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Abstract

How does ageing influence the profitability of firms? This study uses an analysis of corporations listed on the NYSE and TSE between 1978 and 2015 to highlight clear differences between US and Japanese firms with respect to the relationship between age and profitability. It shows that US firms lose efficiency, as measured by total asset turnover as they age, whereas Japanese firms' ability to generate profit from sales declines. This study explores the factors underlying these national differences in the relationship between ageing and profitability, focusing on rigidity of resource allocation. By examining the technological distance, we calculate resource allocation rigidity of the firms. The results show at all ages, Japanese firms are more rigid than their US counterparts, although the slope is steeper in the case of US firms. These observations suggest that Japanese firms' operating profit margins decline as they age because they are less likely to change how they allocate resources and tend to stay in their existing business sectors, even if they are underperforming. In other words, these findings suggest that being flexible about allocation of resources mitigates the negative effect of ageing on profitability. The results suggest that changing patterns of resource allocation retards learning in the business domains in which a firm is already active.

1 Introduction

How does ageing influence the profitability of firms? Just as ageing has negative effects on human beings, it is reasonable to assume that ageing would have a negative influence on the firms' performance. Should this be true, it would be important for firms to stay young at heart; but on the other hand, just as people can learn as they mature, one might expect firms' costs to reduce as they mature, due to learning effects at various levels, which could be called the 'wisdom of age'.

Directing its attention to the flexibility in resource allocation, this study examined how the age of a firm influences its profitability, looking at all the corporations listed on the New York stock exchange (NYSE) and Tokyo stock exchange (TSE) between 1978 and 2015.

First, descriptive statistics are used to demonstrate the very different relationships between age and profitability in the US and Japanese firms. The profitability of Japanese firms declines consistently from the age of 11 years onwards, whereas US firms do not suffer until they are more than 100 years old. Second, an estimation strategy described in earlier research is used to estimate how ageing influences the profitability of firms. This showed that profitability decreased as firms aged in both the US and Japan, although there were clear national differences in the pattern of ageing effects. Japanese firms suffered more from ageing than US firms. Return on assets (ROA) can be divided into return on sales and total asset turnover. The return on sales statistic captures how efficient a firm is at generating profits from its revenue while total asset turnover represents how efficient a firm is at deploying its asset to generate revenue. The total asset turnover of US firms declined with age, whereas the profitability (measured as operating profit margin) of Japanese firms decreased with age.

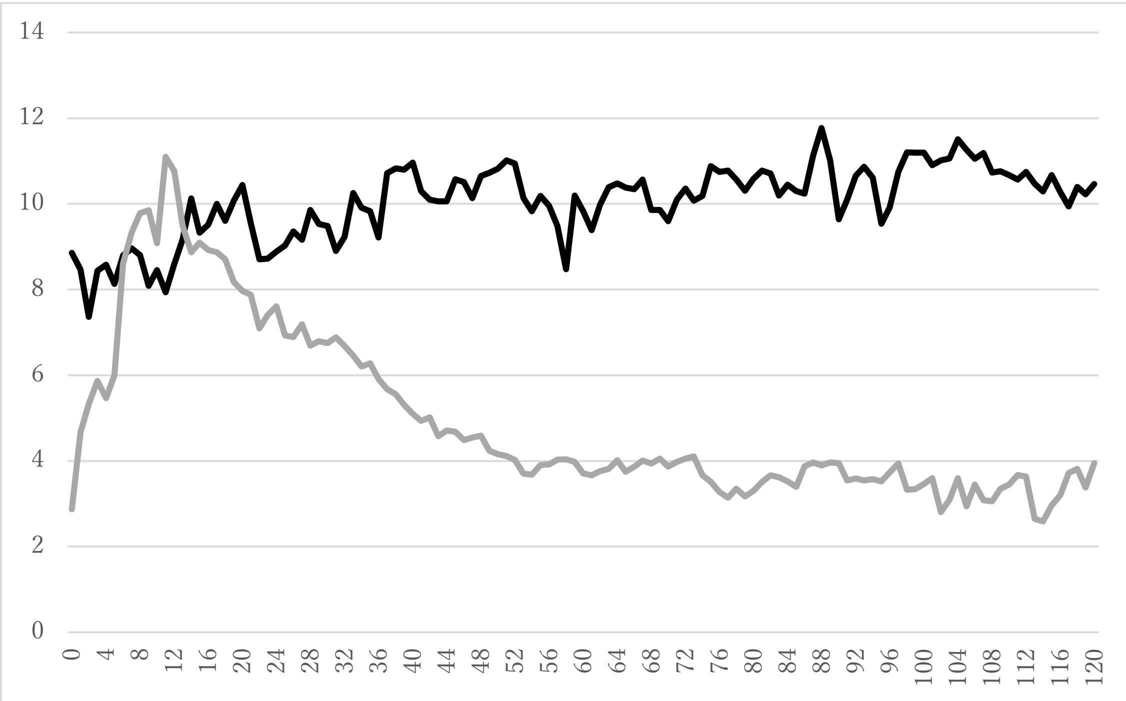
Last, this study discusses the causes of the different ageing patterns of US and Japanese firms, in particular it explores resource allocation strategies. Rigidity of resource allocation is measured as 'technological distance' which represents the extent to which a firm's research and development (R&D) technological portfolio changes over time. Firms that tend to stay in the same technological area for a long time have a high technological distance. If the firm mobilises its target area flexibly and change R&D portfolio often, it means that the rigidity of resource allocation is lower.

US firms tend to withdraw from sectors where they are underperforming and reallocate resources to more promising areas of the business, which mitigates the effects of ageing on profitability. However, the efficiency with which firms deploying their assets to generate revenue is negatively associated with age. Japanese firms are suffering from aging more than U.S. firms due to their relatively inflexible resource allocation. In other words, resources are ‘stickier’ in Japan than in the US, which allows more learning effects in the existing businesses. On the other hands, since Japanese firms are less likely to reallocate resources and more likely to remain investing in existing businesses even if they are underperforming, their operating profit margin decreases with age.

2 Age and Profitability

The following figure plots the relationship between a firm’s age and its profitability. Age is measured as the age of a firm as a legal entity and profitability is measured as ROA. ROA is calculated from operating profits, taking into account depreciation, so it can be interpreted as an indicator of how efficiently a firm uses its assets to generate profit from its main business.

Figure 1: Firm Age and Profitability



Source: *COMPUSTAT* database and DBJ *Firm Financial Databank*

* Full-count between 1978-2015 (excluding finance, insurance and real estate sectors)

Figure 1 shows a clear difference between US and Japanese firms. It shows that US firms retain their profitability better than Japanese firms. US firms’ profitability peaks at the age of 105 years and decreases marginally with age, whereas Japanese firms’ profitability peaks at the age of 11 years and declines more rapidly with age thereafter. This figure illustrates that Japanese firms suffer from aging more than US firms. This figure provides descriptive evidence of a difference in the pattern of ageing in US and Japanese firms; the rest of this study reports the empirical estimation of the relationship between age and profitability whilst controlling for variance in other factors that would influence ROA.

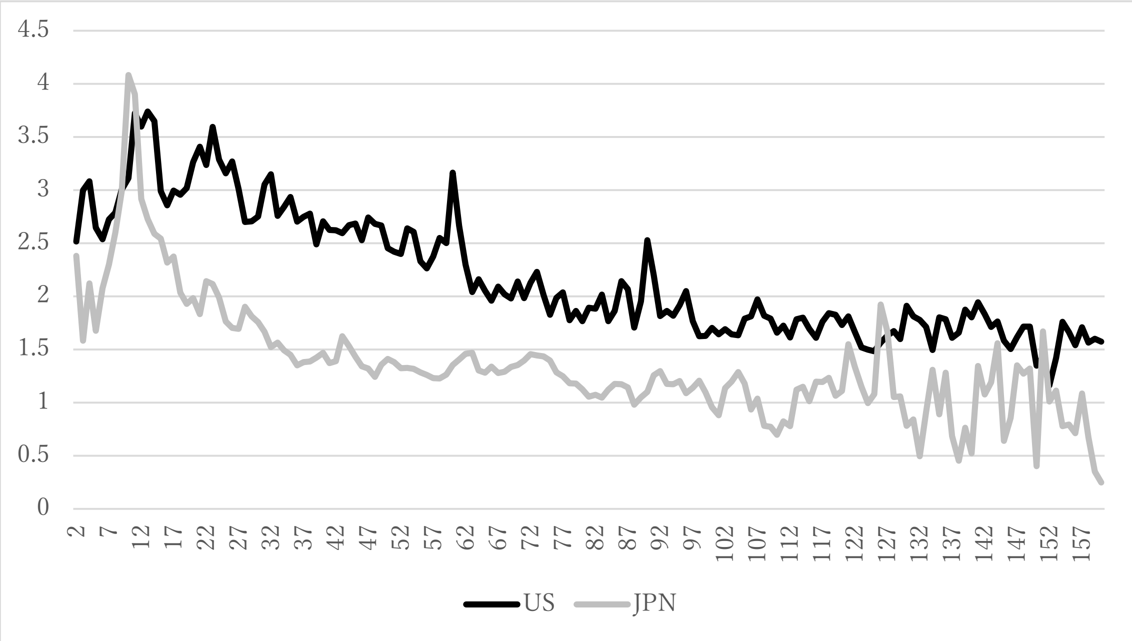
3 Why Does Profitability Decrease with Age?

Why does firms' profitability decline as they age? This section reviews earlier research on factors found to influence relationship between the age and profitability of firms.

Loderer and Waelchli (2010) published the first study exploring the effects of ageing on profitability. They reported that a firm's age was negatively associated with its profitability, expressed in terms of profit margin, ROA and Tobin's Q (Loderer & Waelchli, 2010). They observed that older firms were less efficient than their younger industry peers, in that they had higher costs, slower growth, older assets and were less active in R&D and investment. They proposed two non-exclusive explanations for the negative effect of age on profitability: organisational rigidity and rent-seeking behaviour. Loderer and Waelchi's (2010) study was the first to explore the relationship between age and profitability empirically, but their analysis did not control for possible country effects and, as Figure 1 illustrates, there is a significant difference between US and Japanese firms with respect to the relationship between age and profitability. Hence the aim of this study was to explore how and why ageing influences US and Japanese firms differently.

One might suppose that firms' profitability decreases with age because their (or their investors') appetite for risk and uncertainty decreases. Previous literature on risk and uncertainty has suggested that the uncertainty associated with a business decreases with age, because managers and employees learn about their business over time. Therefore, uncertainty that investors and stakeholders face decreases as the firm ages (Berger & Udell, 1995; James & Wier, 1990). This is consistent with the fact that variability in stock returns is negatively related with a firm's incorporation age and listing age (Cheng, 2008). Less uncertainty on the business implies that the rate of return that the firms are supposed to provide is declining. It is reasonable, therefore, to assume that firms' profitability declines with age because the uncertainty surrounding the business is also declining. This assumption might also lead one to assume that firms take fewer risks as they get older. In other words, we are suggesting that older firms tend to take fewer risks because there is less uncertainty surrounding their business. ROA volatility has been used as an index of risk-taking (Acharya, Amihud, & Litov, 2011; Faccio, Marchica, & Mura, 2011) and on this basis Figure 2 examines whether firms are likely to take less risk as they age.

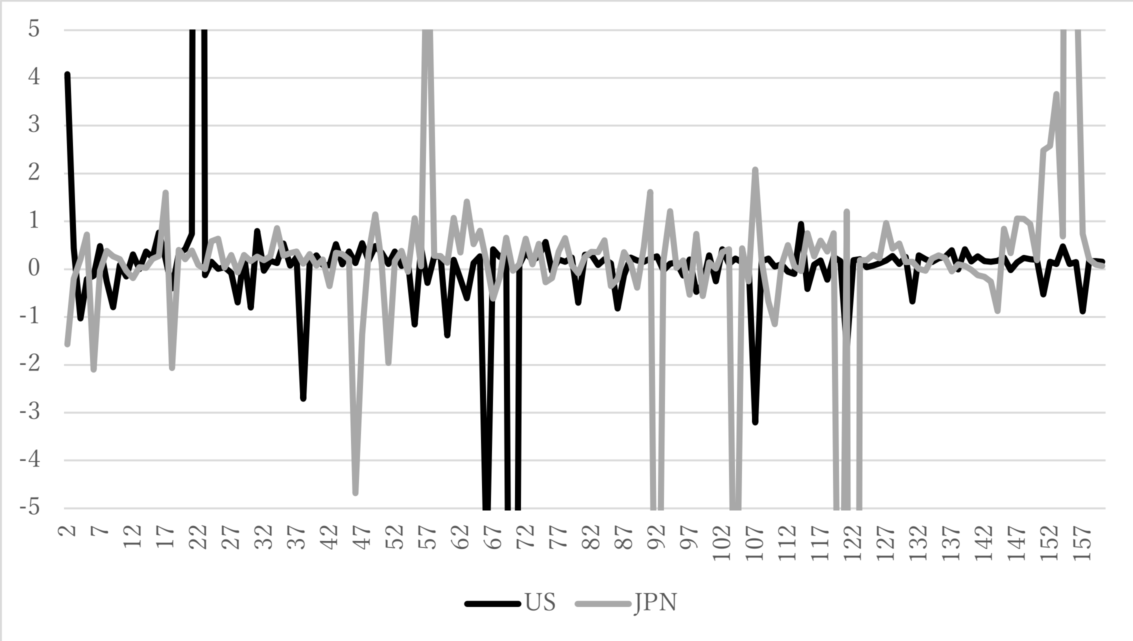
Figure 2: ROA Volatility measured by 3Y ROA Volatility



Source: *COMPUSTAT* database and DBJ *Firm Financial Databank*

Figure 2 illustrates that ROA volatility decreases as firms age, both in the US and in Japan. The ROA volatility of Japanese firms decreases steadily, whereas that of US firms does not show such steady decline. This figure might lead one to suppose that compared with US firms, Japanese firms show a bigger decline in appetite for risk as they age. However, the level of ROA volatility highly depends on the absolute value of ROA. If the absolute value of ROA is at the low level, the volatility cannot be greater. Using ROA volatility as an index of risk-taking underestimates the risk-taking of the firms whose ROA is relatively low and overestimates the risk-taking of firms whose ROA is relatively high. Hence it is necessary to use the average of ROA to weight ROA volatility as an indicator of risk-taking. We calculate the coefficient of variation in three-year ROA volatility discounted with the three-year moving average of ROA. As Figure 3 illustrates, in the coefficient of variation in ROA is not correlated with age in Japan or the US, which suggests that the age-related decrease in ROA in Japanese firms is not the result of risk-averse behaviour, but the result of decreasing profitability.

Figure 3: 3Y Coefficient of Variation in ROA



Source: *COMPUSTAT* database and DBJ *Firm Financial Databank*

* For the visibility, the figure is marked off at ± 5.0.

Another reason why firms' profitability decreases as they age might be that their level of diversification into unrelated businesses changes. Firms' profitability might depend on their diversification. As the original industry matures, firms tend to diversify its business based on the resources accumulated in the business (Conner & Prahalad, 1996; Penrose, 1980; Wernerfelt, 2006). Most previous literature on diversification has observed that profitability tends to fall if a firm diversifies into unrelated areas (Rumelt, 1982). This raises the possibility that Japanese firms tend to conduct more unrelated or conglomerate diversification as they age, compared with US firms. Anecdotal evidence suggests that Japanese firms tend to diversify their technological base. Japanese firms in the digital watch industry tend to initiate parallel R&D of competing technologies at a much earlier stage than US firms (Numagami, 1996). If Japanese firms' technological diversification is more extensive than that of US firms this might eventually diminish their profitability. We return to this issue in later analyses in this paper and show that in fact there is not much difference in the extent to which US and Japanese firms diversify, at least in terms of technology.

Why, then, does the performance of Japanese firms decline as they age whereas that of US firms does not? This study explores flexibility in allocation of managerial resources. If a firm allocates managerial resources flexibly, shifting them from areas of the business that are losing their competitive advantage to areas with better prospects it should maintain its profitability as it matures. However, much of the previous literature indicates that firms' allocation of resources tends to become less flexible with age, a phenomenon which is referred to as organisational rigidity.

The organisational rigidity hypothesis is often based on analogy with biological ageing, in particular human ageing. In humans ageing affects various functions, such as hearing, eyesight, memory, fertility and thermoregulation. Two theories of ageing have recently proposed. The damage theory attributes symptoms of ageing to the accumulation of damage. For example, cells accumulate free radical damage over time. The programmed ageing theory posits that ageing is essentially programmed by the internal processes such as DNA methylation.

As firms age their organisational rigidity increases, which eventually reduces their performance. Organisational rigidity may arise because past success prompts firms to codify their approach through organisation and processes. The resource-based view of the firm offers a similar explanation: in developing a competitive advantage a firm accumulates managerial resources and optimises them for its value-chain and customers (Penrose, 1980; Peteraf, 1993). As a result, when the firm is faced with the emergence of a new technology which threatens future competitiveness it finds it difficult to reallocate resources to that technology (Christensen, 1997; Christensen & Bower, 1996).

Furthermore, it has previously been observed that there are national differences in rigidity of resource allocation. Dore is one of the first scholars to have conducted international comparative studies and has pointed out the relative flexibility and rigidity of US firms and Japanese firms respectively. For example, Dore explored the Japanese labour market and in-house training and employment customs in Japan - such as long-term employment - in the 1970s and 1980s, and concluded that managerial resource allocation in Japanese firms tended to be sticky (Dore, 1973, 1986, 1988). Dore found that Japanese firms took a more rigid approach to hiring, firing, and wages than firms in Anglo-Saxon countries, whose policies tended to be aligned with neo-classical labour market economists' assumptions. Furthermore, Dore reported that financial resource allocation was also less flexible in Japan than in the US (Dore, 2000). Dore attributed these differences to cultural factors, such as the Japanese emphasis on the workgroup community, exchange of employee loyalty and employers' paternalism. In contrast to the culturalists' viewpoint, economists and economic historians have argued that the rigidity Dore observed in Japanese firms was the rational outcome of the institutional settings that developed in the inter-war period (Aoki, 1988, 2001; Okazaki & Okuno, 1999). All of these studies observed that Japanese firms tended to exhibit greater organisational rigidity than US firms.

Moreover, the previous literature in the new institutional economics has observed that institutions, which provides incentive as formal rules and informal restraints to economic agents, have strong influenced the economic performance (Arthur, 1994; Goldstone, 1998; North, 1990; Pierson, 2000; Williamson, 1985). It argues that the reason why economic performances across countries has not been converging is the fact that institutions have strategic complementarity and their changes are path dependent (David, 1989; Mowery & Rosenberg, 1998; Rosenberg, 1994). Small historical events can influence the locus of institutional change, although it is not necessarily deterministic. These studies have suggested that the level of organisational rigidity must vary across the countries because institutions shape the nature of transactions and resource allocation in a society.

Since Loderer and Waelchli (2010) did not include a country variable in their analysis, it does not capture how the relationship between age and profitability varies across countries. If US firms are less vulnerable to organisational rigidity than their Japanese counterparts as they age, this would explain the different national patterns in ageing and profitability found in this study.

4 Analyses

Our main analyses are divided into two parts. First, like Loderer and Waelchi (2010), this study investigates how a firm's age is associated with its profitability, measured by ROA, and how this relationship differs between the two countries. We then develop our ideas through further analyses, in which we disaggregate ROA into operating profit margin (operating income divided by sales revenue) and asset turnover (sales revenue divided by total assets), and then regress them as dependent variables. This simple decomposition strategy is used to examine the differences in the associations between age and profitability and efficiency across firms in both countries.

The second part of this paper focuses on how firms' R&D activities change as they age and explores how profitability is related to flexibility in allocating managerial resources. It is natural to assume that the extent to which firms can change their primary field of business depends on the national institutional context. This study uses longitudinal data on the R&D portfolios of US and Japanese firms to argue that ROA decline in Japanese firms can be attributed to rigidity in resource allocation.

4.1 Impact of ageing on ROA

The sample for our first analysis consisted of all of the US and Japanese firms listed on the NYSE and TSE respectively for some period between 1978 and 2015. The data on US firms were obtained from *COMPUSTAT* and the data on Japanese firms from *Corporate Financial Databank* provided by the Development Bank of Japan. We excluded firms in the finance, insurance and real estate sectors (SIC 6000-6999) from the sample. We constructed separate panels of data for the US and Japan and used them to estimate firm-fixed-effect models in order to compare the effects of age in the two countries. The US data consisted of 22,829 firm-year observations from 958 firms and the Japanese data consisted of 49,109 firm-year observations from 2,758 firms.

The dependent variable in our models is *ROA*, which is calculated as operating profits after depreciation divided by total assets. The independent variable is *Age*, which is the number of years elapsed since the legal foundation of the firm. We included in our estimation models some control variables that represent the firms' business characteristics, mostly are the same as the control variables used by Loderer and Waelchi (2010). *Size* represents the firms' size, measured as the logarithm value of total assets; *SG&A* is selling, general and administrative expenses and *COGS* is the cost of goods sold divided by sales revenue.

Past investment may influence a firm's profitability, which is captured both by capital and R&D investment. *Capex* is the ratio of capital expenses (net of depreciation and amortisation charges) to the book value of total assets and *R&D expense* is the amount of internal R&D expenditure. These two variables were entered as one-year lagged values. Since the *Corporate Financial Databank* does not provide R&D data, we utilized the individual data from the *Survey of Research and Development* carried out by the Japanese Ministry of Internal affairs and Communications and obtained the firms' R&D data. The analysis included the growth of the firms in terms of sales and the number of employees, *Sales_growth* and *Emp_growth*, which are the growth rates from the previous year.

Finally, market characteristics can also influence firms' profitability significantly. If market competition in the primary industry to which a firm belongs is fierce one would expect it to be less profitable. This study included a *Market Competition* variable to account for the effect of market competition; this was measured as one minus the sales concentration ratio in the firm's primary industry: 1-$\sum_{i=1}^{N}(\text{sales}_{\text{it}}/\text{market\_sales}_{\text{t}})^2$. In this equation sales_{it} denotes the sales revenue of firm *i* in year *t* and $\text{market\_sales}_{\text{t}}$ denotes the aggregated sales in *i*'s primary industry in year *t*. The primary industry is based on the firm *i*'s two-digit SIC code.

Data on the capital expenditure, and depreciation and amortisation charges of Japanese firms, which were used to calculate *Capex*, are available only from 2001, and data on the number of employees (needed for *Emp_growth*) only from 2002, the models including these variables are based on a much smaller number of observations in the case of Japanese firms (20,159 firm-year observations from 2,478 firms). Moreover, since many of the firms in both the US and Japan do not conduct R&D, for example firms in the service sector, the number of observations in the models including the R&D variable is also lower (US: 12,313 firm-year observations from 593 firms; Japan: 7,992 firm-year observations from 1,090 firms).

Ideally one would include industry dummies in the analyses, because industrial heterogeneity can significantly influence firms' profitability; however, we were unable to do so as we estimated fixed-effect models, which cannot include firm-level variables that are constant across the time series. Hence, like Loderer and Waelchi (2010), we used the values of deviation from the industrial mean so that it can discount industry influence in the analysis. We used the two-digit SIC codes as the industrial classification variable, and the industrial mean of all listed firms in the US and Japan, not just those listed on the NYSE and TSE. The detailed definitions of these variables are given in Table 1.

Table 1: Definition of Variable

Variable (Unit: US/JPN)	Definition
ROA(%)	Operating income after depreciation divided by book value of total assets.
Age	The number of years elapsed since the year of foundation of each firm. The foundation year is obtained from *Compustat* for the U.S. firms, and *Corporate Financial Databank* for Japanese firms. Since there are many missing values in the databases, we supplement them manually by looking up the companies' website.
Size (Thousand dollars / Million yen)	The size variable is the logged value of total assets. We use the value of deviation from the industrial mean (based on 2-digit code) in each country in each year.
SG&A (Thousand dollars / Million yen)	The book value of selling, general and administrative expenses We use the value of deviation from the industrial mean (based on 2-digit code) in each country in each year.
COGS	Cost of goods sold divided by sales revenue. We use the value of deviation from the industrial mean (based on 2-digit code) in each country in each year.
Capex	Capex is calculated as follows: (capital expenses - depreciation and amortization charges) / the book value of total assets. To

	account for the precedency of investment, we use one-year lagged value.
Sales_growth (%)	The value of sales growth rate in year t is (Sales_t – Sales_t-1)/ Sales_t-1. We use the value of deviation from the industrial mean (based on 2-digit code) in each country in each year.
Emp_growth (%)	The growth rate of the number of employee in year t is (Employee_t – Employee_t-1)/ Employee_t-1. We use the value of deviation from the industrial mean (based on 2-digit code) in each country in each year.
Market Competition	The sales concentration ratio which is calculated as: $1-\sum_{i=1}^{N}(\text{sales}_{it}/\text{market\_sales}_t)^2$. Sales_{it} denotes sales revenue of firm *i* in year *t* and market_sales_t denotes aggregated sales in *i*'s primary industry (based on 2-digit SIC code) in year *t*.
R&D Expense (Thousand dollars / Million yen)	The absolute amount of internal R&D expenses. For Japanese firms, we use the item of '*Internal R&D Expenditure*' in *the Survey of Research and Development*. We use the value of deviation from the industrial mean (based on 2-digit code) in each country in each year. To account for the precedency of investment, we use one-year lagged value.

Table 2 and Table 3 report descriptive statistics for the US and Japanese firms. Table 4 shows estimates of ROA. This study used three different models for each country. All models suggest that a firm's age is negatively associated with its profitability (significant at the 1% level), which is consistent with the results of Loderer and Waelchi (2010). However, the coefficients depended on the model. In Model 1 the coefficient of age was -0.080 for US firms and -0.070 for Japanese firms, but in models 2 and 3 it was much more negative for the Japanese firms (Model 2: -0.054 for US firms and -0.089 for Japanese firms; Model 3: -0.028 for US firms and -0.084 for Japanese firms). Many of the firms listed in NYSE and TSE can be considered well-established, so the negative impact on ROA is lower than in Loderer and Waelchi's study, as their sample consisted of all listed firms with data on CRSP, COMPUSTAT and COMPUSTAT Industry Segment between 1978 and 2004 (see Table 4 in Loderer and Waelchi, 2010). However, in our models (Model 2 and 3), Japanese firms listed on the TSE suffered a greater decline in profitability as they aged than the US firms listed on the NYSE; the impact of ageing on Japanese firms was closer to that observed in Loderer and Waelchi's study. These results indicate that overall age has a negative influence on profitability but the magnitude of the effect varies with country.

Table 2: Descriptive Statistics and Correlation Matrix (US)

Variable	Obs.	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10
1. *ROA*	22,829	10.317	10.187	-275.680	187.810	1									
2. *Age*	22,829	61.673	43.139	0	271.000	0.029	1								
3. *Size*	22,829	7.398	1.863	-0.091	13.590	-0.037	0.266	1							
4. *SG&A*	22,829	1217.374	3661.838	-283.0	96915.0	0.025	0.139	0.553	1						
5. *COGS*	22,829	0.640	0.279	0	26.562	-0.254	0.043	-0.052	-0.105	1					
6. *Capex*	22,634	0.021	0.059	-0.818	1.276	0.247	-0.086	-0.070	-0.024	0.056	1				
7. *Sales_growth*	22,829	16.581	370.670	-1069.886	54241.664	0.08	-0.10	-0.057	-0.030	-0.017	0.167	1			
8. *Emp_growth*	21,568	23.210	1856.397	-100.0	2.70e+05	0.026	-0.028	-0.007	-0.007	-0.007	0.019	0.060	1		
9. *Market Competition*	22,829	0.864	0.130	0	0.987	-0.018	0.128	0.149	-0.001	-0.091	-0.178	-0.012	-0.001	1	
10. *R&D expense*	12,831	0.030	0.061	0	3.958	-0.084	-0.047	0.043	0.102	0.092	-0.042	0.029	0.007	0.142	1

Table 3: Descriptive Statistics and Correlation Matrix (JPN)

Variable	Obs.	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10
1. *ROA*	49,109	4.610	5.431	-361.105	125.514	1									
2. *Age*	49,109	53.878	20.178	1.000	170.000	-0.142	1								
3. *Size*	49,109	18.088	1.450	12.830	24.207	0.111	0.195	1							
4. *SG&A*	49,109	4.31e+07	1.40e+08	33000.000	3.27e+09	0.036	0.088	0.567	1						
5. *COGS*	49,109	0.761	0.143	0.000	5.585	-0.447	0.132	-0.004	-0.106	1					
6. *Capex*	26,357	-0.068	0.051	-0.597	0.458	-0.093	-0.044	-0.254	-0.192	-0.021	1				
7. *Sales_growth*	49,109	-14.912	1748.737	-9644.885	1.70e+05	0.249	-0.011	0.045	-0.005	-0.048	-0.034	1			
8. *Emp_growth*	20,199	1413.717	6.13e+06	-9.74e+06	8.66e+08	0.016	0.025	0.023	0.004	-0.011	-0.020	0.019	1		
9. *Market Competition*	49,109	0.896	0.105	-0.000	0.981	-0.014	-0.057	-0.102	-0.142	0.036	0.048	0.000	-0.015	1	
10. *R&D expense*	15,272	0.003	0.004	0.000	0.150	0.046	-0.066	-0.044	0.017	-0.322	-0.035	-0.061	-0.057	0.037	1

Table 4: Estimation Result (Dependent Variable: *ROA*)

	US			Japan		
VARIABLES	Model1	Model2	Model3	Model1	Model2	Model3
Age	-0.080***	-0.054***	-0.028***	-0.070***	-0.089***	-0.084***
	(0.009)	(0.009)	(0.010)	(0.002)	(0.009)	(0.011)
Size	-0.148*	-0.216**	-0.592***	0.281***	1.737***	0.957***
	(0.087)	(0.091)	(0.098)	(0.049)	(0.133)	(0.223)
SG&A	-0.000***	-0.000***	-0.000**	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
COGS	-0.034***	-0.024***	-0.007	-47.279***	-59.035***	-59.721***
	(0.006)	(0.006)	(0.005)	(0.339)	(0.495)	(1.034)
Capex		16.341***	18.298***		7.894***	14.231***
		(1.210)	(1.698)		(0.930)	(1.440)
Sales_growth	-0.000	-0.000	0.000	0.000***	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Emp_growth		0.000	0.001***		0.000	-0.000
		(0.000)	(0.000)		(0.000)	(0.000)
Market_Competition	-0.875	-0.285	0.310	-3.683***	-0.699	-4.801**
	(0.853)	(0.878)	(1.085)	(0.411)	(1.648)	(2.363)
R&D_expense			-0.007			-85.252***
			(0.006)			(23.167)
Constant	16.236***	14.033***	13.767***	11.723***	11.149***	15.179***
	(0.622)	(0.657)	(0.846)	(0.378)	(1.653)	(2.348)
Observations	22,829	20,655	11,895	49,109	19,805	7,873
R-squared	0.012	0.020	0.030	0.341	0.469	0.419
Number of firms	958	941	595	2,758	2,448	1,062

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Assuming that the negative effect of age on a firm's profitability does indeed vary by country, why is this? We hypothesise that it is due to the mechanism by which age influences profitability. To explore this idea we decomposed ROA into *profit margin* (operating profits after depreciation divided by sales revenue) and *asset turnover* (sales revenue divided by total assets) and then regressed these variables on the same variables as those in the models in Table 4. Table 5 and Table 6 report the results of these analyses. It can be seen in Table 5 that although age was not correlated with profit margin in US firms, there was a negative correlation (significant at the 1% level) between age and profit margin for the Japanese firms, in all models. The opposite pattern of results was observed when asset turnover was the dependent variable (see Table 6). In the case of the US firm all models suggested that age had a negative influence on asset turnover, but the results for the Japanese firms were inconsistent. In the case of the Japanese firms the coefficient of age was negative in Model 1, positive in Model 2 and non-significant in Model 3.

Table 5: Estimation Result (Dependent Variable: *Profit Margin*)

	US			Japan		
VARIABLES	Model1	Model2	Model3	Model1	Model2	Model3
Age	-0.024	0.024	0.006	-0.068***	-0.103***	-0.109***
	(0.039)	(0.023)	(0.011)	(0.003)	(0.010)	(0.012)
Size	2.573***	1.572***	1.202***	1.440***	2.773***	2.105***
	(0.369)	(0.223)	(0.113)	(0.065)	(0.150)	(0.245)
SG&A	-0.000**	-0.000**	-0.000**	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
COGS	-0.083***	-0.037**	-0.009	-68.860***	-92.383***	-84.624***
	(0.027)	(0.015)	(0.006)	(0.446)	(0.558)	(1.136)
Capex		13.504***	4.449**		10.288***	18.492***
		(2.961)	(1.944)		(1.050)	(1.581)
Sales_growth	0.000	0.000	-0.000	0.000***	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Emp_growth		0.000	0.001***		0.000	-0.000
		(0.000)	(0.000)		(0.000)	(0.000)
Market_Competition	-9.773***	-9.797***	-0.837	-1.382**	2.140	-2.394
	(3.626)	(2.147)	(1.242)	(0.541)	(1.860)	(2.595)
R&D_expense			0.002			-209.435***
			(0.007)			(25.440)
Constant	14.852***	13.600***	7.858***	9.618***	9.714***	15.231***
	(2.645)	(1.606)	(0.969)	(0.497)	(1.866)	(2.578)
Observations	22,829	20,655	11,895	49,109	19,805	7,873
R-squared	0.004	0.006	0.017	0.365	0.625	0.532
Number of firms	958	941	595	2,758	2,448	1,062

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Estimation Result (Dependent Variable: *Asset Turnover*)

	US			Japan		
VARIABLES	Model1	Model2	Model3	Model1	Model2	Model3
Age	-0.006***	-0.006***	-0.005***	-0.003***	0.005***	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Size	-0.119***	-0.126***	-0.166***	-0.181***	-0.265***	-0.241***
	(0.004)	(0.004)	(0.005)	(0.003)	(0.007)	(0.010)
SG&A	-0.000	0.000	0.000**	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
COGS	-0.001***	-0.001**	-0.000*	0.459***	0.180***	-0.100**
	(0.000)	(0.000)	(0.000)	(0.024)	(0.026)	(0.048)
Capex		-0.126**	-0.204**		0.278***	0.167**
		(0.056)	(0.087)		(0.050)	(0.067)
Sales_growth	-0.000	-0.000	0.000	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Emp_growth		-0.000	-0.000		0.000	-0.000
		(0.000)	(0.000)		(0.000)	(0.000)
Market_Competition	0.297***	0.320***	0.048	-0.183***	-0.588***	-0.202*
	(0.040)	(0.041)	(0.056)	(0.029)	(0.088)	(0.110)
R&D_expense			-0.001***			-11.958***
			(0.000)			(1.083)
Constant	1.515***	1.541***	1.911***	1.449***	1.432***	1.219***
	(0.029)	(0.031)	(0.043)	(0.026)	(0.088)	(0.110)
Observations	22,829	20,655	11,895	49,109	19,805	7,873
R-squared	0.101	0.109	0.191	0.119	0.093	0.138
Number of firms	958	941	595	2,758	2,448	1,062

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

To sum up, all models in Table 4 supports the claim that ageing is negatively associated with profitability in both US and Japanese firms, although the magnitude of the impact of age varies. Japanese firms seem to be more strongly influenced by age than US firms. Furthermore, the way in which age influences profitability also differs between the two countries. In Japanese firms ageing is associated with a decline in the efficiency with which profits are generated from sales revenue, whereas in the US a firm's age has more impact on the efficiency with which assets are deployed to generate revenue.

What reasons are there for these differences? National differences in institutional behaviour, especially with respect to the flexibility of resource allocation, are one possible explanation, as noted in Section 2. Because allocation of managerial resources is relative flexible in the US, it is easier for the firms to shift resources quickly from unprofitable business fields to more promising ones. Of course, the swift shift might incur some costs: for example, a firm may need to rewrite its business plan, learn about a new business environment and develop new skills when it enters a new area. Thus, US firms' flexible resource allocation may make them less efficient at using their assets although it protects them from loss of efficiency in generating profits from revenue.

In contrast resource allocation in Japan is relatively inflexible. This inflexibility may help companies to generate sales through efficient use of their assets, as they operate in areas where they have established competence. But as a sector matures price competition becomes fierce as so companies may become less efficient in the sense that their business becomes less profitable. Our results on Japanese firms, showing that ageing is more negatively associated with *Profit Margin* than with *Asset Turnover*, may reflect such a process. The next step in our analysis was an exploration of flexibility of resource allocation through examination of longitudinal data on R&D rigidity.

4.2 Investment diversity and rigidity in R&D

To estimate the rigidity of firms' resource allocation this study investigated the dependence of R&D activities on past investment. To look at temporal changes in resource reallocation we calculated technological distance between firms' technological portfolios in the recent and more distant past. As discussed earlier, profitability could also be related to diversification; to examine this hypothesis we estimated diversification in R&D and compared figure for the US and Japan. We used patent data to estimate firms' R&D investment activities. Data on patents given by the United States Patent and Trademark Office (USPTO) patents were obtained from *PatentsView* and the *Derwent Innovations Index* and data on patents given by Japan Patent Office (JPO) patents from the *IIP Patent Database*. The observation period was from 1956 to 2017 for US firms listed on NYSE and from 1964 to 2012 for Japanese firms listed on the TSE.

One obstacle to be overcome in collecting data on patents acquired by consolidated firms is that information about consolidation is required. In most cases patent applications only give the name of the individual firm concerned, so information about firm ownership must be obtained from other sources in order to construct consolidated-level information about patents. As ownership structures can change over time, for example through mergers and acquisitions (M&A), time-series information about ownership was needed for this study.

Moody's / Mergent Industrial Manual and the *NISTEP firms' name dictionary* were used to compile information about consolidation. *Moody's / Mergent Industrial Manual* gives the names of the subsidiaries owned by each firm, which we used to search for patents. Since the descriptions on individual firm information provided in *Moody's / Mergent Industrial Manual* are not necessarily fully standardised, we manually looked up the subsidiaries and collected lists of names according to standardised rules[1]. We collected information on subsidiaries from *Moody's / Mergent Industrial Manual* with five-year time window. For example, if the 2000 *Mergent Industrial Manual* reported that parent firm A owns subsidiaries B and C, we recorded patents obtained by firms A, B and C between 1996 and 2000 as A's consolidated patents.

Consolidation information about Japanese firms was obtained from the *NISTEP firms' name dictionary*. This database includes consolidated firms' names, changes of name, and historical information about M&A and their timing, which we used to construct time-series data on consolidation.

Before examining R&D rigidity, we compared the R&D diversification of US and Japanese firms. Diversification may influence a firm's profitability and the rigidity of its R&D activities, as discussed in Section 2. We estimated technological diversification by calculating the patent-HHI of each firm. Patent-HHI of firm *i* is calculated as $\sum_{j=1}^{N} (\mathrm{NP_{ijt}}/\mathrm{NP_{it}})^2$, where NP_{it} denotes the total number of patents obtained by firm *i* in year *t*, and NP_{ijt} denotes the number of patents obtained by firm *i* in field *j* in year *t*. Technological field data were based on the four-digit International Patent Classification (IPC) subclasses.

We used technological distance as an indicator of R&D rigidity. The technological distance construct, proposed by Jaffe (1986), was originally intended as a measure of the degree of similarity between technological investment portfolios (which Jaffe called 'technological positions') of two different firms. Thus, we estimated R&D rigidity by calculating the similarity between a firm's current and previous technological investment portfolio. The more similar a firm's current and previous portfolios, the more rigid its R&D resource allocation. Technological distance was calculated as follows.

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[1] We collect the names of all firms listed as 'subsidiaries', 'affiliations' 'affiliated companies' or 'consolidated companies' excluding firms as follows. 1. Firms listed as 'unconsolidated' or with notes specifying that they were unconsolidated. 2. Firms where less than 51% of the stock was held by the parent firm. 3. Firms owned by a parent firm's subsidiary (i.e. subsidiaries of a subsidiary).

The vector for the technological position of firm *i* in year *t* is written as

(1) $$F_{it} = \left(\frac{NP_{i1t}}{NP_{it}}, \frac{NP_{i2t}}{NP_{it}}, \cdots, \frac{NP_{ijt}}{NP_{it}}\right)$$

where F_{it} is 1 X j vector, NP_{it} denotes the number of patents obtained by firm *i* in year *t* and NP_{ijt} is the number of patents obtained by firm *i* in field *j* in year *t*. The technological distance (P_{it}) between firm *i*'s technological position in year *t* (F_{it}) and year *t-1* (F_{it-1}) is obtained from the following equation:

(2) $$P_{it} = F_{it} \cdot F_{it-1}^{'} \Big/ \left[\left(F_{it} \cdot F_{it}^{'}\right)\left(F_{it-1} \cdot F_{it-1}^{'}\right)\right]^{1/2}$$

Technological distance assumes a value between 0 and 1, and it is unity if the two vectors are identical, which implies that the firm did not changes its investment profile at all between *t-1* and *t*, and zero if the two vectors are orthogonal, which implies that the firm changed its technological position completely.

We carried out sampling with the following procedure in order to capture the consolidated-level patents as precisely as possible. First, we limited our samples to firms belonging to R&D-intensive sectors such as chemicals, metal products, machinery, devices and so on[2]. Second, in the case of US firms we considered only firms that were over a hundred years old in 2015. The primary reason for focusing on these very old firms was that we aimed to observe those which were mostly likely to be rigid in their resource allocation. If ageing is associated with organisational rigidity, as Loderer and Waelchi (2010) argued, one would expect very old firms to exhibit much more rigid resource allocation than young firms. If, however, we found that Japanese firms' resource allocation was more rigid than that of even very old US firms, our hypothesis of the rigidity in resource allocation would be more persuasive. In other words, limiting our sampling of US firms to very old firms were a deliberately conservative analytical strategy.

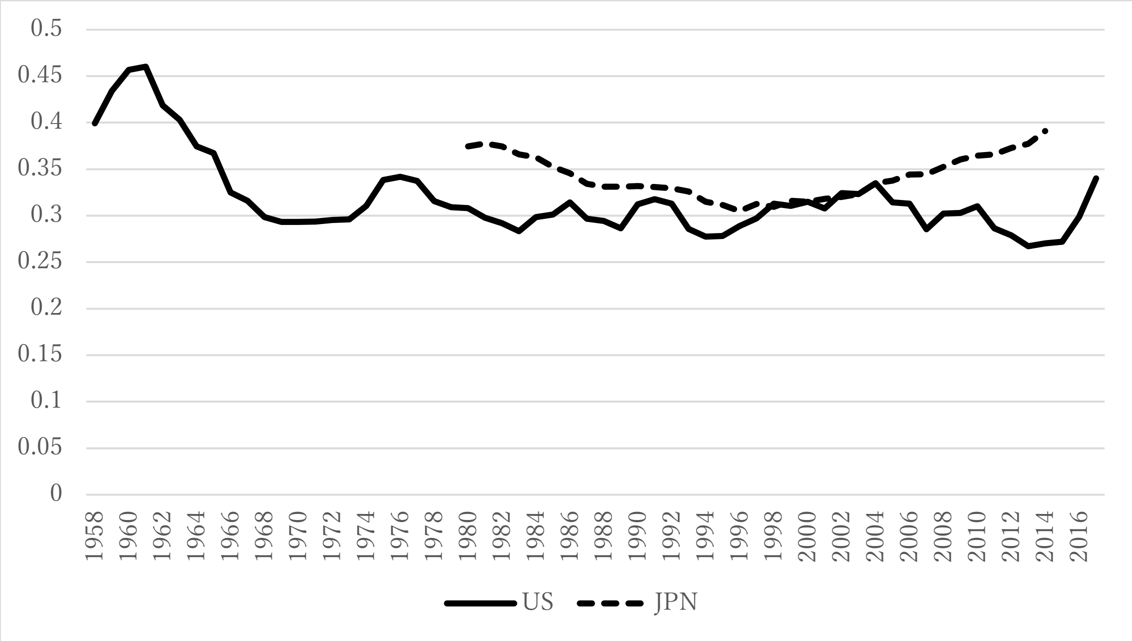
Another reason is that in order to investigate the technological diversification and switching of US firms at a consolidated level, we had to look up their subsidiaries manually in *Moody's* / *Mergent Industrial Manual* and work out the exact history of their ownership structure. This task compelled us to reduce the US sample size significantly. In the end, our US sample for this analysis consisted of 112 very old firms, including General Electric, 3M, Ford, and Du Pont, and the Japanese sample of 586 firms in R&D-intensive sectors.

Figure 4 shows the sample means of Patent-HHI by year, and Figure 5 shows

[2] US firms with the following codes: US SIC 2600-2699; 2800-2899; 3300-3899; and 9997 (Conglomerate) and Japanese firms with the following codes: Japanese SIC 1100-1199; 1400-1499; 1600-1699; 2200-3199.

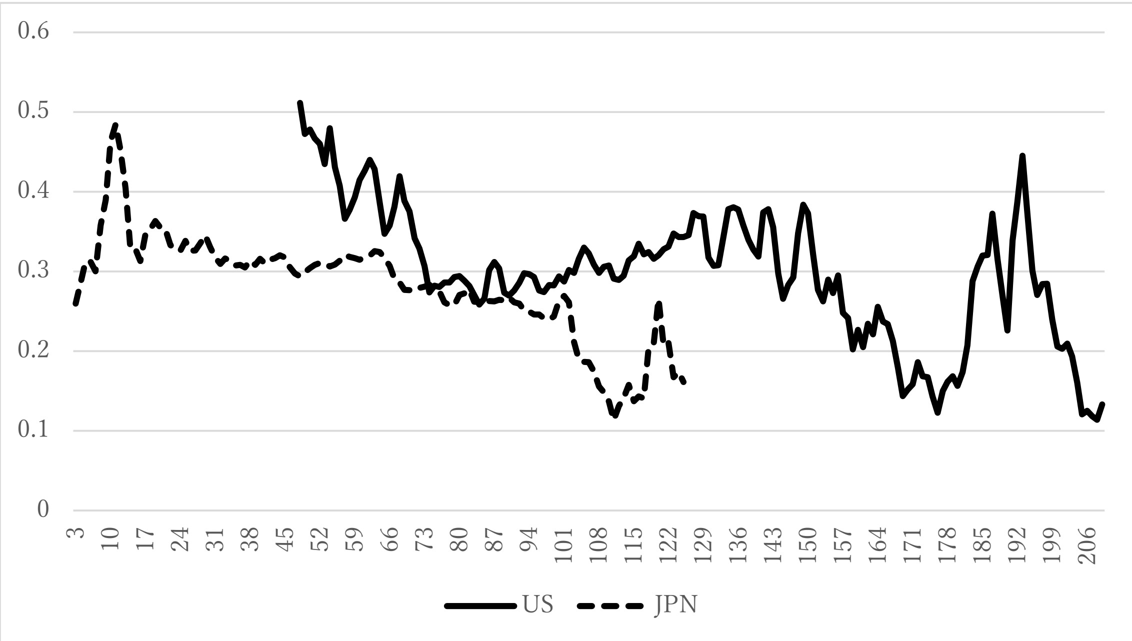
them by age. We took averages of the last three years (including the focal year) to smooth the lines. It can be seen from Figure 4 that although the Japanese firms had higher values, implying a greater concentration of technological investment, in some years, overall the extent of technological diversification in the two countries was very similar. The US and Japanese age cohorts are so different that comparison was difficult, but Figure 5 shows that the US and Japanese firms in the 60- to 90-year-old cohort had similar levels of technological diversification. Interestingly, in the case of US firms Patent-HHI increases from the age of 100 years, whereas in the case of Japanese firms it continues to decline. This implies that US firms that have been in existence for over 100 years are more likely to concentrate their R&D resources in certain fields, whereas even very old Japanese firms consistently continue to diversify their R&D resources. The important finding is, however, around the age of 70, which is the cohort with the highest density in the population of Japanese firms as illustrated by Figure 6, US and Japanese firms have a very similar level of diversification. As there are few firms around the age of 100, they do not have much effect on the overall effect of age on profitability. In contrast to the anecdotal evidence (Numagami, 1996), these results show that it is difficult to explain the difference between US and Japanese firms' profitability in terms of technological diversification.

Figure 4: Technological Diversification by Year (3-year average)



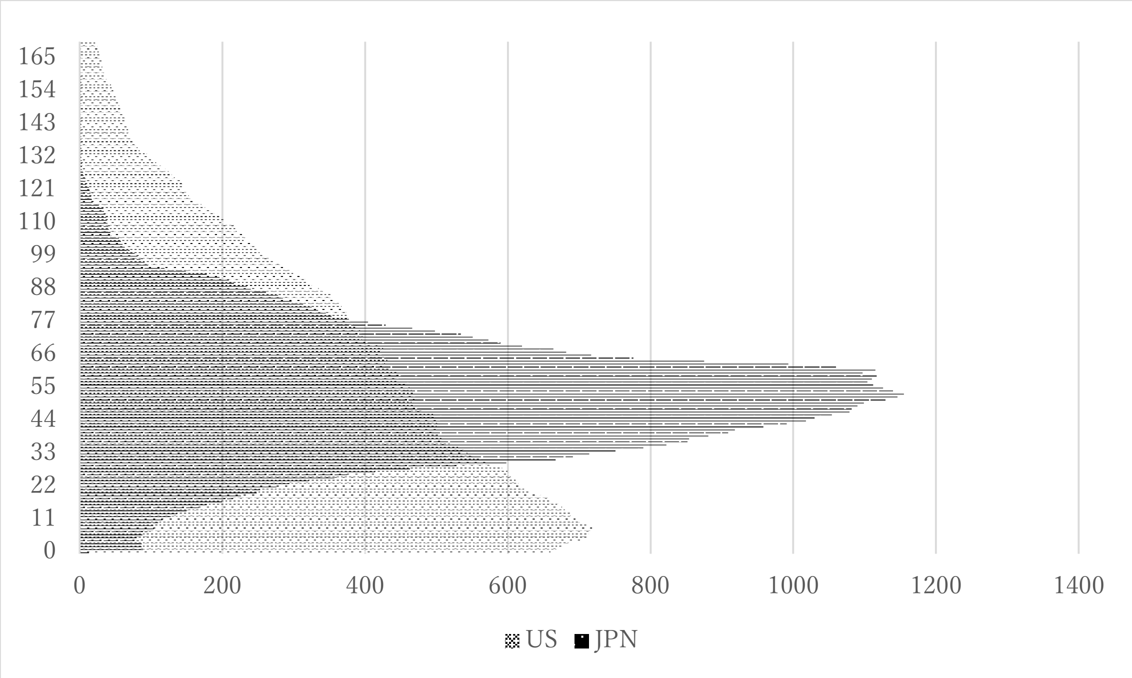
Source: *PatentsView* and *Derwent Innovations Index* for USPTO patents, and *IIP Patent Database* for JPO patents.

Figure 5: Technological Diversification by Age (3-year average)



Source: *PatentsView* and *Derwent Innovations Index* for USPTO patents, and *IIP Patent Database* for JPO patents.

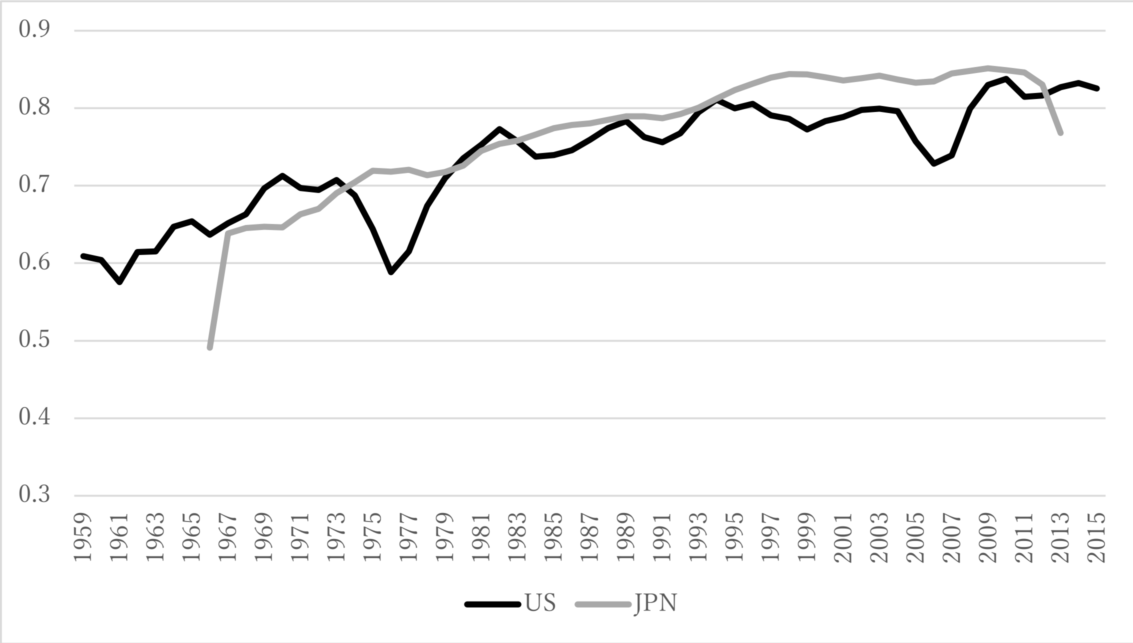
Figure 6: Cohort of the Firms in the U.S. and Japan



Source: *COMPUSTAT* database and DBJ *Firm Financial Databank*
* Full count during the periods between 1978-2015

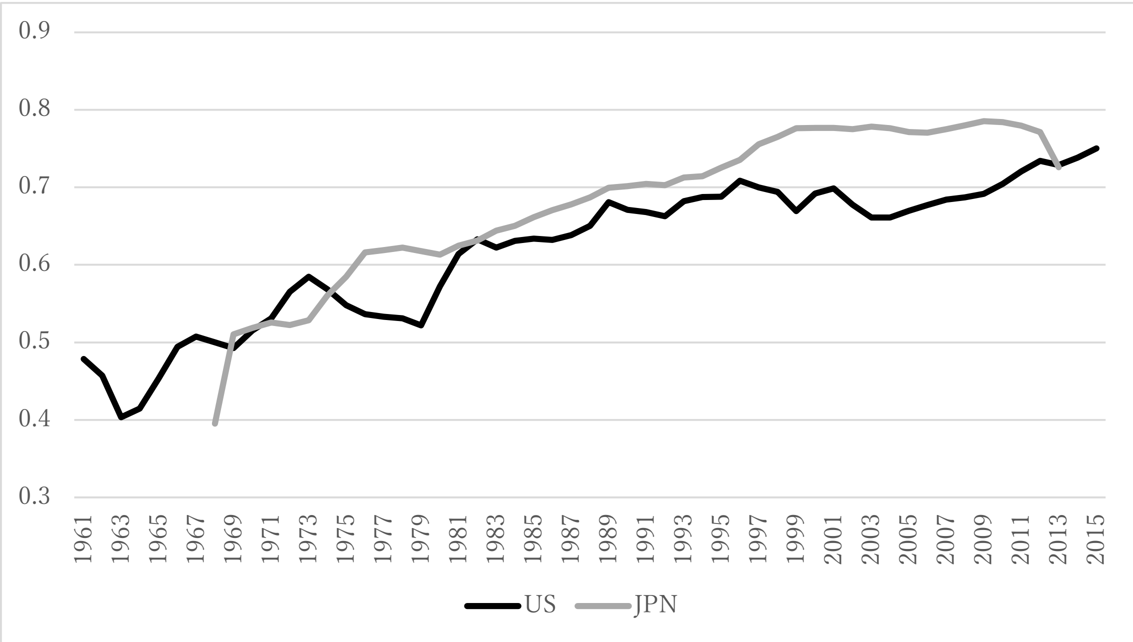
We now move on to the analysis of R&D rigidity, which was measured as technological distance. We calculated three technological distance variables for each firm: the distances between technological positions in year *t* and years *t-1*, *t-3*, *t-5*. Figures 7, 8, and 9 show the sample means of technological distance by year. In these figures all the data for both countries show a pattern of gradual increase until the 1990s, which implies that the firms became gradually less flexible in resource allocation as they expand, so that eventually their technological distance between different periods became similar. After the 1990s, however, the courses taken by US and Japanese firms begin to diverge. In Japanese firms, technological distance from the prior period continues to increase, whereas in US firms, it starts to level off; this divergence becomes more marked in the 2000s.

Figure 7: R&D Rigidity by Year (t-1, 3-year average)



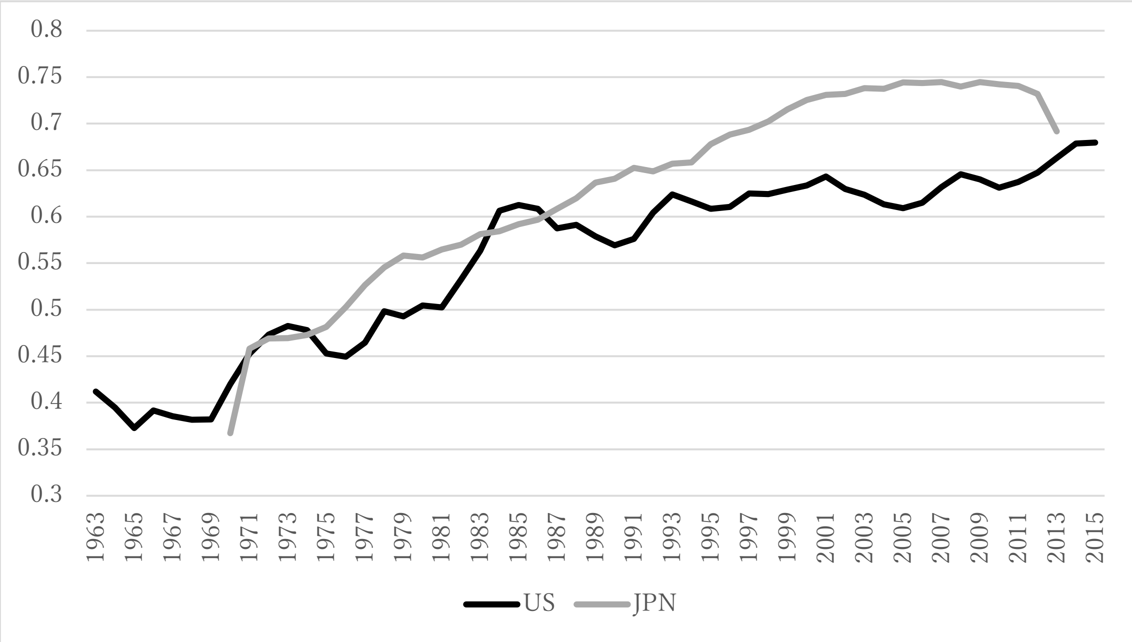
Source: *PatentsView* and *Derwent Innovations Index* for USPTO patents, and *IIP Patent Database* for JPO patents.

Figure 8: R&D Rigidity by Year (t-3, 3-year average)



Source: *PatentsView* and *Derwent Innovations Index* for USPTO patents, and *IIP Patent Database* for JPO patents.

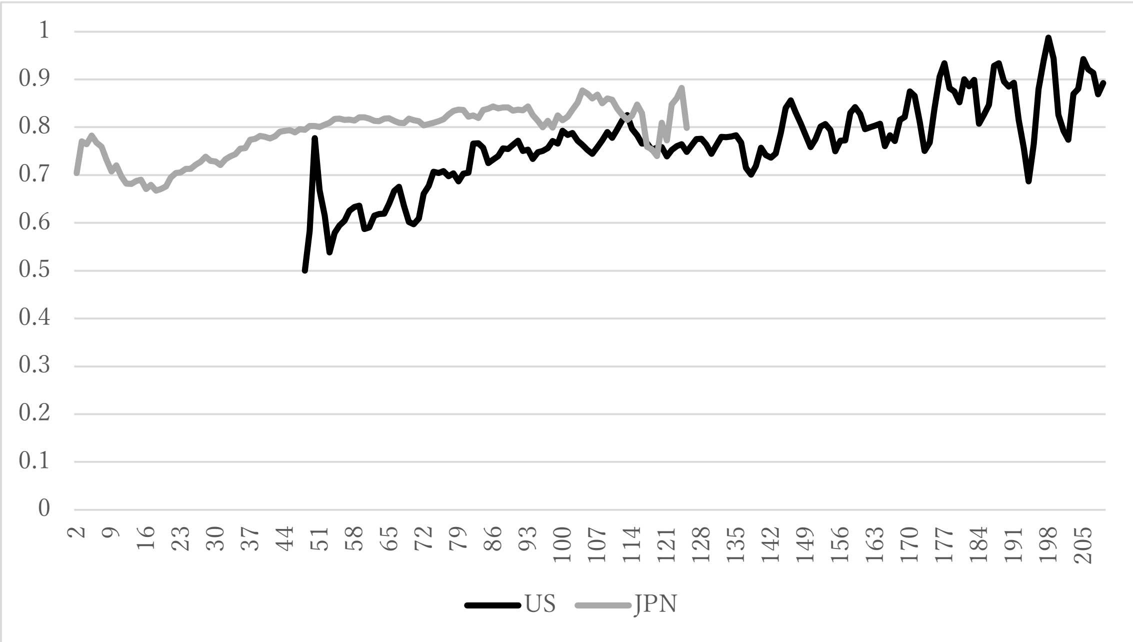
Figure 9: R&D Rigidity by Year (t-5, 3-year average)



Source: *PatentsView* and *Derwent Innovations Index* for USPTO patents, and *IIP Patent Database* for JPO patents.

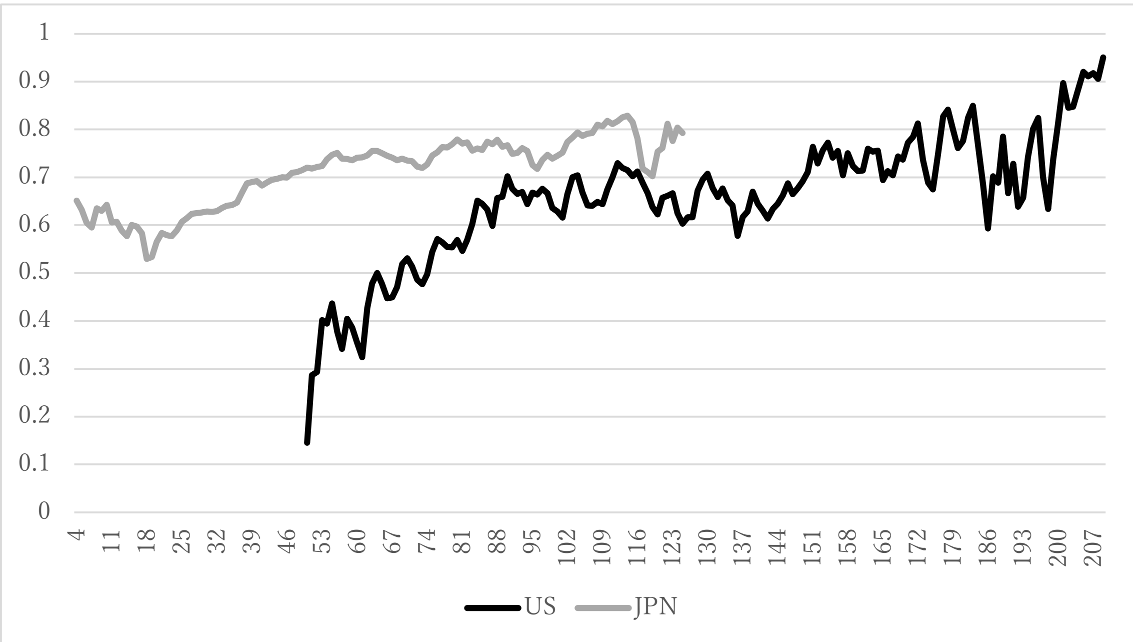
Figures 10, 11 and 12 show the sample means of technological distance for US and Japanese firms. These figures clearly show that as firms get older, their technological positions change less rapidly, in other words their way to allocate resources becomes more rigid. The figures also illustrate that Japanese firms tend to change their technological position more during a given period than US firms of a similar age. The discrepancy is greatest when comparing technological distances between *t* and *t-5* in Figure 12. The distances of Japanese firms that are around 30 years old are similar to those of US firms around the age of 90 or 100 years, and the distances of 110-year-old Japanese firms are similar to those of 170-year-old US firms. There is a lag of 60-70 years between the two countries. This analysis remains to be time-series observation, in which the causal relationship between the rigidity in resource allocation and the profitability is not specified, but it does confirm that age is associated with rigidity of resource allocation across a variety of institutional contexts.

Figure 10: R&D Rigidity by Age (t-1, 3-year average)



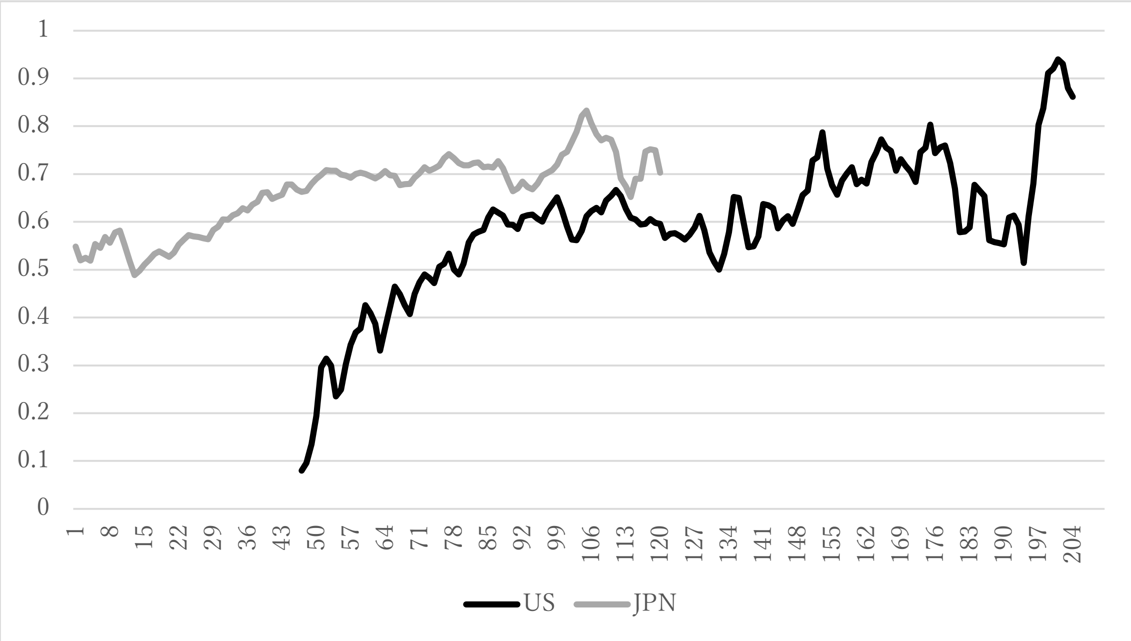
Source: *PatentsView* and *Derwent Innovations Index* for USPTO patents, and *IIP Patent Database* for JPO patents.

Figure 11: R&D Rigidity by Age (t-3, 3-year average)



Source: *PatentsView* and *Derwent Innovations Index* for USPTO patents, and *IIP Patent Database* for JPO patents.

Figure 12: R&D Rigidity by Age (t-5, 3-year average)



Source: *PatentsView* and *Derwent Innovations Index* for USPTO patents, and *IIP Patent Database* for JPO patents.

5 Conclusion

This study uses an analysis of corporations listed on the NYSE and TSE between 1978 and 2015 to highlight clear differences between US and Japanese firms with respect to the relationship between age and profitability. It has shown that US firms are less affected by age than Japanese firms. The empirical analysis showed that operating profit margins decline more sharply with age in Japanese firms, although both US and Japanese firms suffer negative ageing effects. On the other hand, US firms show a decline in the efficiency with which assets are deployed to generate revenue, which does not occur consistently in Japanese firms. In short, the results show that US firms lose efficiency, as measured by total asset turnover as they age, whereas Japanese firms' ability to generate profit from sales declines.

This study explored the factors underlying these national differences in the relationship between ageing and profitability, focusing on rigidity of resource allocation. The distance between firms' technological positions at two time points (technological distance) was as a proxy for rigidity of resource allocation. Technological distance captures the extent to which a firm changed its allocation of R&D resources during the relevant period.

The results of our analysis showed a clear difference in the technological distance and the ageing. At all ages, Japanese firms are more rigid than their US counterparts, although the slope is steeper in the case of US firms. One hundred-year-old US firms have a rigidity equivalent to that of 30-year-old Japanese firms.

These observations suggest that Japanese firms' operating profit margins decline as they age because they are less likely to change how they allocate resources and tend to stay in their existing business sectors, even if they are underperforming. In other words, these findings suggest that being flexible about allocation of resources mitigates the negative effect of ageing on profitability. More concretely, it implies that firms which have a flexible approach to allocation of human and financial resources find it easier to withdraw from unprofitable sectors and acquire personnel for prospective businesses. The other side of this coin is that changing patterns of resource allocation retards learning in the business domains in which a firm is already active.

As previous research has noted, institutions such as worker protections, property rights, the financial market and government funding for R&D differ greatly between countries. One would expect these variables to influence the flexibility of firms' resource allocation strategies. Our findings confirm that this flexibility differs between US and Japanese firms and that this difference may influence the way in which firms age in the two countries. Our findings imply a trade-off between young at heart and wisdom of age exists and it is intervened by the flexibility in resource allocation.

It must be noted that the findings of this study relate to associations between age and performance rather than causal relationships. The precise causal mechanisms by which age influences a firm's performance remain to be elucidated.

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