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Relation between Total Factor Productivity and Patents of Firms

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Introduction

- It is one of important issues to understand what determines the productivity of firms.
- Productivity of the firm will be improved by the technology.
- Patents are considered to be one of the important factors which determine firm's technology.
- Various studies about the patent have been done.
  - There are not many studies about the distribution of the patents.
  - There are few studies about the patents that firms own.
- In this study
  - We investigate distributions about firms' patents.
  - We will argue about relation between technology and patents of firms.

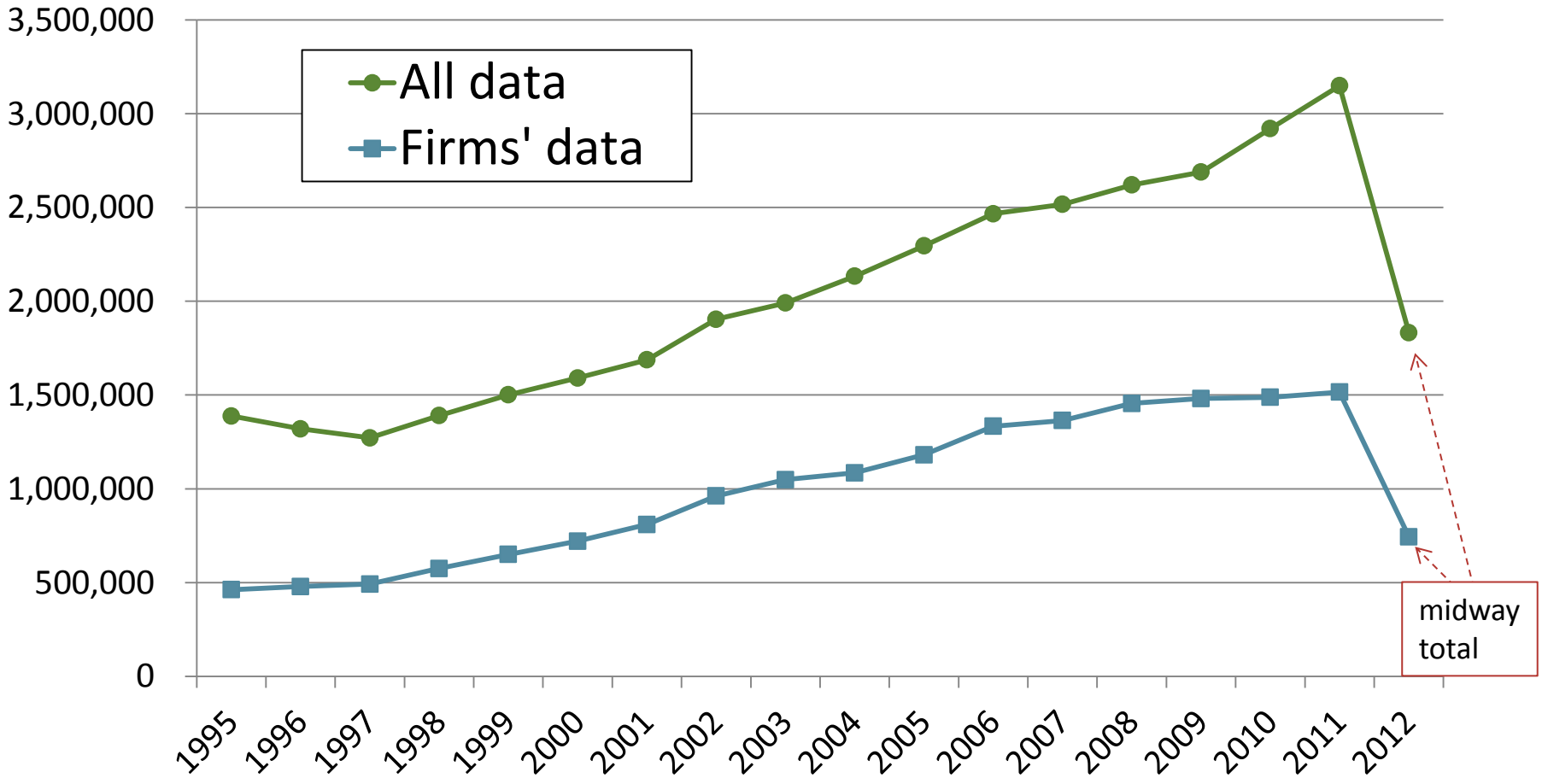
Outline

- Part1
  - Distribution of firms' patent applications
  - Distribution of cited number of firms' patents
  - Summary Part1
- Part2
  - Cobb-Douglas production function and Total Factor Productivity
  - Correlation between TFP and patent applications
  - Summary Part2
  - Future works

Data

- Worldwide patent database PATSTAT which EPO (European Patents Office) maintains
- Patent database of OECD (Organization Economic Cooperation and Development)
- Bureau van Dijk's compiled above databases and added firms' ID code (BvDID).
  - We can aggregate the patents which each firm owns.
  - We can link the patent data to the financial data (sales, number of employee) of each firm.

Number of patent applications



Top 10 of patent applications

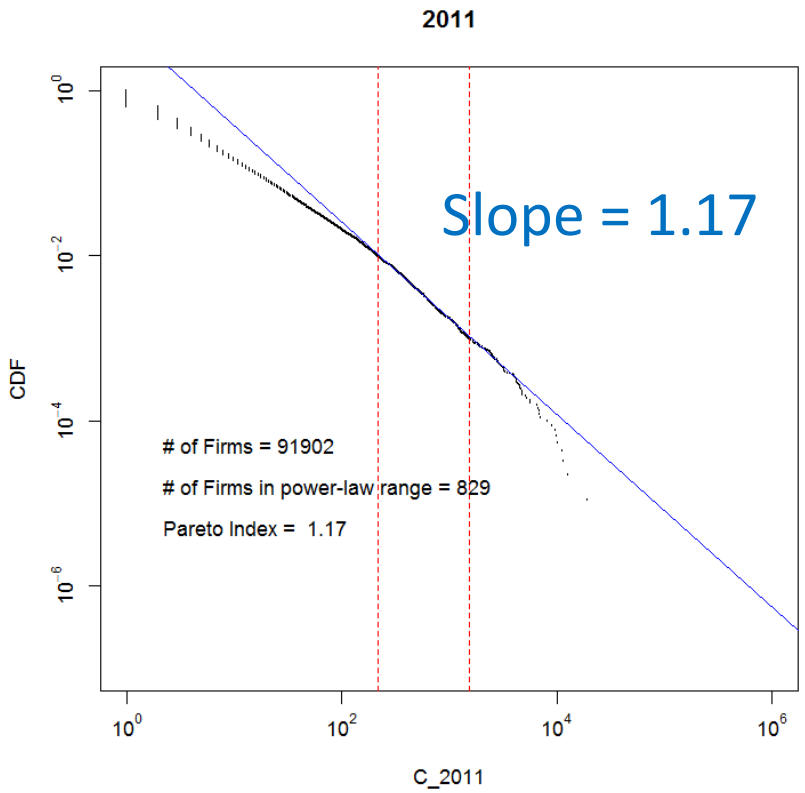
- The top firms are manufacturing and telecommunication industries.

	2010	2011
1	20,867 (Samsung)	19,378 (Samsung)
2	12,670 (IBM)	12,751 (IBM)
3	12,089 (LGE)	11,594 (ZTE)
4	10,861 (Panasonic)	11,373 (LGE)
5	10,176 (Qualcomm)	10,356 (Panasonic)
6	9,525 (ZTE)	9,927 (Bosch)
7	9,422 (Bosch)	9,706 (Qualcomm)
8	8,465 (Sony)	9,087 (Canon)
9	8,365 (Canon)	8,154 (Sony)
10	7,125 (Microsoft)	7,124 (Microsoft)

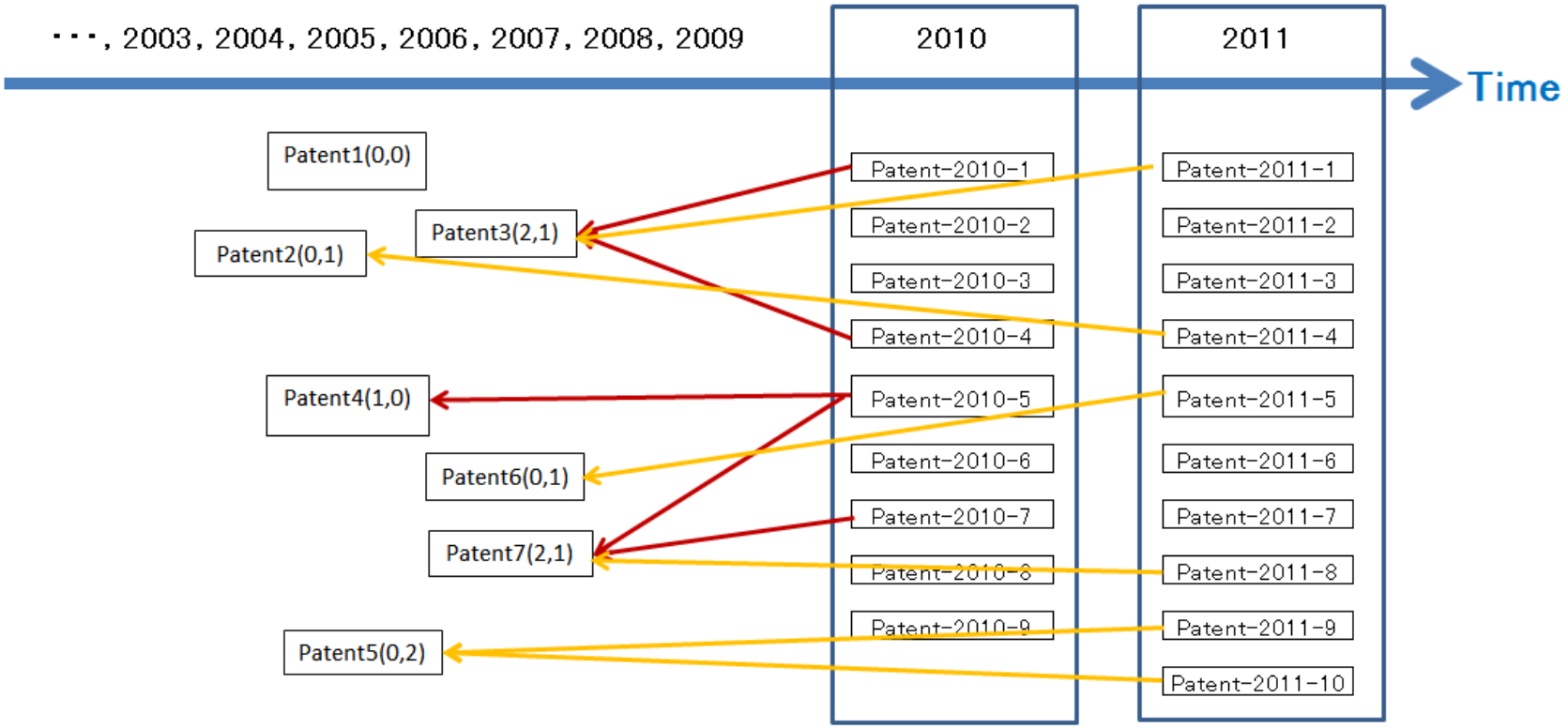
Distribution of firms' patent applications

- C_{2011} is the number of patent applications owned by firm in 2011.
- The distribution of C follows power-law distribution.
  - The power-law index is not changed annually.
  - The values of indices are between 1.12 to 1.17.

- CDF of C_{2011}



Cited number of each patent

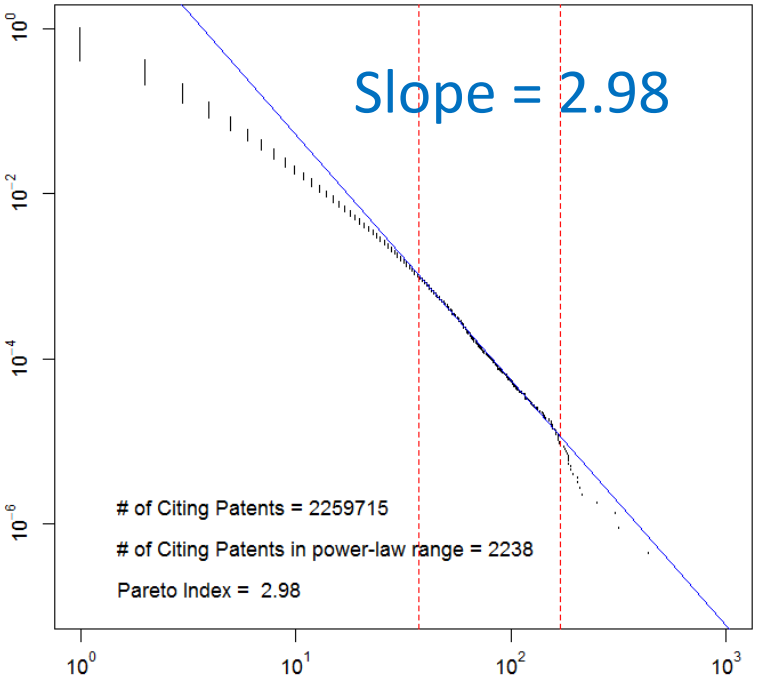


Patent($\mathbf{d_{2010}}$,$\mathbf{d_{2011}}$) is cited $\mathbf{d_{2010}}$ times in 2010 year and is cited $\mathbf{d_{2011}}$ times in 2011 year.

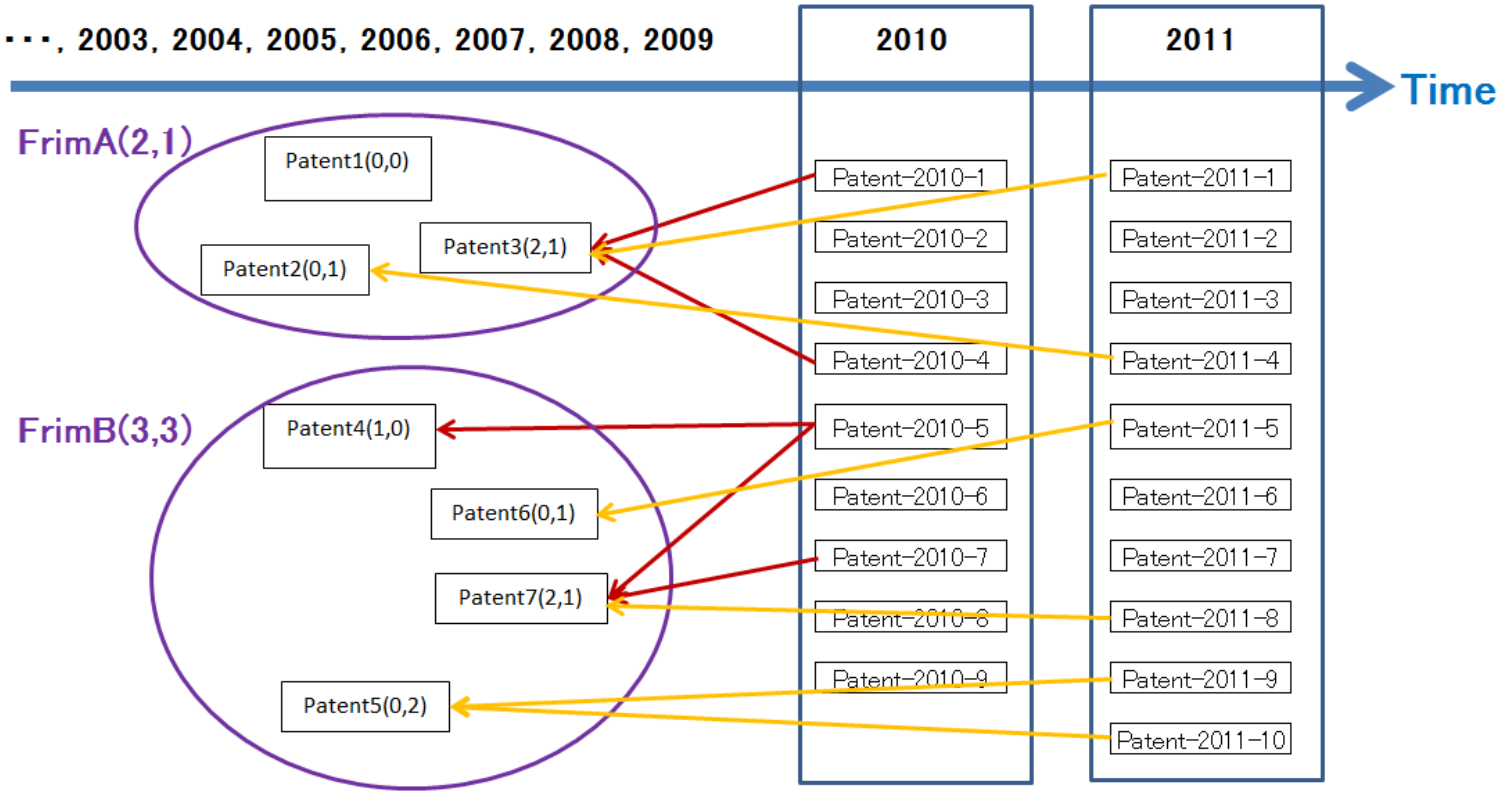
Distribution of cited number of patent

- The distribution of d dose not follow power-law.
  - When the distributions are supposed power-law distributions, the values of indices are between 2.98 to 4.05.

- CDF of d_{2011}



Cited number of each firm's patent



Firm(D_{2010},D_{2011}) has patents that are cited totally D_{2010} times in 2010 year and are cited totally C_{2011} times in 2011 year.

Ex) FirmA(2,1)=Patent1(0,0)+Patent2(0,1)+Patent3(2,1)

Top 10 of cited number

- The ratio of the manufacturing industry becomes high.

Top 10 of applicants

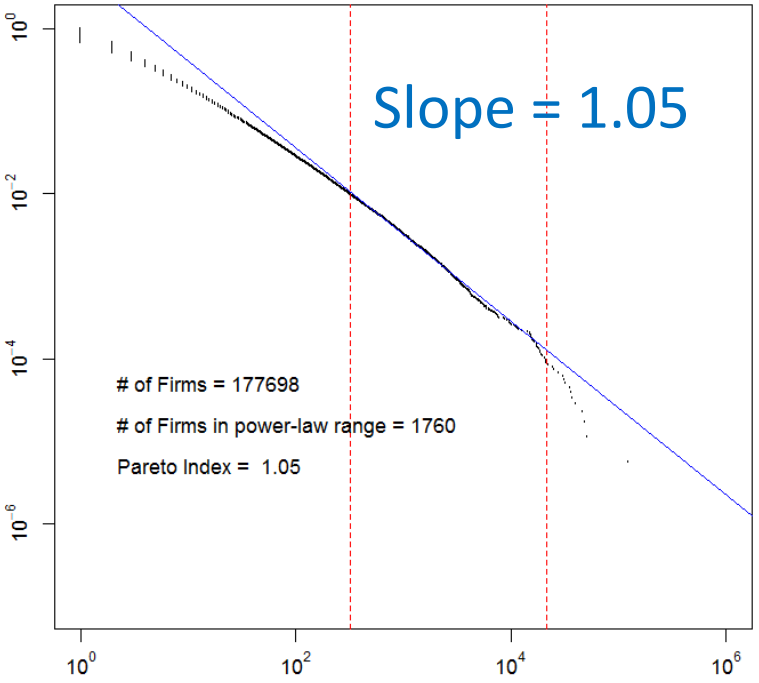
	2010	2011
1	Samsung	Samsung
2	IBM	IBM
3	LGE	ZTE
4	Panasonic	LGE
5	Qualcomm	Panasonic
6	ZTE	Bosch
7	Bosch	Qualcomm
8	Sony	Canon
9	Canon	Sony
10	Microsoft	Microsoft

	2010	2011
1	127,369 (IBM)	124,912 (IBM)
2	48,415 (Microsoft)	52,066 (Samsung)
3	48,052 (Samsung)	48,693 (Microsoft)
4	42,508 (Canon)	46,466 (Canon)
5	38,681 (Panasonic)	40,463 (Panasonic)
6	37,679(Hitachi)	37,656 (Hitachi)
7	36,350 (Toshiba)	36,300 (Toshiba)
8	35,328 (Intel)	35,320 (Intel)
9	31,364 (Sony)	32,179 (Motorola)
10	30,175 (Motorola)	31,922 (Sony)

Distribution of cited number of firms' patents

- The distribution of D follows power-law.
  - The power-law index is not changed annually.
  - The values of indices are between 1.05 to 1.09.

- CDF of D_{2011}



Summary Part1

- Distribution of number of patent applications
  - Individual's applications
    It is hardly distributed.
  - Firm's applications（new result）
    The distribution follows power-law distribution. The values of indices are between 1.12 to 1.17.

- Distribution of cited number of patent
  - Individual's patents（This result is reported a little.）
    The distribution does not follow power-law distribution.
  - Firm's patents（new result）
    The distribution follows power-law distribution. The values of indices are between 1.05 to 1.09.

Cobb-Douglas Production Function and Total Factor Productivity

- What is the variable which relate to the firm's technology?
- The Cobb–Douglas functional form of production functions is as follows:

$$Y = F(K, L) = AK^{\alpha}L^{\beta}.$$

  - Y: total production output (measured in terms of Sales [1000US$])
  - K: capital input (measured in terms of Plant Assets [1000US$])
  - L: labor input (measured in terms of the Number of Employee)
  - α and β: the output elasticities of capital and labor, respectively
  - A: Total Factor Productivity (TFP)
    efficiency which above variables are inputted
- TFP of each firm's A_i are determined by the residual R_i of the multiple regression analysis.

$$\log Y_i = \alpha \log K_i + \beta \log L_i + \log a + \log R_i \qquad A_i = aR_i$$

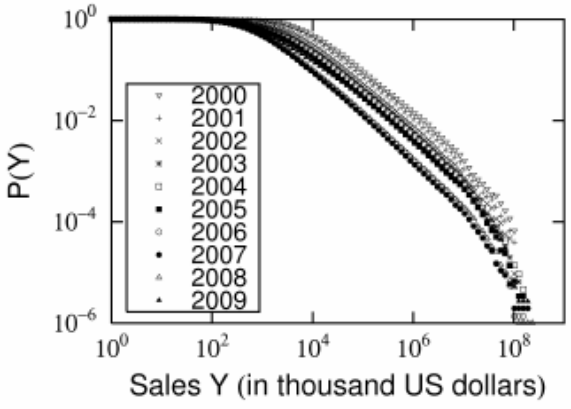
It is considered that A contains some technological effect that can not be measured by K and L.

Power-laws observed in Sales, Assets and the Number of Employee

In many case of firm sizes, the cumulative distribution function CDF (or probability density function PDF) of firm sizes obeys power-law.

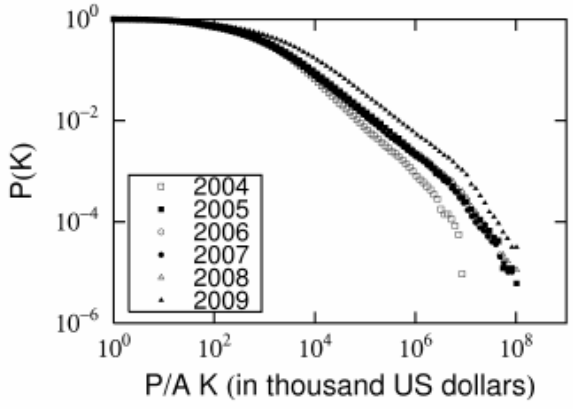
Sales

$$P_{>}(Y) \propto Y^{-\mu_Y}$$



Plant Assets

$$P_{>}(K) \propto K^{-\mu_K}$$

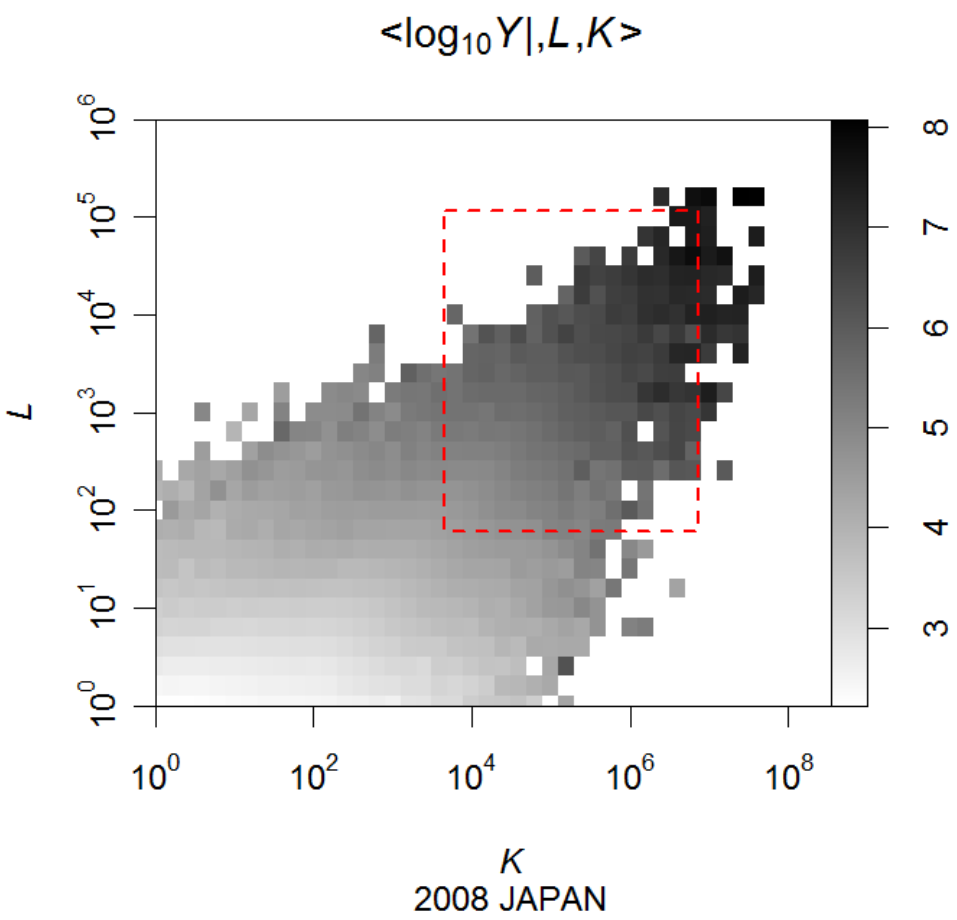


The Number of Employee

$$P_{>}(L) \propto L^{-\mu_L}$$

Ex）Power-laws observed in Japanese Firms

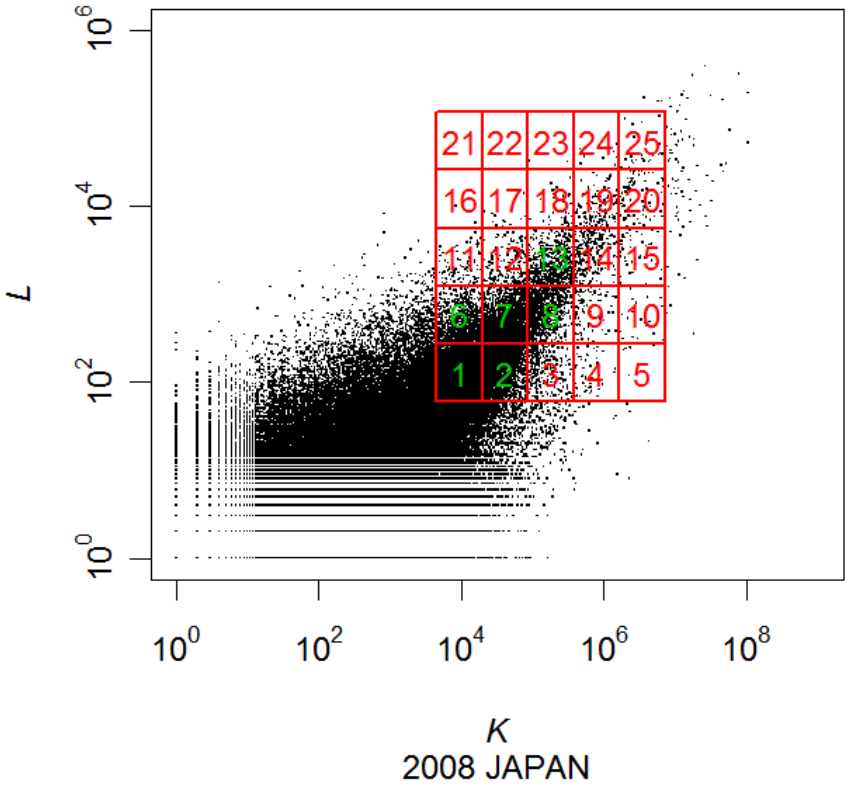
Estimation α, β and a

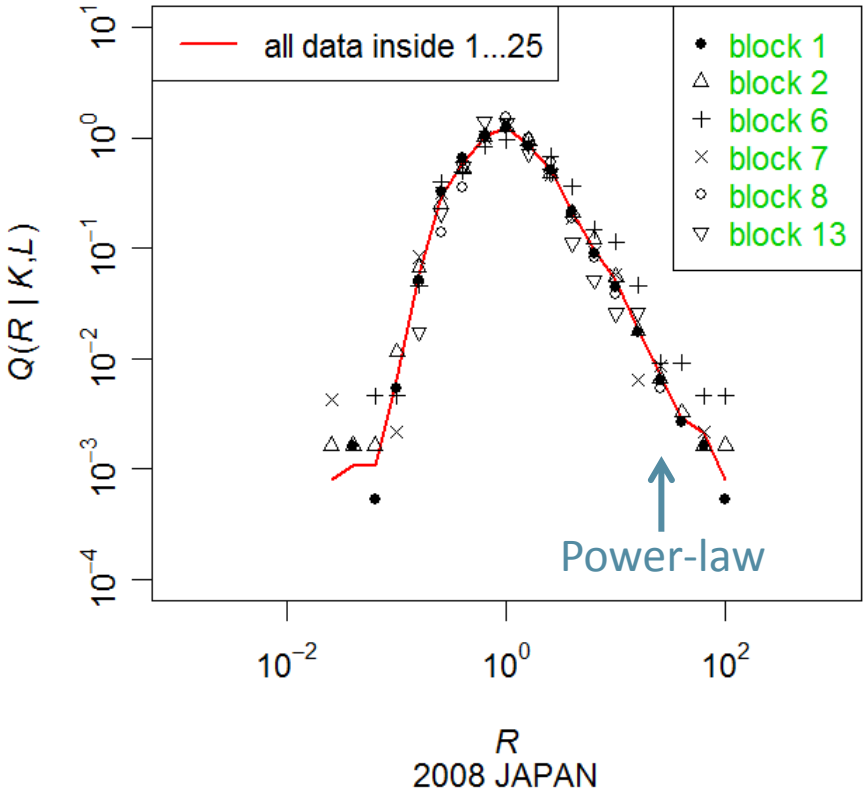


- Divided K, L into bins, then calculate $\langle \log Y \,|K, L\rangle$ in each bins.
- Using data in the power-law regions (inside red line), we estimate α, β and a by multiple regression

$$\langle \log Y \,|K, L\rangle = \alpha \log K + \beta \log L + \log a$$

Distribution of R

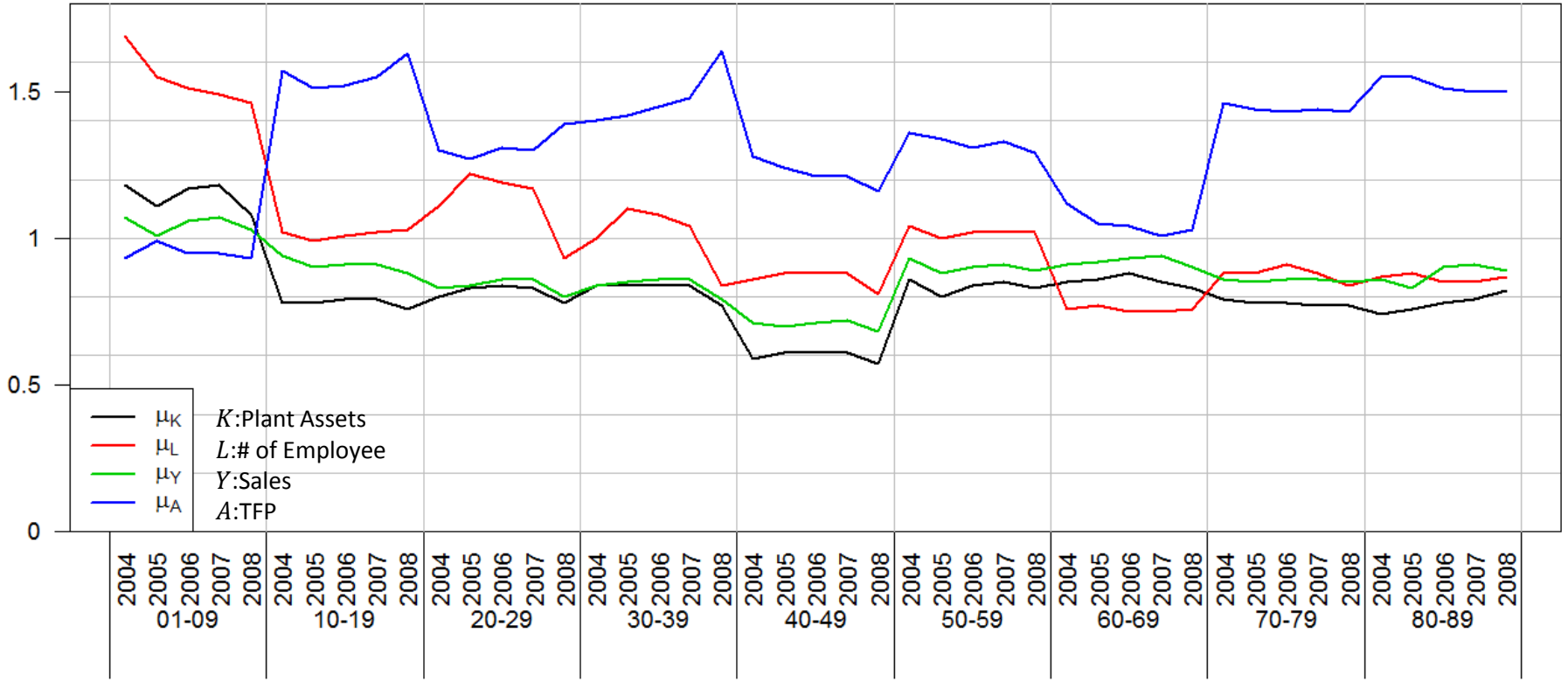




- Calcuration each firms' $R_i = \frac{A_i}{a} = \frac{Y_i}{aK_i{}^{\alpha}L_i{}^{\beta}}$ by using fitted parameters α, β and a.
- Upper tail of distribution of R_i is power-law.

Power-Law Indices for Industries

All countries data classified by SIC (Standard Industrial Classified)



01-09 Agriculture, Forestry, Fishing, **10-19** Mining, Construction,
20-39 Manufacturing, **40-49** Transportation, Communications, Utilities,
50-59 Trade, **60-69** Finance, Insurance, Real Estate, **70-89** Service

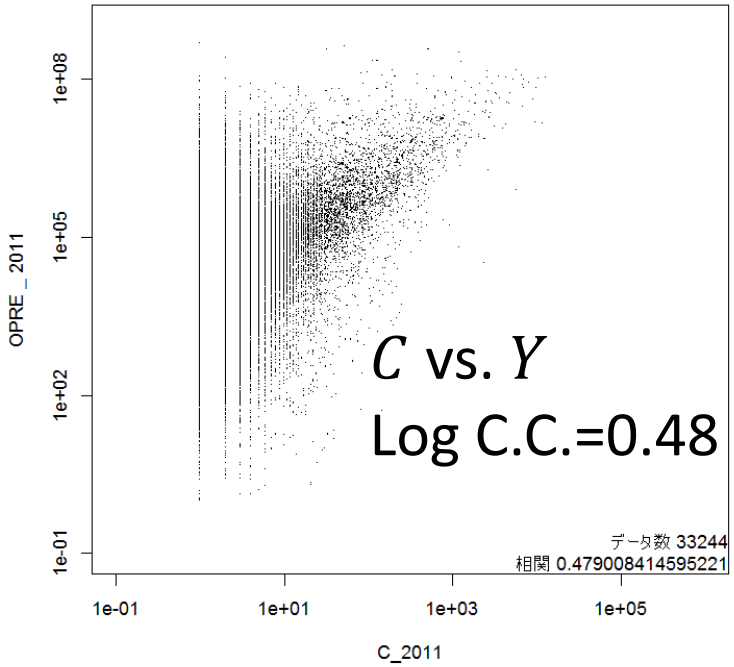
Higher 2-digit for Major Group Classification

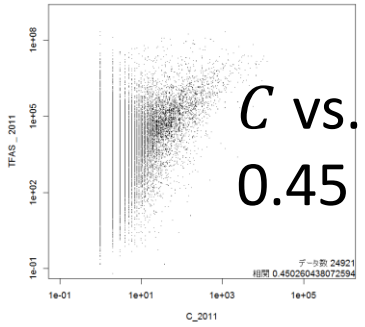
Correlation between C and A

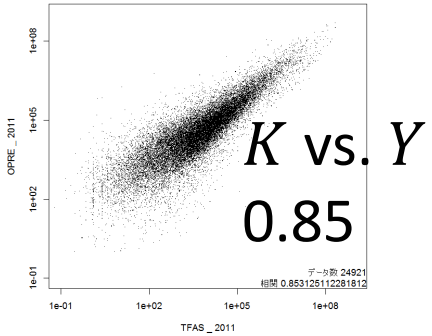
- A:TFP, C:number of patent applications, D:number of patent cited, K:Plant Assets, L:number of employee, Y:sales
- Both A and C follow the power-law distribution. If A correlate with C, the relation
$$A = BC^{\gamma}$$
will be satisfied.
In this case, production function becomes
$$Y = AK^{\alpha}L^{\beta} = BC^{\gamma}K^{\alpha}L^{\beta}.$$
- Actuary, the correlation coefficient between A and C is almost zero.
  - Correlation between A and D is almost same.
  - We must confirm carefully correlation between C and Y.

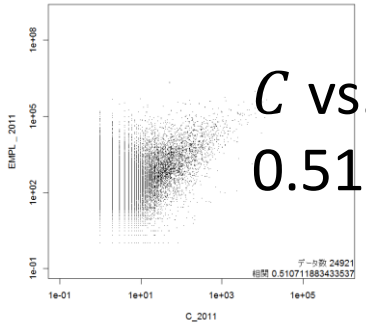
Correlation between C and Y

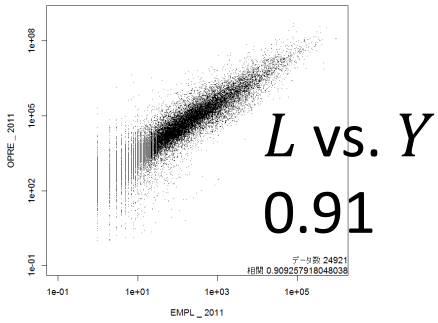
2011











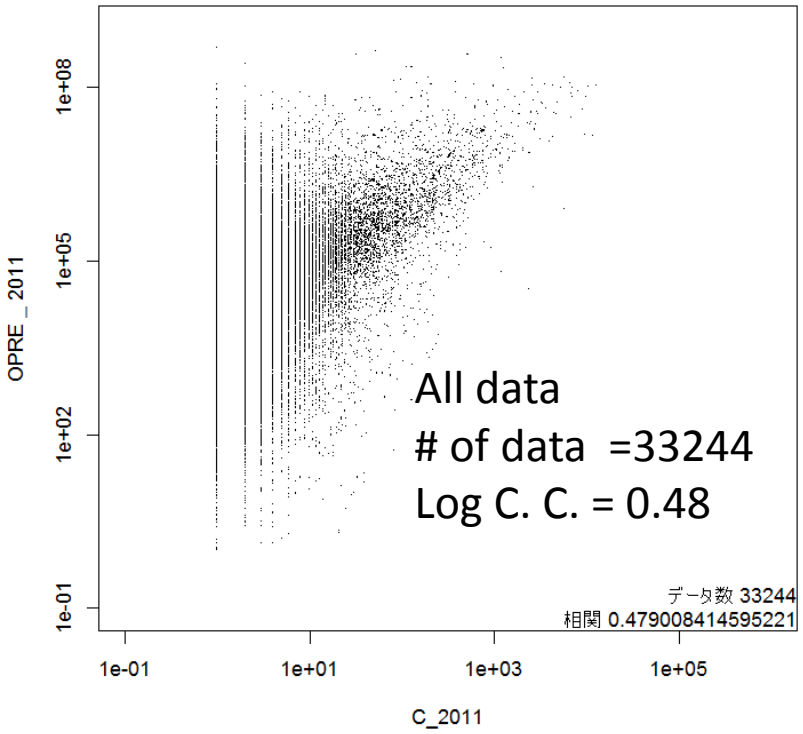
- C and Y correlates but it is not strong correlation.
- It could be spurious correlation through the K or L.

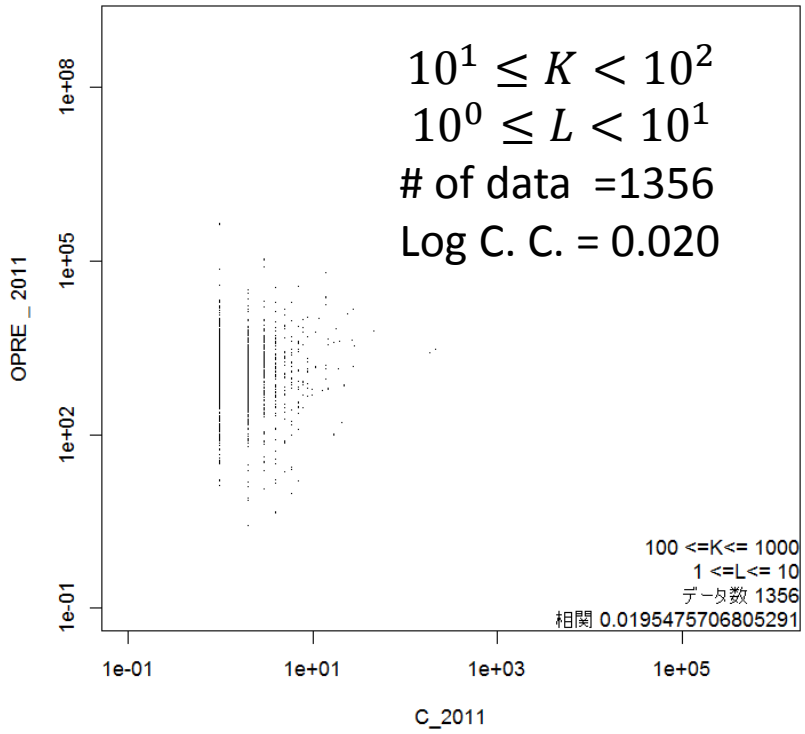
Correlation between C and Y in the condition that K and L are fixed

- If A correlate with C, production function is
$$Y = AK^{\alpha}L^{\beta} = BC^{\gamma}K^{\alpha}L^{\beta}.$$
- When K and L are fixed in narrow region, the relation of C and Y becomes
$$Y = BC^{\gamma} \times \text{Const.}$$
- K, L fixing corresponds to the conditions of the size of firms.
- The correlation coefficient of C and Y is confirmed in the various conditions.

Correlation between C and Y of the small size firms

2011 C vs. Y

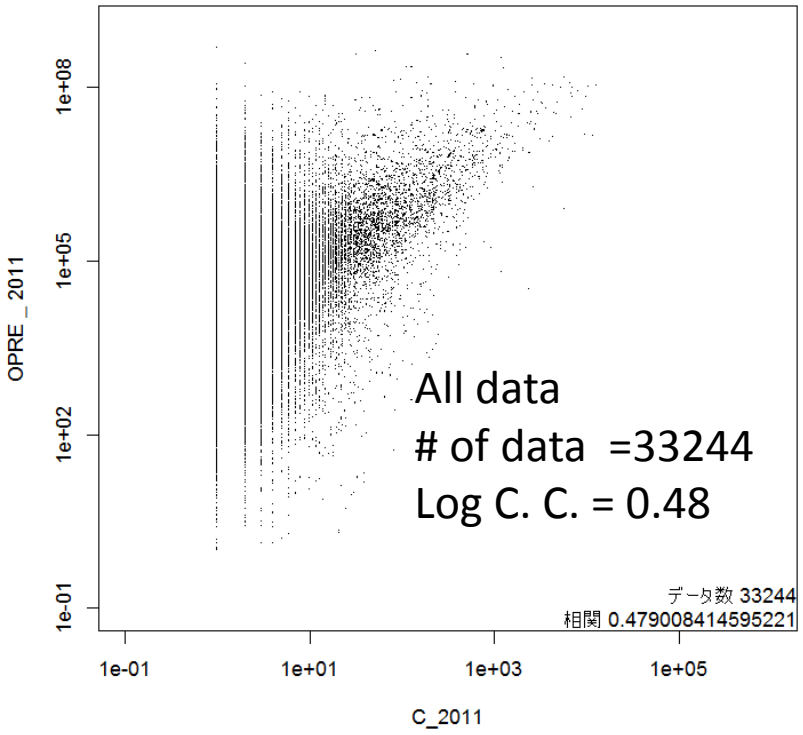


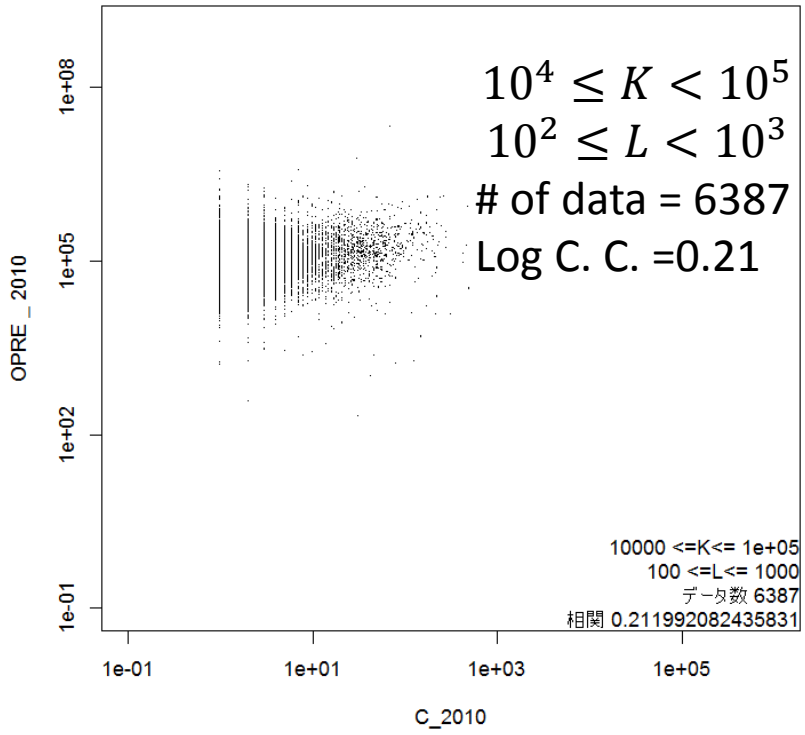


$$Y = AK^{\alpha}L^{\beta} = BC^{\gamma}K^{\alpha}L^{\beta}$$

Correlation between C and Y of the large size firms

2011 C vs. Y





$$Y = AK^{\alpha}L^{\beta} = BC^{\gamma}K^{\alpha}L^{\beta}$$

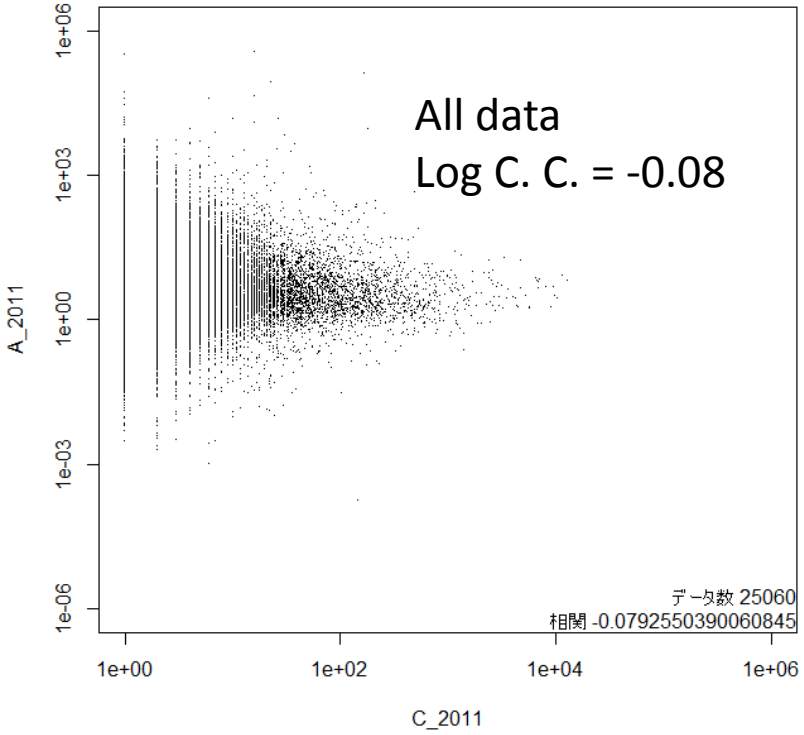
Summary of correlation between C and Y

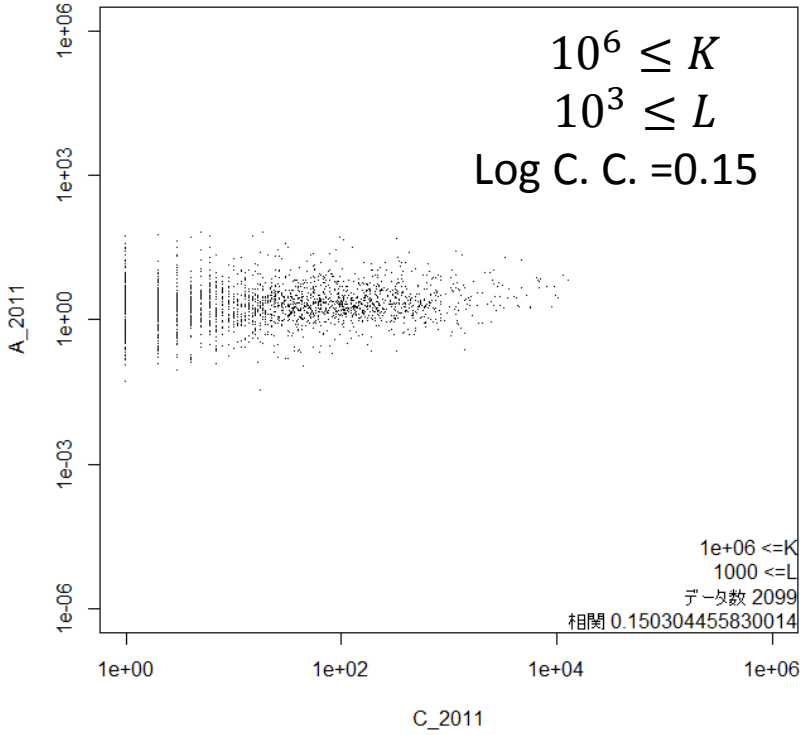
	$\log L$	0	1	2	3	4	5
$\log K$		1	2	3	4	5	6
0	1	0.00(627)	-0.03(131)		← Power-law region of L →		
1	2	-0.03(1414)	-0.02(1114)	0.08(39)			
2	3	0.02(1356)	0.01(4043)	0.06(528)	-0.18(9)		
3	4	0.14(490)	0.05(6157)	0.20(4054)	0.05(91)		
4	5	0.27(50)	0.13(1150)	0.22(6308)	0.17(1603)	0.17(10)	
5	6		-0.14(24)	0.10(764)	0.17(2317)	-0.01(369)	
6	7	↕ Power-law region of K		-0.13(26)	0.23(308)	0.18(498)	0.19(37)
7	8				0.45(34)	0.20(94)	0.40(48)
8	9						0.76(4)

Values are correlation coefficient between $\log C$ and $\log Y$ in each region.
Numbers inside parentheses are numbers of data in each region.
The red regions have relatively large values of correlation.
The blue regions have too few numbers of data.

Correlation between C and A of the large size firms

2011 C vs. A





Summary Part2

- Total factor productivity A correlate to number of patent applications C. However, the correlation is not very large.
- You have to remove the effect by firm size carefully to see the above correlation.
- It is considered that A contains some technological effect.
- C is considered to be one of the factors which constitute A.

Future work

- I have checked that the correlation between cited number of firms'patents D and A was weaker than the correlation between C and A. This result is differ from expected result.
  - I was thinking that D is one of the values which explains the novelty of the patent.
  - Quality of patents is determined by the cited number?
- How to measure quality of the patent.
  - The Canon has released the patent income on the web site (2-3 million $), but it is a rare sample of firms.
  - It may be necessary to create the impact factor of the company, such as the impact factor of the journal paper.
  - It may be necessary to measure quantity like the page rank in a citation network.