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Innovation and Competition

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Innovation and Competition※

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Abstract

This paper presents the relation between innovation and competition at industry level (based on the Japan Standard Industrial Classification [JSIC] 3-digit level) and firm level. Using data of manufacturing sector in Japan, 2007-2017, from the basic survey of Japanese business structure and activities and so on, this study examines how innovation index, R&D expenditure, is related to competition indices such as HHI or markups. It finds that there exist so called inverted U relations between them. From the viewpoint of competition policy, it implies that it is important to keep competitive pressure on industries with high HHI or firms with high markups to make them innovative, and to induce further economic growth.

1. Introduction

Firms are making efforts to attract consumers' interests for their own goods or services, in order to survive in markets concerned. Those kinds of efforts can be followed by innovation which would give wide range of choices to consumers or promote economic growth. Since it is often said that there exist two types of effects on the relation between innovation and competition, escape competition effect and Schumpeter effect, this study is trying to find out what kind of relation there is or is not in Japan.

Section 2 briefly summarizes previous works in this area and section 3 explains data analysis conducted. Then, section 4 concludes.

2. Previous works

There are actually tons of papers on this topic, innovation and competition. Motta (2004) theoretically

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analyzes the relation between the number of firms in a market and investment and shows that when the number of firms increases, each firm's investment becomes small but not the total market investment. i.e. more firms in the market provide more investments in the industry. Aghion et al (2005) says that there are two kinds of effects on the relation between innovation and competition, escape competition effect and, so called, Schumpeter effect. For those two effects, it shows both theoretically and empirically that the relation between innovation and competition is inverted U shape. Hashmi (2013), on the other hand, revisits Aghion et al (2005) by using the United States data, and shows that the inverted U relation does not arise. It discusses that the relation between innovation and competition depends on industrial characteristics which varies country by country, and in the United States, because technology gap in a same industry is large and big companies tend to have technical advantage, there is no escape competition effect but Schumpeter effect, which makes the relation simply linear and negative. Meanwhile in the United Kingdom, that technical gap is small and both price escape effect and Schumpeter effect work which provides the inverted U relation on competition and innovation. Goettler and Gordon (2014) shows the inverted U arises between competition and innovation by using simulation models when the competition level is measured by product substitution. IMF(2019) empirically shows the inverted U shape of the relation between markup and patents using data of 27 countries including Japan. For previous works using Japanese data, Doi(1986) says that the inverted U relation on innovation and competition can exist theoretically, but empirically Schumpeter effect does not exist by using Japanese R&D data in 1972 and patent data from 1973-1975. Niidaet al（1987） empirically shows that R&D activities is more difficult in oligopolistic industries by using R&D data in 1984. Yagi and Managi (2013) applies Aghion et al (2005) to Japanese patent data from 1964 to 2006 and finds that the inverted U relation can be observed but fragile in terms of robustness.

3. Data analysis

(1) Data[1]

This study conducts data analysis at both industry level (based on JSIC 3-digit level) and firm level using the data of manufacturing sector in Japan (hereinafter, "industry(s)" means one(s) based on JSIC 3-digit level in manufacturing sector.). The data source of this analysis is the basic survey of Japanese business structure and activities, provided by the Ministry of Economy, Trade and Industry, METI (hereinafter refer to "the basic survey"). This paper focuses on manufacturing sector (but industry of ordnance and accessories[2]) between 2007 and 2017 for the following three reasons; 1) Over 20 % of Japan's GDP still comes from manufacturing sector, the largest share among any industry sectors[3]; 2) Even though the classification of industries of the basic survey has revised several times so far, the

[1] All data were used after being organized by the authors.

[2] This industry comprises establishments primarily engaged in manufacturing gun, bullet, cannonball, ammunition except guns bullet, special armored car.

[3] "industry sectors" here includes not only manufacturing sector but other sectors. Cabinet Office (2020), P6)

classification have been relatively stable since 2007; 3) During the period of 2007 and 2017, more than 40 percent of all firms in total covered by the survey belong to manufacturing sector (143,955 out of 328,641 firms in total).

Another data source is trade statistics of Japan, provided by Ministry of Finance, MOF. The data of import volume of each product belonging to manufacturing sector above was collected from the MOF website and combined into the data of the basic survey.

(2) Industry-level analysis

The estimated formula is as follows:

$$R\&D\ expense_{j,t} = \beta_1 + \beta_2 HHI_{j,t-1} + \beta_3 {HHI^2}_{j,t-1} + \beta_4 sale_{j,t-1} + \beta_5 importvolumes_{j,t-1} + yeardummy + \varepsilon_{j,t}$$

where

R&D expense (logarithm): Summation of in-house R&D expense and contract R&D expense in each firm in each industry[4]

sale (logarithm): Summation of each firm's sale in each industry

HHI: Summation of squared market share of each firm in each industry[5]

HHI^2: HHI squared

importvolumes (logarithm): Summation of each import volume by unit such as kg, cubic meters and so on[6]

yeardummy: dummy variable of fiscal year (April to March)

ε: error term

j: industry, and

t: fiscal year

"*R&D expense*" above represents innovation, or more precisely innovation "incentive" of the industry concerned because it seems to represent firms' incentive to innovate (i.e. it is supposed that firms which are eager to make innovation happen tend to spend more money on R&D.) and *R&D expense* here is summation of *R&D expense* of each firm in each industry. Then "*HHI*" above represents the degree of competition, even though HHI in this paper does not based on, so called relevant market or particular field of trade in competition law (because "industry" in this paper is not

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[4] The data of in-house R&D expense or contract R&D expense which are below 0 are dropped (The number of data dropped is 6).

[5] Market share is based on sale. Due to the data restriction, in a case of firms which do business, for instance, in industry A and B, those firms' market share in industry A or B is calculated on a basis of its sale in industry A *and* B. If the sale in industry A is very small while one in industry B is very large, the market share in industry A would be overvalued and it might affect the estimated parameter of market share in industry A.

[6] Since there are 7 units: cubic meters, carat, kg, meters, pieces, square meters, thousand pieces (littler is converted into kg, so is metric ton[1,000kg]), there are 7 variables.

necessarily equal to the relevant market or the particular field of trade.)[7]. Also it is estimated with/without import volumes to control competitive pressure from outside. "*sale*" is included to control the size of industries.

The results are in table 1 and they show that R&D expense in industries would increase as HHI increase but it starts to decrease once HHI passes a certain threshold, i.e. the inverted U shape. In our data, those thresholds are 0.32 (in a case of column (1) and (3)) and 0.38 (in a case of column (2) and (4)). HHI in approximately top 5% of industries in total in our data is above 0.32[8,9].

<Table 1: Results of estimation at industry level>

	(1)	(2)	(3)	(4)
1-year lagged HHI	3.6064***	4.4684***	3.4662***	4.2075***
	(1.330)	(1.2969)	(1.2456)	(1.2406)
1- year lagged HHI Squared	-5.4976***	-5.8688***	-5.2849***	-5.5145***
	(1.8418)	(1.8395)	(1.8063)	(1.8192)
1-year lagged sale (logarithm)	0.6872***	0.4934***	0.6931***	0.5208***
	(0.1417)	(0.1288)	(0.1228)	(0.1137)
1-year lagged Import volumes (logarithm)	YES	YES	NO	NO
industry fixed effect	YES	YES	YES	YES
fiscal year dummy	YES	NO	YES	NO
observation	576	576	576	576
R-squared（within)	0.1546	0.1154	0.1399	0.0923
R-squared（between）	0.0443	0.0132	0.7304	0.7346
R-squared（overall）	0.0417	0.0126	0.6854	0.6839

Note
1: standard error in parenthesis
2 *p<0.10; **p<0.05; ***p<0.01

[7] Even though competition authorities often use HHI in their practices; for example, Japan Fair Trade Commission, JFTC, uses HHI to set safe harbor thresholds for merger review (JFTC[2004]PartIV1(3)), it should be noted that HHI in this paper is not necessarily equal to HHI in relevant market or a particular field of trade in competition law, and hence, there exist a certain limits to utilize the thresholds in this paper in practice. See also footnote 5.

[8] For example, HHI of industries such as "Tires and Inner Tubes", "Silk reeling, Spinning, Chemical Fibers and Twisting and Bulky yarns", "General Industry Machinery and Equipment", "Boilers, Engines and Turbines", "Optical Instruments and Apparatus, and Lenses" and "Household Electric Appliances" are over 0.32 depending on fiscal years surveyed.

[9] For a reference, the results of industrial statistics survey by METI in 2008 show that HHIs in 7% of all goods were over 5000, and 25% of them were over 2500. Please note that the industrial statistics survey is goods-based, and the basic survey in this paper is industry-based.

(3) Firm-level analysis

It is often controversial what the most suitable index for firm's market power is and how should it be calculated[10]. IMF(2019) uses the firm's markup for firm's market power, which is calculated as *the ratio of the output elasticity of the variable input considered to the expenditure share of that input* and explains that while the latter can be readily computed from any dataset containing firm-level information on sales and input expenditure, the former has to be estimated from production function. Then it estimates the former using an *industry-specific* Cobb-Douglas production function following Ackerberg, Caves and Frazer (2015). Following the IMF(2019), i.e. markup is estimated in a same way, that is the ratio of the output elasticity of the variable input considered (numerator) to the expenditure share of that input (denominator), this study, however, estimates an *industry-specific* Cobb-Douglas production function to estimate numerator by the following two models, fixed effect model[11] and the model proposed by Levinson and Petrin (2003) (hereinafter referred to "LP model")[12]. More concretely, the numerator in this study is the output (i.e. sale) elasticity of "costs to sale" at industry level and the denominator is the ratio of "costs to sale" to "sale" at firm level (After all, markups is different firm by firm.).

This study also tests if the production function estimated has a feature of constant returns to scale (hereinafter referred to "CRS") because if CRS holds, it means AVC (average variable costs) is equal to MC (marginal costs) and markups based on average variable cost (hereinafter "AVC markup"), *p/AVC,* can be the index for firms' market power. After all, CRS assumption is rejected in most of industries[13]. Please refer to Annex 1 for the results of production functions estimated to calculate markups in fixed effect model and LP model as well as CRS tests.

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[10] This study uses so called markup for firm's market power. In general, markup is calculated by $p/_{MC}$ or $p/_{AVC}$ if we assume constant return to scale, where *p*:price, *MC*: marginal cost, *AVC*: average variable cost. Considering *p=AVC+AFC* (average fixed cost) +*profit per unit*, however, markup can be large not only when *profit per unit* is large but also when *AFC* is large. If the latter is the case, markup may not be an appropriate index for firm's market power. In this sense, there is a room to reconsider to use markup for firm's market power.

[11] Estimated formula is $y_{jt} - \bar{y} = \beta_l(l_{jt} - \bar{l_\iota}) + \beta_k(k_{jt} - \bar{k_\iota}) + \beta_x(x_{jt} - \bar{x_\iota}) + (e_{jt} - \bar{e_\iota})$ using firm level data (fiscal year dummy variable is included when estimated), where y=logY, x=logX, k=logK, l=logL (Y=sale, X=cost of sale[more precisely, cost to sale minus salary], K=fixed assets and L=number of employees) and e=error term, j=industry, t=fiscal year. The data of firms with top 1% and bottom 1% of sale, cost to sale, fixed assets and number of employees are dropped since they include extremely high or low numbers. Here it is supposed that factors which may affect not only *y* but also *k*, *l* or *x* are constant in short run. The markup for each firm is calculated by $\widehat{\beta_{x,J}} \Big/ \left(X_{i,t:i\in j} \big/ Y_{i,t:i\in j} \right)$, where i=firm.

[12] Proxy variable here is salary level per employee (total salary/total number of employee). The data of firms with top 1% and bottom 1% of sale, cost of sale, fixed assets and salary level per employee are dropped since they include extremely high or low numbers. The markup is calculated in the same way of the fixed effect model. The papers referred to for this estimation are Nakamura(2014), Nakamura(2018) and Tanaka (2010).

[13] The results were the same when AVC markups were used. Please refer to Annex 2.

Estimated formula is as follows:

$$R\&D\ expense_{i,t} = \beta_1 + \beta_2 markup_{i,t-1} + \beta_3 markup_{i,t-1}^2 + \beta_4 sale_{i,t-1}$$

$$+ importvolumes_{j,t-1} + year\text{dummy} + \varepsilon_{i,t}$$

where

R&D expense (logarithm): in house R&D expense plus contract R&D expense of firm *i*[14]

*markup*s: one in fixed effect model[15], one in LP model[16]

sale (logarithm)*:* each firm's sale

importvolumes (logarithm): import volume by unit such as kg, cubic meters and so on of industry *j* to which firm *i* belongs[17].

yeardummy: dummy variable of fiscal year (April to March)

i: firm

j:industry, and

t:fiscal year.

The descriptive statistics of markups are in Table 2. The histograms of each markup are in Figure 1. The year average of markups is in Table 3 and correlation coefficients among them are in Table 4.

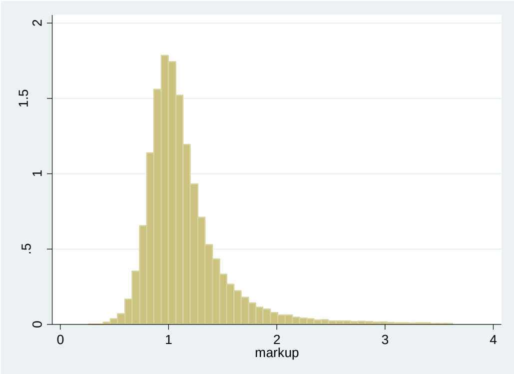
<Table 2: Summary statistics on markups>

	Obs	Mean	Std. Dev	Min.	Max.
Fixed effect model	111,565	1.1524	0.3865	0.2603	3.6247
LP model	110,448	1.2665	0.4269	0.2734	4.1330

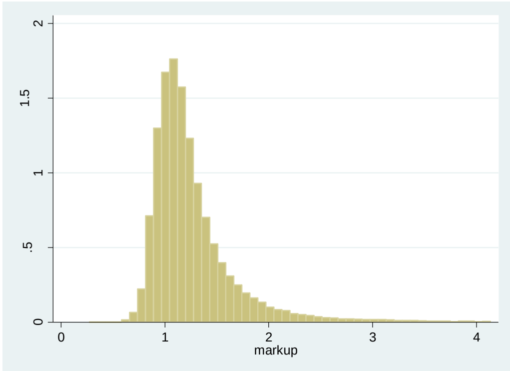
14 Ibid 4
15 The data of firms with top 1% of markup is dropped since it includes extremely high numbers.
16 Ibid 15
17 Ibid 6

<Figure 1: Histograms of markups>

(a) Fixed effect model



(b)LP model



<Table 3: Year average of markups>

Fiscal Year	Fixed effect model	LP model
2007	1.1364	1.2496
2008	1.1257	1.2354
2009	1.1418	1.2571
2010	1.1588	1.2720
2011	1.1521	1.2678
2012	1.1530	1.2706
2013	1.1531	1.2682
2014	1.1498	1.2609
2015	1.1540	1.2682
2016	1.1765	1.2903
2017	1.1776	1.2931

<Table 4: Correlation coefficients between markups>

	Fixed effect model	LP model
Fixed effect model	1	-
LP model	0.9927	1

The results are in Table 5 and it shows that R&D expense would increases as markups increase but it starts to decrease once markups pass a certain threshold, i.e. the inverted U shape. In our data, those thresholds are 2.3 in fixed effect model and 2.6 in LP model. (Each corresponds to approximately top 3% of total firms' data.).

<Table 5: Results of estimation at firm-level>

	Fixed effect model			LP model		
	(5)	(6)	(7)	(8)	(9)	(10)
1-year lagged Markup	0.6628***	0.6488***	0.7147***	0.7236***	0.7234***	0.8023***
	(0.1173)	(0.1160)	(0.1155)	(0.1119)	(0.1115)	(0.1107)
1- year lagged Markup Squared	-0.1444***	-0.1394***	-0.1531***	-0.1389***	-0.1377***	-0.1529***
	(0 .0317)	(0.0314)	(0.0314)	(0.0265)	(0.0264)	(0.0263)
1-year lagged sale (logarithm)	0.4060***	0.4126***	0.4054***	0.4340***	0.4391***	0.4309***
	(0.0276)	(0.0274)	(0.0264)	(0.0287)	(0.0286)	(0.0274)
import volumes (logarithm)	YES	YES	YES	YES	YES	YES
firm fixed effect	YES	YES	YES	YES	YES	YES
fiscal year dummy	YES	YES	NO	YES	YES	NO
industry dummy	YES	NO	NO	YES	NO	NO
observation	16364	16364	16364	16018	16018	16018
R-squared（within)	0.0326	0.0265	0.0226	0.0364	0.0291	0.0256
R-squared（between）	0.5415	0.5566	0.5570	0.5490	0.5763	0.5781
R-squared（overall）	0.5765	0.5851	0.5855	0.5863	0.6069	0.6086

Note
1: standard error in parenthesis
2 *p<0.10; **p<0.05; ***p<0.01

4. Conclusion

The results above show that an innovation incentive of industries or firms gets weak once the degree of competitive pressure passes a certain thresholds. To consider the results from the viewpoint of competition policy, they imply mainly two things. The first one is rather abstract: it is important to keep competitive pressure on the industries with high HHIs or firms with high markups to make them innovative, and to induce further economic growth. The second one is that HHI or markup can be informative for competition agencies to review M&As carefully in terms of innovation. For example, the results of industry-level analysis above says that R&D activities would be increased as HHI increase but it starts to decrease once HHI passes 0.32 or 0.38. If you look at the actual M&A cases where one of main issues was innovation competition such as Dow/Dupont case in 2017 or Bayer/Monsanto case in 2018, the HHIs in the sector that European Commission had concerns were

0.3~ in Dow/Dupont[18] and 0.3~ in Bayer/Monsanto[19], that cover the threshold (0.32~0.38) above. Even though the industries in this paper, on which HHIs is based, are not necessarily equal to relevant markets or particular fields of trade in competition law, the results here can be useful reference for the agencies to review M&As carefully in terms of innovation[20].

[18] Press release of European Commission (27 March 2017) says that the transaction would have had a significant impact on innovation competition by, for example, removing the parties' incentives to continue to pursue ongoing parallel innovation efforts in a number of important herbicide (Post HHI based on patent shares [based on external citations]: 3500-4000), insecticide (5000-5500) and fungicide (3000-3500) innovation areas (European Commission [2017] Annex1, Table 5). The final decision of EC was, of course, based on not only HHI but also other factors.

[19] European Commission (2018) Table 137(P396), The final decision of EC was, of course, based on not only HHI but also other factors.

[20] See also footnote 5

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Estimation results of production functions to calculate output elasticity of variable input (costs to sale) in fixed effect model and LP model

1. Dependent variables are sale (logarithm).
2. *p<0.10; **p<0.05; ***p<0.01
3. “rejected” in the column of CRS means that the assumption of constant returns to scale is rejected.

No	industries	fixed effect model				LP model		
		capital(log)	labor(log)	costs to sale(log)	CRS	capital(log)	costs to sale(log)	CRS
1	Livestock Products	0.0464***	0.1457***	0.6570***	rejected***	0.1867***	0.7754***	not rejected
2	Seafood Products	0.0267***	0.1648***	0.7254***	rejected***	0.0926*	0.7265***	rejected***
3	Flour and Grain Mill Products	-0.0030	0.1776***	0.7317***	rejected***	0.0889	0.7961***	not rejected
4	Miscellaneous Foods and Related Products	0.0651***	0.2333***	0.5469***	rejected***	0.1806***	0.6398***	rejected***
5	Soft drink and Carbonated Water, Alcoholic Beverages, Tea, Tobacco	0.0169**	0.1416***	0.6623***	rejected***	0.0825**	0.7258***	rejected***
6	Prepared Animal Foods and Organic Fertilizers	0.0143	0.0441*	0.7573***	rejected***	-0.0390	0.8240***	rejected***
7	Silk Reeling Plants, Spinning Mills, Twisting And Bulky Yarns, etc.	0.0429*	0.0841***	0.7858***	rejected***	0.2545*	0.7723***	not rejected
8	Woven Fabric Mills and Knit Fabrics Mills	0.0018	0.1711***	0.7339***	rejected***	0.1085	0.8324***	not rejected
9	Dyed and Finished Textiles	0.0227	0.2579***	0.6840***	not rejected	0.0249	0.8141***	rejected**
10	Miscellaneous Fabricated Textile Products	0.0375*	0.2286***	0.5587***	rejected***	0.1064	0.7414***	not rejected
11	Textile and Knitted Garments	0.0347***	0.1949***	0.5589***	rejected***	0.0307	0.6894***	rejected***
12	Miscellaneous Textile Products	0.0796***	0.2832***	0.5587***	rejected***	0.0690	0.7261***	rejected***

No	industries	fixed effect model				LP model		
		capital(log)	labor(log)	costs to sale(log)	CRS	capital(log)	costs to sale(log)	CRS
13	Sawing, Planing Mills and Plywood	0.0288***	0.0911***	0.8147***	rejected***	0.1535***	0.7786***	rejected*
14	Miscellaneous Wood Products, except Furniture	-0.0073	0.0664	0.8226***	rejected**	-0.0897	0.7615***	rejected***
15	Furniture and Fixtures	0.0054	0.1919***	0.6981***	rejected***	0.1631*	0.7255***	not rejected
16	Pulp and Paper	-0.0153	0.1474***	0.7204***	rejected***	0.00005	0.8498***	rejected***
17	Paper Products	0.0228***	0.1582***	0.7296***	rejected***	0.0657	0.7985***	rejected***
18	Printing and Allied industries	0.0184***	0.2873***	0.5881***	rejected***	0.1208***	0.7537***	rejected***
19	Chemical Fertilizers and Industrial Inorganic Chemicals	-0.0088	0.1311***	0.6991***	rejected***	0.1946***	0.7779***	not rejected
20	Industrial Organic Chemicals	0.0331***	0.0977***	0.8356***	rejected**	0.0925**	0.7801***	rejected***
21	Oil and Fat Products, Soaps, Synthetic Detergents, Surface-Active Agents and Paints	0.0545***	0.3934***	0.5186***	rejected**	0.2060***	0.7068***	not rejected
22	Drugs and Medicines	0.0491***	0.6197***	0.3655***	rejected**	0.1616***	0.5495***	rejected***
23	Miscellaneous Chemical and Allied Products	0.0518***	0.2501***	0.5207***	rejected***	0.2266***	0.5622***	rejected***
24	Petroleum Refining	0.0987***	0.1174	0.7193***	not rejected	-0.0629	0.8022***	not rejected
25	Miscellaneous Petroleum and Coal Products	0.0093	0.1878***	0.7263***	not rejected	0.1310*	0.7837***	not rejected
26	Plastic Products	0.0214***	0.1601***	0.7256***	rejected***	0.0927***	0.7779***	rejected***
27	Tires and Inner Tubes	0.0427	0.1529*	0.3533***	rejected***	0.0883	0.6214***	not rejected
28	Miscellaneous Rubber Products	0.0560***	0.1360***	0.6262***	rejected***	0.2052***	0.7230***	not rejected
29	Leather Tanning, Finishing and its Products, Furs Skins	0.1249***	0.1204***	0.7236***	not rejected	0.1988	0.5825***	not rejected

No	industries	fixed effect model				LP model		
		capital(log)	labor(log)	costs to sale(log)	CRS	capital(log)	costs to sale(log)	CRS
30	Glass and its Products	0.0066	0.1841***	0.6902***	rejected***	0.1184	0.7176***	rejected**
31	Cement and its Products	0.0215**	0.1566***	0.7444***	rejected***	0.1567***	0.8000***	not rejected
32	Miscellaneous Ceramic, Stone and Clay Products	0.0328***	0.2058***	0.7027***	rejected***	0.1015*	0.7168***	rejected***
33	Iron Casting, Crude Steel and Steel materials	0.0088	0.0848***	0.8001***	rejected***	0.1257***	0.8027***	not rejected
34	Steel Casting and Miscellaneous Iron and Steel	0.0044	0.1437***	0.7695***	rejected***	0.1143***	0.7812***	rejected***
35	Primary Smelting and Refining of Non-Ferrous Metals	-0.0351**	0.1407***	0.7623***	rejected***	0.1219**	0.7972***	not rejected
36	Secondary Smelting and Refining of Non-Ferrous Metals	0.0155**	0.1779***	0.7053***	rejected***	0.0841***	0.8099***	rejected***
37	Fabricated Constructional and Architectural Products	0.0031	0.1987***	0.7339***	rejected***	0.1147***	0.7728***	rejected**
38	Miscellaneous Fabricated Metal Products	0.0015	0.2598***	0.6629***	rejected***	0.1502***	0.7142***	rejcted***
39	Boilers, Engines and Turbines	-0.0473**	0.2974***	0.6687***	not rejected	0.1191	0.7872***	not rejected
40	Pumps and Compressors	0.0345**	0.2259***	0.6265***	rejected***	0.0952	0.6915***	rejected***
41	General Industry Machinery and Equipment	0.0281***	0.1332***	0.7238***	rejected***	0.1169***	0.7736***	rejected***
42	Miscellaneous General-Purpose Machinery and Machine Parts	-0.0367***	0.2041***	0.6859***	rejected***	0.0332	0.7237***	rejected***
43	Metal Working Machinery and its Equipment	-0.0105	0.2238***	0.7130***	rejected***	0.1468***	0.7203***	rejected***
44	Production Machinery and its Equipment	0.0200***	0.2355***	0.7238***	rejected**	0.1602***	0.7377***	rejected***
45	Office Machines and Service Industry Machines	0.0113	0.1626***	0.7266***	rejected***	0.1971***	0.7293***	not rejected

No	industries	fixed effect model				LP model		
		capital(log)	labor(log)	costs to sale(log)	CRS	capital(log)	costs to sale(log)	CRS
46	Measuring Instruments, Analytical Instruments, Testing Machines, Surveying Instruments	0.0099	0.3638***	0.4841***	rejected***	0.1965***	0.6197***	rejected***
47	Medical Instruments and Apparatus	0.0935***	0.6494***	0.3620***	rejected***	0.2278***	0.5709***	rejected***
48	Optical Instruments and Lenses	-0.0060	0.2211***	0.6919***	rejected***	0.0976	0.7316***	rejected***
49	Electronic Parts, Devices and Electronic Circuits	0.0256***	0.1494***	0.7211***	rejected***	0.1061***	0.7547***	rejected***
50	Industrial Electrical Apparatus	0.0060	0.2161***	0.6952***	rejected***	0.1142***	0.7525***	rejected***
51	Household Electric Appliances	0.0399***	0.1062***	0.7789***	rejected***	0.0945	0.8205***	not rejected
52	Electronic Equipment	-0.0012	0.2629***	0.4709***	rejected***	0.0196	0.6785***	rejected***
53	Miscellaneous Electrical Machinery Equipment and Supplies	0.0350***	0.2216***	0.7076***	rejected**	0.1504***	0.7265***	rejected***
54	Communication Equipment and Related Products	0.0047	0.1846***	0.7263***	rejected***	0.0681***	0.7628***	rejected***
55	Electronic Data Processing Machines, Digital and Analog Computer, Equipment	0.0197	0.2758***	0.6812***	not rejected	0.1011	0.7538***	rejected**
56	Motor Vehicles, Parts and Accessories	-0.0023	0.1422***	0.7788***	rejected***	0.1241***	0.8179***	rejected***
57	Miscellaneous Transportation Equipment	0.0052	0.1804***	0.7770***	rejected***	0.0970***	0.7572***	rejected***
58	Miscellaneous Manufacturing Industries, n.e.c	0.0159**	0.3276***	0.6218***	rejected***	0.1530***	0.7072***	rejected***

AVC model

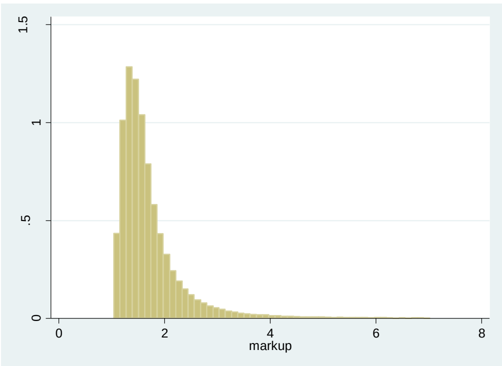
Estimated function is the same as in section 3(3) but markup here is AVC markup $(\frac{Sale_{i,t-1}}{total\ cost\ of\ sales_{i,t-1}})$[21]

The descriptive statistics of AVC markup is in table 6. The histogram is in figure 2. The year average of the markups are in table 7 and correlation coefficients among them are in table 8. Estimation results is in table 9. It shows that R&D expense would increase as AVC markups increase but it starts to decrease once the markups pass a certain threshold. In our data, the threshold is 4.4 which corresponds to approximately top 2% of total firms data.

<Table 6: Summary statistics on AVC markups>

	Obs	Mean	Std. Dev	Min.	Max.
AVC model	140,805	1.7324	0.6870	1.0391	7.0270

<Figure 2: Histograms of AVC markup>



<Table 7: Year average of markups>

Fiscal Year	Fixed effect model	LP model	AVC model
2007	1.1364	1.2496	1.7069
2008	1.1257	1.2354	1.6853
2009	1.1418	1.2571	1.7228
2010	1.1588	1.2720	1.7437
2011	1.1521	1.2678	1.7368
2012	1.1530	1.2706	1.7363

[21] The data of firms with top and bottom 1% of markup is dropped since it includes extremely high or low number

Fiscal Year	Fixed effect model	LP model	AVC model
2013	1.1531	1.2682	1.7313
2014	1.1498	1.2609	1.7248
2015	1.1540	1.2682	1.7378
2016	1.1765	1.2903	1.7655
2017	1.1776	1.2931	1.7678

<Table 8: Correlation coefficients among markups>

	Fixed effect model	LP model	AVC model
Fixed effect model	1	-	-
LP model	0.9927	1	-
AVC model	0.9847	0.9933	1

<Table 9: Results of estimation in AVC model>

	(11)	(12)	(13)
1-year lagged Markup	0 .3090***	0.3093***	0.3519***
	(0.0565)	(0.0565)	(0.0559)
1- year lagged Markup Squared	-0.0348***	-0.0347***	-0.0395***
	(0 .0078)	(0.0078)	(0.0078)
1-year lagged sale (logarithm)	0.4443***	0.4490***	0.4387***
	(0.0251)	(0.0250)	(0.0240)
import volumes (logarithm)	YES	YES	YES
firm fixed effect	YES	YES	YES
fiscal year dummy	YES	YES	NO
industry dummy	YES	NO	NO
observation	19228	19228	19228
R-squared（within）	0.0340	0.0285	0.0255
R-squared（between）	0.6215	0.6330	0.6359
R-squared（overall）	0.6769	0.6859	0.6884

Note
1: standard error in parenthesis
2 *p<0.10; **p<0.05; ***p<0.01