Paper to be presented at the DRUID Academy Conference 2016 in Bordeaux, France on January 13-15, 2016

Swamp or Leapfrog? : a Firm-level Empirical Analysis of Innovation Strategy during Recession

Hayoung Park
Seoul National University
Technology Management, Economics and Policy Program
hayoung@snu.ac.kr

Taewon Kang
Seoul National University
Technology Management, Economics and Policy Program
dream264@snu.ac.kr

Jeong-dong Lee
Seoul National University
Technology Management, Economics and Policy Program
leejd@snu.ac.kr

Abstract

The economy follows cyclical pattern. In the time of crisis, firms usually form a myopic strategy to cope with a hard time, and simultaneously reduce willingness to invest into long-term and uncertain activities, such as innovation. On the contrary, a few firms act remarkably contrariwise – they strengthen and invest in the long-term strategy. In fact there have been many previous literatures to consider the link between business cycle and firm's innovation. These studies have shown mixed results how firm's innovation activities deal with economic fluctuation, either pro-cyclically or counter-cyclically, and so far there is a lack of consensus whether increase, decrease or no response. Moreover the studies have only represented the interaction of cycle and innovation at the aggregate level, not explained any consequences of such innovation changes. Based on this background and considering the fact that a few firms aggressively invest during recession, this study raises questions: Why do they set up such an active strategy against the tidal wave? Does 'the window of opportunity' occur in a time of economic turmoil? If so, what is a new growth engine?? In order to answer, this study, rooted in Schumpeterian economic perspectives, puts an emphasis on the R&D investment strategy as a proxy of innovation in the economic downturn and investigates the impact of the strategy on the firm's growth after the hard-time. Empirical analysis is performed using firm-level micro data in global chemical and petroleum refining industries. For more details we examine 1,224 firms from 2005 through 2011 and regard the period between

2008 and 2009 as recession. As the results, this study finds an independent relation of firm's growth between before and after the economic downturn and more importantly, innovation strategy during recession determines firm's growth in the following period. Meanwhile, firms which counter-cyclically invest innovation tend to show high growth after crisis, so that R&D investment during recession works as the momentum of leapfrogging. The results imply that recession period provides a new possibility for growth so that it should be careful not to cut R&D investment as a short-sighed confrontational action.

Jelcodes:O32,D21

Swamp or Leapfrog? : a Firm-level Empirical Analysis of R&D investment Strategy during Recession

Hayoung Park, Taewon Kang, Jeong-Dong Lee

Seoul National University

NOTE: Preliminary draft – Please do not cite and distribute without permission

Abstract

The economy follows cyclical pattern. In the time of crisis, firms usually form a myopic strategy to cope with a hard time, and simultaneously reduce willingness to invest into long-term and uncertain activities, such as innovation. On the contrary, a few firms act remarkably contrariwise – they strengthen and invest in the long-term strategy. In fact there have been many previous literatures to consider the link between business cycle and firm's innovation. These studies have shown mixed results how firm's innovation activities deal with economic fluctuation, either pro-cyclically or counter-cyclically, and so far there is a lack of consensus whether increase, decrease or no response. Moreover the studies have only represented the interaction of cycle and innovation at the aggregate level, not explained any consequences of such innovation changes. Based on this background and considering the fact that a few firms aggressively invest during recession, this study raises questions: Why do they set up such an active strategy against the tidal wave? Does 'the window of opportunity' occur in a time of economic turmoil? If so, what is a new growth engine?? In order to answer, this study, rooted in Schumpeterian economic perspectives, puts an emphasis on the R&D investment strategy as a proxy of innovation in the economic downturn and investigates the impact of the strategy on the firm's growth after the hard-time. Empirical analysis is performed using firm-level micro data in global chemical and petroleum refining industries. For more details we examine 1,224 firms from 2005 through 2011 and regard the period between 2008 and 2009 as recession. As the results, this study finds an independent relation of firm's growth between before and after recession and more importantly, innovation strategy during recession determines firm's growth in the following period. Meanwhile, firms which counter-cyclically invest innovation tend to show high growth after crisis, so that R&D investment during recession works as the momentum of leapfrogging. The results imply that recession period provides a new possibility for growth so that it should be careful not to cut R&D investment as a short-sighed confrontational action.

Keywords: Recession; Window of opportunity; Firm R&D strategy; Firm Growth

I. Introduction

In general, business cycle affects the performance of the individual firms, industries, and overall economy. (Domowitz, Hubbard and Peterson, 1988; Gabisch and Lorenz, 1987; Zarnowitz, 1985) Especially during downturn, firms face a hard time as the demand and sales decreases while the uncertainity increases. Also, restructuring in the industry occurs as the gap among the firms' competitveness widens. Gulati, Nohria and Wohlgezogen (2010) conducted an empirical analysis of the firms that went through the recession in 1980, 1990, and 2000. According to their result, 17% of the firms left the market due to the recession, 9% of the firms showed high growth, and 85% of the firms which were leading the market before recession resulted in losing the leader standing in the market. In addition, Dobbs, Karakolev and Raj (2007) shows top 35% of the firm before the economic crisis fell to rank at the bottom 40%, while 14% of firms in low ranked group jumped to the top due to the IT bubble burst in the early 2000s.

Firms' business environment plays an important role in setting up the strategies. (Lane and Lubatkin, 1998; Miller, 1988; Teece, Pisano and Shuen, 1997) Dutton and Duncan (1987) and Dutton and Jackson (1987) claims reaction type and its level are remarkably settled depending on how a firm complies with the external changes. Commonly, firms recognize recession as a crisis; therefore they immediately set with defense oriented strategy[1] for survival when they are confronted the economic downturn. At this point, especially the willingness to invest in the long term and uncertain activities such as R&D decreases. According to the OECD report, firms in OECD countries decrease 4.5% of their R&D budget in 2009 as a result of the financial crisis in 2008.

On the other hand, contrarily to the common actions, some firms established more aggressive strategy in response to the recession. As Covin and Slevin (1989) claimed that such a proactive strategic posture and organic structure during the difficult business circumstances results in an outstanding performance, and in real world, there are many cases the extended R&D investment showed positive effects to the performance after the recession. Toyota extended the R&D expense by recruiting over 300 researchers during the US

[1] Downsizing strategy such as business reshuffle, layoff, multilateral cost reduction, securing cash-flow, etc. (Zook and Darrell, 2001)

recession in the 1990s, as opposed to others including General Motors and Chrysler, the original leaders of US automobile market. And this opened starting point of expanding the market share in US market for Toyota. (Kim, 2012) Meanwhile, iPod, which led Apple to be a leader of IT industry, was developed as a result of continuing R&D investment even during the IT bubble and 9.11 event. In 2001, Apple's R&D budget remained at 8% of the sales while the operating profit was -6.2%. (Jung, Gang, and Shin, 2010) In 2008 financial crisis, the latest world economic depression periods, Samsung electronics succeeded in expanding the market share of the semiconductor industry[2] by focusing on high value products through the large scale R&D investment. (Kim, 2012) Additionally, there are many cases around the various industries including DuPont, Conning, Canon, Asahi Beer, which secured the leading position in the industry by expanding the R&D investment during the recession.

Based on the real-life situation described above, it can be meaning to see whether this phenomenon can be generalized. Thus, this study aims to answer the question; (i) does 'the window of opportunity[3]' occur in a time of economic turmoil? (ii) if so, what is a new growth engine, which in other words, what strategy drives the leap? In order to solve the problems, this study spotlights the economic downturn as an opportunity for new growth by reflecting some part of the concept of neo-Schumpeterian stream of researches on economic catching-up. And then we put an emphasis on the innovation which enables firms to leap forward after the hard-time.

Some research has shown that the economic slump worked as an opportunity to some firms through case studies[4]. Meanwhile, most of the previous literatures that review the relationship between recession and firm innovation are not setting to an agreeable conclusion on how economy changes affect the firm's R&D investment decision, and also they have less attention to the performance resulted from the relationship between economic fluctuation and firm's R&D investment. Hence we try to demonstrate the possibility of recession as a window of opportunity through quantitative analysis and after that draw the optimal R&D investment strategy during crisis by tracking back to firms' performances in recovery period.

---

[2] From 6.8% in 2008 to 9.7% in 2011, increased 42.6%

[3] This term was used for the first time in Perez and Soete (1988) in order to explain catching-up process by latecomers.

[4] Mathew (2005) and Ki (2010) showed economic downturn was an opportunity for followers catch-up through flat panel display industry and steel industry, respectively.

For the empirical analysis, we used the data of 1,255 firms in the global chemical and petroleum refining industry and used R&D investment as an innovation proxy. We considered the analyzing period to be 7 years from 2005 to 2011, and considered year 2008-2009 as a recession.

This article is organized as follows: The second section reviews the previous literatures and sets the hypothesis. The third section details the conceptual and analytical underpinnings of the methodologies. The fourth section summaries the empirical analysis results and lastly, it concludes with the implications of the analyses.

II. Literature Review and Hypotheses

1. Neo-Schumpeterian steam and 'window of opportunity'

Neo-Schumpeterian, expanding from arguments of Schumpeter (1911(1934)) that innovation is the basis of economic growth and change, proved that innovation can be endogenously explained and argued instability of capitalism economy and innovation as two faces of the same coin (Archibugi and Filippetti (2013)) Based on this stance, neo-Schumpeterian stream of research identifies innovation as a key element to make economic catch-up possible. More specifically, if 'window of opportunity' opens up from exogenous factors, strategic choices can lead to successful catch-up. (Lee, 2013)

Perez and Soete (1988) explained the concept of 'window of opportunity' as emergence of techno-economic paradigm makes comparatively less experience, managerial ability, and capital. This eventually means narrower gap between leader and follower, opening an opportunity for the follower. Lee and Park (2010) summarized 'window of opportunity' as change of techno-economic paradigm, business cycle, and government's intervention or regulation change.

Among them, business cycle – 'window of opportunity' that recession brings – is related with the term of 'creative destruction (Schumpeter, 1942)', which implies economic fluctuation generates a shake-out in existing industries and entrepreneurs create innovation.

Mathew (2005) studied cases of flat panel display industry of Japan, Korea, and Taiwan during economic fluctuation, caused by mismatch of investment and production or supply and demand in many industries that need large-scale investment in a short period. He concludes that during recession, followers have advantage because competition for resources relaxes and elements prices get cheaper. On the same line, Ki (2010) also showed recession was an opportunity for Korean catch-up in steel industry where industrial leadership changed from the United States to Japan and to Korea. Lee and Mathew (2012) suggested successful catch-up cases of Korea and Taiwan. Here the authors argued that economic downswing would be an opportunistic period for latecomers, especially since technology transfer and knowledge acquisition would be easier and cheaper, and thus it would be an opportunity for 'fast followers' to establish and upgrade supply chain.

2. Business environments and strategies of firms

The 'window of opportunity' from recession, identified in previous studies, is the business environment – an external factor – for a company. For a long period time, previous research studied the relationship between firm strategy and result with external environment. (e.g., Miller & Friesen, 1983, Lane & Lubatkin, 1998) From business point of view, Bourgeois (1984) stated that firms manipulate the environment and create new environment for achieving goals. Teece, Pisano and Shuen (1997) emphasized the dynamic capability in accordance with environments since external environments of firms affect establishment of firm strategies. Nelson and Winter (1982), developed Schumpeter's insights with evolutionary approaches, argued that firms and environments interact with each other as economic agents, and drive evolutionary changes following co-evolution of technology environment changes. At this time, each firm is heterogeneous and therefore their decision making processes and strategies are also heterogeneous.

3. Recession and innovation activity

Previous studies on relationship between economic fluctuation and firm innovation have mostly focused on decision making process of firms due to economic fluctuations.

These studies can be largely divided into two: one with pro-cyclicality perspective that R&D expenditure would decrease under recession and another with counter-cyclicality perspective that R&D expenditure would increase under recession. The former does not differentiate R&D with other investment activities, and argues that an under economic depression when investment in general shrinks R&D investment would also decrease. (Cincera et al., 2012) Also, since R&D expenditure is highly related with firm's cash flow, or internal capital (Hall, 1992; Hall, 2002) decrease in sale and limit in cash liquidity would lead to reduction in R&D expenditure, which Rafferty and Funk (2004) defined as 'Cash-flow effect.' Fatas (2000) studied relationship between short-term economic fluctuation and long-term growth, and explained R&D expenditure changes along with economic fluctuation not through direct demand effect but limitation of credits. Rafferty (2003) mentioned cash flow inside firms affects R&D investment and direct economic measures are required to prevent decrease in R&D investment from diminishing cash flow under recession. Also while proving Schumpeterian creative destruction, Francois and Lloyd-Ellis (2003) argued that under economic downturn new innovation tends to be delayed and firms wait for the next booming stage. Aghion et al. (2005) clarified that without credit restriction general R&D expenditure proportion shows counter-cyclicality but with credit restriction the proportion shows pro-cyclicality, and this pattern is seen more clearly with small and medium enterprises. On the other hand, counter-cyclicality perspective relates to R&D expenditures' characteristics such as adjustment cost and opportunity cost. Researches in this stream claims firms normally adjust limited resources between short-term productivity activities and long-term R&D activities. However in recession, the opportunity cost of R&D is lower because productivity activities shrink due to reducing demand. Hence such 'inter-temporal substitute effect' between productivity activities and R&D activities eventually increase firm's R&D investment during economic downturn. (Bean, 1990; Saint-Paul, 1993; Aghion and Saint-Paul, 1998) Rafferty and Funk (2004) defined this argument as 'Opportunity cost effect.' In addition, Bond et al. (1999) and Cincera (2003) explained recession affects the decision making process for launching new R&D projects, not for continuing existing R&D projects due to the R&D expenditure's properties such as long-term nature and high fixed cost. From similar viewpoints, Bloom and Reenen (2007) claims the decision of R&D investment does not react sensitively to the business cycle because of high adjustment cost and output uncertainty, so it tends to persist over time.

In contrary there are a number of researches explaining difference in firm characteristics lead to difference in R&D expenditure patterns during economic fluctuations. Kanerva and Hollanders (2009) confirmed that more innovative firms continue and expand R&D under recession and Cincera et al. (2012) mentioned that the largest and the smallest firms in size rather expanded their R&D investment during 2008 economic crisis, although in general European firms' R&D investments somewhat decreased. In addition, Fillippetti and Archibugi (2011) explained that recession strengthens relationship between national innovation system and firms' innovation activities, and a stronger national innovation system decreased the effect of diminishing innovation from recession. Amore(2015) showed innovative experience from past recession becoming an decision-making factor to invest on innovation during new recession.

Regarding relationship between R&D expenditure and firm performance, Dugal and Morbey(1995) showed firms that increased R&D expenditure during recession had improved growth in sales, and Foster(2003) argued expanding R&D investment during recession provides bases for higher business result after recession.

4. Hypotheses

In previous study, they demonstrate latecomers' catch-up processes were possible through the recession as the window of opportunity. As expanding their arguments, this study have a standpoint that incumbents also utilize economic turbulence as a chance to grow. In this aspect, we set up Hypothesis 1.

Hypothesis 1. Firm growth before recession continues after recession.

In other words, if Hypothesis is rejected, by meaning that previous growth pattern does not guarantee the future growth through recession, we are able to conclude firms may prepare to take off for a new growth through the economic downturn.

Meanwhile we identify that firms are affected by business environment when they set up a strategy, and then R&D investment has cyclical patterns according to economic fluctuation. Based on this previous analyses and to prove optimal R&D investment strategy during economic slump by backward induction, we assume the relation between R&D

investment during recession and its performance after recession.

Hypothesis 2. Pro-cyclical R&D investment is positively related to growth after recession.

Hypothesis 3. Counter-cyclical R&D investment is positively related to growth after recession.

In addition, for clarifying Hypothesis 3, we separate counter-cyclical R&D investment into persistent and increase patterns. Then considering the nature of R&D such as high adjustment cost and sunk cost[5], as well as the results of R&D such as the accumulation of knowledge and firm growth, we set up Hypothesis 4 as below.

Hypothesis 4. Persistent R&D investment is positively related to growth after recession.

III. Methods

1. Data

The data for the empirical analysis is extracted from Bureau van Dijk ORBIS database program. ORBIS provides basic financial information such as revenue, profit, capital stock, and debt as well as additional information on management structure, affiliated companies, and patents of 120 million of firms around the world. This study constructs unbalanced panel data from 2005 to 2011, and considered year 2008 – 2009 as a recession. We limit the industry to manufacturing industry, as well as choose chemical and petroleum refining industry[6]. Both chemical and petroleum refining industry are typically one of the cyclical industries affected by global economic situation and oil price fluctuation. They are features of global operation based on international trade and economics of scale with massive investment and capital. Besides, the competitiveness of the firm in these industries is determined by innovation, specifically process innovation in petroleum refining industry while product innovation in chemical industry. (Song et al., 2014; Lee, 2014) Especially, in the period from 2005 to 2011, global economic recession was occurred because of global

[5] Previous studies claims that R&D investments tend to persist because of high adjustment cost for change (Harhoff, 2000; Lach& Schankerman, 1989; Himmelberg & Peterson, 1994) as well as sunk cost which is uncollectable before it realizes (Manez et al., 2009).

[6] US SIC 28 Chemical and Allied Product; US SIC 29 Petroleum Refining and Related Industries

financial crisis from U.S. in 2008 and following fiscal crisis in Europe. Moreover, due to this global economic recession, the crude oil price was significantly dropped, converted from the trend in early 2000s which the crude oil price steadily increased, according to U.S. Energy Information Administration (EIA)[7]. Therefore, because chemical and petroleum refining industries are mainly used as intermediate input, they greatly suffered from the influence of recession by downturn of investment and demand (Jeong et al., 2010). From this fact, this study chooses chemical and petroleum refining industries as the sample for analysis due to their characteristics and responsiveness to economic recession. Finally the number of observation is 8,586 from 1,224 firms including both listed and unlisted firms.

2. Model

The linear regression equation for the empirical analysis is as follows.

$$Y_{it} = \beta_0 + \sum_{j=1}^{5} \beta_j X_{ij,t} + \sum_{j=6}^{n} \beta_j C_{ij,t} + \varepsilon_{it}$$

i=1, 2,…,n, t=1,2,..,T Equation(1)

(Y: growth rate of the firm, X: explanatory variables, C: control variables, $\varepsilon_{i,t}$: error terms)

Dependent variable is the growth rate of the firm i in period j. The growth rate is calculated by the differences of the sales with log-transformation ($Y = lnS_{i,t} - lnS_{i,t-1}$). Sales explain both short- and long-run changes of the firms, so many previous studies used it as the proxy of the firm growth.

X is explanatory variable. This study considers X as (i) high growth firms in year 2006-2007(pre-recession period) and (ii) firms identifies as R&D strategy (pro-cyclical or counter-cyclical) during recession. In order to verify the hypothesis 1, persistently top 25% of

[7] They show the chart data of crude oil prices, updated monthly and quarterly. Access available at https://www.eia.gov/finance/markets/spot_prices.cfm

firms during pre-recession period are defined as high growth firms. Then we take them as a dummy variable, ‘h_growth’, which is 1 for the high growth firms and 0 for the others.

Additionally in order to test the other hypotheses, we classifies firms into pro-cyclicality, i.e., reducing their R&D expense (negative volatility) during recession and counter-cyclicality groups, i.e., maintaining (persistency) or increasing (positive volatility) their R&D expense during recession, based on their R&D intensity during pre-recession period. Eberhart et al. (2004) regarded the firms which is at least 5% change on their R&D intensity, as volatility group. Amore (2015) checked robustness with different rate, 3% and 7%. As previous research set their own operational definitions for R&D volatility, in this study we use 7% as a baseline and tested further 5% and 10% for checking robustness. Hence the firms increased or decreased their R&D intensity over 7% during recession set the variable ‘var_up’ and ‘var_down’, respectively, and others set ‘per’ means persistent group.

To analyze the effect of ‘var_up’, ‘var_down’, and ‘per’ in post-recession period, we use time dummy variable, ‘T’, which indicates 1 for post-recession period and 0 for others. After that we set some interaction variables using the variables described above. For example, ‘per’ means ‘per’ firms’ growth during economic downturn, whereas ‘per*T’ means ‘per’ firms’ growth after recession. Other interaction variables are defined as same way.

Variable C in the equation (1) is control variable which influences on the firm growth. Even though innovation has high-risk characteristics, the opportunity for high growth is generated from successful innovation (Segarra and Teruel, 2014; Smallbone et al., 1995). Segarra and Teruel (2014) draw the result through manufacturing and service industry in Spain that the firm with large R&D investment tended to achieve high growth rate. So we considered the level of R&D intensity as a control variable. Meanwhile after the Gibrat (1931), there has been a wide variety of research which studied the relationship between the firm size and the growth rate. One of their research streams resulted that small sized firms grow faster. (Caves, 1998; Amara et al., 1998; Wilson and Williams, 2000) In this point of view, we control the firm size as estimated by log-converted number of employee. Lastly each country and year is controlled as dummy variable. Table 1 is the summary of the variables.

[Table 1] Definition of variables

Variable name		Definition
Dependent variable	Y	The growth rate of the firm i in period j, $Y = lnS_{i,t} - lnS_{i,t-1}$ (S_t: sales of period t, S_{t-1}: sales of period $t-1$)
Explanatory variable	h_growth	Dummy variable of high growth firm (The firms in top quarter of the growth rate in 2006 and 2007)
	var_up	The firm which increased its R&D intensity more than 7% from pre-recession period to recession period.
	per	The firm which did not change its R&D intensity from pre-recession period to recession period
	var_down	The firm which decreased its R&D intensity more than 7% from pre-recession period to recession period.
	var_up * T	Interaction variable between var_up and T (per*T and var_down*T are defined as same way.)
Control variable	R&D_in	R&D intensity of the firm i in period j (= R&D investment / Sales)
	Ln_size	Firm size of the firm i in period j (= ln(the number of employees))
	T	Dummy variable of period T=0(recession period: 2008, 2009), T=1(post-recession period: 2010, 2011)

The final model for the estimation is as follows.

$$y_{it} = \beta_0 + \beta_1 h\_growth + \beta_2 var\_up_i + \beta_3 per_i + \beta_4 T + +\beta_5 (var\_up \cdot T)_i + \beta_6 (per \cdot T)_i + \beta_7 R\&D\_in_{i,t-1} + \beta_8 Ln\_size_{i,t-1} + Year + Country + \varepsilon_{it} \quad \text{Equation (2)}$$

Regression analysis is done by panel data from 2008 to 2012 in order to found the firm growth in recession period and post-recession period. Reference group is the firms reducing their R&D intensity during recession, indicated by variables, var_down_i and $(var\_down \cdot T)_i$. Additionally for our study, we use the Hausman and Taylor (1981) specification because of time invariant variables.

IV. Results

1. Descriptive statistics analysis

[Figure. 1] shows 3 years transition probability matrix (TPM) within the analyzed period. We divided each year into quantile range, and then draw transition probabilities from t-1 period to t period. The TPM represents each year's growth dynamics, and in more details, the value of diagonal describes the level of growth persistence whereas the value of off-diagonal means mobility. As look at the results, the TPMs of both year 2007-2010 and 2008-2011, when includes economic turmoil periods, show lower growth persistence and higher mobility. It means that firm growth can be less affected by previous growth. Moreover the correlation coefficient of TPM supports the argument ([Table 2]), as shown lower and insignificant correlation coefficient of the year 2007-2010 and 2008-2011 than others. Hence it is to say that firm's growth dynamics are more active during economic downturn and firm's previous growth pattern cannot guarantee the future growth due to such dynamics.

2005-2008		Growth(t)				
		1	2	3	4	Total
Growth (t-1)	1	32.79	22.00	21.35	23.86	100
	2	25.71	31.15	25.27	17.86	100
	3	18.85	28.98	32.57	19.61	100
	4	22.66	17.86	20.81	38.67	100
Total		100	100	100	100	

(a)

2006-2009		Growth(t)				
		1	2	3	4	Total
Growth (t-1)	1	29.08	20.70	25.05	25.16	100
	2	23.86	28.32	26.03	21.76	100
	3	19.93	31.92	29.85	18.30	100
	4	27.12	19.06	16.03	34.75	100
Total		100	100	100	100	

(b)

2007-2010		Growth(t)				
		1	2	3	4	Total
Growth (t-1)	1	27.34	17.86	25.05	29.74	100
	2	23.31	29.41	26.69	20.59	100
	3	22.22	32.14	28.00	17.65	100
	4	27.12	20.59	20.26	32.03	100
Total		100	100	100	100	

(c)

2008-2011		Growth(t)				
		1	2	3	4	Total
Growth (t-1)	1	25.30	19.30	25.52	29.88	100
	2	22.33	29.85	28.76	19.06	100
	3	23.97	32.03	25.16	18.85	100
	4	28.46	18.76	20.61	32.17	100
Total		100	100	100	100	

(d)

[Figure 1] Probability Transition Probability of growth rates over time

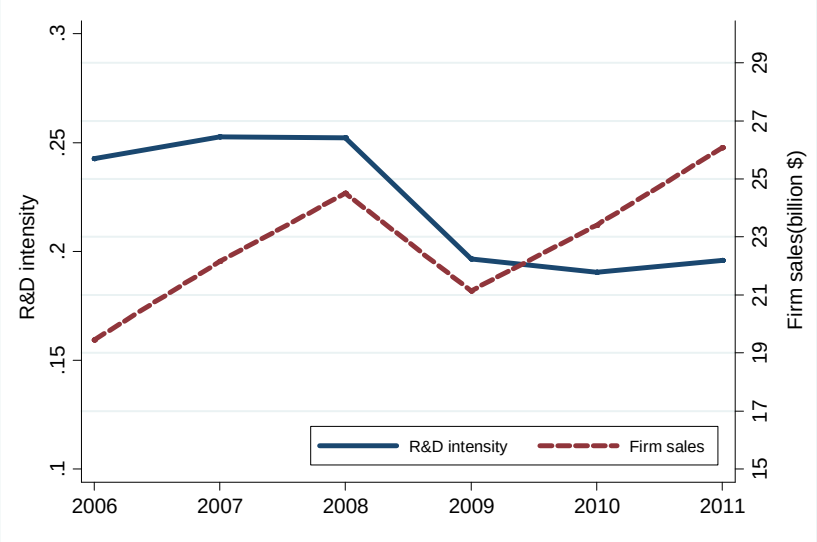
(a) From 2005 to 2008, (b) From 2006 to 2009, (c) From 2007 to 2010, and (d) From 2008 to 2011

[Table 2] Correlation of the years in figure 2

years	Correlation
2005-2008	0.135***
2006-2009	0.072**
2007-2010	0.019
2008-2011	0.029**

Pearson correlation; * p < 0.10; ** p < 0.05; *** p < 0.01

[Figure. 2] describes overall 1,224 firms' average trend of sales and R&D intensity over the period 2006-2011. Sales shows more fluctuating tendency than R&D intensity, however during recession, the graph definitely shows the decrease tendency on both sales and R&D intensity. Additionally, though sales data represent rapid recovering trend, R&D intensities are still remained at lower level after the recession. It means firms set a defense oriented strategy during economic downswing, as well as they keep the strategy even in following period.

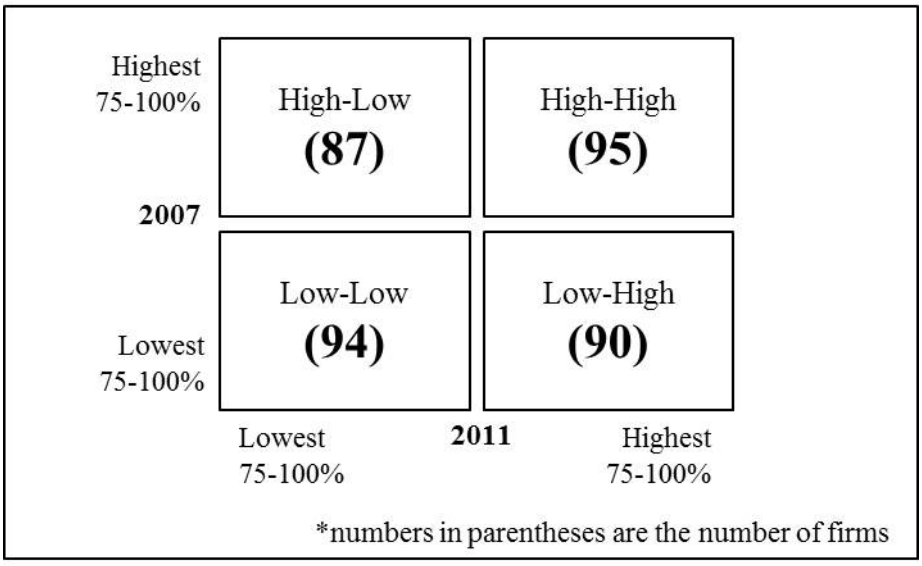


[Figure 2] Average sales and R&D intensity trends over the period 2006-2011

For analyzing the effect of R&D strategy during crisis, we compare the firm groups which are categorized according to a growth ranking before and after recession ([Figure. 3]). We split the distribution of firm growth into a quantile range, and then we identify the firm belonged to fourth range (75-100%) as high-growth (H) while the firm belonged to first range (0-25%) as low-growth (L). Each firm is re-classified into four groups according to their index of the year 2007 and 2011; HL, HH, LL, and LH. For example, a firm, tags ‘L’ in 2007 but turns to ‘H’ in 2011, is included ‘LH’ group. As the result, the number of firms which are affiliated to HL, HH, LL, and LH counts 87, 95, 94, and 90 respectively within total 1,224 firms.

2007-2011		Growth(t)				
		1	2	3	4	Total
Growth (t-1)	1	**30.7**	18.0	21.9	**29.4**	100
	2	19.3	26.8	31.7	22.2	100
	3	21.6	34.3	26.8	17.3	100
	4	**28.4**	20.9	19.6	**31.1**	100
Total		100	100	100	100	

(a)



(b)

[Figure 3] Categorization of groups by growth quantile before and after recession

(a) TPM of the year 2007-2011, and (b) the number of firms in the groups

The correlation of R&D intensity and sales by group is represented in [table 3]. Regardless of previous growth level, high growth firms after recession shows lower correlation coefficient than low growth firms. In other words, the R&D intensity of HH and LH is less fluctuate with sales while, it of HL and LL are deeply reduced by change of sales. Through the results, it is important to persistently invest R&D with long-term perspective in order to catch the opportunity from economic turmoil situation.

[Table 3] Correlation between R&D expenditures and sales by groups

Before Crisis (2007)	After Crisis (2011)	Correlation
H	H	0.346***
L	H	0.286***
H	L	0.728***
L	L	0.928***

Pearson correlation; * p < 0.10; ** p < 0.05; *** p < 0.01

2. Regression analysis

In this section, we draw an optimal R&D investment strategy under recession in order to jump after hard time. This study analyzes 4,896 observations through the year 2008-2011 to investigate growth patterns during and after economic downturn. (More information about the basic statistics, see Appendix)

[Table 4] represents the regression results, analyzed using the equation (2). Firstly the variable ‘h_growth’ shows statistically non-significant result. It means high growth firms before recession does not last their growth patterns after recession, thereby rejecting Hypothesis 1. Accordingly, we arrive at a conclusion that firm’ growth pattern in a pre-recession period does not guarantee the future growth, and new growth opportunities are able to emerge in economic downturn.

The result deducted before, also implies the confrontational strategy of recession is important for upcoming period to leap at the chances. Interaction terms, ‘var_up·T’, ‘var_down·T’, and ‘per·T’, describes the effect of the confrontational strategies during economic crisis on following firm’s growth. Firms who keep their R&D intensity during recession show the positive and significant result on growth rate after the recession (‘per·T’), while others does not have significant differences (‘var_up·T’ and ‘var_down·T’). Moreover to check the same effect during recession, the variable ‘var_up’ shows the negative and significant result on growth, compared to others (‘var_down’ and ‘per’). This result seems that excessively increasing R&D is ineffective during economic slump situation because of the nature of R&D, for example, high adjustment costs but requiring time to get outcomes. Therefore we conclude that continuing investment in R&D can be a driving force for new

growth after economic downturn, so consequentially Hypothesis 2 is rejected, while both Hypothesis 3 and 4 are accepted.

In addition to the effect of R&D investment's direction (i.e., how mode) we discussed above, the control variable, 'R&D_in', describes the effect of R&D investment's degree (i.e., how much). The result tell that originally R&D intensive firms which invest large amount of money to R&D before recession have positive possibility to high growth after recession if they maintain the investment during the economic turmoil. However as shown the result through 'var_up', it also means that a sudden expansion to R&D during recession can bring a negative effect on firm growth. However we need to be careful with the interpretation of this result since in general, there is a time gap between R&D inputs to yield its outputs as one of R&D characteristics. Hence in case we extend the period used in analysis, the result may be change.

Finally the result of 'ln_size' presents negative relation between firm size and firm growth. It means that as getting larger in size, the firm slowly grows, and this is a concordant result with previous literatures.

In this study, we deduct a differentiated perspective from previous studies, which mostly focused on fluctuating responses in R&D expenses to business cycle. However we illuminate more on the recession as 'window of opportunity' and by adding persistent perspective of R&D investment, draw a proper R&D investment strategy during crisis for the next growth. To sum up, economic downturn may provide a chance to growth and countercyclical investment on R&D, especially keeping R&D intensity, is able to lead a quantum jump after recession. Particularly as opposite to the cases introduced in the first section, our result shows that an excessive expansion in R&D investment is not a good idea during economic slump. Therefore, we conclude that it is important to invest persistently on R&D with considering the scale of R&D which firms have invested and the economic circumstances, rather than ambiguously increasing R&D investment.

[Table 4] Regression recults

: Effect of innovation strategy under recession on growth during/after recession (at 7% baseline)

2008-2011				
Dependent Variable(Y)		**Model 1**	**Model 2**	**Model 3**
Explanatory Variable	h_growth	-0.008 (0.025)	-0.001 (0.026)	-0.006 (0.025)
	var_up	-0.101*** (0.018)		-0.098*** (0.018)
	per	-0.013 (0.028)		-0.003 (0.028)
	var_up * T		0.037** (0.018)	0.026 (0.018)
	per * T		0.063** (0.028)	0.063** (0.028)
Control Variable	R&D_in (t-1)	0.139*** (0.008)	0.138*** (0.008)	0.139*** (0.008)
	Ln_size (t-1)	-0.012* (0.007)	-0.016*** (0.007)	-0.015** (0.007)
	T	0.055*** (0.019)	0.078*** (0.016)	0.038* (0.021)
	constant	-0.427** (0.215)	-0.432* (0.221)	-0.414* (0.216)
	Year	Included	Included	Included
	Country	Included	Included	Included
Wald Chi2		501.00	472.80	504.18
Obs		4,894	4,894	4,894
No of firms		1,224	1,224	1,224

- Numbers in parentheses are standard errors; * p < 0.10; ** p < 0.05; *** p < 0.01

V. Conclusion

Many case studies and reports were produced, regarding some firms' growth, which utilized the difficult times as an opportunity after the recession. However, there are only limited studies provided, which quantitatively analyze the strategies firms used during the recession and their performance after the recession. To fill this gap, in this study, empirical analysis using firm level panel data, collected in yearly basis, were provided to verify how the dynamic characteristic of recessions may provide opportunities to firms and identified

what kinds of R&D investment strategies were effective not only during the recession but also after the recession.

Analysis shows that there is no relationship between the growth before and after the recession, which imply that there has been change in growth patterns of firms during the recession. Each firm may improve their growth after the recession depending on their response during the economic downturn and therefore, economic recession brings opportunities to firms.

On the other hand, firms' R&D investment was compared before and after the recession at 5%, 7%, and 10% volatility depending on firms' decisions to increase, decrease, or maintain their R&D investment level during the recession relative to before the recession. Using the above comparison, it was confirmed that firms which maintained their R&D investment exhibited high growth rate even after the recession. This may be due to the nature of R&D such as high fixed and adjustment cost, as we discussed before, and also due to the characteristic of the knowledge which is the result of R&D. Technological knowledge that is produced by R&D tend to be firm-specific and exist in a form of tacit knowledge. According to this standpoint, Pake and Kitzan (1983) claims that it is important to maintain R&D because reducing internal R&D personnel can be costly in that the firm-specific knowledge accumulated within them will also be lost.

However, firms which aggressively increased their R&D expenditure during recession showed lower growth rate compare with others, and their growth rate after the recession showed statistically insignificant values. This result may be due to the economic constraints of recession in that excessive investment may result in adverse effect. But since there exist an time gab between R&D input to yield its output, which may alter the result when the data's time interval is expanded, more careful interpretation and analysis is required to see more detailed implications. Due to the limitation of data used in this research, it is left to the future studies.

In summary, this research identified that firms which maintained its R&D investment during the recession showed higher growth rate after the recession. It has been approximately 6 years since the global financial crisis in 2008-2009, originated from the United States and Europe, occurred. And yet the global economy still hasn't fully recovered its growth rate and

it is stagnated. This recession has caused greater damage to the world economy than previous recessions in terms of its magnitude and shock. (Jung, 2010) However, result from this study re-confirms that firms' innovation capability provides new cornerstone for firms' growth. Thus, this study implies that firms should consistently innovate regardless of the economic condition to prepare the future and the government should provide policy tools that can assist firms to maintain their innovation activities during the recession

There are some limitations in this study. Due to the limitation in data, only one case of recession (2008-2009) was considered. Recessions can be caused by various factors and each of them may differ in the magnitude of shock and its duration. Moreover, different industry sectors may have different impacts from the recession. For example, 2001 IT bubble recession mainly had influence on electronics, energy and transportation sectors and had minor impact and shorter duration than the global financial crisis in 2008-2009. (Jung, 2010) In the similar way, another limitation of this study is that since the data from chemical and petroleum refining industry were used in the analysis, the R&D investment may be biased due to the rapid rise of shale gas started in the similar time interval. In addition, the entry and exit of firms during the data time interval were not considered in the analysis. Lastly, the endogeneity issue was not properly addressed in the analysis, which shows the limitation of the model used in this study. Strategies that aims to increase, decrease, or maintain R&D expenditure may be dependent to each firm's change in profit during the recession and therefore it is important to consider endogeneity issue, which will be analyzed in future studies.

Appendix 1.

		Obs.	Mean	S.D.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.	Y	4,896	0.062	0.406	1.000										
2.	var_up	4,896	0.229	0.420	-0.123***	1.000									
3.	per	4,896	0.068	0.252	-0.044***	-0.147***	1.000								
4.	var_down	4,896	0.203	0.402	0.022	-0.275***	-0.137***	1.000							
5.	T	4,896	0.500	0.500	0.107***	-0.545***	-0.271***	-0.505***	1.000						
6.	var_up x T	4,896	0.229	0.420	0.083***	-0.297***	-0.147***	-0.275***	0.545***	1.000					
7.	per x T	4,896	0.068	0.252	0.021	-0.147***	-0.073***	-0.137***	0.271***	-0.147***	1.000				
8	var_down x T	4,896	0.203	0.402	0.034	-0.275***	-0.137***	-0.255***	0.505***	-0.275***	-0.137***	1.000			
9.	h_growth	4,896	0.070	0.256	0.015*	-0.036***	-0.055***	0.072***	0.000	-0.036	-0.055***	0.072***	1.000		
10.	R&D_in	4,896	0.209	1.103	-0.204***	0.037***	-0.038***	0.003	-0.014	-0.002	-0.039***	0.009	0.061***	1.000	
11.	ln_size	4,896	4.828	2.858	0.006	-0.012***	0.180***	-0.088***	-0.011	-0.016	0.175***	-0.106***	-0.094***	-0.069***	1.000

Appendix 2.

Effect of innovation strategy under recession on growth during/after recession (at 10% baseline)

2008-2011				
Dependent Variable(Y)		**Model 1**	**Model 2**	**Model 3**
Explanatory Variable	h_growth	-0.009 (0.025)	-0.002 (0.026)	-0.005 (0.251)
	var_up	-0.107*** (0.019)		-0.104*** (0.019)
	per	-0.018 (0.024)		-0.009 (0.025)
	var_up * T		0.038** (0.019)	0.026 (0.019)
	per * T		0.056** (0.024)	0.054** (0.025)
Control Variable	R&D_in (t-1)	0.139*** (0.008)	0.138*** (0.008)	0.139*** (0.008)
	Ln_size (t-1)	-0.012* (0.007)	-0.016*** (0.007)	-0.014** (0.007)
	T	0.055*** (0.020)	0.076*** (0.020)	0.036 (0.022)
	constant	-0.426** (0.215)	-0.428** (0.220)	-0.413* (0.215)
	Year	Included	Included	Included
	Country	Included	Included	Included
Wald Chi2		503.40	472.27	506.18
Obs		4,894	4,894	4,894
No of firms		1,224	1,224	1,224

- Numbers in parentheses are standard errors; * p < 0.10; ** p < 0.05; *** p < 0.01

Effect of innovation strategy under recession on growth during/after recession (at 5% baseline)

2008-2011				
Dependent Variable(Y)		**Model 1**	**Model 2**	**Model 3**
Explanatory Variable	h_growth	-0.010 (0.025)	-0.004 (0.026)	-0.008 (0.025)
	var_up	-0.096*** (0.018)		-0.093*** (0.018)
	per	-0.006 (0.031)		-0.001 (0.032)
	var_up * T		0.036** (0.018)	0.025 (0.018)
	per * T		0.047 (0.031)	0.046 (0.032)
Control Variable	R&D_in (t-1)	0.140*** (0.008)	0.139*** (0.008)	0.139*** (0.008)
	Ln_size (t-1)	-0.013* (0.007)	-0.017*** (0.007)	-0.015** (0.007)
	T	0.057*** (0.019)	0.082*** (0.019)	0.043** (0.021)
	constant	-0.428** (0.216)	-0.432** (0.229)	-0.417** (0.216)
	Year	Included	Included	Included
	Country	Included	Included	Included
Wald Chi2		501.18	472.79	502.70
Obs		4,894	4,894	4,894
No of firms		1,224	1,224	1,224

- Numbers in parentheses are standard errors; * p < 0.10; ** p < 0.05; *** p < 0.01

Acknowledgement

The authors acknowledge supporting from SK Innovation's MOT (Management of Technology) Funding Program.

References

Aghion, P., Angeletos, G., Banerjee, A. & Manova, K. (2005). Volatility and Growth: Credit Constraints and Productivity-Enhancing Investment. NBER Working Papers 11349.

Aghion, P., & Saint-Paul, G. (1998). Uncovering some causal relationships between productivity growth and the structure of economic fluctuations: A tentative survey. Labour, 12(2), 279–303.

Amaral, L. A. N., Buldyrev, S. V., Havlin, S., Leschhorn, H., Maass, P., Salinger, M. A., ... & Stanley, M. H. (1997). Scaling behavior in economics: I. Empirical results for company growth. Journal de Physique I, 7(4), 621-633.

Amore, M. D. (2015). Companies learning to innovate in recessions. Research Policy, 44(8), 1574-1583.

Archibugi, D., & Filippetti, A. (2013). Innovation and Economic Crisis: lessons and prospects from the economic downturn. Routledge.

Bean, C. (1990). Endogenous growth and the procyclical behavior of productivity. European Economic Review, 34(2-3), 355-363.

Blackburn, K. (1999) Can stabilization policy reduce long run growth?. Economic Journal, 109, 67–77.

Bloom, N., Bond, S., & Van Reenen, J. (2007). Uncertainty and investment dynamics. Review of Economics Studies, 74(2), 391-415.

Bond, S., Harhoff, D., & Van Reenen, J. (1999). Investment, R&D and Financial Constraints in Britain and Germany. Institute for Fiscal Studies Working Paper #W99/05, 45 pages.

Caves, R. E. (1998). Industrial organization and new findings on the turnover and mobility of firms. Journal of economic literature, 1947-1982.

Chan, H. W., Faff, R. W., Gharghori, P., & Ho, Y. K. (2007). The relation between R&D intensity and future market returns: does expensing versus capitalization matter?. Review of Quantitative Finance and Accounting, 29(1), 25-51.

Cho, S., & Nam, S. (2010). The determinants of R&D expenditures during a recession. Korea Journal of Business Administration, 23(2), 873-892.

Cho, S., Nam, S., & Jeon, K. (2010). The effects of R&D expenditures to Firm's performance during a recession. Logos Management, 8(2), 1-22.

Cincera, M. (2003). Financing constraints, fixed capital and R&D investment decisions of Belgian firms, in P. Butzen and C. Fuss (eds.), Firms' Investment and Finance

Decisions: Theory and Empirical Methodology, Cheltenham, UK: Edwar Elgar, pp.129-147.

Cincera, M., Cozza, C., Tübke, A., & Voigt, P. (2012). Doing R&D or not (in a crisis), that is the question…. European planning studies, 20(9), 1525-1547.

Dobbs, R., Karakolev, T., & Raj, R. (2007). Preparing for the next downturn. McKinsey Quarterly, 3, 81.

Dugal, S., & Graham, M. (1995). Revisiting corporate R&D spending during a recession. Research Technology Management, 38(4), 23.

Eberhart, A., Maxwell, W., Siddique, A. (2004). An examination of long-term abnormal stock returns and operating performance following R&D increases. J.Finance, 59, 623–650.

Fatas, A. (2000). Do business cycle cast long shadows? short-run persistence and economic growth. Journal of Economic Growth, 5(2), 147-162.

Filippetti, A., & Archibugi, D. (2011). Innovation in times of crisis: National Systems of Innovation, structure, and demand. Research Policy, 40(2), 179-192.

Foster, R. N. (2003). Corporate performance and technological change through investors' eyes. Research-Technology Management, 46(6), 36-43

Francois, P., & Lloyd-Ellis, H. (2003). Animal Spirits through Creative Destruction. The American Economic Review, 93(3), 530-550.

Gulati, R., Nohria, N., & Wohlgezogen, F. (2010). Roaring out of recession. Harvard Business Review, 88(3), 62-69.

Hall, B. (1992). Investment and research and development at the firm level: does the source of financing matter?. Working Paper.

Hall, B. (2002). The financing of research and development. Oxford Review of Economic Policy, 18(1), 35-51.

Harhoff, D. (2000). Are There Financing Constraints for R&D and Investment in German Manufacturing Firms? The Economics and Econometrics of Innovation, Springer US: 399-434.

Himmelberg, C. P., & Petersen, B. C. (1994). R & D and internal finance: A panel study of small firms in high-tech industries. The Review of Economics and Statistics, 38-51.

Hirschey, M. (1982). Intangible capital aspects of advertising and R&D expenditures. The Journal of industrial economics, 375-390.

Jung, A. (2014). The effect of industry characteristics on the relationship between R&D expenditure and firm performance. Ph.D Thesis, Hanyang University.

Jung, T., Kang, M., & Shin, H. (2010). Winners and losers after global crisis, SERI issue paper. November 2010. Available at http://www. seri.org (accessed 03 October 2015).

Kanerva, M., & Hollanders, H. (2009). The impact of the economic crisis on innovation. Analysis based on the Innobarometer 2009 survey. Thematic Paper, European Commission, DG Enterprises, Brussels, dicembre.

Kim, M. (2012). Survival strategy during economic downturn. FKI issue paper. FIP-2012-0006. December 11 2012. Available at http://www.fki.or.kr (accessed 03 October 2015).

Lach, S,. & M. Schankerman. (1989). Dynamics of R & D and Investment in the Scientific Sector. The Journal of Political Economy, 880-904.

Lee, D. (2014). An analysis on the international competitiveness of Korea, China and Japan's petrochemicals. Ph.D Thesis. Soonchunhyang University.

Lee, K. (2013). Schumpeterian analysis of economic catch-up: Knowledge, path-creation, and the middle-income trap. Cambridge University Press.

Lee, K., & Park, T. Y. (2010). Catching-up or leapfrogging in Indian IT service sector: Windows of opportunity, path-creating and moving up the value-chain in TCS, Infosys, and Wipro. In Asialics Conference.

Lev, B. & T. Sougiannis. The capitalization, amortization, and value-relevance of R&D. Journal of Accounting & Economics, 21, (Feb 1996), 107-138.

Mañez, J. A., ROCHINA-BARRACHINA, M. E., Sanchis, A., & Sanchis, J. A. (2009). The role of sunk costs in the decision to invest in R&D. The Journal of Industrial Economics, 57(4), 712-735.

Organization for Economic Co-operation and Development. (2012). OECD Science, technology and industry outlook. Available at http://www.oecd.org/sti/ (accessed 18 November 2015).

Pakes, A., & Nitzan, S. (1983). Optimum Contracts for Research Personnel, Research Employment, and the Establishment of “Rival” Enterprises. Journal of Labor Economics, 1(4), 345-65.

Perez, C., & Soete, L. (1988) Catching up in technology: entry barriers and Windows of opportunity. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), Technical change and economic theory (pp.458-479). London: Pinter Publishers.

Rafferty, M. (2003). Do business cycles influence long-run growth?. Eastern Economic Journal, 29(4), 607-618.

Rafferty, M., & Funk, M. (2004). Demand shocks and firm-financed R&D

expenditures. Applied Economics, 36(14), 1529-1536.

Saint-Paul, G. (1993). Productivity growth and the structure of the business cycle. European Economic Review, 37(4), 861-890.

Samsung Economic Research Institute. (2009). Business strategy during recession. Samsung Economic Research Institute. Seoul.

Schumpeter, J. A. (1911(1934) The theory of economic development, Cambridge, MA: Harvard University Press

Schumpeter, J. A., (1942) Capitalism, Socialism and Democracy, New York, NY: Harper.

Segarra, A., & Teruel, M. (2014). High-growth firms and innovation: an empirical analysis for Spanish firms. Small Business Economics, 43(4), 805-821.

Seo, R., & Cho, S. (2009). R&D expenditures and firm's performance during a recession. Korea Accounting Assiciation, Conference presentation, 2009(2), 1-33.

Shin, H., Kim, S., & Hong, S. (2009). The meaning of offensive management and its strategy during recession. SERI research paper. May 6 2009. Available at http://www.seri.org (accessed 03 October 2015).

Smallbone, D., Leig, R., & North, D. (1995). The characteristics and strategies of high growth SMEs. International Journal of Entrepreneurial Behavior & Research, 1(3), 44-62.

Song, T. (2014). National energy industry forecasting and implication. Deloitte Anjin Review, no.2, 38-49.

U.S. Energy Information Administration(EIA), What drives crude oil prices?, available at https://www.eia.gov/finance/markets/spot_prices.cfm (accessed 18 November 2015)

Wilson, J. O., & Williams, J. M. (2000). The size and growth of banks: evidence from four European countries. Applied Economics, 32(9), 1101-1109.

Zook, C., & Darrell, R. (2001). How to think strategically in a recession. Harvard Management Update, 6(11), 3-4.