, and nominal exchange rates. For details, see Sato *et al.* [2012].

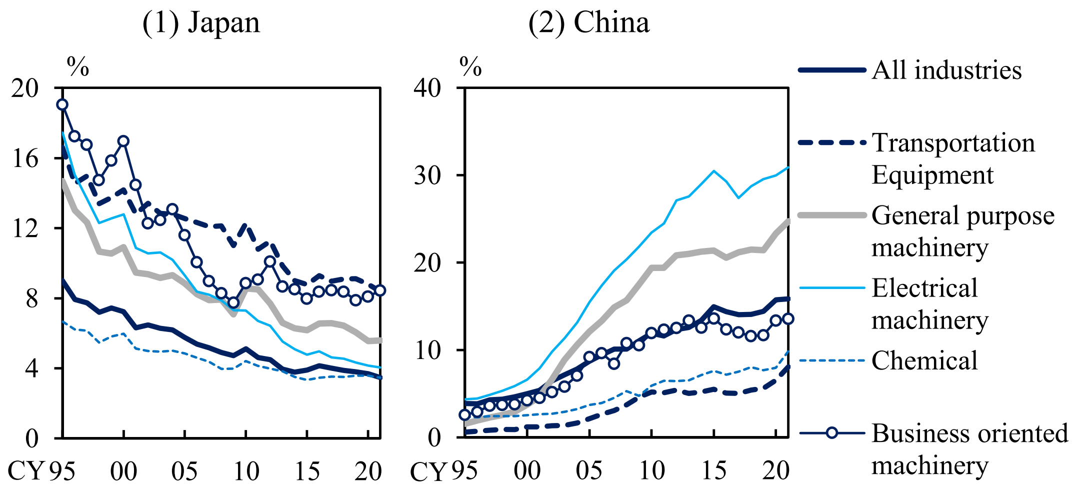
[7] With regard to the terms of trade, we calculated the terms of trade for the manufacturing industry (the ratio of the export deflator to the import deflator) using the JIP database's input-output table, and the trend was the qualitatively similar to the terms of trade at the macro level.

[8] The industry classification is based on the medium classification of the Japan Standard Industrial Classification.

[9] BACI is a database compiled by a French research institute CEPII using UN Comtrade trade microdata. This database provides the value and volume of imports and exports by country and by goods.

Chinese firms have expanded, which indicate that the environment surrounding Japanese firms may have become even more competitive (Figure 3).

(Figure 3) Japan and China's Shares of World Exports



Source: BACI-CEPII database

Based on these observations, we use the following panel regression to examine the relationship between price markups and factors such as the competitive environment and investment activity. For the dependent variable, we take changes in price markups of a Japanese manufacturing firm *i* in sector *s* at year *t*; $\varDelta\mu_{s,i,t}$ and consider the relationship,

$$\varDelta\,\mu_{s,i,t} = \beta_s + \gamma_t + \delta\varDelta COMP_{s,t} + \eta\varDelta INV_{s,i,t} + \kappa Z_{s,i,t} + \varepsilon_t, \qquad (8)$$

where $\varDelta(\cdot)$ is the difference operator, β_s, γ_t denotes industry and time fixed effects, $COMP_{s,t}$ denote a vector of proxy variables for the competitive environment such as the REER by industry as calculated by the RIETI ($REER_{s,t}$), and/or the share of Japan and China's exports in total world exports ($JPEXP_{s,t}$, $CNEXP_{s,t}$). $INV_{s,i,t}$ indicates variables for investment activity at the firm level, such as the logarithm value of tangible and intangible fixed assets: $\log TA_{s,i,t}$, $\log IA_{s,i,t}$, and R&D investment $\log RD_{s,i,t}$. $Z_{s,i,t}$ denotes a vector of control variables such as its own one-period lag and foreign direct investment $\varDelta(\log FDI_{i,t})$ and ε_t is the error term which is assumed to be $N(0,\sigma^2)$. Estimation is conducted by instrument variables by taking time *t-1* explanatory variables.

The estimation results are summarized in Figure 4. First, we consider model (1) which uses only REERs. The results indicate that there is a positive relationship between price markups and industry-specific REERs (an increase in the REER indicates an appreciation). Given the tendency that the REER resembles the relative productivity of the trading sector, it can be viewed that firms responded to the inflow of cheaper foreign products by lowering their price markups to maintain their competitiveness (Guerrieri, Gust, and López-Salido [2010], Amiti, Itskhoki, and Konings [2019]). Models (2)-(5) are specifications that include the effects of changes in export shares. The estimation results show that a decrease in Japan's export share and an increase in China's export share significantly depress price markups. Model (6) is the specification that also includes investment activities (R&D, investment in intangible and tangible assets). It shows that all investment variables are significant and have positive effects on price markups. This suggests that the channels identified in previous studies have operated effectively in Japan.[10] In this regard, the results also suggest that the fierce competition from other countries has pushed down price markups in Japan's manufacturing industry, but various investment activities have acted to offset such effects.

(Figure 4) Determinants of Price Markups $\Delta\mu_{s,i,t}$ (Manufacturing)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta REER_{s,t}$	0.22***	0.18***	0.21***		0.18***	0.23***
	(0.02)	(0.02)	(0.02)		(0.02)	(0.02)
$\Delta JPEXP_{s,t}$		1.04***		1.00***	0.93***	0.68***
		(0.12)		(0.12)	(0.12)	(0.14)
$\Delta CNEXP_{s,t}$			-0.17***	-0.10**	-0.07*	-0.09**
			(0.04)	(0.04)	(0.04)	(0.05)
$\Delta \log RD_{s,i,t}$						0.01***
						(0.002)
$\Delta \log TA_{s,i,t}$						0.04*
						(0.02)
$\Delta \log IA_{s,i,t}$						0.003*
						(0.002)
Time FE	○	○	○	○	○	○
Industry FE	○	○	○	○	○	○
N	71,707	71,707	71,707	71,707	71,707	57,532
Adj R^2	0.251	0.255	0.253	0.244	0.256	0.236
Periods	2003-21	2003-21	2003-21	2003-21	2003-21	2007-21

Note: ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively, and standard errors of the parameters in parentheses. $\Delta(\cdot)$ is the two-period cumulative change, and the instrument variables are the prechange levels of REER, various export shares, and FDI.

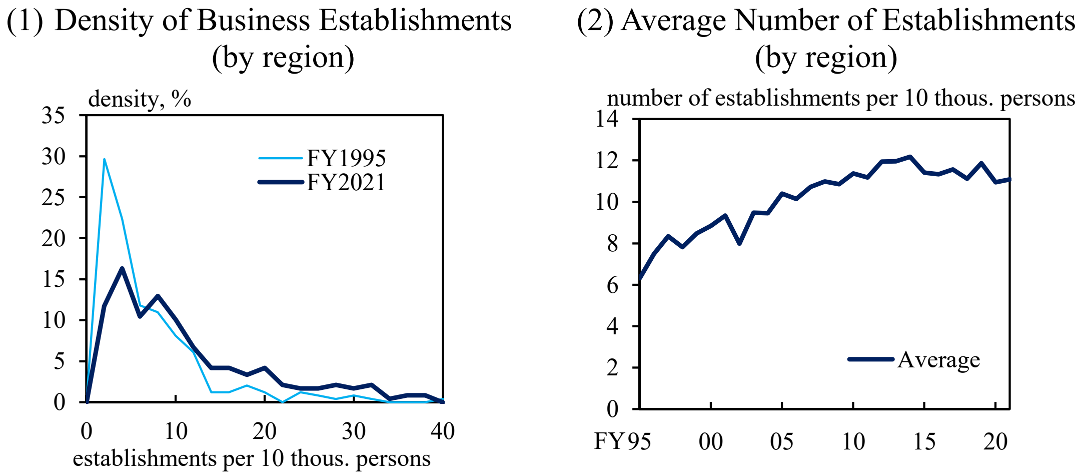
3.2 Non-manufacturing

This subsection analyzes the relationship between price markups and changes in the degree of competition in the non-manufacturing sector. Looking back at a quarter of a century, the early 1990s was a period when the international division of labor began to develop and relatively low-cost products from other countries in Asia entered the Japanese

[10] Initiatives such as R&D and investment in intangible assets can be interpreted as "product innovation" that creates demand and breaks new ground, while efficiency improvements by cutting costs can be interpreted as "process innovation".

market. The early 1990s also coincided with the period of deregulation, as symbolized by the implementation of the Large-Scale Retail Store Law (the *Daiten* law), which led to a significant increase in the number of large-scale retail stores and discount stores, which was likely to have affected the degree of competition in the retail and service sectors.[11] In this situation, it is likely that some firms were forced to reduce their price markups in order to maintain market shares in the highly competitive environment. In addition, a decline in regional population, combined with the supply from these large-scale retail stores, may have also contributed to the severity of price competition due to lower demand (Ohashi [2022]). Given these findings, we consider the number of establishments per person by region (density of establishments per person) as a proxy for the degree of competition in the non-manufacturing sector. This indicator was constructed by combining information on the location of corporate headquarters and the number of business establishments contained in the "Basic Survey of Japanese Business Structure and Activities" with municipal population data obtained from the "System of Social and Demographic Statistics of Japan" of the Ministry of Internal Affairs and Communications. Over the past 25 years, the density of business establishments by region has shifted to the right and the average number of businesses continued to rise until the mid-2010s, suggesting that the competitive environment in each region may have become more severe (Figure 5).[12]

(Figure 5) Density and Number of Establishments in Retail and Services



Note: Covers business establishments in retail and services.
Sources: Ministry of Economy, Trade and Industry; Ministry of Internal Affairs and Communications.

[11] The number of large-scale stores opened per year was an average of 560 in the 1980s. The number grew around threefold in the early 1990s, and then around fourfold in the late 1990s. In relation to this, looking at the results of a survey conducted by the Bank of Japan's Research and Statistics Department [2000], approximately 90 percent of firms listed on the First Section of the Tokyo Stock Exchange responded that the degree of competition had increased since the mid-1990s due to effects such as deregulation.

[12] The distribution of the number of establishments per person by region calculated from the Economic Census (service industry), has also shifted to the right from fiscal 1995 to fiscal 2020.

Based on these observations, we use the following panel regression to examine the relationship between price markups and factors such as the competitive environment and investment activity. For the dependent variable, we take changes in price markups of a Japanese non-manufacturing firm i in municipal l, in sector s at year t; $\varDelta\mu_{s,l,i,t}$ and consider the equation,

$$\varDelta\,\mu_{s,l,i,t} = \beta_s + \omega_l + \gamma_t + \delta\varDelta DENSITY_{s,l,t} + \eta\varDelta INV_{i,t} + \kappa Z_{s,l,i,t} + \varepsilon_t, \qquad (9)$$

where $DENSITY_{s,l,t}$ is the average number of establishments at the municipal level (log),[13] $INV_{s,i,t}$ is the firm-level investment activity variable (as for manufacturing), $\varDelta(\cdot)$ is the difference operator, β_s, ω_l, and γ_t are fixed effects for industry, municipality, and time, respectively, and ε_t is the error term which is assumed to be N(0,σ^2). $Z_{s,i,t}$ is a vector of control variables which includes $DENSITY_{s,l,t-1}$, $INV_{s,i,t-2}$, and $\mu_{s,l,i,t-2}$. Estimation is conducted by instrument variables by taking time *t-1* explanatory variables. The industry classification is based on the major classification of the Japan Standard Industrial Classification (which distinguishes between wholesale and retail trade).[14]

(Figure 6) Determinants of Price Markups $\varDelta\,\mu_{s,l,i,t}$ (Non-manufacturing)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\varDelta DENSITY_{s.l.t}$	-3.66**		-3.65**		-4.64***		-4.55***
	(1.49)		(1.49)		(1.59)		(1.60)
$\varDelta\log RD_{s.i.t}$		0.04	0.04			0.08	0.08
		(0.04)	(0.04)			(0.06)	(0.06)
$\varDelta\log TA_{s.i.t}$				-0.05	-0.05	-0.06	-0.05
				(0.06)	(0.05)	(0.05)	(0.05)
$\varDelta\log IA_{s.i.t}$				0.09	0.10*	0.10*	0.10*
				(0.06)	(0.06)	(0.06)	(0.06)
Firm FE	○	○	○	○	○	○	○
Time FE	○	○	○	○	○	○	○
Industry FE	○	○	○	○	○	○	○
N	107,075	107,075	107,075	107,075	72,831	72,831	72,831
Adj R^2	0.172	0.169	0.169	0.144	0.220	0.211	0.213
Periods	1997-21	1997-21	1997-21	2007-21	2007-21	2007-21	2007-21

Note: ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively, and standard errors of the parameters in parentheses. The instrumental variables are the levels before changes in price markups and population density.

[13] The number of establishments at the municipal level was estimated based on the number of establishments and the location of the head office in the Basic Survey of Japanese Business Structure and Activities.

[14] The industries included in the analysis are electricity, gas, heat supply and water; information and communications; transportation and postal services; wholesale trade; retail trade; real estate and goods rental and leasing; accommodation, eating and drinking services; living-related and personal services and amusement services; and education, learning support.

The estimation results suggest that, in the non-manufacturing sector, the increasing degree of competition acted as a force to reduce price markups (Figure 6). In terms of investment activity, as in the manufacturing sector, investment in intangibles was significant in pushing up price markups, but R&D investment was not significant, partly because non-manufacturing firms are relatively downstream of manufacturing firms. As shown in Figure 1, Japan's non-manufacturing sector experienced a larger decline in price markups and a larger expansion in wage markdowns than the manufacturing sector. Assessing these factors in a comprehensive manner, it can be said that non-manufacturing firms had to suppress nominal wages by increasing the proportion of part-time workers in order to generate profits in a competitive environment with an increasing number of stores.

4 Relationship Between Price Markup and Productivity

4.1 Theoretical Background

In this section, we consider the relationship between price markups and aggregate productivity. In theory, a (positive) price markup arises in a monopolistic environment where output is lower than the efficient level of output (derived under perfect competition). In this setting, changes in price markups affect aggregate productivity through allocative efficiency (Hall [1998, 1990], Basu and Fernald [2002], Petrin and Levinsohn [2012], Baqaee and Farhi [2020]). In this regard, Baqaee and Farhi [2020] use a general equilibrium model with industrial linkages. In other words, this method can be viewed as a means of extracting the pure component of technological progress by excluding monopoly distortions from TFP fluctuations (e.g., the Solow residual). In this section, we purify the Solow residual, a measure of TFP, by removing the effects from monopoly distortions (Baqaee and Farhi [2020]).[15] In this context, the influential study by Baqaee and Farhi [2020] decomposed TFP into contributions from (1) allocative efficacy due to price markups and (2) pure technological progress in a general equilibrium model with industrial linkages. Their results suggest that TFP growth in the United States has been boosted by both (1) efficiency improvements in firms with high price markups (both reduction of price markups and scale expansion) and (2) pure technological progress. In this paper, we follow their method and decompose TFP (the Solow residual) in Japan using the following formula (see Appendix A.2 for details),

[15] Under perfect competition, TFP is consistent with the Solow residual, which is considered as a proxy variable for technological progress. However, since the Solow residual includes business cycle factors, there are also ways to purify TFP for business cycle factors such as changes in capacity utilization (Kawamoto [2005], Fueki and Kawamoto [2009]).

$$\underbrace{\Delta logY_t - \widetilde{\Lambda}'_{t-1}\Delta logL_t}_{\text{TFP}} \simeq \underbrace{\widetilde{\lambda}'_{t-1}\Delta logA_t}_{\text{Technological Progress}} \underbrace{- \widetilde{\lambda}'_{t-1}\Delta log\mu_t^{DLEU} - \tilde{\Lambda}'_{t-1}\Delta log\Lambda_t,}_{\text{Efficiency of Resource Allocation}} \qquad (10)$$

where Y_t, L_t, A_t denote real output (value added), labor input, and TFP, μ_t^{DLEU} is the price markup of variable costs (see Equation [11]), $\widetilde{\lambda}'_t$ is the Domar weight of intermediate goods,[16] $\tilde{\Lambda}'_t$ denotes Domar weights of labor and capital, and Δ denotes the difference operator. In this setting, the left-hand side of equation (10) represents the change in TFP. The first term on the right-hand side represents the contributions of pure technological progress, which conceptually includes innovations that create demand for new goods and services through R&D and other means. The second and subsequent terms on the right-hand side represent contributions of allocative efficiency, which includes price markups (including wage markdowns) and the spillovers of these distortions through production networks. We also compute the "technology frontier" introduced by Baqaee and Farhi [2020], which is similar to the counterfactual output without distortions from price markups.

There are two strands in the literature for excluding allocative efficiency from productivity: the statistical approach and the structural model approach (Goldin *et al.* [2024]).[17] In the statistical approach, it is common to decompose TFP into (1) internal effects, (2) reallocation effects, (3) entry effects, (4) exit effects, etc (Ikeuchi *et al.* [2022]). With respect to equation (10), the above effects (2) to (4) can be said to be included in the contribution of allocative efficiency, while (1) is included in both pure technological growth and allocative efficiency.[18]

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[16] A Domar weight is generally a concept that expresses the importance of the industry in total value added. There are several variations on whether this is captured on a total revenue basis or a cost of production basis. The weights considered in this paper are on a cost basis.

[17] In the statistical approach, it is common to construct a macro TFP index and decompose its fluctuations into contributions from inter- and intra-firm changes (Ikeuchi *et al.* [2022], Baily *et al.* [1992], Foster, Haltiwanger, and Krizan [2001]). The equilibrium model approach is based on an equilibrium relationship for a macro TFP and shows how shocks to technological progress can lead to improvements directly and through reallocation of factor and input shares (Baqaee and Farhi [2020], Basu and Fernald [2002], Petrin and Levinsohn [2012]).

[18] The technological progress contribution in equation (10) captures technological progress under the assumption that the production network is fixed (fixed production factor based Domar weights), and other factors are included in the efficiency of resource allocation. Since the production network also changes as a result of firms' technological progress, the internal effects of the statistical approach include some of the change contribution to the efficiency of resource allocation in addition to technological progress.

4.2 Data

TFP is estimated in value-added terms, and data from the JIP database provided by RIETI are used to calculate labor and capital shares. In addition, when calculating the production network matrix at the firm level, there is a bias in the distribution of firms if only listed firms are used. For this reason, this paper uses the Basic Survey of Japanese Business Structure and Activities, which covers a wide range of industries and firm sizes, to decompose TFP for the entire economy. In addition, when calculating TFP, the JIP database, which is closer to the macro level, is used for (1) cost share information and (2) financial data from the Basic Survey of Japanese Business Structure and Activities, rather than TFP estimated on the basis of listed firms in Section 2. We confirmed that TFP calculated using this method is not significantly different from TFP in Section 2 and TFP published by the Bank of Japan, and TFP in the JIP database. Since the price markup in the original formulation of Baqaee and Farhi [2020] is defined as markup of variable cost (μ_{it}^{DLEU}), we use the following equation from Mertens [2022] to calculate this analog.[19] Using elasticities (θ), price markup (μ_{it}), and wage markdown (v_{it}) estimated in Section 2, the markup of variable cost can be written as,

$$\mu_{it}^{DLEU} = \frac{\theta^X + \theta^L}{\theta^X v_{it} + \theta^L} \mu_{it} v_{it}, \tag{11}$$

where θ is the output elasticity of production factor of intermediaries (X) and labor (L) which is assumed to differ by manufacturing and non-manufacturing.[20] To calculate the Domar weights, we used the input-output table from RIETI's JIP Database 2021. We also used the "Basic Survey of Japanese Business Structure and Activities" to create firm-level input-output tables by year (about 16,000 firms) by matching firms to industries (Baqaee and Farhi [2020]).

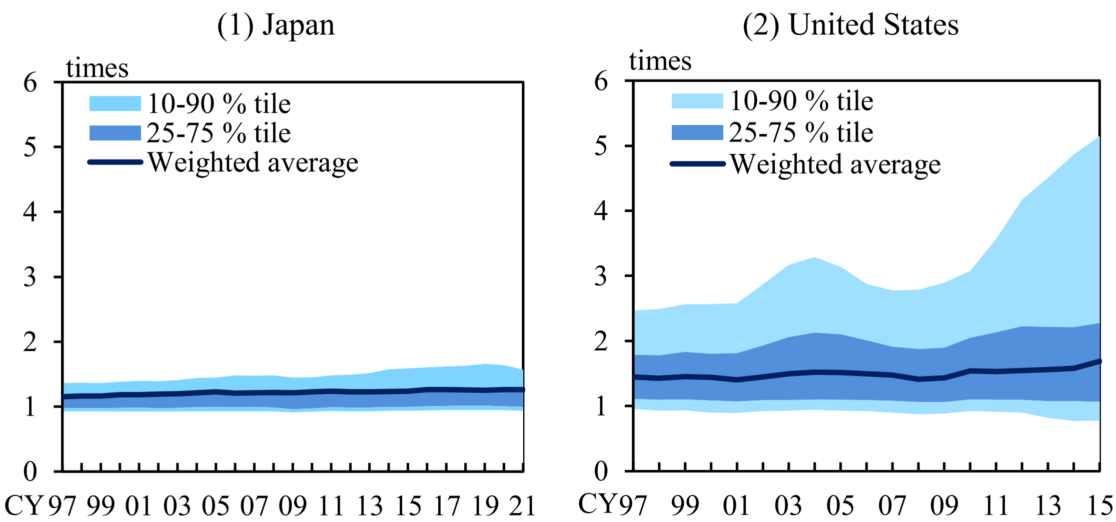
Estimates of the price markups of variable costs μ_{it}^{DLEU} are shown in Figure 7 which shows several features. First, the heterogeneity is greater for the United States, where the

[19] To account for industrial heterogeneity, some estimation results from Aoki, Hogen, and Takatomi [2023] are used in the calculation of equation (10).

[20] The price markup in equation (11) corresponds to the price markup calculated by De Loecker, Eeckout, and Unger [2020], and we follow Mertens [2022] and denote this as μ^{DLEU}. Under the assumption that $\theta^X + \theta^L$ is constant, changes in the level of markup ($\Delta log\mu_t^{DLEU}$) does not depend on each parameter. Since we have confirmed that $\theta^X + \theta^L$ is fairly stable in the long run, and since TFP decomposition and the technological frontier estimates (based on equations [10] and equation [A5], respectively) depend on the rate of change $\Delta log\mu_t^{DLEU}$ rather than the level of markup, we believe that the quantitative results are unlikely to be biased by measurement errors of the parameters.

rise in price markups in the upper 90 percentile since the 2010s is notable. Second, in contrast to the United States, the variation in price markups in Japan is small and less heterogeneous.

(Figure 7) Variation in Price Markup μ_{it}^{DLEU}



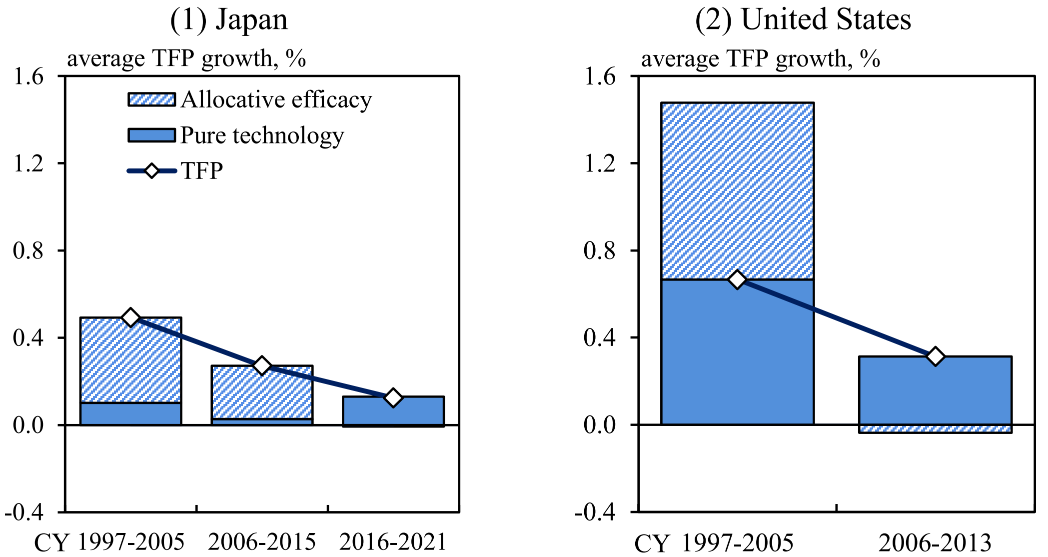
Note: Calculated by trimming the top and bottomo 1 percentile of the price markup distribution.
United States results are from Baqaee and Farhi [2020].
Sources: Baqaee and Farhi [2020]; Development Bank of Japan; Ministry of Economy, Trade and Industry; RIETI.

4.3 Estimation Results

Figure 8 shows the decomposition of TFP growth for Japan and the United States using equation (10). The decomposition of Japan's TFP growth rate suggests that the increase from the late 1990s to the early 2000s was mainly due to improvements in the efficiency of resource allocation, and that the contribution of pure technological progress was smaller than in the United States. Improvements in the allocation efficacy, based on the analysis in Section 3, suggest that the effect of the decline in price markups was greater than the expansion of wage markdowns, thereby boosting productivity. Such efficiency improvements can be interpreted as a type of process innovation, but given that the positive contributions have been diminishing, there may be less room for further improvement. It is also worth noting that the U.S. economy was able to steadily expand TFP through pure technological progress between 1997 and 2013.[21]

[21] In Baqaee and Farhi [2020], while using the user-cost approach as the benchmark, they also decompose TFP growth rates using two other methods: the production function approach and the accounting approach. The long-term trends are similar for all methods.

(Figure 8) Decomposition of TFP Growth



Note: Calculations for the United States are based on benchmark case (user-cost approach) of Baqaee and Farhi [2020].

Sources: Baqaee and Farhi [2020]; Development Bank of Japan; Ministry of Economy, Trade and Industry; RIETI.

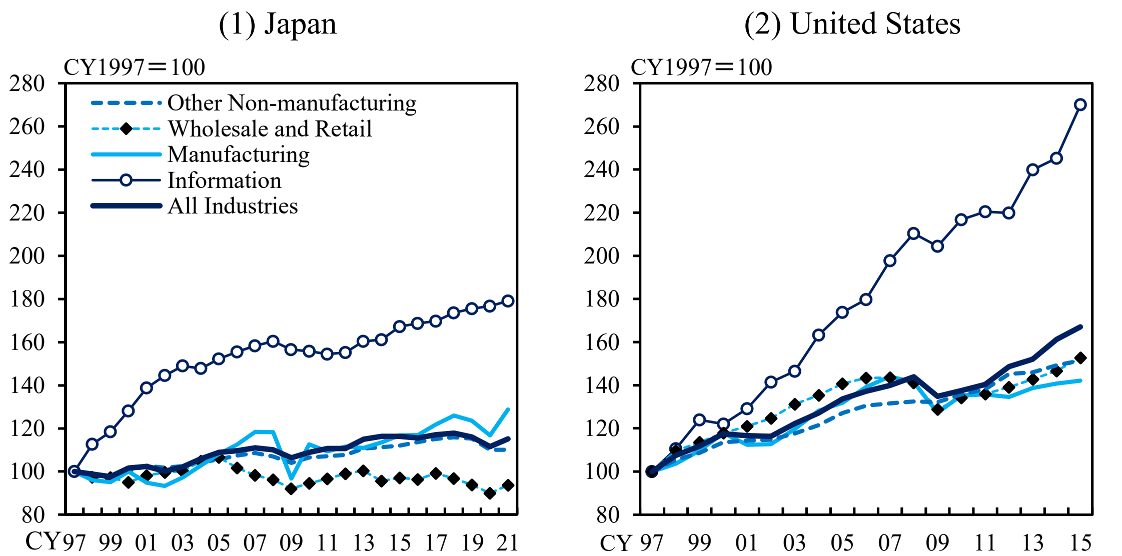
Next, we measure the "technology frontier," which corresponds to the counterfactual output in the absence of price markups; μ_{it}^{DLEU} (see Appendix A.3 for details).[22] The results for the United States show that the technology frontier has continued to expand since the 2010s, driven by technological innovation at superstar firms in the information and telecommunications and other industries (Figures 9 and 10).[23] As shown in Figure 10, the inter-industry spillover effect in the United States has contributed to the expansion of the technological frontier. This can be interpreted, for example, as the effect of technological frontier expansion in the information and telecommunications industry influencing the expansion of the frontier in other industries.

On the other hand, Japan's technological frontier has not expanded as much as that of the United States, and inter-industry spillover effects are smaller. This can be attributed to the lack of progress in the utilization of IT since the burst of the bubble economy and to the fact that domestic investment has not been as strong as in the United States, partly due to the impact of globalization (Goldin *et al.* [2024]).

[22] In the case of technological innovation that increases output with the same factors of production, the price markup expands due to the decrease in marginal cost at an unchanged selling price, and in the case of technological innovation that produces new products and services, the price markup expands by setting a selling price sufficient to cover production costs.

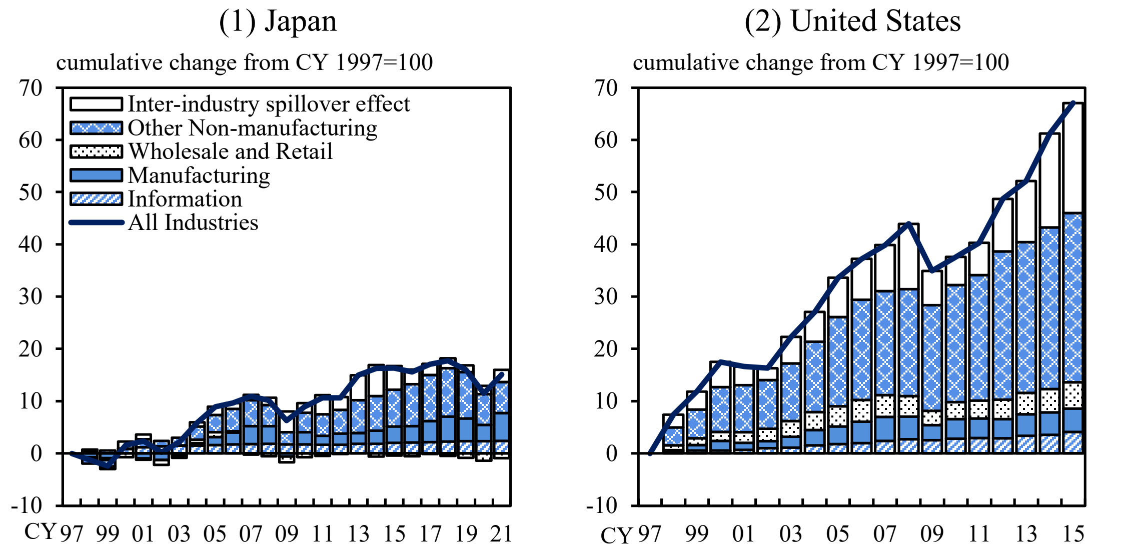
[23] In the United States, price markups expanded due to the increased size of some highly-productive and high-markup firms (Autor *et al.* [2020], Kehrig and Vincent [2021], International Monetary Fund [2019], De Loecker, Eeckhout, and Unger [2020]).

(Figure 9) Technology Frontier by Industry



Note: Technology frontier represents the technology level without price markup distortions. Results for the United States are calculated based on Baqaee and Farhi [2020].
Sources: Baqaee and Farhi [2020]; Development Bank of Japan; Ministry of Economy, Trade and Industry; RIETI.

(Figure 10) Cumulative Change of the Technology Frontier



Note: "Inter-industry spillovers" refers to spillovers between industries indicated in the legend; spillovers within each industry are included in the contribution of the corresponding industry.
Sources: Baqaee and Farhi [2020]; Development Bank of Japan; Ministry of Economy, Trade and Industry; RIETI.

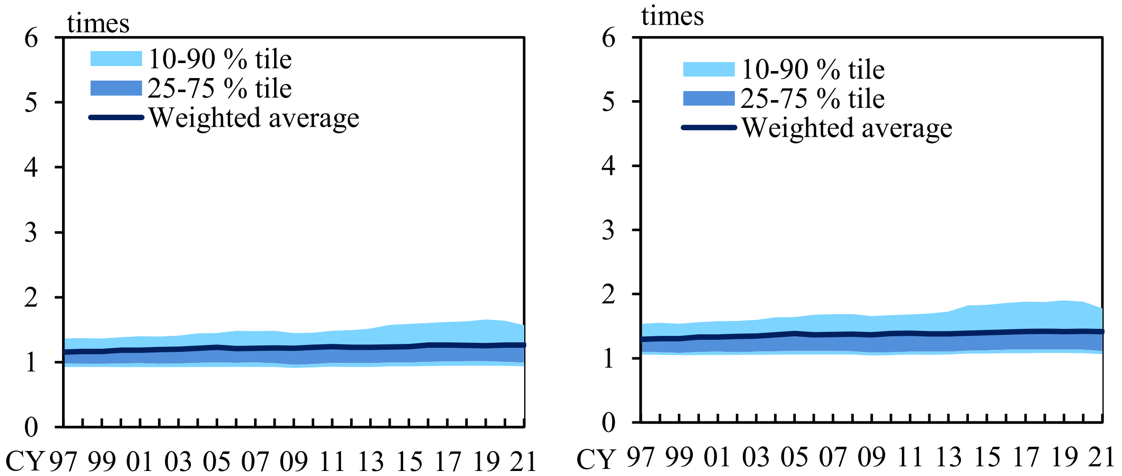
4.4 Comparison of Production Function Approach and Accounting Approach

When measuring price markups, in addition to the production function approach, there is also an "accounting approach" based on corporate accounting items. In the accounting approach, the price markup is defined as the ratio of sales to nominal costs, so we calculate price markups at the firm-level.[24] In this sub-section, we use the accounting approach to calculate the price markups, and as in the previous section, we decompose TFP growth and calculate the technology frontier to check the robustness of the results. We note in advance that the results are generally similar to those calculated using the production function approach.[25]

Price markups calculated from the accounting approach are qualitatively the same as those obtained using the production function approach; the levels of price markups are generally lower, and the degree of heterogeneity is less than the United States (Figure 11, Figure 7 above).

(Figure 11) Heterogeniety of Firm-level Price Markup (Japan)

(1) Production Function Approach (2) Accounting Approach



Note: Calculated by trimming the top and bottomo 1 percentile of the price markup distribution.
Sources: Development Bank of Japan; Ministry of Economy, Trade and Industry; RIETI.

The breakdown of Japanese firms' TFP growth using price markups calculated using the accounting approach suggests that, as with the production function approach, improvements in allocative efficiency were a major source of the increase in TFP growth from the second half of the 1990s to the mid-2010s, and the contribution of pure technological progress was small compared with the United States (Figure 12, Figure 9 above). However, since the mid-2010s, there are some similarities in that TFP growth has expanded due to pure technological progress, and allocative efficiency has pushed down

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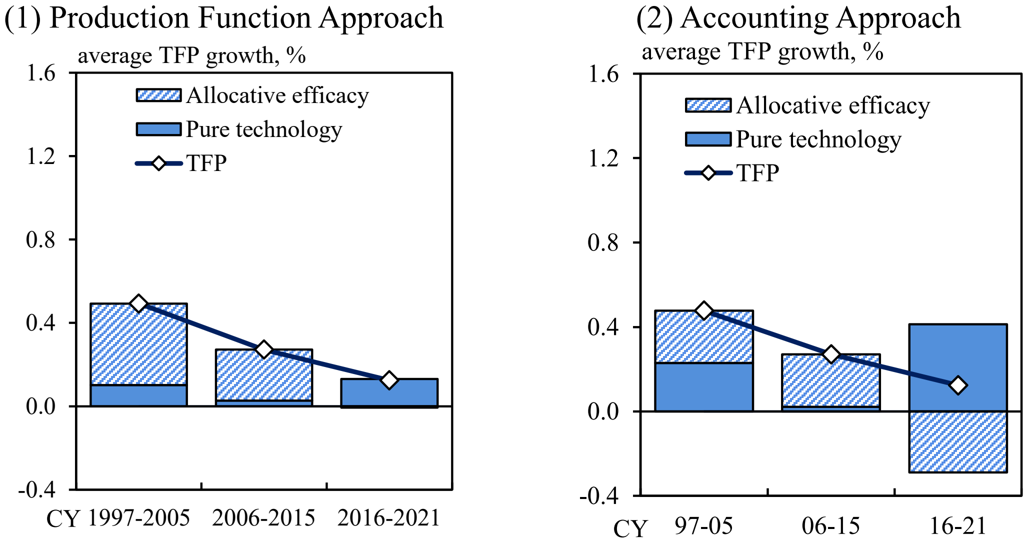
[24] The accounting approach is advantageous as it can be calculated more easily than other methods.

[25] Kikuchi [2024] estimated price markups for Japanese firms (analogous to μ_{it}^{DLEU} in the this paper) using the method of Edmond, Midrigan, and Xu [2015], where they estimated price markups from the cost minimization problem of firms. The accounting approach is conceptually identical to this method, and the trends in the estimated results of this paper are almost the same as the results of Kikuchi [2024].

TFP due to factors such as the rise of wage markdowns.

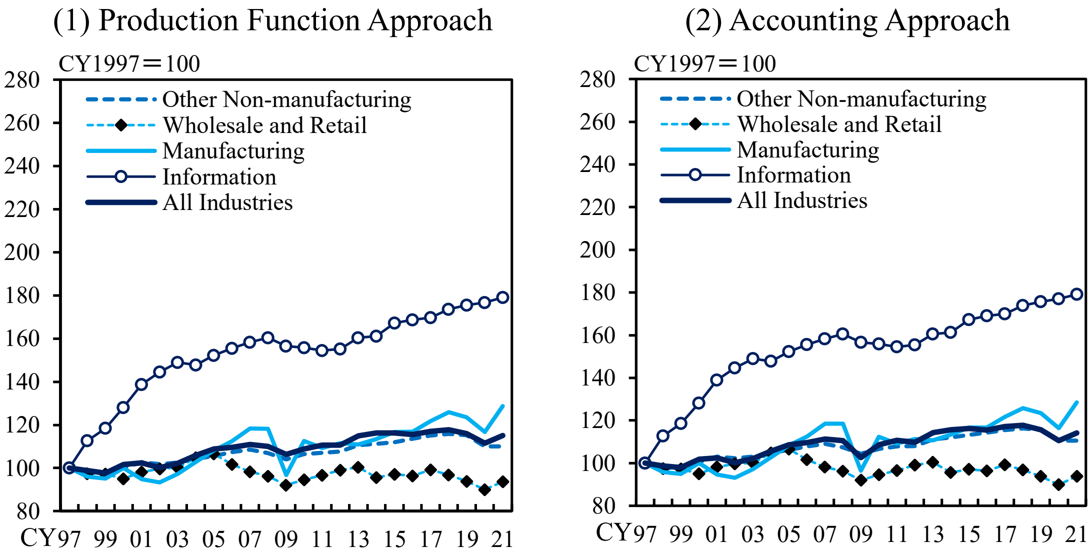
(Figure 12) Decomposition of TFP Growth (Japan)



Sources: Development Bank of Japan; Ministry of Economy, Trade and Industry; RIETI.

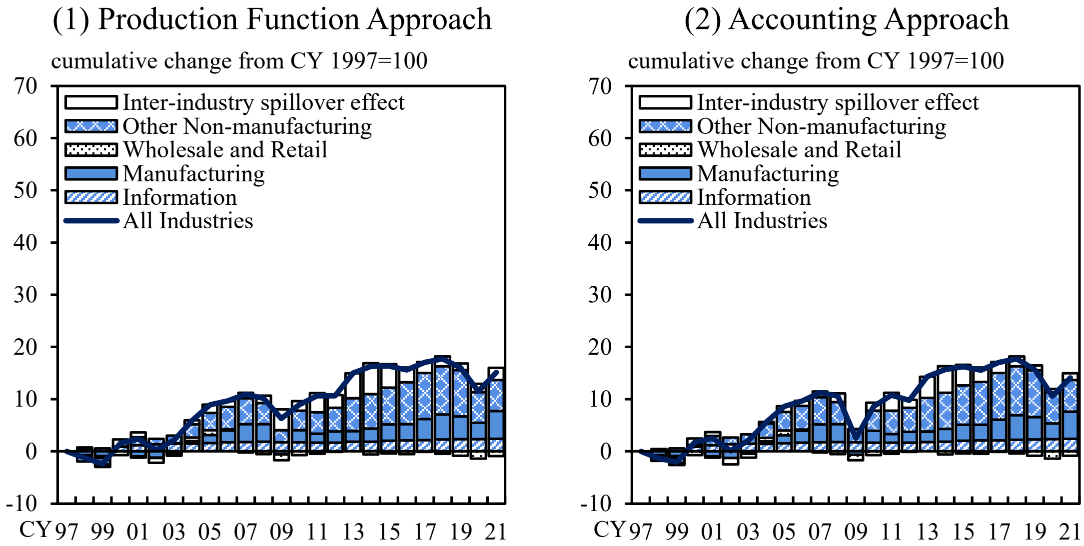
In addition, the results of the measurement of the technological frontier show that, as with the production function approach, Japan's technological frontier has not expanded as much as that of the United States, and the spillover across industries is also smaller (Figures 13 and 14, and Figures 9 and 10 above).

(Figure 13) Technology Frontier by Industry (Japan)



Sources: Development Bank of Japan; Ministry of Economy, Trade and Industry; RIETI.

(Figure 14) Cumulative Change of the Technology Frontier (Japan)



Sources: Development Bank of Japan; Ministry of Economy, Trade and Industry; RIETI.

5 Conclusion

This paper analyzed the long-term trends of Japanese firms' price markups and wage markdowns, determinants of price markups, and their relationship with aggregate productivity. The main results of the analysis are summarized below.

First, since the second half of the 1990s, Japanese firms have made profits by raising their wage markdowns in the face of declining price markups. This mechanism could be one reason why the labor share in Japan has remained fairly stable over the long term. In addition, the decline in price markups and the expansion of wage markdowns can be said to provide a consistent explanation for the fact that it has been difficult to raise prices and wages in Japan for a long time (Hogen *et al.* [2024]). Compared with the United States, there are some similarities, such as rise in wage markdowns, but the trend in price markups is different in that it has declined markedly in Japan, which may have been influenced by differences in the competitive environment and investment activities in the two countries.

Second, an examination on the determinants of price markups in Japan found that, for manufacturing industries, Japan's share of world exports and investment in R&D, intangible assets, and tangible assets have been closely related to price markups. The results also suggest that (1) price markups have declined among firms exposed to intensifying overseas competition, while (2) firms that have been proactive in their investment may have been able to offset some of this downward pressure. For the non-manufacturing sector, the results suggest that the competitive environment has been more severe in regions with a high density of establishments per capita, which has put downward pressure on price markups. As for future research topics, it is interesting to investigate the determinants of wage markdowns.

Third, with regard to price markups and aggregate productivity, it has been suggested that in the United States, TFP growth was mainly boosted by technological progress, while in Japan, the effect of efficiency improvements due to a reduction in price markups was significant. This suggests that, during the same period, Japan focused more on improving productivity through efficiency improvements in production processes than on demand-creating innovations such as R&D. In this analysis, for the sake of comparability with previous studies, we analyzed the effect of fluctuations in price markups on productivity under the assumption that firms on the demand side of the factor market are price takers. However, the effect on productivity when firms have monopsony power in the labor market is a fruitful area for future research.

Based on the above results, we consider some important issues when looking back at the past 25 years in Japan.[26] First is how to think about the trigger for the decline in price markups and the rise in wage markdowns from the second half of the 1990s to the first half of the 2000s. Based on the analysis in Section 3, in manufacturing, the trigger for the change in international competitiveness may have been the fact that firms cut back on capital investment in the wake of the financial crisis in the second half of the 1990s. In the non-manufacturing sector, the trigger may have been the fact that the number of establishments did not decline, despite a shrinking population, due to the effects of deregulation and other factors during the same period, and that the competitive environment became more intense. Another possible factor that cut across industries was that Japan as a whole missed investment opportunities in IT-related fields at a time when IT was making rapid progress worldwide in the second half of the 1990s (Shirota and Tsuchida [2024]).

The second issue is how to think about the relationship between the zero inflation norm observed in Japan over the past 25 years and price markups. First, as a premise for the discussion, the share of zero-inflation items in the consumer price index, which is seen as an evidence of the zero-inflation norm, has increased from the late 1990s to the 2010s, especially for service prices. Moreover, Furukawa *et al.* [2024] show that this increase is associated with a larger degree of curvature of the demand curve faced by firms. This

[26] Fukunaga, Hogen, and Ueno [2024] summarize the issues surrounding the Japanese economy and price developments over the past 25 years, based on a review of previous research.

period also coincides with the decline in price markups shown in this paper. Taken together, it could be that households became more sensitive to price rises during this period, which worked on both sides of the formation of the zero-inflation norm and the decline in price markups. Given these adjustments, it may be that firms had some incentive to raise wage markdowns in order to maintain profits as price markups declined.

Going forward, it is unlikely that factors affecting the competitive environment of firms will suddenly change, but there are signs that wage markdowns could be reaching their peak due to the limited supply of labor. If the labor shortage worsens in the future, firms' ability to negotiate wages in the labor market will weaken, and there is a possibility for wage markdowns to decline. In addition, based on the results of the analysis in this paper, from the perspective of achieving a virtuous cycle of economic growth and price increases, it is important to have a mechanism in which the economy grows through demand-generating R&D and investment in intangible assets, and "product innovation," and in line with this, firms gain price markups and distribute these increased profits via wages.[27] In this respect, given that the past 25 years, Japan has rather focused on process innovation, it is interesting to see whether these tendencies will change and affect trends in price markups and wage markdowns.

[27] For information on the situation surrounding Japan's startups, which are the source of innovation and the driving force behind the competitiveness, see Itai *et al.* [2024].

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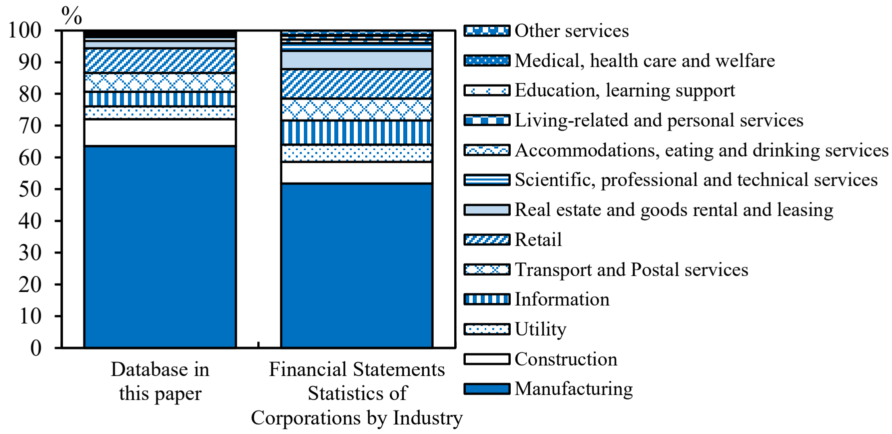
Appendix

A.1 Data

The breakdown of the data by industry is broadly similar to that of large firms in the Annual Report on the *Financial Statements Statistics of Corporations by Industry* (see Figure A-1 [1]). In addition, using the results of Aoki, Hogen, and Takatomi [2023], we looked at the correlation between price markups and wage markdowns for firms with a large scale (100 or more employees) and other firms, and found that both were reasonably correlated, so it is likely that, even if listed firms are used, the long-term trends in the corporate sector can be captured (Figure A-1 [2]). In addition, the nominal variables obtained from the accounting items were deflated using the industry-specific deflators, in accordance with Aoki, Hogen, and Takatomi [2023].

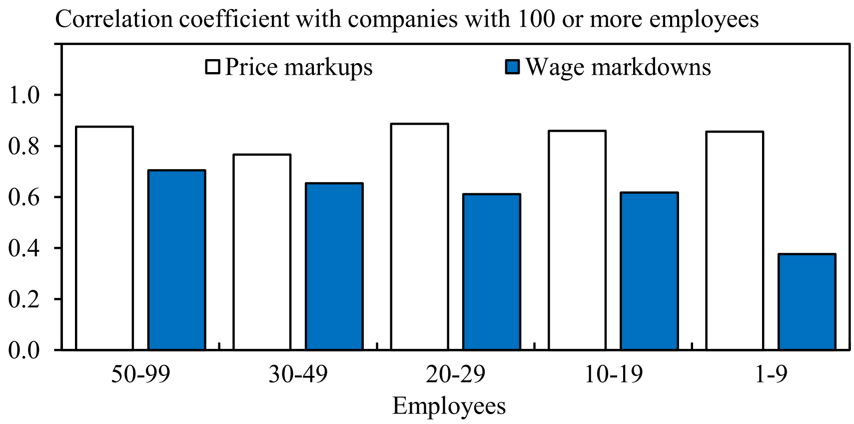
(Figure A-1) Data Summary

(1) Industry Distribution (based on sales)



Note: As of fiscal 2015. The *Financial Statements Statistics of Corporations by Industry* covers firms with a capital of 1 billion yen or more. The database in this paper covers about 20 perecnt of the "Economic Census."
Sources: Development Bank of Japan; Ministry of Finance, etc.

(2) Correlation between price markups and wage markdowns for large and small firms



Note: The estimates of price markups and wage markdowns by firm size are calculated based on Aoki, Hogen and Takatomi [2023].
Sources: Development Bank of Japan; Aoki, Hogen, and Takatomi [2023]

A.2 Decomposition of Productivity

In Section 4.1, we decompose changes in TFP growth into the contribution of pure technological progress and the contribution of changes in the allocative efficiency in equation (10). In this subsection, we explain how to calculate the production factor-based Domar weights, $\tilde{\lambda}_t$, $\tilde{\Lambda}_t$, in the decomposition of equation (10). First, the income-based Domar weight of producer *i* is expressed as $\lambda_i = \frac{p_i y_i}{\sum_{j=1}^{N} p_j c_j}$, which is the income of producer *i* divided by the total added value.[28] The income-based Domar weight can also be expressed as,

$$\lambda' = b'\psi = b'(\mathrm{I} - \Omega)^{-1}, \tag{A1}$$

where, b is the consumption share ($b_i = \frac{p_i c_i}{\sum_{j=1}^{N} p_j c_j}$) and $\psi \equiv (\mathrm{I} - \Omega)^{-1}$ is the Leontief inverse matrix.[29] Note that Ω is an income-based input-output (I-O) table, and Ω_{ij} represents the ratio of expenditure on intermediate input *j* to the income of producer *i* ($\Omega_{ij} = \frac{p_i x_{ij}}{p_i y_i}$).

Next, following Baqaee and Farhi [2020], the production-factor-based Domar weight is defined as,

$$\tilde{\lambda}' \equiv b'\tilde{\psi} = b'(\mathrm{I} - \tilde{\Omega})^{-1} \tag{A2}$$

where, $\tilde{\Omega}$ is a production-factor-based I-O table, and $\tilde{\Omega}_{ij}$ expresses the elasticity of the marginal cost of *i* with respect to the price of *j* ($\tilde{\Omega}_{ij} \equiv \frac{\partial log C_i}{\partial log p_j} = \frac{p_i x_{ij}}{\sum_{k=1}^{N} p_k x_{ik}}$).

The income based I-O table and the production factor based I-O table are related to price markup as,

$$\tilde{\Omega} = diag(\mu^{DLEU})\Omega. \tag{A3}$$

In summary, $\tilde{\Omega}_{ij}$ represents the direct exposure of *i* to *j*, $\tilde{\psi}_{ij}$ represents the direct and indirect exposure of *i* to *j*, and $\tilde{\lambda}_k$ represents the direct and indirect exposure of the household to industry k.

---

[28] p_i represents the price, y_i represents the output, and c_i represents the final demand. $\sum_{j=1}^{N} p_j c_j$ is the total final demand, or nominal GDP. Denoting x_{ji} as the intermediate input from *i* to *j*, then $p_i y_i = p_i c_i + \sum_{j=1}^{N} p_i x_{ji}$ holds.

[29] The Leontief coefficient indicates how much production in each sector is ultimately required when one unit of new final demand arises in a given sector.

A.3 Technological Frontier

Denoting productivity as A and the price markup as μ^{DLEU}, total output Y can be written as $Y(A, \mu^{DLEU})$. The technological frontier is defined as the potential output under perfect competition and this can be expressed as $Y^* = Y(A, 1)$, where there is no markup. The technical frontier is calculated using the following formula,

$$Y^* = e^D \times Y, \tag{A4}$$

where D denotes the distance to the technology frontier. This distance can be approximated using a second order approximation as,

$$\begin{aligned} D \simeq \frac{1}{2} \sum_j \lambda_j \, \theta_j Var_{\Omega(j)} \left(\sum_k \psi_{(k)} \, \Delta log \mu_k^{DLEU} \right) \\ + \frac{1}{2} \sum_j \lambda_j \, \theta_j Cov_{\Omega(j)} \left(\sum_g \psi_{(g)} \, \Delta log \Lambda_g, \sum_l \psi_{(l)} \, \Delta log \mu_l^{DLEU} \right), \end{aligned} \tag{A5}$$

where, μ_k^{DLEU} is the price markup, θ_j is the substitution elasticity, λ_j is the producer's sales share, Λ_g is the income-based Domar weight, and ψ is the inverse of the Leontief matrix. As this formula shows, the technological frontier expands with increases in price markup, substitution elasticity, producer sales share, and the Leontief inverse matrix. In addition, all terms are related to price markup, substitution elasticity, and the characteristics of the production network, and the distance to the technological frontier is determined while these variables are interrelated.

In equation (A5), $\Delta log \Lambda_g = \sum_k \frac{dlog \Lambda_g}{dlog \mu_k^{DLEU}} \Delta log \mu_k^{DLEU}$, and $\frac{dlog \Lambda_g}{dlog \mu_k^{DLEU}}$ is given by the following equation;

$$\begin{aligned} \frac{dlog \Lambda_f}{dlog \mu_k^{DLEU}} = - \sum_j \frac{\lambda_j}{\mu_j} (\theta_j - 1) Cov_{\tilde{\Omega}(j)} \left(\tilde{\psi}_{(k)} + \sum_g \tilde{\psi}_{(g)} \frac{dlog \Lambda_g}{dlog \mu_k^{DLEU}}, \frac{\psi_{(f)}}{\Lambda_f} \right) \\ - \lambda_k \frac{\psi_{kf}}{\Lambda_f}. \end{aligned} \tag{A6}$$

The covariance in equations A5 and A6 were calculated according to to the following;

$$Cov_{\tilde{\Omega}(j)} \left(\tilde{\psi}_{(k)}, \psi_{(f)} \right) = \sum_i \tilde{\Omega}_{ji} \, \tilde{\psi}_{ik} \psi_{if} - \left(\sum_i \tilde{\Omega}_{ji} \, \tilde{\psi}_{ik} \right) \left(\sum_i \tilde{\Omega}_{ji} \, \psi_{if} \right). \tag{A7}$$