Price Rigidity and Market Structure: Evidence from the Japanese Scanner Data

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Abstract

This paper investigates how price rigidity arises out of the specific market structures, such as degree of market concentration and pricing decisions of retailers and manufacturers. Using Japanese scanner data that contains transaction prices and sales for more than 1600 industries from 1988 to 2008, we find statistically significant negative correlation between the frequency of price changes and the degree of market concentration after controlling total sales at the industry and industry-group dummies. The results of two-way analysis of variance at the intra-industry level suggests that the variation of the frequency of price changes depends on the differences among manufacturers as well as those among retailers.

JEL classification codes: L11, E31, C41
Key words: Price stickiness, Market structure, Degree of concentration

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1 Introduction

The relation between price rigidity and market structure has long been discussed since American economist, Gardinar C. Means discussed downward rigidity of price during the recession in relation to the industrial concentration in a Senate Document in 1935.[1] The implication of Means' findings is that price of less competitive market tends to be sticky, which is referred to as the "administered prices" hypothesis (Domberger (1979)). This hypothesis attracts considerable attention of researchers to this very day.[2] This is partly because empirical literatures in this field found strong heterogeneity in price stickiness across commodity items and interests in the determinants of the item-level variation in the frequency of price changes.[3]

As for the relation between market concentration and price stickiness, the results of existing literatures are mixed. Bils and Klenow (2004) examined 231 items in the U.S. CPI and found a statistically significant negative correlation between four-firm concentration rate and frequency of price changes. But they concluded that the degree of concentration is not a robust predictor because the effect on the frequency of price changes is no longer significant if controlled for item-group dummies. According to Álvarez and Hernando (2006), however, the recent survey from firms in the Euro area reveals the relation that higher competition leads to more frequent price changes, which is consistent with administered price hypothesis.

Major obstacles for the investigation is that the number of observations is highly restrictive due to the availability of price data as well as data on market share of individual firms. For example, Domberger (1979) regress partial adjustment coefficient, which is the measure of price adjustment rate on Herfindahl index and concentration ratio using 21 industries sample in the United Kingdom. The signs of coefficient are both positive, which is inconsistent with the inverse relation of the speed of price adjustment and the degree of market concentration. Carlton (1986) could include 27 observations

[1] "Industrial Prices and Their Relative Inflexibility," Senate Document 13, 74th Congress, First Session. Means (1936) classified the wholesales price index into ten group according to how many times prices are changed in a given time period and show that price index with low frequency of price changes tend to change less frequently and fall less in the Great Depression during the early 1930's.

[2] Wolman (2000) discusses the administered price in the context of theoretical development of menu cost models and provides historical review of empirical literature on price rigidity.

[3] Two major determinants are the cost structure and the degree of market competition. See Álvarez (2007) for details. As for the former, substantial part of the literature, for example, Álvarez and Hernando (2007) and Higo and Saita (2007) report that the inverse relation between the share of labor cost and the frequency of price changes.

in the OLS equation of average price age regressed on four firm concentration ratio. His result is consistent with the hypothesis such that the average duration become relatively long for the highly concentrated industry. Carlton points out, however, the result should be regarded with some caution due to the small number of observations. Ariga and Ohkusa (1998) examine the relation between the average response to shocks in target prices and the Herfindahl index using 68 samples from Japanese Consumer Price Index series. Expected sign of coefficient is negative, but estimation result shows positive and statistically insignificant effect of market concentration.

Our scanner data is particularly useful for analysing the relation between the market structure and price rigidity. One reason is that it contains daily transaction prices and sales of products, which is not aggregated in any dimension so that we can calculate various statistics accurately from the data at the most disaggregated level. The other reason is that data covers more than 1600 industries so that we can precisely conduct statistical inference at the industry level as well.[4] At the inter-industry level, we examine the relation between the frequency of price changes and the degree of market concentration, measured by Herfindahl-Hirschman Index and n-firm concentration ratio. At the intra-industry level, we investigate the source of heterogeneity in price setting behavior focusing on the vertical relation between retailers and manufacturers

The empirical results are summarized in the following three findings. First, we find statistically significant negative correlation between the frequency of price changes and the degree of market concentration after controlling total sales at the industry and industry-group dummies. Second, 90% of industries reject both hypotheses that mean frequencies of price changes are equal across manufacturers and that mean frequencies of price changes are equal across retailers. The result suggests that there is significant heterogeneity in mean frequency of price changes across manufucturers and that across retailers as well in this large part of the industries. Thirdly, for relatively small proportion of the indusries, we found that the degree of price stickiness tends to equal among manufacturers as the degree of market concentration becomes higher but the same does not hold for retailers. The price stickiness is uniformly high among individual retail stores and among manufacuturers as well in the industries with highly sticky price.

The remainder of our paper is structured as follows. In Section 2, we describe our scanner data and show the statistics used in our analysis. In Section 3, we discuss our estimation results. Section 4 concludes this paper.

[4]Researchers on the issue of price indexes also interests in these feature of scanner data. See Feenstra and Shapiro (2001) and ILO et al. (2004).

2 Data

2.1 Structure of Scanner Data

This paper employs voluminous scanner data collected by Nikkei Digital Media inc. The company originally provides 3-digit and 6-digit classification of industries, which we follow in this analysis. Our dataset contains 215 industry groups at 3-digit classification and 1,691 industries at 6-digit classification. The number of companies and the number of stores within an industry, which varies across industries, relates to the important industry characteristics. If a industry is highly competitive, for example, the number of firms in the industry may be quite large. It is predictable that the number of stores is positively correlated to the sales volume within the industry. At the most disaggregate level, the data records the price, sales and quantity of item sold in certain outlet within a day. The item is characterized by JAN code[5] and therefore, the each record is not aggregated in any dimension. From this minimum unit of record, we construct various statistic with different levels of aggregation.

The advantages of the our scanner data is that we can identify producer of the item from JAN code. In the case of 13-digit code, the first 2-digit number is country code (45 or 49 for Japan) and the following 7- or 5-digit code is a company prefix according to the year the company is registered. The company prefix are allocated to member company by EAN Association and managed by the Distribution System Research Institute (DSRI) in Japan.[6] Matching the company prefix provided by DSRI, we can calculate company-specific statistics such as company's sales share within a industry and mean frequency of price changes calculated by company.

2.2 Basic Statistic and Empirical Method

This paper is based on the two important statistics: the mean frequency of price changes and the measure of market concentration, such as four firm concentration ratio and the Herfindahl Index. We calculate the frequency of price changes for the industry by first calculating the frequency that is specific to the item defined by JAN code sold in a particular outlet. This is the basic building block on which our analysis based. Formally, let X_{ij}^{l} be the frequency of price changes of the ith item ($i = 1, \ldots, I$) sold in the jth

[5] In Japan, commodity items are allocated 13- or 8-digit identification code, which is called JAN code. See Abe and Kondo (2006) for details.

[6] The DSRI administrates the database of item information corresponding to JAN code, which is called JICFS/IFDB. The information is available at http://www.dsri.jp/.

store ($j = 1, \ldots, J$) within the lth industries. The frequency of price changes is calculated as

$$X_{ij}^l = \frac{D_{ij}^l}{T_{ij1}^l + \cdots + T_{ijM}^l}, \tag{1}$$

where D_{ij}^l is the number of price changes in the ith item sold in the jth store and T_{ijm}^l is the mth price duration of the corresponding item. The denominator equals total observation time for the item in the outlet. This statistic is naturally interpreted as how many times prices are changed during the observation period. We construct our industry level frequency of price changes X^l by taking weighted average of X_{ij}^l by weighting the total sales of ith item sold in the jth store q_{ij}^l, that is,

$$X^l = \sum_{i=1}^{I} \sum_{j=1}^{J} q_{ij}^l X_{ij}^l. \tag{2}$$

The Herfindahl-Hirschman index and n-firm concentration ratio of the lth industry is calculated from firm's sales volume within the industry. Let q_k^l is the total sales of the kth firm ($k = 1, \ldots, K$) in the lth industry. The Herfindahl-Hirschman index is defined as

$$HHI^l = \sum_{k=1}^{K} (s_k^l)^2, \tag{3}$$

where s_k^l is the market share of the kth firm in the lth industry measured by the firm's sales volume, i.e., $s_k^l = q_k^l / \sum_{k=1}^{K} q_k^l$.

The n-firm concentration ratio is defined as follows: Let $r_1^l > r_2^l > \cdots > r_K^l$ represent the descending order of $q_1^l, q_2^l \ldots, q_K^l$. The n-firm concentration ratio can be written as

$$CR_n^l = \frac{\sum_{k=1}^{n} r_k^l}{\sum_{k=1}^{K} r_k^l}. \tag{4}$$

We shall infer the relation between market concentration and the price stickiness from the frequency of price changes, the Herfindahl-Hirschman index and n-firm concentration ratio of the lth industry that are all suitably defined from the available information in our scanner data. In the calculation of the frequency of price changes, we use the sample of entire observation period from March 1988 to April 2008. We calculate the Herfindahl-Hirschman index and market concentration ratio using samples during the year of 2000.

In order to find the source of heterogeneity in the frequency of price changes at the intra-industry level, we employ the frequency of price changes of the ith item sold in the jth store, X_{ij}^l again. Our motivation is to find

out where the variation of X_{ij}^l comes from the difference of the producers, or from the difference of retailers, or from both.[7] For this purpose, we shall conduct two-way analysis of variance test of equality of mean frequency of price changes.[8] The two-way analysis of variance model can be written as

$$X_{ij}^l = (constant) + \alpha_k^l + \beta_j^l + Z_{ij}^l, \tag{5}$$

subject to $\alpha_1^l + \cdots + \alpha_K^l = 0$, $\beta_1^l + \cdots + \beta_J^l = 0$, and $Z_{ij}^l \sim$ i.i.d. $N(0, \sigma^2)$. The hypothesis of interest are there is no significant difference of mean frequency of price changes among manufacturers, that is,

$$H_{0A} : \alpha_1^l = \cdots = \alpha_K^l; \tag{6}$$

and there is no significant difference of mean frequency of price changes among retailers, that is,

$$H_{0B} : \beta_1^l = \cdots = \beta_J^l. \tag{7}$$

It should be noted that we test these hypotheses by industry. We shall report the number of industries in which these hypotheses are rejected and its proportion to the whole industries in the next section.

3 Results

Table 1 summarize the relation between the degree of market concentration and the frequency of price changes at the industry-level. The dependent variable, i.e., industry-level frequency of price changes is defined in Equation (2). As expected from the "administered prices" hypothesis, the sign of variables corresponding to the degree of market concentration (HHI defined in Equation (3), $CR3$, $CR4$, $CR8$ defined in Equation (4)) is negative for 3 different specifications of the regression model and these variables are highly significant. The result is robust after we control for 214 industry group dummies (Models (5)–(8)) and both of the group dummies and total sales of the industry (Models (9)–(12)).

[Table 1 about here.]

[7] In the recent contributions to the empirical study, researchers focus on the price-setting behavior of producers and the one of retailers as well. See for example, Dutta, Bergen, and Levy (2002) and Nakamura (2008).

[8] See Fisher (1973) for details.

Figures 1 and 2 shows the scatter plot for frequency of price changes and the HHI and that for frequency of price changes and $CR4$, respectively. Although it is difficult to graphically judge the correlation of these variables, least squares linear fit to the data shows there is indeed inverse relation between these variables.

[Figure 1 about here.]

[Figure 2 about here.]

Tables 2 and 3 illustrates the two-way analysis of variance tests of equality of mean frequency of price changes. We obtain these figures in the table after excluding industries that did not pass the F-test for joint significance of all variables.[9] First of all, the figures in the last column tell us 90% of industries reject both H_0A: mean frequencies of price changes are equal across manufacturers and H_0B: mean frequencies of price changes are equal across retailers. This result suggests that there is significant heterogeneity in mean frequency of price changes across manufucturers and that across retailers as well in this large part of the industries. The number of the industries that reject only H_0A and that reject only H_0B is both 71, which account for 5 percent of the whole industries. Though proportion of industries is rather small, the test results of these industries indicate us the important feature of the industry. This is because, in these industries in which reject only H_0A (H_0B), there is no significant difference in price stickiness among retaileres (manufacturers).

In order to figure out if these test results relates to the degree of concentration or price stickiness of the industries, we divide 1,533 Industries into quantiles according to the four firm concentration ratio (Table 2) and the industry level price stickiness (Table 3)[10]. The result in the second and third rows in Table 2 implies the degree of price stickiness tends to equal among manufacturers as the degree of concentration becomes higher (third row) but the same does not hold for retailers (second row). This fact may be understood as that the degree of concentration is the manufacturers' side of characteristics and thus is irrelevant to the price stickiness (or flexibility) associated with the retailers' pricing behavior. However, the result in the second and third rows in Table 3 indicates that the variation of the price stickiness among manufacturers becomes small in the highly sticky industries

[9]These industries amount to 128. Subtracting 128 industries from total of 1,661 industries, we get total of 1,553 industries.

[10]The corresponding four firm concentration ratio for each group: very low ($CR4 < 0.65$), low ($0.65 \leq CR4 < 0.83$), high ($0.83 \leq CR4 < 0.95$), very high ($CR4 \leq 0.95$)

(third row) and the same holds true for retailers (second row). This suggests that in the industries within highly sticky group, the price stickiness is uniformly high among individual retail stores and among manufacturers as well.

[Table 2 about here.]

[Table 3 about here.]

4 Concluding remarks

This paper investigates how price rigidity arises out of the specific market structures, such as degree of market concentration and pricing decisions of retailers and manufacturers. Using Japanese scanner data that contains transaction prices and sales for more than 1600 industries from 1988 to 2008, we find statistically significant negative correlation between the frequency of price changes and the degree of market concentration after controlling total sales at the industry and industry-group dummies. We establish the fact that there is significant heterogeneity in mean frequency of price changes across manufacturer and that across retailers as well in this large part of the industries. For relatively small proportion of the industries, we found that the degree of price stickiness tends to equal among manufacturers as the degree of market concentration becomes higher but the same does not hold for retailers. In the industries with highly sticky price, the price stickiness is uniformly high among individual retail stores and among manufacturers as well.

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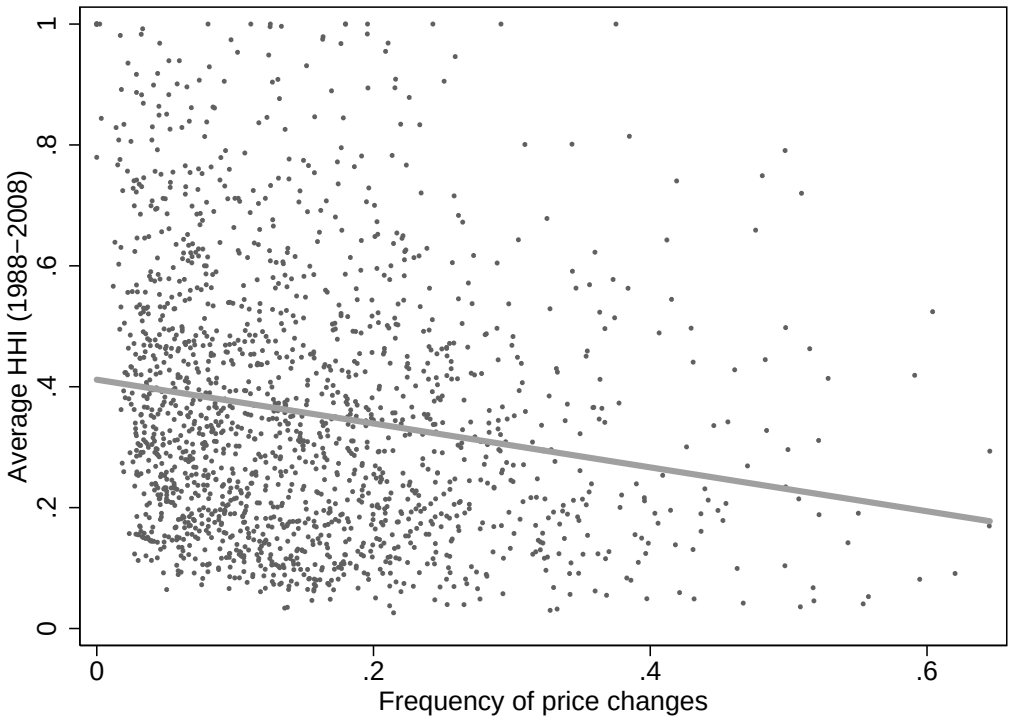

Figure 1: Herfindahl-Hirschman Index and frequency of price changes: The total number of observations is 1,661. Japanese scanner data collected by Nikkei Digital Media inc.

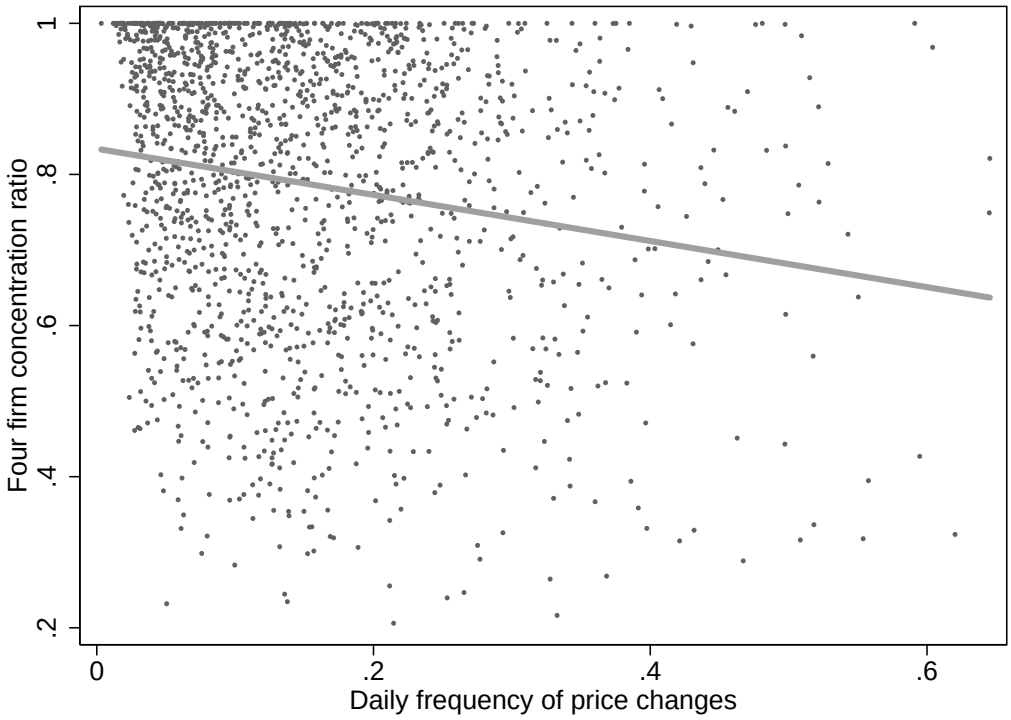

Figure 2: Four firm concentration ratio and frequency of price changes Same data as in Figure 1.

Frequency of Price Changes	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
HHI	–0.062				–0.043				–0.025			
	(0.011)	-	-	-	(0.009)	-	-	-	(0.009)	-	-	-
	[0.000]				[0.000]				[0.004]			
CR3		–0.083				–0.051				–0.025		
	-	(0.012)	-	-	-	(0.011)	-	-	-	(0.010)	-	-
		[0.000]				[0.000]				[0.017]		
CR4			–0.099				–0.059				–0.029	
	-	-	(0.014)	-	-	-	(0.012)	-	-	-	(0.012)	-
			[0.000]				[0.000]				[0.012]	
CR8				–0.154				–0.088				–0.037
	-	-	-	(0.020)	-	-	-	(0.017)	-	-	-	(0.017)
				[0.000]				[0.000]				[0.027]
Industry group dummies	-	-	-	-	*	*	*	*	*	*	*	*
Total sale (in billion yen)	-	-	-	-	-	-	-	-	0.035 (0.000) [0.000]	0.035 (0.000) [0.000]	0.035 (0.000) [0.000]	0.035 (0.000) [0.000]
Constant	0.173	0.214	0.231	0.292	0.456	0.472	0.479	0.508	0.426	0.433	0.437	0.447
	(0.005)	(0.009)	(0.011)	(0.018)	(0.021)	(0.021)	(0.022)	(0.024)	(0.020)	(0.021)	(0.021)	(0.023)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Table 1: The degree of market concentration and the frequency of price changes at the industry-level. *: 214 dummy variables for indusrial group (3-digit classification) are included in the regression equations (5)–(12). All equations are based on 1,661 observations. Standard errors in parenthesis and p-value in square brackets. Japanese scanner data collected by Nikkei Digital Media inc.

	Degree of Concentration				
Test Result	very low	low	high	very high	Total
Reject H_{0A} and H_{0B}	376	365	345	297	1,383
	(24.5)	(23.8)	(22.5)	(19.4)	(90.2)
Reject only H_{0A}	17	18	18	18	71
	(1.11)	(1.17)	(1.17)	(1.17)	(4.63)
Reject only H_{0B}	2	10	19	40	71
	(0.13)	(0.65)	(1.24)	(2.61)	(4.63)
Both Retained	2	1	3	2	8
	(0.13)	(0.07)	(0.20)	(0.13)	(0.52)
Total	397	394	385	357	1,533
	(25.9)	(25.7)	(25.1)	(23.3)	(100)

Table 2: Market concentration and two-way analysis of variance tests of equality of mean frequency of price changes. The null hypotheses are H_0A: mean frequencies of price changes are equal across manufacturers and H_0B: mean frequencies of price changes are equal across retailers. 1,533 Industries are divided into quantiles according to the four firm concentration ratio during the year of 2000. The corresponding ratio for each group: very low (less than 0.65), low (0.65–0.83), high (0.83–0.95), very high (greater than 0.95). Cell percentage is given in parenthesis.

	Price Stickiness				
Test Result	very low	low	high	very high	Total
Reject H_{0A} and H_{0A}	400	396	343	244	1,383
	(26.1)	(25.8)	(22.4)	(15.9)	(90.2)
Reject only H_{0A}	6	6	23	36	71
	(0.39)	(0.39)	(1.50)	(2.35)	(4.63)
Reject only H_{0B}	3	6	18	44	71
	(0.2)	(0.39)	(1.17)	(2.87)	(4.63)
Both Retained	1	2	2	3	8
	(0.07)	(0.13)	(0.13)	(0.20)	(0.52)
Total	410	410	386	327	1,533
	(26.7)	(26.7)	(25.2)	(21.3)	(100)

Table 3: Industry-level price stickiness and two-way analysis of variance tests of equality of mean frequency of price changes. Industry-level price stickiness is weighted average of the frequencies of price changes for individual items in the industry. 1,533 Industries are divided into quantiles according to the industry-level frequency of price changes. The weighted mean frequency of price changes for each group: very low (0.347), low (0.181), high (0.106), very high (0.055). Cell percentage is given in parenthesis. Same hypotheses as in Table 2.