JRC Technical Notes

IPTS WORKING PAPER on
CORPORATE R&D AND INNOVATION - No. 12/2010 - updated

Doing R&D or not (in a crisis), that is the question...

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February 2011

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This Working Paper (No. 12/2010 – updated – February 2011) is issued in the context of *the Industrial Research Monitoring and Analysis (IRMA)*[1] activities that are jointly carried out by the European Commission's Joint Research Centre (JRC) – Institute for Prospective Technological Studies (IPTS) and the Directorate General Research - Directorate C, European Research Area: Knowledge-based economy.

IRMA activities aim to improve the understanding of industrial R&D and Innovation in the EU and to identify medium and long-term policy implications. More information, including activities and publications, is available at: http://iri.jrc.es/ and http://ec.europa.eu/invest-in-research/

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The *IPTS Working Papers on Corporate R&D and Innovation* are published under the editorial responsibility of Fernando Hervás, Pietro Moncada-Paternò-Castello and Andries Brandsma at the Knowledge for Growth Unit – Economics of Industrial Research and Innovation Action of IPTS / Joint Research Centre of the European Commission, Michele Cincera of the Solvay Brussels School of Economics and Management, Université Libre de Bruxelles, and Enrico Santarelli of the University of Bologna.

Printed in Spain

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[1] IRMA activities are according to the approach set out in "Investing in research: an action plan for Europe" (COM, 2003) and in further Communications of the Commission: "More Research and Innovation – Investing for Growth and Employment – A common approach", COM (2005) 488 final, "Implementing the Community Lisbon Programme: A policy framework to strengthen EU manufacturing – Towards a more integrated approach for industrial policy", COM (2005) 474 final.

Abstract

This study investigates how corporate R&D evolves in the light of the contemporary economic crisis. We study empirical evidence from past downturns, discuss the relevant literature, and perform an empirical analysis of recent business survey data (collected during 2009). Pivotal for our considerations is the question whether companies tend to spend more or less on R&D and innovation activities during periods of recession. We empirically analyse what general patterns can be distinguished in this regard, given the particular circumstances of the most recent crisis.

Our findings suggest that company behaviour varies: some companies have recently reduced their innovation activities significantly, while others maintained them and a third group even significantly increased their activities to reap the benefits in the expected upswing. Overall, we observe a deceleration of R&D and innovation activities induced by the crisis, but the trend figures remain positive. Driven by the companies that reinforce their R&D and innovation efforts to thrive through the downturn and thus seek to gather the benefits in the upswing to come, the R&D and innovation landscape is likely to look different in the aftermath of the crisis.

1 Introduction

The turmoil in the global financial markets of 2008 and 2009 and the subsequent economic crisis hit companies in all sectors around the globe. Billions worth of money got burnt almost overnight in a collapsing banking sector. The resulting shock waves in the 'real economy' led to substantial drops in production and trade worldwide, producing the most significant economic crisis the world has faced since World War II (European Commission, 2009a).

Although some are keen to see the recovery of some leading economic indicators as the light at the end of the tunnel, the crisis is likely to persist for some time. Companies facing economic pressure often choose cost-reduction strategies and re-examine their R&D commitments and innovation strategies (Barrett et al., 2009). In the shorter term, the lack of finance may cause stretched or reduced R&D budgets, leading to delays in new product development, slimmed down processes and activities, and even causing R&D and innovation projects to be stopped and delayed. These shifts of R&D strategies and innovation may also lead to substantial re-orientations with longer-term effects on the technological development capacity of businesses as a whole. This is the case when corporate R&D activities are concentrated on fewer core business areas, emerging technological sectors or specific markets only. On a wider scale, these ad hoc changes in the way that companies spend and behave also affect the whole innovation system through technological clusters and university-industry links, which may suffer longer-term damage and may 'dry out' in terms of financial and R&D-capacity. The crisis may also change the way business R&D will be performed in the future, and therefore the perception of the importance of innovation and corporate R&D activities. Thus, the current crisis may well be a fault line in the transition from an industrial to a knowledge-based society (Etzkowitz and Ranga, 2009). In addition, with the crisis placing important financial constraints on companies, it may have an impact on the internationalisation of R&D as cost competition becomes more important.

This paper investigates the adjustments in corporate R&D and innovation strategies as a result of the current economic crisis using recent official statistics and survey data. We discuss how the crisis has affected corporate R&D and innovation activities in general, considering which adjustments of corporate strategies have already been made or are planned to be made. This approach is similar to Archibugi and Filippetti (2009), who analysed the impact of the crisis on innovation in Europe using data from the European Innovation Scoreboard (2009). However, it goes beyond that by using more recent and more complete data from the biggest R&D investors, and builds upon our earlier study on the impact of the global economic and financial downturn and on companies' R&D strategies (Voigt and Moncada-Paternò-Castello, 2009).

We observe corporate innovation activities by assessing their R&D investments. The underlying assumption is that – among a large variety of determinants of innovative performance – intramural R&D is key (Nelson, 2000; OECD, 2005). Empirically, we rely on the results of a recent survey on business R&D investment (hereinafter named the 'R&D Outlook Survey'), which represents about 18 % of the R&D investment of the largest R&D corporations in the EU. The survey gathered information on company-level R&D investment for the 2005-2012 period, with forecast data for the 2009-2012 period. Thus, our empirical analyses are based on a unique set of the most comprehensive data available to date. By assessing the impact of the crisis on companies' behaviour and innovation strategies, we also intend to clarify the longer-term techno-economic impact of the crisis, which may determine post-crisis R&D and innovation landscape.

We do not only examine the impact of the crisis on R&D investment levels, but also more general company characteristics like company size, R&D/technology intensity, headquarters

location and company age. The analysis also covers the impact on R&D investment levels in different world regions and highlights geographic shifts in terms of R&D investment, which is an important aspect as the effects on the different world regions are not homogeneous due to differences in local innovation systems and policies (Archibugi and Filippetti, 2009).

Methodologically, our empirical analysis relies on a quantitative assessment of companies' past, current and future innovation activities, which are approximated by the amount of past, present, and expected future R&D investment. Apart from descriptive statistics, we ran an econometric regression model to control for non-response bias for the survey sample data, and examined certain company characteristics that may explain the observed R&D patterns over time, for instance company size, R&D intensity, the sector of activity and headquarters location.

The paper is structured as follows: section 2 provides a review of the relevant literature and focuses on the patterns and underlying mechanisms of corporate R&D and innovation activities in times of an economic crisis. In section 3, we formulate the hypotheses and describe the characteristics of the empirical data used and the applied methodology. Section 4 provides the results of our analysis. The paper finishes with conclusions in section 5.

2 Literature review: How is corporate R&D evolving in times of crisis and what are the driving mechanisms?

The evolution of corporate R&D is not a trivial matter for any company facing an economic crisis. The challenge is particularly relevant to those relying on corporate R&D and innovation, as engagement in these activities means longer-term commitments with uncertain results. In addition, the present economic crisis coincides with financial turmoil. The International Monetary Fund (IMF) pointed out that those economic crises accompanied by financial crises tend to be 'two-to-three times deeper and two-to-four times longer' than those that are not, and lead to 'negative GDP growth of 4.5 %' (Rhodes and Stelter, 2008).

This may suggest that the effect of GDP drops on R&D spending may be similarly severe and long-lasting. According to Sainsbury (2007) (thus relying on OECD figures), R&D and innovation spending is often one of the first things to be cut. In fact, Business Expenditure on R&D (BERD) as a percentage of GDP across industrialised countries was scaled back in the recession of the 1990s. This rather dim picture at the macro-level is the result of changes in company behaviour due to the crisis. In the next two subsections, we summarise the literature concerning company R&D adjustments in times of crisis and what the general impact for R&D internationalisation may be in this regard.

2.1 What do companies do with their R&D activities in times of crisis?

The impact of an economic downturn on the dynamics of company R&D investment is reflected in the economic literature as a matter of controversy. Traditionally, investing in R&D has been seen as a typical anti-cyclical measure for companies, because the negative impact of a crisis on profitability forces them to search for higher productivity. Thus, in accordance with the Schumpeterian concept of 'creative destruction', a crisis provides opportunities that can often be reaped by re-organising and up-skilling R&D activities. For example, in times of downturn R&D personnel tend to be subject to 'labour hoarding', i.e. the best qualified scientists and engineers are kept on at the expense of lower skilled personnel

(Soete, 2009). Further, opportunity costs[1] of reorganising manufacturing to R&D activities are lower in recessions than in expansions as the demand for directly productive activities (manufacturing) is lower (Stiglitz, 1993; Aghion and Saint-Paul, 1998). Even the likelihood of bankruptcy for firms that do not necessarily reorganise their investments increases in recessions (Aghion and Saint-Paul, 1998). The same argument – that opportunity costs of achieving productivity growth are lower in recessions – also provides incentives for undertaking (additional) research during downturns (Aghion and Saint-Paul, 1998; Canton and Uhlig, 1999).

Yet, Saint Paul (1993), found very little evidence of any pro- or counter-cyclical behaviour in R&D as the cash-intensive nature of R&D eventually offsets the opportunity cost effect. Figures for larger companies by Stephan (2004) suggest a counter-cyclical pattern of R&D as a share of total investment. The author also found R&D investment of SMEs to sometimes be anti-cyclical. For example, in times of low capacity utilisation, engineers devote more time to product improvements instead of extending production capacity, as is the case in times of high capacity utilisation.

Despite many good arguments for R&D being anti-cyclical, the more common view in the economic literature is that companies do not treat R&D differently compared to other activities, which means R&D is assumed to be cyclical. In fact, implementing new ideas, particularly in case of seminal innovations, tends to be postponed during a recession, with companies waiting for the next upswing (Shleiffer, 1986; Francois and Lloyd-Ellis, 2003). However, there is as yet no consensus on Gerhard Mensch's 'innovation acceleration hypothesis' (1975), whereby radical innovation is favoured in depressions out of a sense of despair (Clark et al, 1981).

The inconclusive evidence on whether R&D is cyclical or not might well be related to the different company reactions to a crisis. Companies may decide to cut R&D investment to reduce costs, at the risk of falling behind those competitors who continue innovating. They may also hold to their R&D and innovation investments or increase them hoping to gain competitive advantage later-on. Another matter of key decisions, apart from the level of R&D investment, is the way companies manage their R&D processes and interact with others, e.g. via collaboration or outsourcing.

Companies' access to finance has become more difficult in the current economic crisis, given that it originated from a financial crisis. If companies can choose between shorter-term capital investment and longer-term R&D investment, innovation requires a company to be able to rely on shorter-term earnings plus borrowing alone to cover liquidity needs. Whenever the firm is hit by an adverse (idiosyncratic or aggregate) shock, its current earnings are reduced, and so is its ability to borrow for R&D. A shortening of supply due to capital markets in crisis further tightens companies' credit lines. In fact, even fast-growing companies operating in emerging markets in times of a crisis may have limited access to finance. In this regard, Aghion et al. (2005, 2008) analysis of the role of credit constraints on R&D investment found that R&D tends to be more pro-cyclical for companies facing tighter constraints on capital supply (i.e. many SMEs). In particular, R&D investment as a share of total investment was counter-cyclical in the absence of credit constraints, but became more pro-cyclical as companies faced tighter credit constraints. These effects were only observed during downturns and in the presence of financial constraints. In other words, relative R&D investments plummeted during recessions, but did not increase proportionally during upturns. Furthermore, the level of R&D investment was lower in more credit-constrained companies and decreased further during crisis. Hence, the credit crunch caused by the financial crisis and the subsequent credit constraints may prevent R&D from being counter-cyclical, and

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[1] Opportunity costs in this regard refer to the missing out on foregone profits due to restructuring the business.

thus amplify the business cycle, increase productivity growth volatility and hold back average productivity growth.

The crisis therefore increases an already important risk for innovative and R&D performing firms of facing financial constraints, and significant R&D investment cuts across many sectors and countries could be expected. However, most R&D and innovation activities have a strategic and longer-term nature, making them a rather fixed production factor (Arrow, 1962). Furthermore, R&D investments, are less subject to financial constraints than in physical capital investments (Harhoff, 1998; Bond et al., 1999; Audretsch and Weigand, 1999; Mulkay et al., 2001; Audretsch and Weigand, 1999; Cincera, 2003). In fact, due to the longer-term nature of running R&D projects and high adjustment costs for changing them, financial constraints tend to affect the decision to start new R&D activities rather than the year-to-year level of spending on ongoing R&D projects (Bond et al., 1999; Cincera, 2003). In other words, high adjustment costs for running R&D and innovation projects tend to make them robust against increasing financial constraints. However, this is less the case for firms in sectors that depend more heavily upon external finance, or that are characterised by a low degree of asset tangibility (Aghion et al., 2008).

Despite financial constraints, recessions might offer opportunities for newcomers by weakening the position of firms already present in the market and may thereby stimulate research by outside firms (Canton and Uhlig, 1999). Recessions do not affect all companies and sectors in the same way. High-technology manufacturing, for instance, is far better-positioned compared to low-technology manufacturing, which may be expected to fare particularly badly (NESTA, 2008, p. 13). Evidence suggests that high-tech firms usually adjust their R&D expenditures to the business cycle less than low- and medium-tech ones (Stephan, 2004). This might explain why R&D expenditure is in fact less cyclical than tangible investments or sales.

The above observations point to a somewhat mixed picture of the relationship between the business cycle and R&D investment. While there are many arguments for pro-cyclical behaviour, anti-cyclical behaviour directs our attention to the fact that different companies react differently to an economic crisis. Overall, at the firm level, there is a relationship between R&D investment and company growth: R&D seems to be a good predictor of future growth especially in terms of profit and employment, but also sales, value added and cash flows, while no R&D or a moderate R&D intensity predicts growing debt (Heshmati and Lööf, 2006).

Overall, the crisis may cause companies to reduce R&D activities to a greater or lesser extent due to economic downturn. Investment in R&D is increasingly seen as risk taking, and will not be for the timid (EurActive, 2008). When the perception of R&D risks changes and companies slow down their R&D activities, the launch of new technologies, products and services, including new medicines, could be (at least) delayed and companies could turn their attention toward business innovations rather than technological innovations. The downturn may reward firms that can find more effective ways to innovate, are more agile, incremental, customer-focused, and willing and able to adjust their business (and R&D) strategies at the expense of technological innovation, which in turn can have a large cumulative impact on technological advancement and collaboration with the public sector (Mohandas, 2008). This may cause the financial crisis to have a knock-on effect on the public sector (especially higher education, universities, or public research infrastructures). One may however argue that these effects may take some time to come and are difficult to capture analytically due to the time lag in the corresponding empirical evidence. Much more pressing concerns may arise from the impact of the crisis on R&D internationalisation, addressed in the next section.

2.2   What may be the impact of the crisis on R&D internationalisation?

Another result from the different behaviour of R&D investors in the crisis is a different behaviour in R&D off-shoring. This may lead to increased on-shoring, triggered by companies from China, India, etc., which may step into the gap Western companies are opening up by cutting back their R&D and innovation activities.[2]

R&D internationalisation has been widely examined in the past two decades (see for example Dunning and Narula, 1995, Brockhoff, 1998, OECD, 1998, Hatzichronoglou, 2008, OECD, 2010). Until the 1980s, R&D internationalisation was rather uncommon as companies tended to centralise R&D in their home country. Afterwards, however, R&D internationalisation gained momentum and became an important driver of globalisation, with foreign affiliates' R&D expenditure growing many times faster than those of domestic companies (UNCTAD, 2005 and OECD, 2008).

In this context, theoretical (Dunning and Narula, 1995; Kuemmerle, 1997) and empirical studies (among others see: Kuemmerle, 1999; Kumar, 2001; Von Zedtwitz and Gassmann, 2002) have highlighted a shift from 'home-base exploiting' to 'home-base augmenting' R&D strategies. These studies observed that large companies established R&D laboratories abroad not only to adapt home-developed technologies and products to local market conditions, but even with the aim of tapping into knowledge and technological sources in centres of scientific excellence located worldwide. The underlying location strategies combine multiple dimensions, comprising the technological strengths of the countries with respect to those of the company (Patel and Vega, 1999; Le Bas and Sierra, 2002), institutional factors – such as public support to R&D, IPR systems, quality of technological infrastructures – and lowering costs of qualified research, especially in emerging countries (UNCTAD, 2005).

From the company point of view, R&D location decisions are however complex and subject to a number of underlying factors. Thursby and Thursby (2006) found four outstanding factors: output market potential, quality of R&D personnel, university collaboration, and intellectual property protection. Further, for companies locating in emerging economies, the growth potential in the market and the R&D personnel quality were the most important factors. However, R&D personnel quality and intellectual property protection were the most important factors for those locating in developed countries (at home or in another country). In addition, for more than 75 % of the respondents, the R&D location decision was part of an expansion and relocation for less than 30 %.

It is interesting to note that R&D costs seem to hold little importance up to now in the internationalisation of business R&D. This is supported by recent surveys showing that low labour costs of researchers was the least important of 12 location factors for R&D investment (European Commission, 2009b), although they were more important for companies located outside of their home country. Yet, emerging countries start to show up on the international patenting scene, and performing R&D in these countries may offer companies not only cost reduction, but also faster access to research talent and fast growing markets (UNCTAD, 2005, OECD, 2008). China and India are playing an increasingly more important role on the international R&D stage (The Economist Intelligence Unit, 2004; UNCTAD 2005; Cincera et al., 2010). Our analysis of the crisis impact on R&D investment therefore also addresses whether the behaviour of companies in terms of R&D location for these countries has changed.

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[2]   Argument put forward by W. Gehrisch, Deputy Secretary General of the European Industrial Research Management Association [EIRMA], in Research Europe (11/12/2008).

3   Data, variables, hypotheses and methodology

3.1   Data

The broad concept of innovation has been disentangled over the years, considering, for example, non-R&D and organisational innovation as complementary to the old definitions of product/process innovation. However, in-house R&D still plays a key role for corporate investment in science and technology (EUROSTAT, 2008).In addition, the distribution of corporate R&D investment is very concentrated. Around 80 % of global R&D business investment is concentrated in the biggest R&D players, as shown in the *EU Industrial R&D Investment Scoreboard* (hereafter referred to as the 'Scoreboard')[3]. The Scoreboard lists the top 1000 R&D performers from the EU and top 1000 non-EU R&D performers.

Since 2005, the 1000 EU companies listed in the Scoreboard have been asked to complete an annual survey[4] to state their expectations with respect to their R&D activities for the coming years (volume, expected changes, location, etc.). The response rate is between 10 % and 15 % (between 95 and 130 companies per year). However, there is little overlap among the samples from one year to the next, which is a serious obstacle for constructing a consistent time series.

In order to address the issue of past and expected R&D investment trends and distributions during the crisis, the R&D Outlook survey was conducted between April and August 2009. The 1000 EU companies of the 2008 Scoreboard were contacted via email and phone and thus asked to fill-in a short questionnaire.[5] For each participating company, the questionnaire included the past data of the Scoreboards and eventual responses to previous surveys. In total, 90 firms have answered at least one question, namely the one concerning current R&D investment (year 2007/2008). This sample of 90 responding companies from the EU represents about one fifth of EU R&D investment of the 2008 Scoreboard, a considerable share (see Table 1).

Table 1: R&D investment in the *2008 Scoreboard* and in the *R&D Outlook survey* per sector

Sectors	R&D investment share of the total R&D Scoreboard	R&D investment share of the total R&D Survey
Automobiles & parts	22.8 %	38.8 %
Pharmaceuticals & Biotechnology	16.6 %	10.7 %
Technology Hardware & Equipment	13.4 %	0.9 %
Aerospace & defence	6.4 %	9.3 %
Chemicals	5.6 %	7.3 %
Electronic & Electrical Equipment	4.8 %	1.8 %
Industrial Engineering	4.7 %	9.3 %
Software & Computer Services	3.7 %	0.7 %
Fixed-line telecommunications	3.4 %	2.7 %
Banks	2.2 %	2.0 %
Main 10 sectors	83.6 %	83.5 %
Other 29 sectors	16.4 %	16.5 %
Total 39 sectors	100.0 %	100.0 %

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[3]   For further details, see: http://iri.jrc.ec.europa.eu/research/scoreboard.htm.

[4]   The EU annual Survey on R&D Investment Business Trends is part of the Industrial Research Investment Monitoring (IRIM) initiative and accompanies the EU Industrial R&D Investment Scoreboard. The activity is jointly carried out by DG RTD-C and JRC-IPTS. The questionnaire is sent to the 1000 EU companies (appearing on the Scoreboard of the previous year) and to previous survey respondents. For details see: http://iri.jrc.ec.europa.eu/research/survey.htm

[5]   For details see Cincera et al. (2010).

For most of the 90 responding companies, the time series combine past and prospective data. The longest series goes from reference year 2005 to 2012. Fifty-one firms are included in this time series, representative of 10.8 % of the total R&D performed by the 1000 EU companies of the 2008 Scoreboard.

As regards general company characteristics, some special characteristics of the sample companies in the R&D Outlook survey have to be outlined. Although the sample companies have larger R&D investment volumes than the average company in the 2008 Scoreboard,[6] the statistical test presented in Table A3 in the Appendix indicates that their R&D investment growth in the past has nevertheless been similar and is thus highly correlated to the rates observed in past Scoreboards. Moreover, R&D investment trends and distributions as resulting from the R&D Outlook survey appeared to be fairly similar to those of the Annual Survey.[7] This indicates a robust sample and therefore reliability of our further analysis. In fact, we performed several simulations with different overlaps of years thus using different subsets of the sample (controlling for those companies which revealed above average variations in the figures stated), and the sample proved to be robust. Overall, this suggests that the responses to the R&D Outlook survey provide a good indication of R&D investment trends and its distribution. Moreover, the sample is representative with regard to the ten most important R&D investment sectors (according to the Scoreboard), but contains a significantly higher share of automobiles & parts, aerospace & defence, and industrial engineering companies (Table 1). On the other hand, R&D investments in the pharmaceuticals & biotechnology, technology hardware & equipment, electronic & electrical equipment, and software & computer services appear somewhat under-represented compared to the 2008 Scoreboard.

3.2 Hypotheses

Based on the literature review – presented above in Section 2 – we constructed several hypotheses that shall be tested in the empirical part of this study. These hypotheses, as well as the variables they involve, are listed in Table 2 and shall be briefly outlined here.

Hypotheses H1A/B refer to the central question we address in this study, i.e. do companies generally tend to spend more or less on R&D and innovation activities in the current economic crisis? (R&D and innovation activities approximated here with their R&D investments). This (as well as all other hypotheses) will be empirically tested using the R&D Outlook survey results. Given the fact that some firms will react in a counter-cyclical way as argued above, while others will inevitably reduce their R&D activities, it is moreover interesting to verify whether there is a series of firm characteristics assumed to influence the individual company responses to the shock induced by the crisis. In this regard, the hypotheses H2A-F will be tested.

Another block of testing will be performed with regard to the geographic location of corporate R&D and innovation activities. We are thus interested in discovering whether there are characteristic trend patterns and, if so, where R&D and innovation activities tend to be cut and where they tend to be expanded. In this regard, for instance, we assumed that firms performing R&D in the EU countries mainly prevail over those carrying out their R&D activities outside the EU (H3). The situation is also assumed to hold for firms that increased their R&D activities within the EU over the periods 2005-2008 and 2009-2012.

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[6] The statistical tests reported in Tables A1 to A2 in the Appendix show that, in terms of R&D in 2007 and 2008, the average firm in the sample is larger than the average firm in the Scoreboard. In other words, larger firms in terms of their R&D investment volumes show a higher propensity to participate in the R&D Outlook survey.

[7] The EU annual Survey on R&D Investment Business Trends: See European Commission (2009b).

Table 2: Hypotheses on firms' adjustments in R&D activities in response to the current crisis

	Hypotheses	Expected impact on R&D	Variable / proxy
H1	**Counter- / pro-cyclical behaviour of R&D investment**:		ΔRD0512
	H1A: firms generally spend more on R&D in a downturn.	+	
	H1B: firms generally spend less on R&D in a downturn.	−	
H2	**Company characteristics influencing R&D investment**:		
H2A	Company size is positively linked to flat or increased investment in R&D in times of a crisis (counter-cyclical behaviour).[8]	0 / +	SIZE08; SQSIZE08
H2B	Firms with higher R&D intensity preserve their R&D activities in a crisis (possibly increase it even further).	+	RDint08; SQRDint08
H2C	Firms operating in a high-tech sector (vs medium- & low-tech) maintain a high level R&D spending (no decrease).[9]	+	H-;MH-;ML-; L-tech
H2D	Firm age is linked directly to persistence of high R&D spending (i.e. young firms tend to decrease while mature firms keep their levels of R&D spending constant or even increase).[10]	+	AGE; OLD; NEW
H2E	Profitability and high R&D spending remains positively linked also in times of a crisis.	+	PR08; PR07
H2F	Firms located in an EU Member State belonging to the euro area preserve higher R&D spending in a crisis.[11]	+	EURO
H3	**Geographic location of R&D budget cuts and increases** Firms locating their R&D activities mostly in the EU preserve higher R&D spending in a crisis.	+	RDEU; ΔRDEU0512

Definitions of the variables and employed approximations as follows:

ΔRD0512	Growth rate of average R&D investment from 2005 to 2008 compared to those resulting as average expected R&D investment for the period 2009-2012. It is used to test hypothesis H1 and the block of hypotheses H2A-F. For the latter it enters as the dependent variable in the equations to be estimated
SIZE08	Firm size in 2008 (approximated by number of employees)
SQSIZE08	represents the square of ***SIZE08***
RDint08	R&D intensity in 2008 (R&D investment over firm's net sales)
SQRDint08	represents the square of ***RDint08***
H-tech	Dummy for high-tech sectors (Biotechnology; Electronic equipment; Health; Household goods; Pharmaceuticals; Semiconductors; Software and Telecommunication)
MH-tech	Dummy for medium-high-tech sectors (Aerospace & defence; Automobiles & parts; Basic resources; Chemicals; Electrical equipment; Household goods; Industrial machinery; Media and Transport)
ML-tech	Dummy for firms operating in medium-low-tech sectors (Electricity, Gas & Water; Food and Telecommunication)

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[8] In fact, firms of a certain size, however, have more financial resources at their disposal and are presumably better placed to deal with a liquidity squeeze that is likely to arise in a crisis. Company size is therefore assumed to be positively linked to the persistence of R&D activities in response to the current crisis (spending continued and/or increased). However there are examples of very large firms in some sectors that experienced notable difficulties due to the crisis. The banking and automotive sectors are two notable examples.

[9] In general, firms with a higher R&D intensity and/or those operating in high-tech sectors are assumed to naturally face higher incentives to maintain or even expand their R&D activities during a crisis due to both the opportunity and adjustment cost arguments as discussed in section 2 (to be tested in terms of H2B and H2C).

[10] Hypothesis H2D will test whether older companies (proxy: years since formation) may take advantage of their reputation and therefore face lower borrowing costs (Diamond, 1989); as it is likely to be the case for firms that benefit from high profitability rates (hypothesis H2E).

[11] According to the theory of optimal currency areas (Mundell, 1961), firms in the euro area are assumed to be affected in a similar way (positively or negatively) in case of an exogenous shock (hypothesis H2F). In fact, access to the capital market for these firms should be easier and less costly due to lower transaction costs. Hence, we assume a positive link.

L-tech	Dummy for firms operating in low-tech sectors (Basic resources; Construction; Financial; General industrial and Oil & gas)
AGE	Firm age (years since founded)[12]
OLD	Dummy for old firms (i.e. firm created before 1900)
NEW	Dummy for new firms (i.e. firms created after 1975)
PR08	Profit margin in 2008
PR07	Profit margin in 2007
EURO	Dummy (=1) for firms' headquarters being located in euro area
RDEU	Percentage of R&D performed inside the EU in 2008
ΔRDEU0512	Percentage change of R&D performed within the EU in 2005-2008 to 2009-2012.

3.3 Methodology

The hypotheses outlined in Table 2 are tested qualitatively and quantitatively. In fact, preliminary findings on the three main hypotheses (H1, H2, and H3) can be found through descriptive analyses illustrating how individual companies have adjusted their R&D activities in times of crises (inductive conclusion). The corresponding findings are complemented with an econometric analysis. In order to verify the robustness of our empirical results, a Heckman regression analysis was performed, controlling biases that could potentially arise due to possible systematic non-responses to the R&D Outlook survey by certain firms (or firm groups).[13] In fact, our results appeared to be fairly robust and the parameters remained virtually unchanged. Furthermore, the Mill's ratio is not significant, thus indicating that the sample selection bias is negligible.[14]

4   Empirical findings

4.1 Are firms spending more or less on R&D in the current crisis?

Referring to hypothesis H1, i.e. whether companies spend more or less on R&D in a downturn, **a sharp drop of R&D investment from 2008 to 2009 was found** (negative annual growth rate of 3.7 %), which contrasts with the high increase during the previous period (i.e. annual growth rate of 10.2 % from 2007 to 2008; see Table 3). Moreover, this reduction in R&D investments appears to be limited in time, as the forecasts based on a sub-sample of 51 firms for the successive years (2009-2012) indicate a trend of increasing resources allocated to R&D and innovation activities (annual growth rates of R&D investment of 4 % from 2009-2010 to 6.3 % in 2011-2012).

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[12] See Cincera and Veugelers (2010) for more details about the way this variable is constructed and the sources for collecting this information.

[13] For the corresponding methodology see Heckman (1979). See Cincera et al (2010) for a more detailed discussion.

[14] The results that are not reported here can be obtained upon request.

Table 3: Annual growth rate of R&D investments (90 respondents)

Period[a]	# obs	representativeness in 2008[b]	Annual growth rate of R&D investments (ΔR)						
			$\Delta R06$	$\Delta R07$	$\Delta R08$	$\Delta R09$	$\Delta R10$	$\Delta R11$	$\Delta R12$
2005-2012	51	10.80	0.019	0.002	0.102	-0.037	0.040	0.057	0.063
2005-2009	75	12.03	0.029	0.002	0.098	-0.029			
2007-2009	81	12.24			0.093	-0.029			
2007-2008	90	18.22			0.107				

Source: Own calculations.
Notes: a) Period over which R&D investments are available for each year
b) Representativeness of sub-samples of firms' R&D with respect to the 1000 EU companies' R&D of the 2008 Scoreboard.

In fact, evidence from the R&D Outlook survey suggests that, on average, firms tend to cut down their R&D and innovation activities in a crisis, but – after the first shock – increase their R&D investment again (i.e. support to the 'somewhat mixed picture of the relationship between business cycle and R&D investment' as outlined above in Section 2). Hence, the first impact of the crisis manifested by a cut in R&D and innovation spending is not likely to be long lasting, but is rather expected to be reversed in the coming years. Actually, there even seems to be an expectation of an over-proportional R&D increase for the coming years (aftermath of the crisis), which supports the hypothesis of a R&D investment counter-cyclical relationship as argued before. If so, there is also good reason to believe that R&D is a good predictor of future profit and employment growth.

The R&D trends outlined above are confirmed by the 2009 Scoreboard (for the largest EU companies), which shows a lower R&D investment growth than previously. In addition, further contraction of R&D investment is anticipated according to the latest EU annual survey on R&D investment business trends.[15]

4.2 What are the company characteristics determining the adjustment of corporate R&D activities in the light of a crisis?

Table 4 presents the results of the econometric analysis and illustrates the main drivers of firm R&D growth rates over the 2005-2008 period compared to those expected for 2009-2012 (H2A-F block of hypotheses). Evidence from the analysis suggests that firms with a large R&D activity volume (cfr. hypothesis H2A) and (at the margin, from a statistical point of view) firms with a high R&D intensity (cfr. hypothesis H2B) tend to decrease their R&D investments over the period under investigation. This negative impact of R&D intensity on the expected R&D growth contradicts the *a priori* expected positive relationship between these two variables due the opportunity and adjustment cost arguments discussed in Section 2.

Table 4: Factors explaining R&D growth rate (average 2005-2008 to average 2009-2012)

Explanatory variable	Estimated coefficient	s.e.			Estimated coefficient	s.e.	
Constant	21.202	7.271	*				
R&D intensity 2008	-0.128	0.074	***	Biotechnology	-30.229	64.057	
R&D intensity 2008 (square)	0.001	0.001		Chemicals	-2.079	0.348	*
Size in 2008	-3.482	1.471	**	Construction	-2.545	0.625	*
Size in 2008 (square)	0.166	0.075	**	Electrical equip.	-1.886	0.582	*
Belgium	0.150	0.851		Electronic equip.	-2.338	0.466	*

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[15] This survey was conducted at the end of 2009/beginning of 2010 (see the 2009 EU Survey on R&D investment business trends for more details).

Denmark	-0.571	0.760		Financial	-0.987	0.278	*
Finland	-0.356	0.399		Gen. industrial	-1.908	0.495	*
France	-3.141	0.853	*	Health	-2.177	0.465	*
Germany	-0.289	0.409		Household goods	0.198	0.594	
Italy	-1.100	0.930		Ind. machinery	-2.331	0.489	*
Slovenia	-0.834	0.870		Media	-1.556	0.460	*
Spain	-0.156	0.543		Oil & gas	-2.357	0.533	*
Sweden	-0.393	0.411		Pharmaceuticals	-0.633	0.818	
The Netherlands	-1.143	0.606	***	Semiconductors	-0.874	0.755	
UK	-0.686	0.564		Software	0.164	1.230	
Automobiles & parts	-2.200	0.826	**	Telecom.	-2.985	0.788	*
Basic resources	-2.365	0.635	*	Transport	-2.144	0.720	*
Number of observations	49						
R²	0.856						

Source: Own calculations
Notes: s.e. = robust standard errors; Control groups: Austria and aerospace & defence
*, **, *** stands for statistically significant at the 10 %, 5 %, and 1 % level, respectively

In terms of the EU R&D intensity gap vis-à-vis the US these results are daunting for the EU for two reasons. First, the R&D gap is not likely to decrease during the 2005-2012 period, since the two types of companies that decrease their R&D investments the most in the EU are the largest and the most R&D intensive. In addition, as we will discuss in Section 4.3, companies which operate in high R&D intensity sectors and are decreasing their R&D spending, are the ones that expect their EU share to drop considerably, doubling their share in the US, and tripling it in China and India.

However, the conclusion as regards the relationship between firm size and R&D investment needs to be qualified. Indeed, a 'U-shaped' relationship between size and R&D was found. Hence, given the sample of companies, both the largest and even more so the smallest firms are increasing resources allocated to research. This finding confirms previous studies that found U-shaped relationships between innovation and firm size (Gellman Research Associates, 1976; Acs and Audretsch, 1981; Veugelers, 1995) and therefore can not be considered as specific to the current economic crisis.

At the macro level, the estimated coefficients associated with France and The Netherlands are negative, suggesting a lower R&D growth rate from the 2005-2008 sub-period to the 2009-2012 one for these two countries as compared to the sample average. For the other countries, no particular trend seems to emerge in any of the EU Member States. Indeed, except for the two mentioned countries, the crisis appears to affect all European economies alike.

For a majority of industry and services sectors a decrease of R&D investment seems to predominate over the 2005-2012 period, for instance automobiles and parts, basic resources, chemicals, construction, electrical and electronic equipment, financial, general industrial, health, industrial machinery, media, oil & gas, telecommunication and transport. Interestingly, with the exception of electronic and telecommunication equipment, all these sectors are classified as medium- or low-tech industries. This result again mitigates the conclusion as regards the EU R&D intensity gap that firms operating in low- and medium-tech sectors (as compared to high-tech ones) are not necessarily expected to increase their R&D budget the most in the near future (cfr. hypothesis H2C).

Table 5 below reports some further results widely confirming that firms' R&D intensity negatively affects R&D growth rates, while a 'U-shaped' relationship emerges between firm size and R&D growth rate. From Column 3 and 4 in Table 5 can be seen that the firms' age does not appear to have any particular influence on the probability to increase R&D expenditure (or not) (cfr. hypothesis H2D).

Furthermore, firms located in EU Member States not belonging to the euro area do not appear to relatively increase their R&D investments over the period considered (benchmarked to those that have headquarters within the euro area; cfr. hypothesis H2F).

Based on an inclusion of dummy variables controlling the corresponding level of R&D intensity in industry and services sectors, we can conclude that those firms that operate in medium-low R&D intensive sectors systematically increase their R&D less than the high R&D intensive control group (cfr. hypothesis H2C).

Finally, columns (8) and (9) of Table 5 show the impact of firms' profitability rate on the forecasted R&D increase (cfr. hypothesis H2E). Accordingly, firms with a relative high profitability in 2008 tend to report higher increases of their R&D investment between 2005-2008 and 2009-2012, which supports the thesis of the counter-cyclical behaviour in this regard, given no/low financial constraints. In turn, those firms with lower profit rates, which presumably have less internal financial resources at their disposal for increasing and/or maintaining their pre-crisis R&D investment levels, are limited also in their crisis-response strategy; likely to result in a rather pro-cyclical R&D investment strategy due to existing liquidity constraints.[16] Indeed, before the current economic crisis emerged – which we arbitrarily assume to be in the second half of 2008 – this variable did not seem to play any significant role in determining firms' R&D changes (given the examined period). Hence, our empirical results provide strong support for the arguments put forward by Aghion et al. (2005, 2008) as outlined in Section 2: R&D investment as a share of total investment appears to be counter-cyclical in the absence of credit constraints, but it becomes more pro-cyclical as firms face tighter credit constraints (e.g. due to the impact of the financial crisis) and this effect is only observed during downturns.

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[16] See Cincera and Ravet (2010) for a more detailed discussion.

Table 5: Company characteristics determining corporate R&D investment growth rate (average 2005-2008 to average 2009-2012)

	(1)		(2)	(3)		(4)		(5)		(6)		(7)		(8)		(9)	
Constant	21.202	**	13.638	20.300	***	28.951	*	24.691	*	20.781	**	20.516	**	20.339	**	19.763	**
	(7.271)		(14.889)	(9.697)		(4.819)		(5.636)		(6.927)		(7.003)		(7.777)		(7.466)	
R&D intensity in 2008	-0.128	***	-0.141	-0.126		-0.139	**	-0.157		-0.151	***	-0.128	***	-0.142	**	-0.167	**
	(0.074)		(0.092)	(0.082)		(0.043)		(0.117)		(0.083)		(0.074)		(0.063)		(0.072)	
Square of R&D intensity in 2008	0.001		0.001	0.001		0.001		0.003		0.001		0.001		0.002		0.002	
	(0.001)		(0.002)	(0.002)		(0.001)		(0.005)		(0.002)		(0.001)		(0.001)		(0.002)	
Size in 2008	-3.482	**	-3.027	-3.311		-4.654	*	-4.144	**	-4.168	**	-3.482	**	-3.450	**	-3.309	**
	(1.471)		(1.789)	(1.920)		(0.918)		(1.054)		(1.511)		(1.471)		(1.591)		(1.510)	
Square of size in 2008	0.166	**	0.148	0.158		0.218	*	0.196	**	0.204	**	0.166	**	0.164	***	0.158	***
	(0.075)		(0.087)	(0.095)		(0.048)		(0.055)		(0.079)		(0.075)		(0.081)		(0.077)	
Year founded			0.003														
			(0.004)														
Old firms (created before 1900)				0.042													
				(0.444)													
New firms (created after 1975)				0.160													
				(0.557)													
% of R&D performed in the EU in 2008						-0.014											
						(0.013)											
Change in % of R&D performed in the EU (2005-2008 to 2009-2012)								-0.031									
								(0.022)									
Low-tech sectors										1.199							
										(0.855)							
Medium-low-tech sectors										-3.132	*						
										(1.044)							
Medium-high-tech sectors										0.206							
										(0.535)							
EU Member states in the Euro area												0.686					
												(0.564)					
Profit rate in 2008														2.592	**		
														(1.139)			
Profit rate in 2007																2.786	
																(1.699)	
Number of observations	49		49	49		44		38		49		49		49		49	
R²	0.856		0.864	0.858		0.968		0.985		0.871		0.856		0.883		0.876	

Source: Own calculations
Notes: Robust standard errors in brackets; *, **, *** stands for statistically significant at the 10 %, 5 %, and 1 % level, respectively

4.3 Where does R&D tend to be contracted and where is it expanded?

Descriptive statistics can serve to address hypothesis H3 and thus help illustrate potential geographic trend patterns. Figures 1 and 2 show a geographic shift in the distribution of the largest R&D investors in the EU.

Figure 1: Annual growth rate of R&D investments in the main world regions
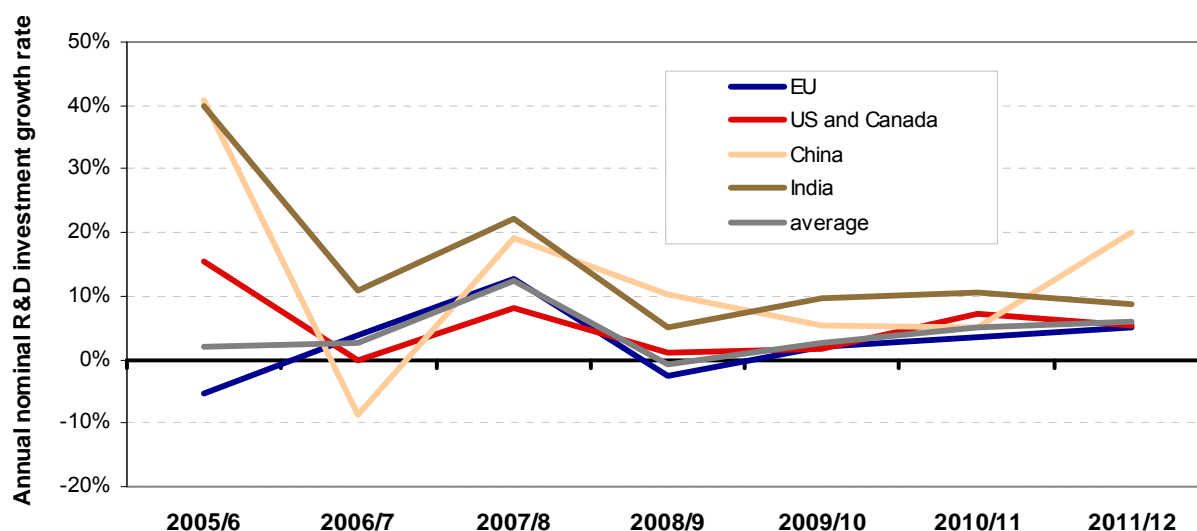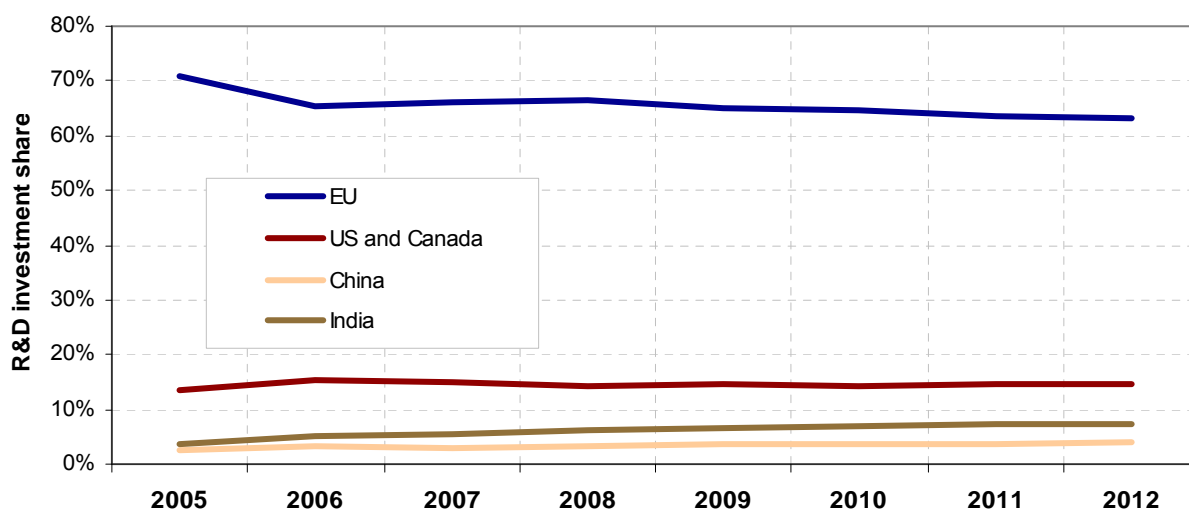

**Figure 2:** R&D investment shares across the main world regions

Source: Own calculations based on the R&D Outlook survey for 51 companies with complete time series for 2005-2012.

Figure 1 shows that annual growth rates of expected investments in R&D are converging, i.e. firms are also expecting growth rates in China and India to be more similar to those of the EU or the US in the future. Nevertheless, the R&D Outlook survey respondents expect a growth differential to persist. Although this growth differential (with higher R&D investment growth outside the EU rather than inside) appears to decrease (Figure 2), the share of R&D investment in the EU is further eroding (though less quickly than in the China/India boom years).

Figure 3 illustrates some internationalisation differences. Accordingly, larger companies, with more than €50 million R&D investment, appear to distribute their R&D activities geographically to a much higher degree than the smaller firms in the sample. For the former, the share of R&D investment in the EU is 20 % lower than with regard to the smaller firms. Yet for both sub-samples (larger and smaller firms), the share of R&D investment in the EU is expected to decrease.

Figure 3: R&D investment shares across world macro regions – large vs. 'small' corporations
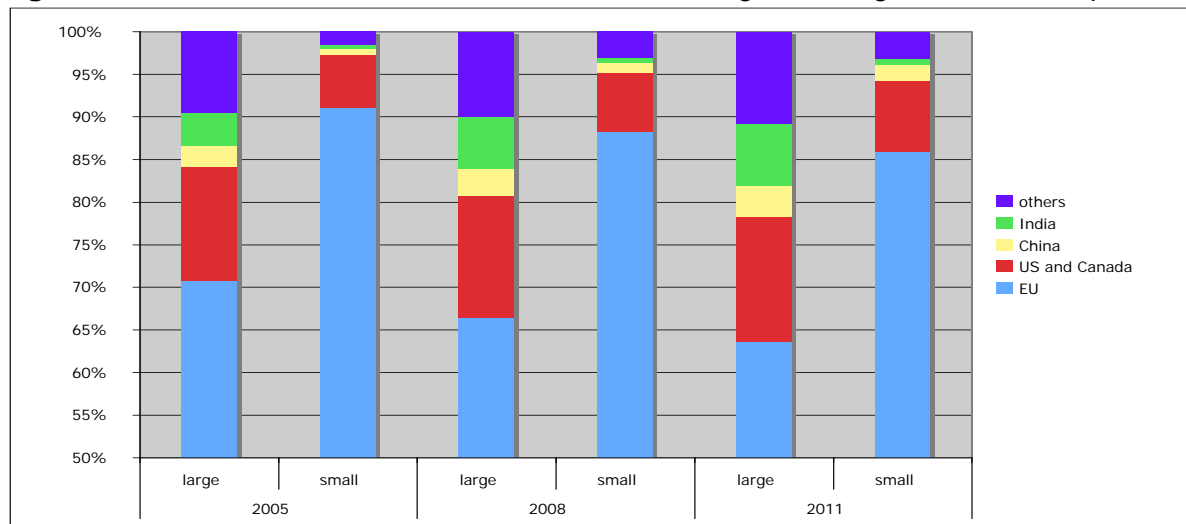
Source: Own calculations based on the quantitative survey for 19 companies with R&D above € 50 million with complete time series for 2005-12 (large corporations) vs. 32 companies with R&D below € 50 million with complete time series for 2005-12 ('small' corporations).

Further observations concerning the R&D internationalisation patterns are shown in Figure 4, which illustrates both the absolute R&D investment value and its geographical distributions, in 2005, 2008 and 2011, respectively.

Figure 4: R&D investment in macro regions – firms with increasing/decreasing R&D spending
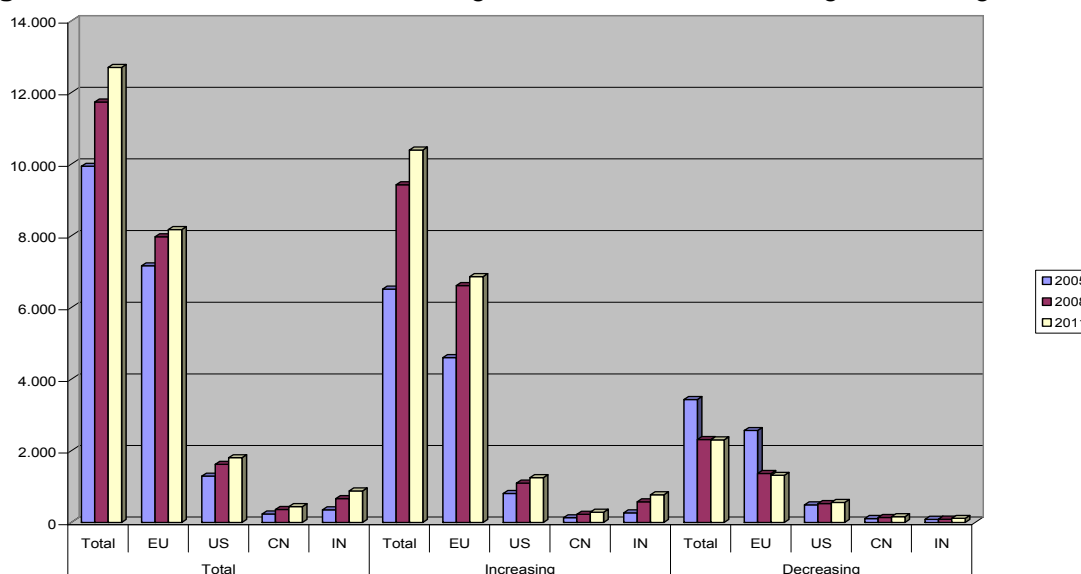
Source: Own calculations based on the quantitative survey for 57 companies with R&D values in 2005, 2008 and 2011.

Figure 4 is based on an alternative sub-sample of 57 firms (representing 2/3 of total observations and half of the R&D investment of all 2008 R&D Outlook survey respondents). Firms in this sub-sample show an overall R&D increase in the past as well as in their predictions for 2011. This is true for all geographical areas, with India being apparently more attractive than China. Among these firms, however, we observe two general patterns: those increasing their R&D during 2005-2011 have done so predominantly within the EU and, in relative terms, also in India. Rising figures are confirmed for these companies also with regard to the US and China, though they appear to be less significant. On the other side, those firms decreasing their R&D investment between 2005-2008 have done so exclusively in the EU, while their actual and predicted R&D investment in the other three areas remains stable or is even slightly increasing. In other words, if a European company is about to expand its overall R&D activities, it is likely to increase its R&D investment within the EU too.

If a certain company has a prevailing tendency of decreasing R&D investments, the investments in the EU are likely to be contracted first. One may ask why is this so? The answer may be in response to a crisis. In fact, the outlined company strategy of relocating R&D from the EU to other areas might be a reduction of R&D activities in general (overall contraction) or subject to cost reduction needed in light of the crisis. Given the latter, firms would tend to keep their R&D commitment outside the EU in order to exploit advantages there (access to technology and key markets, outsourcing/cost reduction, especially in China and India). Therefore, these advantages might be considered as more important in a 'defensive' competitive strategy leading to R&D cuts in Europe. In turn, if firms wish to expand their overall R&D activities they tend to do it especially where they are already strong. Since all companies in the sample are EU companies, it is not surprising to see in the data that a large part of such an increase may stay in the EU.

Further observation of the R&D investment trends and expectations in the different regions is assumed to provide insights concerning underlying dynamics (Figure 5).

Figure 5: Corporate R&D investment trajectories and its geographical emphasis
(firms are grouped per R&D intensity/industry)
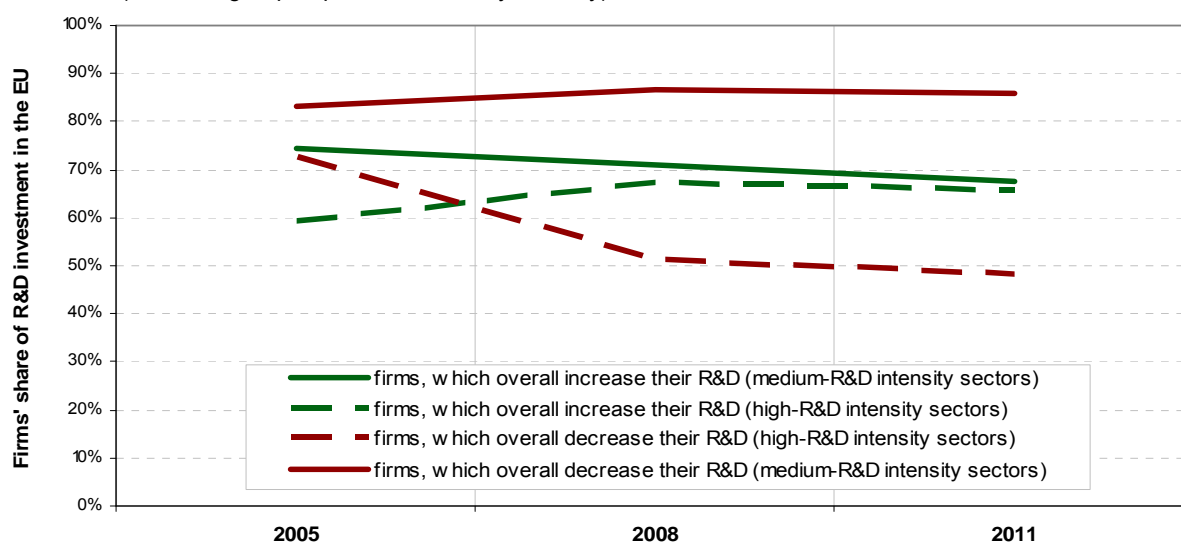
Source: Own calculations based on the quantitative survey for 51 companies with R&D values in 2005, 2008 and 2011.

Figure 5 reveals that those companies, which are operating in high-R&D intensity sectors and plan to increase their R&D between 2005 and 2011, expect the EU R&D investment share to increase slightly, mainly through reducing their R&D investment share in the US. Those

companies with decreasing R&D spending expect their EU share to drop considerably, doubling their share in the US, and tripling it in China and India.

With regard to companies in the medium-R&D intensity sectors, in turn, for the companies increasing R&D investment, the EU share will drop a little, basically due to a shift towards China and India. For those with decreasing overall R&D spending, the EU share is expected to increase slightly, basically through a shift away from the US towards the EU (with some increases also in China and India). In fact, this is the exact opposite trend pattern as outlined above in terms of highly R&D-intensive companies, which calls for further analysis in this regard. Moreover, although these observations are based on a relatively small sample, they illustrate that the sectoral dimension of the geographical R&D investment shifts should not be underestimated and therefore deserve further analytical attention.

Finally, the results of the econometric analysis concerning the impact of firms' share of R&D performed within the EU on the annual growth rate of R&D as well as its expected changes over the analysed period (cfr. hypothesis H3) do not confirm nor contradict the conclusions based on the previous descriptive analysis (Figures 2 to 5), where it was found that firms increasing their R&D over 2005-2011 were likely to do so predominantly within the EU.[17]

5   Conclusions

The main objective of this study has been to analyse the responsiveness of the largest R&D companies in the EU to the current economic and financial crisis. To that end, we rely on a specific survey, the R&D Outlook survey conducted by the European Commission in 2009 covering 2005-2012. The sample is unique with respect to its focus on investments in R&D and innovation activities and in particular in its timeliness. Although the sample is limited in several dimensions (see discussion in section 3), the arising empirical results were shown to be robust. The main R&D investment trends in the sample are in line with the figures reported in past Scoreboards. Further, the sample has proven to be representative and without selection bias.

On average, R&D performing companies appear to have contracted their R&D budgets during the current crisis. Yet this drop in R&D resources is quite modest and appears to be confined to a certain time period.

The firms least affected by the crisis appear to be the largest and, even more so, the smallest ones. A U-shaped relationship between firm size and R&D has been confirmed by other studies too and, therefore, can not be considered as specific to the current crisis.

In general, the top performers in profitability in 2008 are those increasing R&D activities the most. But, the top R&D investors reduced their's prior the crisis. In fact, according to the survey results, the most R&D intensive companies in the EU also had the most significant R&D investment cuts in the EU over 2005-2012.[18] If these trends are not reversed the R&D intensity deficit[19] of the EU vis-à-vis the US (measured as R&D over GDP) is likely to increase (further).

In turn, firms' age or the location of a company's headquarters in the euro area were not found to have a significant impact on the adjustment of corporate R&D and innovation activities.

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[17]   The econometric results are indeed not statistically significant at the 5 % statistical level. See Table 5, columns 4 and 5 in this regard.

[18]   For firms operating in the medium-low-tech sectors the percentage cut in R&D budgets was also found quite high (but at comparably lower absolute volumes due to their lower propensity to invest in R&D.

[19]   Cincera and Veugelers (2010) showed that this gap was of 46 % in 2007.

In geographic terms, the share of R&D conducted by EU companies outside Europe has increased slowly but steadily during the last few years and is expected to continue to do so, particularly in India and China. Thus, larger companies are engaging much more internationally. Nevertheless, the tendency for faster growth of R&D investment outside the EU has been found for both small and large companies. In contrast, those companies that have been increasing their R&D over the 2005-2011 period invested predominantly within the EU (but also in China, India and the US), while those which decreased their R&D investment between 2005 and 2008 have done so exclusively in the EU (with R&D in the other three macro regions remaining stable or slightly increasing). Both patterns point to an increasing share of emerging countries in terms of the global BERD. From a policy-makers' point of view, concerns may arise if the structure of R&D investment in the EU is seriously affected, e.g. when critical mass of R&D for a certain sector is gradually lost. Yet, according to the conclusions of a recent study (Belderbos et al, 2010), the trend that EU firms are locating R&D activities outside the EU should not be seen as a trend to be reversed by policy. Indeed, as pointed out by the authors, 'EU firms that exploit global technological expertise are also the companies that manage to maintain the strongest production activities in the EU'. In fact, the absolute amount of R&D investment in the EU is expected to increase by around 40 % between 2005 and 2012. This reveals that R&D internationalisation is not a zero-sum game but also a way to enrich the R&D activity at home.

In brief, a large share of companies we observed has reduced R&D activities due to the crisis. Hence, in terms of the relationship between the business cycle and R&D investment, a pro-cyclical response to the crisis seems to be predominant over a more counter-cyclical behaviour although contraction in corporate R&D and innovation activities appears limited and also confined to a given time period.

In order to mitigate this drop in research and innovation, EU Member States could adopt measures to increase and better coordinate counter-cyclical stimulus for R&D.[20] On the supply side, measures aimed at decreasing the costs for financing these activities, such as R&D tax credit and R&D subsidies, are promising and also fairly popular instruments. Public effort meant to boost the venture capital sector and to improve business environment in order to attract human capital (from within the EU and from abroad) are further options. On the demand side, by smart public procurement – giving preference to innovative products and services – R&D activities and innovativeness can be stimulated. The latter anyway appears to be relevant with regard to the major societal challenges, such as climate change, ageing population, access to food and water resources, etc., and are therefore a promising proposal per se.

Besides the structural change analysis, the question raised above concerning the 'critical mass of R&D and whether it eventually becomes gradually lost in course of R&D internationalisation' increases the necessity of further addressing the importance of location factors, which we envisage via the analysis of a combined sample of all the Survey responses and all EU Scoreboards over the past years. This may lead to a better insight of the relationship between the factors addressed in the questionnaires with future expectations, sector groups, or the choice of location. Further dimensions that would be worth looking into include the distinction of radical innovations versus incremental ones. It would be interesting to know whether the former are favoured in downturns as compared to the latter. Another two interesting questions concern the relationship between the impact of the crisis and the time span characterising the research project, i.e. 'are long-lasting R&D projects expected to be more counter-cyclical?' and 'do firms concentrate more of their R&D investment on fewer-

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[20] The European Commission recently has given a new stimulus to further unleash and develop R&D and innovation in order to reap their whole potential (European Commission, 2010).

core-business areas or on emerging technological sectors and markets only?'. This could be achieved by matching the data set used in this paper with patent data.

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Annex I

Table A1   R&D investments in 2007: Survey vs. scoreboard two-sample t test with equal variances

Variable	# obs	Mean	Std. Err.
R07_2008 Scoreboard	1000	126.36	15.30
R07_R&D Outlook survey	90	245.14	74.31
Combined	1090	136.17	15.34
Diff		-118.79	55.65
diff = mean(rdsb) - mean(rdsu)	t = -2.1347		
Ho: diff = 0	degrees of freedom = 1088		
Ha: diff < 0	Ha: diff ≠ 0	Ha: diff > 0	
Pr(T < t) = 0.0165	Pr(|T| > |t|) = 0.0330	Pr(T > t) = 0.9835	

Table A2   R&D investments in 2008: Survey vs. scoreboard two-sample t test with equal variances

Variable	# obs	Mean	Std. Err.
R07_2008 Scoreboard	1000	130.41	15.67
R07_R&D Outlook survey	90	271.20	85.12
Combined	1090	142.03	16.03
Diff		58.12	58.12
diff = mean(rdsb) - mean(rdsu)	t = -2.1347		
Ho: diff = 0	degrees of freedom = 1088		
Ha: diff < 0	Ha: diff ≠ 0	Ha: diff > 0	
Pr(T < t) = 0.0089	Pr(|T| > |t|) = 0.0156	Pr(T > t) = 0.9922	

Table A3   Annual growth rate (2007-2008) of R&D investments: Survey vs. scoreboard two-sample t test with equal variances

Variable	# obs	Mean	Std. Err.
ΔR07_2008 Scoreboard	983	52.89	28.39
ΔR07_R&D Outlook survey	90	10.01	4.39
Combined	1073	49.30	26.01
Diff		58.12	93.87
diff = mean(rdsb) - mean(rdsu)	t = 0.4567		
Ho: diff = 0	degrees of freedom = 1071		
Ha: diff < 0	Ha: diff ≠ 0	Ha: diff > 0	
Pr(T < t) = 0.6760	Pr(|T| > |t|) = 0.6479	Pr(T > t) = 0.3240	

Annex II: Questionnaire of the European Commissions' 2009 R&D Outlook survey

The information you provide usually takes less than 30 minutes to compile and will be treated as confidential, following the European Commission's standards of data protection and privacy (disclaimer below). It will be used only within this study and will be aggregated for the analysis. No access will be granted to individual answers.

Data for your company from previous Scoreboards and Surveys is already filled-in the questionnaire. You may want to correct these data where appropriate.

We will inform you of the results of this exercise as soon as they are available.

Thank you very much for your collaboration.

Definition of R&D investment

For the purposes of this questionnaire, **'R&D investment' is the total amount of R&D financed by your company** (as typically reported in its accounts). It does not include R&D financed from public sources.

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1. What was your company's R&D investment in the past? *Please estimate the amounts which should not be directly available.*

	2005	2006	2007	2008
R&D investment (€ million)				

2. Please estimate your company's R&D investment in the future?

Rationale: Periodicity based upon current context and expected trends.

	2009	2010	2011	2012
R&D investment (€ million)				

3. Please estimate the geographic distribution of your company's R&D investment for the following years?

Rationale: company based in country X is doing R&D in country Y.

R&D carried out:	in 2005	in 2006	in 2007	in 2008	in 2009	in 2010	in 2011	In 2012
in the European Union	%	%	%	%	%	%	%	%
in Switzerland	%	%	%	%	%	%	%	%
in other European countries	%	%	%	%	%	%	%	%
in the United States & Canada	%	%	%	%	%	%	%	%
in Japan	%	%	%	%	%	%	%	%
in China	%	%	%	%	%	%	%	%
in India	%	%	%	%	%	%	%	%
in South Korea	%	%	%	%	%	%	%	%
in other countries (please specify those with significant shares): ….	%	%	%	%	%	%	%	%

4. The past R&D data quality is:
    low
    medium
    high

5. The future R&D depends on factors whose uncertainty is:
    low
    medium
    high

6. Any other comments:

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Abstract

This study investigates how corporate R&D evolves in the light of the contemporary economic crisis. We study empirical evidence from past downturns, discuss the relevant literature, and perform an empirical analysis of recent business survey data (collected during 2009). Pivotal for our considerations is the question whether companies tend to spend more or less on R&D and innovation activities during periods of recession. We empirically analyse what general patterns can be distinguished in this regard, given the particular circumstances of the most recent crisis.

Our findings suggest that company behaviour varies: some companies have recently reduced their innovation activities significantly, while others maintained them and a third group even significantly increased their activities to reap the benefits in the expected upswing. Overall, we observe a deceleration of R&D and innovation activities induced by the crisis, but the trend figures remain positive. Driven by the companies that reinforce their R&D and innovation efforts to thrive through the downturn and thus seek to gather the benefits in the upswing to come, the R&D and innovation landscape is likely to look different in the aftermath of the crisis.

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