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R&D investment strategies
of Danish firms following
the 2009 economic crisis

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R&D investment strategies of Danish firms following the 2009 economic crisis

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Preface

At the beginning of the financial crisis in 2008, many Danish firms were faced with a difficult choice: Should they gamble and be proactive and increase their investments in research and development (R&D) to enhance their competitiveness or should they be careful and consolidate by cutting their R&D investments?

There is no clear-cut answer to the question as it is highly dependent on the situation of the individual firms. However, we can gain an impression of how the firms' choices during the financial crisis affected their subsequent development. In 2009, Danish Technological Institute asked Danish firms on behalf of the Danish Agency for Science, Technology and Innovation about their expectations to the development in their R&D investments in the light of the financial crisis. The firms' answers are the basis for the present analysis of the firms' R&D investments in connection with the crisis.

Many firms chose to cut back on their research investments, and the level of R&D investments has not increased significantly since then. However, our analysis also shows that firms that chose to increase their R&D investments in connection with the financial crisis tended to be more successful than those that reduced their R&D investments. This result is also valid if we adjust for the size, sector, financial standing, etc., of the firms

The Danish Agency for Science, Technology and Innovation commissioned Danish Technological Institute to carry out the analysis.

We hope that you enjoy reading the analysis.

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1. Summary

In 2009, when the economic crisis was a reality, the business sector experienced a serious economic recession that had a negative impact on turnover and employment, etc. However, another question rose in the wake of the economic crisis: Would Danish firms be able to remain competitive in the long run? One critical factor for businesses through the crisis to remain competitive is investment in research and development (R&D) in order to innovate. In 2009, the Danish Agency for Science, Technology and Innovation asked Danish firms about their intended R&D strategy (defined as change in investment in R&D). Now, several years later, we have the opportunity in retrospective to examine whether the firms have realised their R&D strategy, what some of the driving factors behind realising the strategy was, and depending of the intended R&D strategy and realised development in R&D, what the actual economic outcome was for the Danish firms in this study.

The study has been structured around three different perspectives:

1. Identifying the factors correlated with firms' choice of intended R&D strategy in light of the economic crisis
2. Identifying factors correlated with the firms' realised R&D investments
3. Examining which factors correlated with economic performance in the following years; including correlation with intended strategy and realised R&D investments.

Main results from the analysis of the survey firms

- 50 pct. of the firms in the analysis planned increasing or unchanged investment in R&D in the wake of the crisis.
- The analysis does not find a correlation between firms' plans to increase R&D investments in wake of the crisis and their solidity.
- 52 pct. of the firms in the analysis did not realise the planned increase in R&D investments
- More export-oriented firms had a higher tendency to plan an increase in their R&D investments in wake of the crisis than less export-oriented firms.
- The analysis shows that a realisation of the planned increase in R&D investments seems to be positively correlated with growth in the firms' turnover and employment, when controlling for sector, size, R&D intensity, export share, educational level, solidity and previous growth. The positive correlation can, however, be a result of unobserved factors not controlled for in the analysis.

The Danish firms reacted to the economic crisis in two different ways:

- A proactive¹ strategy with the intention to increase their R&D investment was pursued by 50 pct. of the surveyed firms in the sample² (including firms with intention to maintain their level of R&D investment)
- A reactive strategy with the intention to decrease their R&D investments, was pursued by 50 pct. of the surveyed firms in the sample

The characteristics³ of the firms may be crucial for the choice of R&D strategy. The proactive firms (defined as firms with intention to maintain or increase R&D investments) in the survey generally had a larger volume in terms of employment, turnover, and equity compared to the reactive firms. Even though there were differences between the two groups of firms, we are not able to find a statistical difference between the two groups of firms from observed firm characteristics; e.g. turnover, export, solidity, and educational level. However, this could to some extent be the result of a relatively low sample size, which makes it more difficult to detect significant differences in the observed characteristics.

The firms did not to a high degree realise their intended R&D strategy from early 2009. Examining the development in R&D investment, we found that:

- 48 pct. of the proactive firms increased their investments in R&D after 2009.

Even though the R&D strategy was not always realised, firms with a proactive R&D strategy had a significantly higher likelihood of increasing their R&D investments. The only firm characteristic with a borderline significant correlation with firms' likelihood of increasing their R&D-investments was their export share and industry. The tendency for the firms in the sample was that firms with a higher export share also had a higher likelihood of increasing their R&D investments. The reason for this could be that doing business on an international market probably implies a higher pressure of competition forcing the firm to focus on R&D to be more innovative when developing new products and services.

On average, the firms intending a proactive R&D strategy performed better than the reactive firms on growth in turnover, export and value added per employee from 2009.

Based on a statistical test, we have isolated the correlation of the realization of the intended R&D strategy from firm characteristics such as business sector, size, export share, educational level, and solidity. The test results reveal that in the sample of firms:

- The realised R&D investment strategy was significant correlated with the firms' development in turnover and number of employees in 2008-2012. Proactive firms that realised their strategy had a significantly higher growth rate than reactive firms that fulfilled their strategy.

¹ The term proactive is in this analysis a bit narrowly defined as firms not cutting their R&D investments. For many firms it might very well have been a wise proactive strategy to cut R&D investments in the wake of the crisis.

² Based on 163 firms. Approximately 1,000 firms were surveyed, but a large group of firms are not included in the sample, because they didn't answer the question or weren't R&D active during the period, had missing information or was part of the financial sector. This data wash creates a bias towards the larger and constantly R&D active firms.

³ Expectation probably also plays an important role, but they are very hard to model.

- That there is no significant correlation between realization of R&D strategy and the firms' development in value added per employee.
- Firm characteristics, such as the firms' business sector, were correlated with their growth rates. However, somewhat surprisingly, factors regarding economic capacity, (size and solidity), were not significantly correlated with growth rates, all other factors being equal. However, this could also be the result of a low sample size as mentioned above.

The analysis indicates a correlation between R&D investment strategy and economic performance. However, we have to stress that this is no proof of causality. The strategy may affect the performance, but the economic performance may also affect the choice of strategy. Hence, the results may follow our hypothesis, but it is not a proof of causality.

In summary, the firms in the sample took notice of the economic crisis in 2009 by choosing either a proactive or a reactive R&D strategy, and, in the following years, the choice of R&D strategy correlated with their economic performance. However, this study has only focused on the economic performance for the individual firms. Other factors that might influence the intended R&D strategy and the realised R&D strategies, such as expectations, collaboration with other firms or universities or the general framework conditions for doing business and carrying out R&D, have not been included in this study.

2. Sammenfatning

I forbindelse med den økonomiske krise i 2009 oplevede virksomheder globalt set en økonomisk tilbagegang, hvilket havde en negativ effekt på omsætning og beskæftigelse. I kølvandet på den økonomiske krise rejste der sig et andet spørgsmål: Ville danske virksomheder være i stand til at fastholde deres konkurrenceevne på lang sigt? En af de kritiske faktorer for at fastholde konkurrenceevnen er forskning og udvikling (FoU) og den deraf afledte innovation. I 2009 spurgte Teknologiske Institut på foranledning af Styrelsen for Forskning og Innovation danske virksomheder om deres planlagte FoU-strategi (defineret ved forventet stigning eller fald i FoU-investeringer) i lyset af den økonomiske krise⁴.

Nu flere år senere har vi en unik mulighed for at undersøge, om virksomhederne rent faktisk realiserede deres planlagte FoU-strategi, hvad der var drivkræfterne for at realisere strategien og ikke mindst, afhængig af planlagt FoU-strategi og efterfølgende realisering, hvordan det gik med de undersøgte virksomheders økonomiske resultat.

Dette studie bygger på en unik adgang til survey-data om virksomhedernes planlagte FoU-strategi ved indgangen til den økonomiske krise og på muligheden for at følge hver enkelt virksomheds økonomiske performance i de efterfølgende år.

Studiet har til formål at undersøge samspillet mellem de undersøgte virksomheders planlagte FoU-strategi og virksomhedernes økonomiske performance. I forlængelse heraf er der gennemført tre forskellige delanalyser med sigte på at:

1. Identificere faktorer, som var korreleret med virksomhedernes planlagte FoU-strategi i lyset af den økonomiske krise.
2. Identificere faktorer, som var korreleret med realisering af den planlagte FoU-strategi.
3. Undersøge de faktorer, herunder planlagt FoU-strategi og realisering, der var korreleret med virksomheders faktiske økonomiske performance.

⁴ Forsknings- og Innovationsstyrelsen (2009): Erhvervslivets forskning, udvikling og innovation i Danmark 2009. Udarbejdet af Teknologisk Institut

Væsentligste resultater for virksomhederne i analysen

- 50 pct. af virksomhederne i analysen planlagde stigende eller uændrede investeringer i FoU som svar på krisen, mens 50 pct. planlagde en reduktion i deres FoU-investeringer.
- Analysen kan ikke påvise en sammenhæng mellem virksomhedernes planer om at øge FoU investeringerne i forbindelse med finanskrisen og virksomhedernes soliditet (hvor stor en andel af en virksomhedens aktiver, der er finansieret af egenkapitalen).
- 52 pct. af virksomhederne i analysen realiserede ikke den planlagte forøgelse af FoU-investeringerne.
- Mere eksportintensive virksomheder var mere tilbøjelige til at planlægge stigende FoU-investeringer i forbindelse med krisen end mindre eksportintensive virksomheder.
- Virksomhederne i analysen, som gennemførte en planlagt forøgelse af deres FoU-investeringer, synes at have haft højere vækst i omsætning og beskæftigelse, når der kontrolleres for sektor, størrelse, FoU-intensitet, eksportandel, uddannelsesniveau, soliditet og tidligere vækst. Dette kan dog også skyldes andre forhold, som analysen ikke tager højde for.

Analyserne viser, at virksomhederne ved krisens start har reageret på to forskellige måder:

- 50 pct. af virksomhederne⁵ i undersøgelsen planlagde en proaktiv⁶ FoU-strategi, som sigter på at øge eller fastholde deres FoU-investeringer.
- 50 pct. af virksomhederne planlagde en reaktiv strategi, som sigter på at mindske FoU-investeringerne.

Virksomhedernes karakteristika kan have en afgørende betydning for valg af FoU-investeringsstrategi. De proaktive virksomheder var umiddelbart større målt på antal ansatte, omsætning og soliditet. Men forskellene mellem de to grupper af virksomheder er begrænsede, og der er rent statistisk ikke forskel på de to grupper på forskellige observerbare virksomhedskarakteristika såsom omsætning, eksport, soliditet og uddannelsesniveau m.m.

Virksomhederne i undersøgelsen er ikke alle lykkedes med at realisere deres strategiske intentioner umiddelbart efter udbruddet af den økonomiske krise. Ved at undersøge udviklingen i FoU-investeringer finder vi, at:

- Blot 48 pct. af virksomhederne med en proaktiv strategi øgede deres FoU investeringer efter 2009. Hertil skal dog tilføjes, at virksomheder, der havde planlagt en proaktiv FoU-strategi, oftere havde en stigning i deres FoU-investeringer end virksomheder, der havde planlagt en reaktiv FoU-strategi.

Selvom ca. halvdelen ikke realiserede deres FoU-strategi, er valget af strategi stadig korreleret med den faktiske udvikling i virksomhedernes FoU-investeringer. Med andre ord havde virksomhederne, der svarede, at de ville have en proaktiv FoU-investeringsstrategi,

⁵ 163 ud af 1.000 virksomheder deltager i analysen. De andre virksomheder er frasorteret fordi de ikke har, har svaret på spørgsmålet, ikke haft FoU aktiviteter i alle årene, der mangler andre informationer eller de er en del af den finansielle sektor. Denne udvælgelse betyder, at større virksomheder vil være overrepræsenteret.

⁶ "Proaktiv" er her defineret som firmaer, der ikke reducerer deres F&U investeringer. Denne "smalle definition" ser bort fra. At det for nogle firmaer kan være hensigtsmæssigt med en proaktive strategi, som fører til en reduktion en af deres F&U investeringer som følge af krisen.

en signifikant højere sandsynlighed for at øge deres FoU-investeringer efter 2009 end virksomheder med en reaktiv FoU-strategi.

Blandt de virksomhedskarakteristika, som ellers er undersøgt, er eksport og branche de eneste faktorer, hvor der er til tilnærmelsesvis signifikant forskel mellem de virksomheder, som øgede deres FoU-investeringer, og dem, som ikke øgede deres FoU-investeringer. En mulig forklaring på dette kan være, at tilstedeværelsen på de internationale markeder givetvis medfører et øget konkurrencepres på virksomhederne og dermed også et pres for at øge investeringerne i FoU med henblik på at udvikle nye og mere konkurrencedygtige produkter og services.

Analysen viser, at de virksomheder i undersøgelsen, der planlagde en proaktiv FoU-strategi, i årene efter den økonomiske krise i 2009, udviste en bedre økonomisk performance målt på vækst i omsætning, eksport og værditilvækst per medarbejder i forhold til virksomheder, som planlægger en reaktiv FoU-strategi.

Endelig er der gennemført en statistisk test, hvor vi ser på, hvordan selve gennemførelsen af den planlagte FoU-strategi korrelerer med virksomhedernes performance. Når man korrigerer for andre observerbare virksomhedskarakteristika såsom branche, virksomhedsstørrelse, eksportandel, uddannelsesniveau og soliditet, viser det sig:

- At FoU-gennemførelsen af en proaktiv investeringsstrategi var signifikant korreleret med de analyserede virksomheders udvikling målt på vækst i omsætning og udvikling i antal ansatte i årene efter krisen. Proaktive virksomheder, som realiserede deres ambition om øgede FoU-investeringer, havde sammenlignet med virksomheder med en realiseret reaktiv FoU-strategi en højere vækst. Derimod fandt analysen ingen signifikant sammenhæng mellem realisering af højere FoU-investeringer og værditilvækst per medarbejder.
- At virksomhedernes vækst var korreleret med branchetilhørsforhold, mens økonomisk kapacitet målt på virksomhedsstørrelse og soliditet ikke var signifikant korreleret med de undersøgte virksomheders vækst.

Endelig skal det understreges, at analysen kun indikerer en sammenhæng mellem den planlagte FoU-strategi og vækst i de undersøgte virksomheder. Opmærksomheden skal henledes på, at strategien nok kan have en effekt på den økonomiske performance, men den økonomiske performance kan lige såvel have betydning for valg af FoU-investeringsstrategi. Det er således ikke noget bevis for kausalitet.

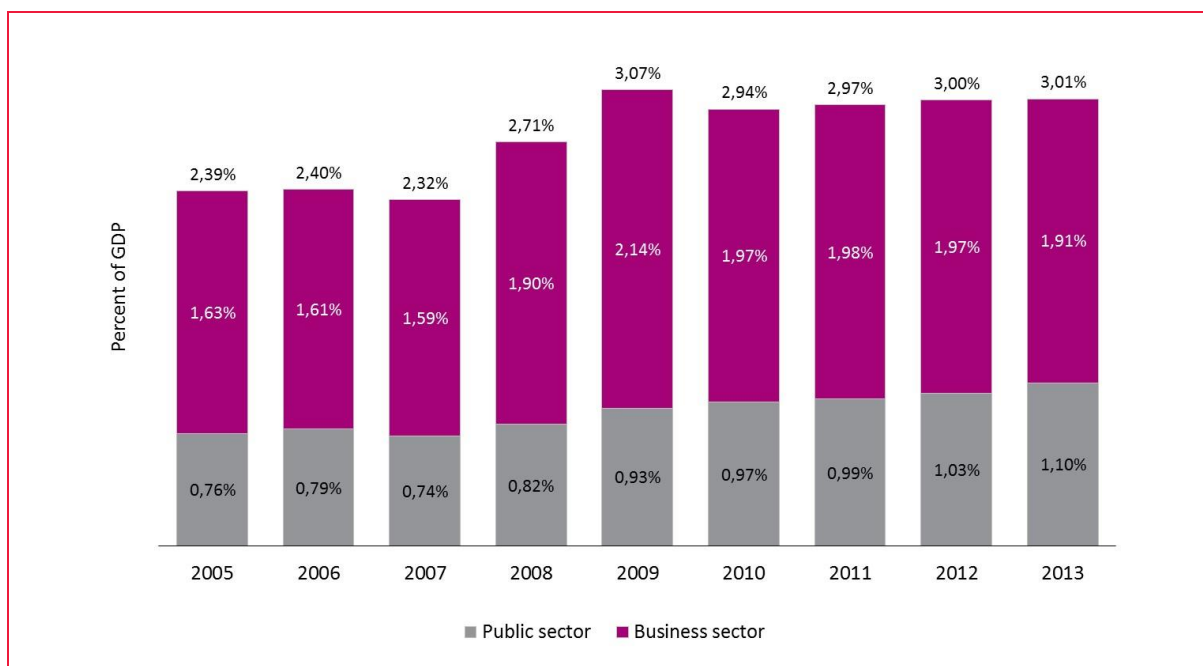
Sammenfattende reagerede danske virksomheder på den økonomiske krise i 2009 ved enten at planlægge en proaktiv eller reaktiv FoU-strategi, hvilket i de efterfølgende år har haft sammenhæng med virksomhedernes økonomiske performance. Dette studie har udelukkende haft fokus på den enkelte virksomheds økonomiske performance og ser derfor bort fra, at andre faktorer også kan have betydning for investeringerne i FoU såsom f.eks. markedsforventninger, samarbejde med andre virksomheder og universiteter samt de generelle rammebetingelser.

3. Introduction

Overall, European gross domestic expenditure on research and development (GERD) dropped after the economic crisis. However, R&D investments were more resilient than the economy as a whole. The European R&D intensity increased from 1.85 pct. of GDP in 2007 to 1.92 pct. in 2008 and 2.01 pct. in 2009.⁷ In other words, R&D investments seem to have been less affected than the entire economy.

A closer look also reveals that business enterprise expenditure on R&D (BERD, in the following 'business R&D investments') were more affected than public R&D investments.⁸ This was also the case in Denmark, where the business R&D investments decreased from 2.14 pct. of GDP in 2009 to 1.97 pct. in 2010. Meanwhile, public sector R&D investments (Government R&D funding) increased from 0.93 pct. of GDP to 0.97 GDP.

Figure 3.1: Development in R&D investments in Denmark



Source: Danish Agency for Research, Technology and Innovation (2015): 'Erhvervslivets investering i forskning, udvikling og innovation 2015'. (Danish Agency for Research, 2015).

An economic crisis can cause firms to reduce their investments in R&D. A European survey shows that the strategies for R&D investments in connection with the economic crisis have varied across firms. Some firms increased their R&D investments, whereas other reduced their R&D investments. Especially new and small firms or new market entrants were willing to follow an offensive strategy and increase their R&D investments.⁹

⁷ European Commission (2011): 'Innovation Union Competitiveness report 2011. Part I: Investment and performance in R&D – Investing in the future'.

⁸ European Commission (2011): 'Innovation Union Competitiveness report 2011. Part I: Investment and performance in R&D – Investing in the future'.

⁹ Archibugi, Filippetti & Frenz (2013): 'The impact of the economic crisis on innovation: Evidence from Europe', Technological Forecasting & Social Change, vol. 80, pp. 1247-1260

In light of these overall European trends, it is worth examining how Danish firms coped with the economic crisis and how this affected their economic performance in the following years.

At the beginning of 2009, we asked 1056¹⁰ Danish firms about their R&D strategies in light of the economic crisis. This gave a direct measure for the firms' intended R&D strategies in response to the extraordinary circumstances in the years of the economic crisis.

These survey responses were combined with firm level data from Statistics Denmark on economic performance and realised R&D investments in a given year for the period from 2007 to 2012.

The combination of survey data and firm level data on the realised R&D investments in 2009 onwards and economic performance in subsequent years gives us a unique opportunity to examine the effects of different R&D strategies (cf. Annex 1 for details about data and methodology).

3.1. Definition of proactive/reactive R&D strategy

Whether firms intended to react proactively or reactively with their R&D investments as a response to the economic crisis is defined by their answer to the following question about their own firm:

'Do you expect an increase or a decrease in investment in research and development in 2009-2010?'

This question originates from a survey that was carried out in the spring of 2009 immediately following the economic crisis.¹¹ Reactive firms are defined as firms that answered 'a drop' in expected investment level. Proactive firms are defined as firms that answered 'an increase' or 'flat/unchanged'. In this analysis, we have defined 'unchanged' as proactive in light of the severity of the crisis and the general focus on cost cutting that many firms implemented.

This operationalization of the R&D strategy has a number of advantages and limitations.

The question asks specifically for a two-year period, which better encapsulates a strategic ambition. In other words, this operationalization measures the strategic ambitions better than a question only covering expectations for 2009.

The definition of proactive firms is based on the firms' intentions according to their R&D investments. Consequently, it is not certain that the firms actually realise this ambitions. The realisation of the intended strategic approach is examined as a relevant research question in itself.

The definition specifies the strategy in the time immediately after the economic crisis, as firms were asked in the spring 2009. Therefore, firms may have changed their approach

¹⁰ 163 of these are included in the analysis. The rest are excluded due to missing, answer, missing observations or lack of R&D activity.

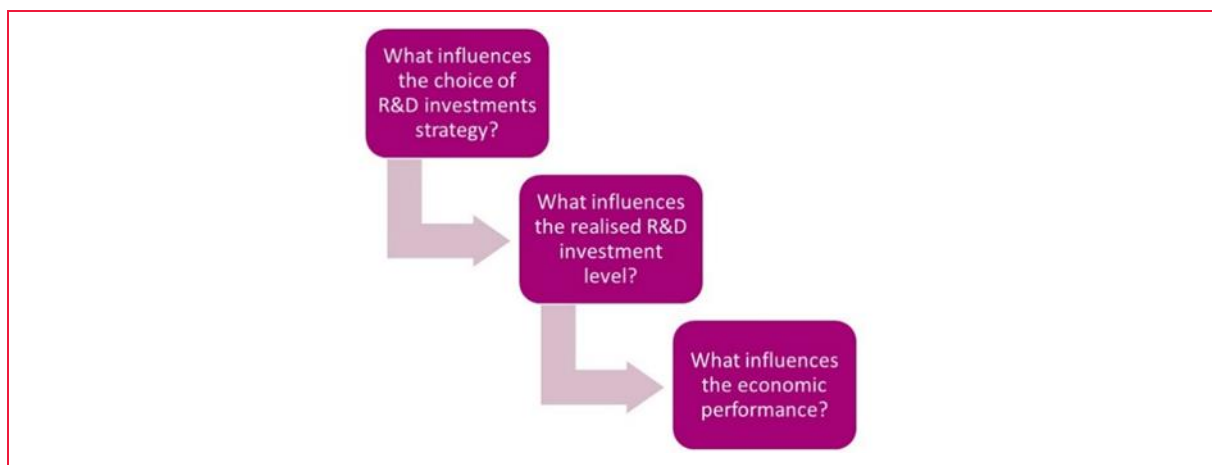
¹¹ Forsknings- og Innovationsstyrelsen (2009): Erhvervslivets forskning, udvikling og innovation i Danmark 2009. Prepared by Danish Technological Institute

over time as a response to external factors such as market developments. In other words, the time series based on this definitional distinction between proactive and reactive firms are based on the firms' intended strategy immediately after the crisis and not their strategies over the entire period or its realisation.

3.2. Hypotheses and expectations

To investigate the potential impact of the intended R&D strategy in light of the economic crisis, this paper follows three analytical steps.

Figure 3.2: Analytical steps



Analytically, we will examine three different perspectives of the potential impact of intended R&D strategy on realised R&D investments and economic performance of the firms in the study. We will:

1. identify the factors that were correlated with the firms' choice of intended R&D strategy in light of the economic crisis;
2. identify factors that were correlated with the realised R&D investment level; and
3. examine which factors were correlated with the economic outcomes.

In terms of factors, we include the chosen R&D strategy, market and business characteristics measured by, e.g., business sector, size, educational and economic capacity (size and solidity).

3.2.1. Choice of intended R&D strategy

We expect that the economic crisis was a major game changer leading to different strategic responses. In other words, firms could react by either developing new products, etc., by increasing their R&D investment or focusing on cost-minimising including cutting their R&D investments. Therefore, we examine the following overall hypothesis:

Hypothesis 1: *The economic crisis led to different responses regarding R&D strategies (Measured by intended change in R&D investment).*

Hereby, we just assume that the choice of intended R&D strategy in light of the economic crisis differs among R&D active firms. This leads to the following hypothesis on what characterizes firms with proactive and reactive strategies:

Hypothesis 2: *The performance of the proactive firms in 2009 (the year after the outbreak of the economic crisis) is characterised by different firm characteristics than the reactive firms, and this explains the choice of intended R&D strategy.*

In other words, the intended R&D strategy was closely related to the firm characteristic including the economic performance of the individual firms.

It is important to emphasise that there are certain unobservable factors that we cannot take into account, but they still may influence firms' choice of intended R&D strategy. One of these potential confounders might be the firms' expectations concerning the duration of the crisis. Another potential confounder that we cannot measure is the market developments of the individual firms. We can only take account of such market developments by considering the firms' business sectors, but these business sectors may still exhibit some significant firm-level differences.

3.2.2. Intended vs. realised development in R&D investments

We do not expect that all the firms fulfilled the intended R&D strategy. The strategy was set out in a period of turmoil and was characterised by uncertainty concerning market development, e.g., depth of the crisis, access to finance, etc. Funding opportunities at the time were specifically uncertain. Therefore, we examine the following hypothesis:

Hypothesis 3: *Economic uncertainty in the wake of the economic crisis made it difficult for firms to forecast their R&D investments in the years following the economic crisis.*

A variety of factors may have influenced the firms' realisation of their R&D strategy following the economic crisis. However, we still expect that the intended R&D strategy was an important driver for the realised development in R&D investments in the years following the economic crisis. This leads to the following hypothesis:

Hypothesis 4: *The R&D investment strategy itself was an important driver for realising the intended R&D strategy in the years following the economic crisis.*

In other words, we assume that the strategy itself is an important driver for increases in R&D in the following period. This should be controlled for the firms' economic capacity (solidity and size) and other firm characteristics.

3.2.3. Economic performance

We assume that the intended R&D strategy in itself has an important impact on the economic development of firms. Hence, firms intending to pursue a proactive strategy performed better than firms pursuing a reactive strategy did:

Hypothesis 5: *Firms intending to pursue a proactive strategy performed economically better than firms intending to pursue a reactive strategy in the years following the economic crisis.*

However, these differences may be due to the different characteristics of two types of firms. Characteristics of the firms such as size, business sector, R&D intensity, export share, solidity, and education level are likely to influence the firms' economic performance. In other words, we would assume that the economic development is influenced by both firm characteristics and the strategy conditions. We assume that the strategy itself is an important explanatory factor for the economic performance all other factors are being equal. However, we also assume that the realisation of the intended strategy is an important factor. This leads to the following hypothesis:

Hypothesis 6: *The realisation of a proactive strategy was important for firms' economic performance in the years following the economic crisis.*

Again, we will emphasise that there are certain unobservable factors that we cannot take into account, but they may still influence firms' choice of R&D investment strategy

4. Choice of R&D strategy

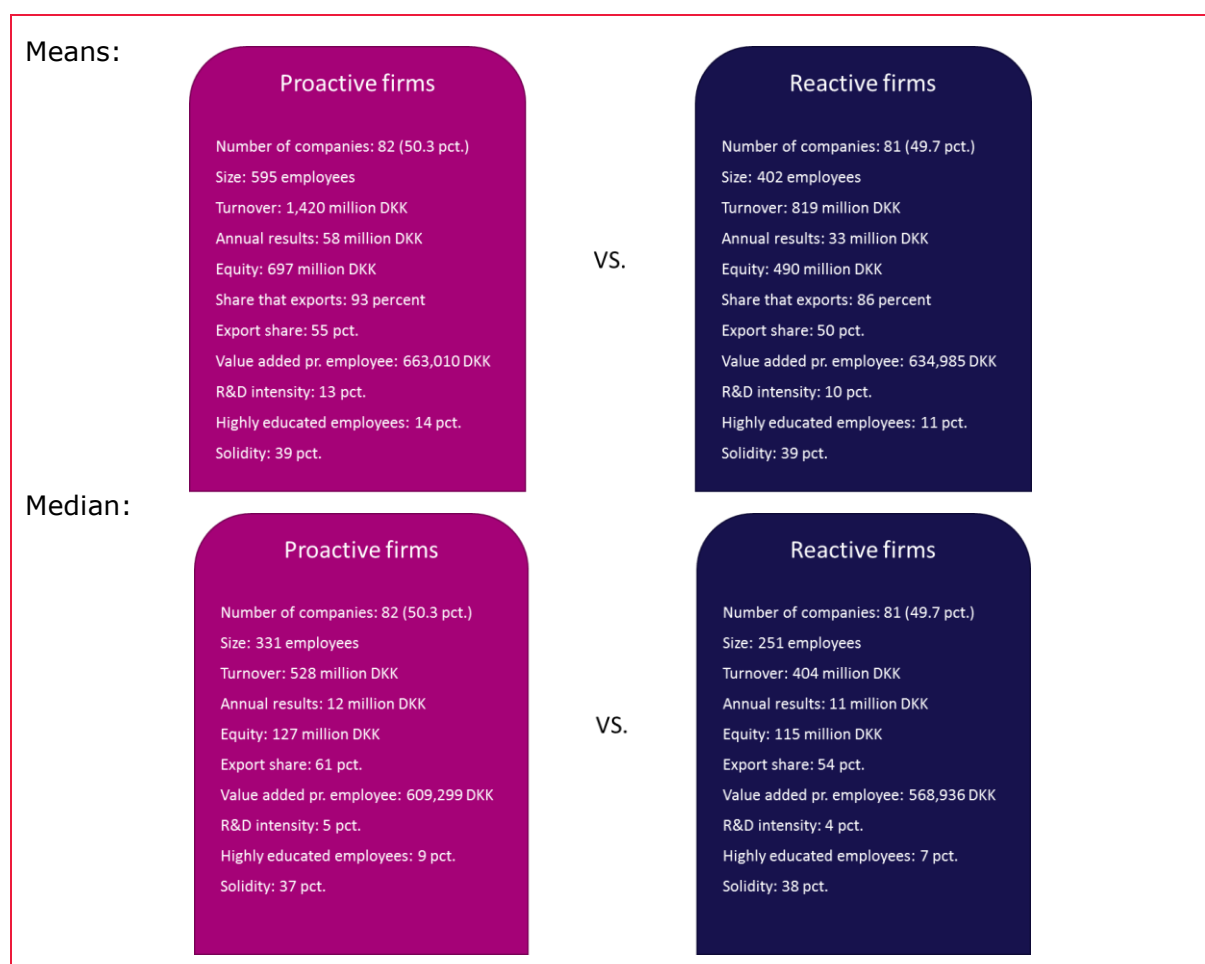
In this section, we will examine hypotheses related to the choice of R&D investment strategy in the light of the economic crisis in 2009.

4.1. Choice of R&D strategy

This section covers hypothesis 1: The economic crisis led to different responses regarding R&D strategies (Measured by intended change in R&D investment).

The survey shows that the firms are evenly split between firms intending to pursue a proactive and reactive strategy, respectively. Figure 4.1 shows the characteristics of the proactive and the reactive firms respectively at the starting point of the economic crisis in year 2009.

Figure 4.1: Characteristics of the typical proactive and reactive firms, start year 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (databases FIRM, UDD and FUI). N=163. The mean differences are not statistically significant - T-tests with $p > 0.1$ (size with $p = 0,136$ and turnover with $p = 0,154$).

Note: See Annex 1 for definitions of the variables.

First, we notice that 50 pct. of the firms intend to pursue a proactive strategy, while 50 pct. intend to pursue a reactive strategy. This way we can confirm our initial hypothesis that the firms intend to pursue different strategies. However, it is somewhat surprising that such a large share of the firms intend to pursue a proactive strategy at a time when focus on minimising costs would have been expected.

4.2. Economic factors were not correlated with the choice of R&D strategy

This section covers hypothesis 2: *The performance of the proactive firms in 2009 (the year after the outbreak of the economic crisis) is characterised by different firm characteristics than the reactive firms, and this explains the choice of intended R&D strategy.*

Figure 4.1 also reveals that the firm characteristics seem to differ between the proactive and reactive firms to some extent. Proactive firms had a higher volume in terms of employment, turnover, and equity, but the two groups had approximately the same export share, productivity, share of employees with a higher education, and financial solidity. In other words, proactive and reactive firms had to some extent different firm characteristics when faced with the economic crisis in 2009. Even though these differences are not statistically significant, it is important to consider these factors in the analysis, since they can be potential confounding variables.

The firms' choice of intended R&D investment strategies in the survey is analysed through a logistic regression to discover whether the different characteristics of the firms were correlated with their choice of R&D investment strategies. As the models include multiple factors characterising the firms (by number of employees, the educational and economic base as well as the economic development before the crisis (measured by growth in employment), it is possible to isolate their respective influence all other factors being equal.

Figure 4.2 shows Odds Ratios (likelihood) for choosing a proactive strategy over a reactive strategy. An Odds Ratio of 1 indicates that the variable does not affect the likelihood of achieving R&D investment all other variables being equal. An Odds Ratio value above 1 imply improved odds (a positive effect, and higher Odds Ratios values indicate increasing impact.) while a value below 1 indicates decreased odds (a negative impact) on the choice of intended R&D strategy.

Figure 4.2: Logistic regression for the choice of R&D investment strategy

The dependent variable is a binary variable for firms' R&D investment strategy with a proactive strategy as 1. The cells contain the Odds Ratios for choosing a proactive strategy over a reactive strategy. Odds Ratios over 1 indicate increased Odds for the choice of a proactive strategy, while Odds Ratios values at 1 or below 1 indicates no or negative impact on the choice of proactive R&D investment strategy.

	Parameter estimates	Standard error	Significance	Odds ratio
	B	S.E.	Sig.	Exp(B)
Educational level	1,685	1,866	,367	5,393
Export share	,849	,542	,117	2,338
R&D Intensity	,611	1,022	,550	1,843
Size	,473	,395	,231	1,605
Previous growth in employment	-,005	,007	,510	,995
Solidity	-,047	,297	,874	,954
(Constant)	-1,871	1,122	,095*	,154
Low-tech manufacturing	,120	,439	,785	1,127
Trade	-1,147	,881	,193	,317
Knowledge services	,371	,780	,635	1,449
Other sectors	,202	,626	,747	1,224

Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM, the R&D database FUI and the educational database UDD).

*** Indicates p-levels<0.01, ** Indicates p-levels<0.05, *Indicates p-levels<0.1. N=149.

R&D intensity, export share, size, and educational level seem to increase the odds of intending to pursue a proactive strategy, but none of these factors is statistically significant. This result might be due to the test's relative small sample size.

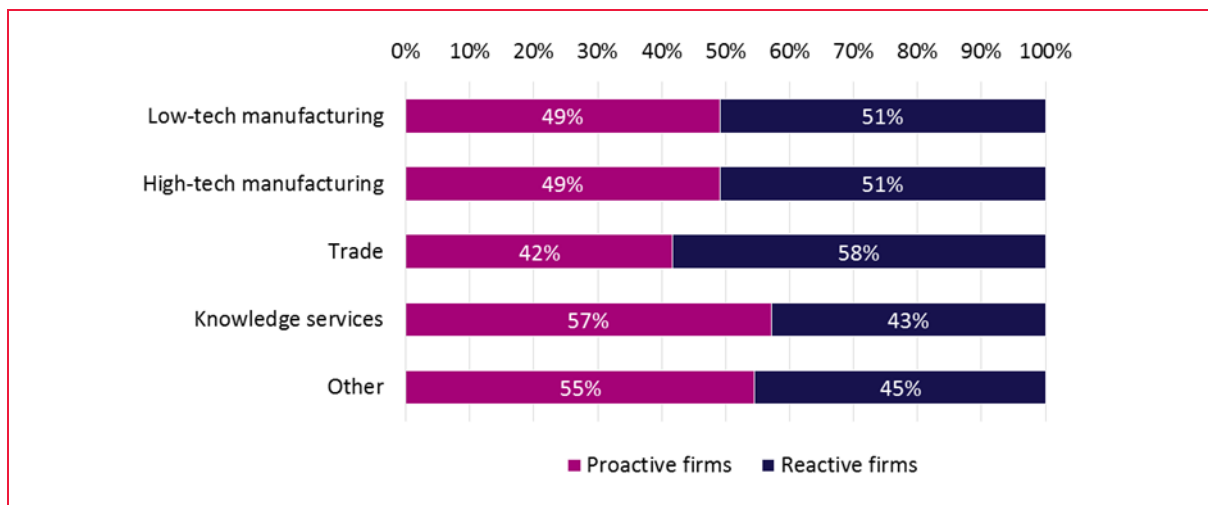
Even though, we see the expected signs for many of the factors, we do not have significant statistical results to support our hypothesis that the intended R&D strategy is correlated by the chosen set of firms observed characteristics. Furthermore, it should be emphasised that the model cannot include other potentially relevant factors such as the market developments of the individual firm or the firms' expectations concerning the duration and financial implications of the economic crisis.

4.3. Profile of proactive and reactive firm by individual business factors

Above we tested different factors, all other factors being equal, for their likelihood of explaining the firms' intention to pursue a proactive R&D strategy in the survey over a reactive strategy. To get a better understanding of the relationship it is worth examining the bivariate relations between the respective factors and the choice of R&D investment strategy. The main result is that we find a tendency towards a correlation between a proactive R&D strategy and number of employees, R&D-intensity, educational level and export intensity. However, these observations are not statistically significant. Furthermore, the economic capacity measured by solidity does not contribute to explaining the choice of R&D strategy. All the factors are presented below.

The firms' intended R&D strategy is unrelated to their business sector (see Figure 4.3) The business sector 'Trade' has the lowest percentage of proactive firms while 'Knowledge services' have the highest percentage of proactive firms. However, the share of proactive firms ranges from 42 pct. to 57 pct., which is not statistically significant.

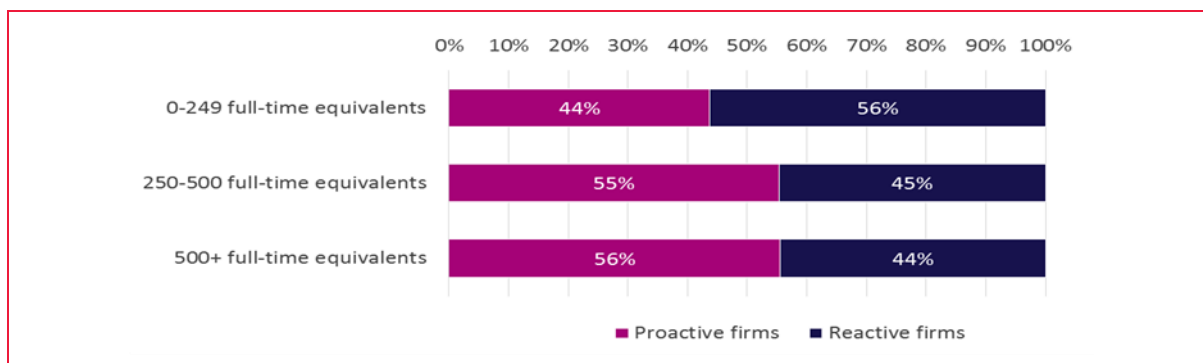
Figure 4.3: R&D strategy by business sector, 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=163 (Low tech industry=55, high tech industry=53, trade=12, knowledge services=21, other=22). The R&D strategy does not differ significantly (ANOVA-test, p=0.914).

By number of employees, firms with 250-500 full-time equivalents and large firms (500+ full-time equivalents) have the largest share of proactive firms, i.e. 55 pct. and 56 pct. respectively (see Figure 4.4). With 44 pct. proactive firms, small and medium sized firms (0-249 full-time equivalents) have a smaller share, but the difference is not statistically significant.

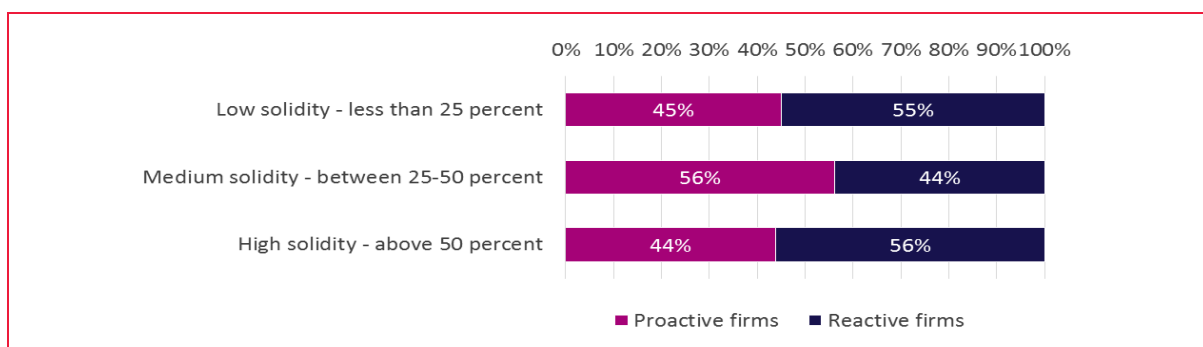
Figure 4.4: R&D strategy by firm size, 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=163 (0-249 full-time equivalents=71, 250-500 full-time equivalents=47, 500+ full-time equivalents=45). The R&D investment strategy does not differ significantly (ANOVA-test, $p=0.165$).

The solidity of firms appears to have some correlation with the intended R&D strategy (see Figure 4.5). The percentage of proactive firms is highest for firms with medium solidity, while firms with low and high solidity respectively have a lower share of proactive firms, but the differences are not statistically significant.

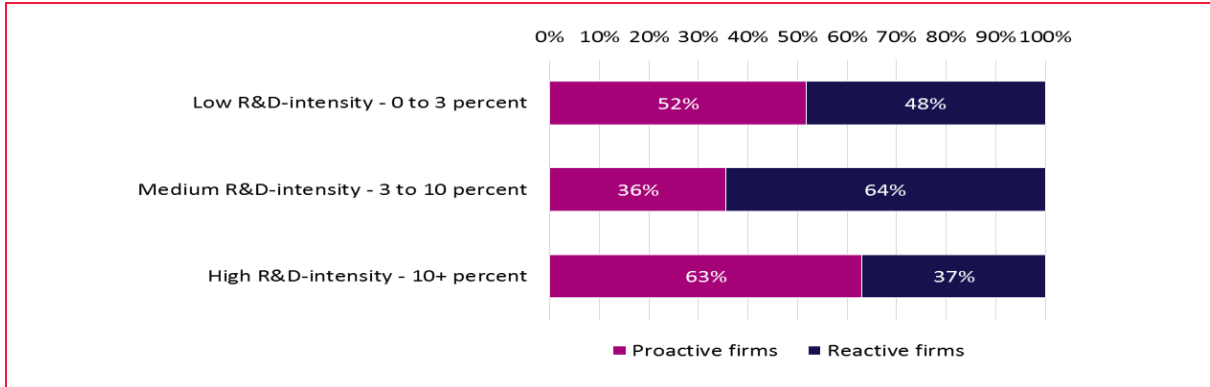
Figure 4.5: R&D strategy by solidity, 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=163 (low solidity=40, medium solidity=82, high solidity=41). The R&D investment strategy does not differ significantly (ANOVA-test, $p=0.908$).

Firms with a high R&D intensity are most likely to pursue a proactive R&D strategy, (see Figure 4.6). However, it is surprising that firms with a low R&D intensity appear to be more proactive than firms with medium R&D intensity. But again, none of the differences are statistically significant.

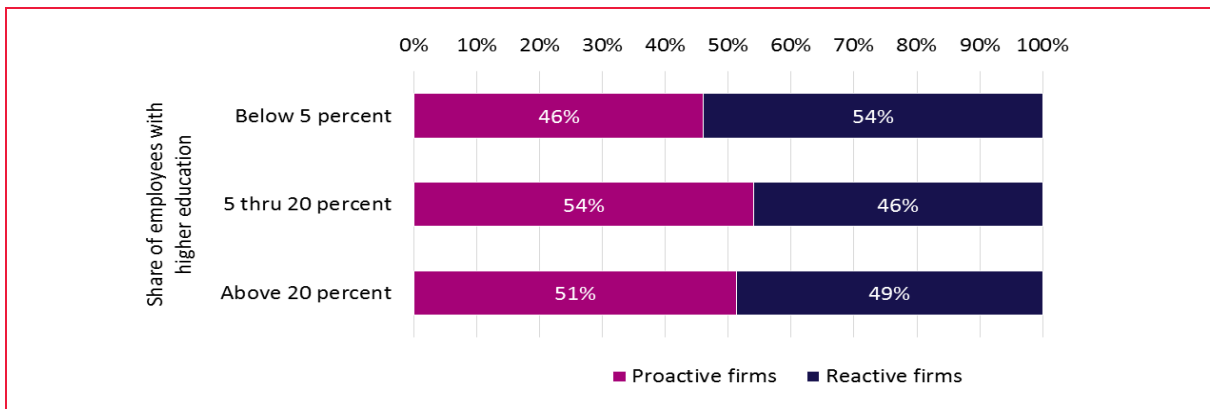
Figure 4.6: R&D strategy by R&D intensity (share of R&D personal), 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM the R&D database FUI). N=149 (low R&D intensity=58, medium R&D intensity=45, high R&D intensity=46). The R&D strategy does not differ significantly (ANOVA-test, $p=0.366$).

The educational level of the employees in the firms does not seem to be correlated with the firms' intended R&D strategy in connection with the economic crisis (see Figure 4.7). The percentage of proactive firms ranges from 46 pct. for the firms with the lowest educational level, to 54 pct. for firms with a medium share of highly educated employees and 51 pct. for firms with a high educational level.

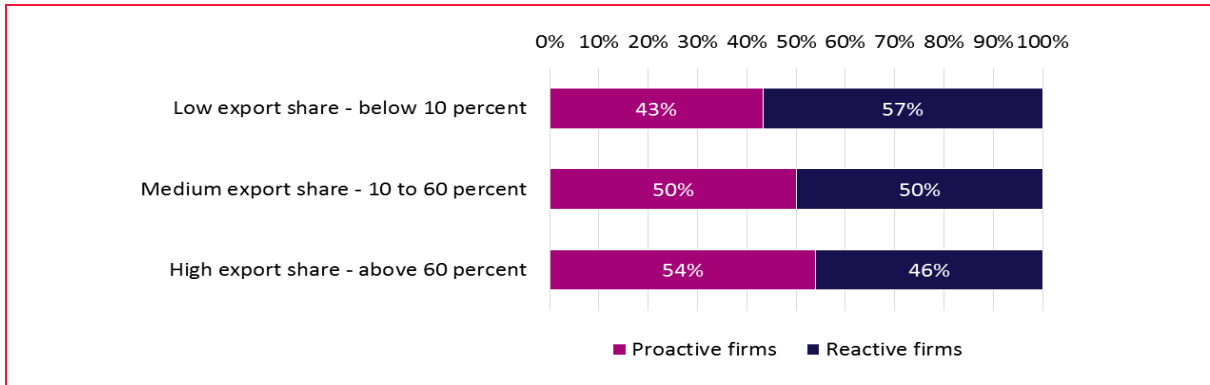
Figure 4.7: R&D strategy by educational level, 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM and the educational database UDD). N=163 (below 5 pct. = 63.5 thru 20 pct. = 63, above 20 pct.= 37). The R&D investment strategy does not differ significantly (ANOVA-test, $p=0.500$).

Finally, the share of proactive firms seems to increase the higher their export share (see Figure 4.8). Firms with a low export share have a share of proactive firms of 43 pct., while 54 pct. of the firms with a high export share are proactive. However, this difference is still not sufficiently large to be statistically significant.

Figure 4.8: R&D strategy by export share, 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=165 (low export share=37, medium export share=48 high export share=78). The R&D strategy does not differ significantly (ANOVA-test, $p=0.302$).

5. Realisation of the intended R&D strategy

Even though, the firms have the intention to pursue a proactive R&D strategy and even seem to have the economic preconditions to realise the strategy, the firms might not be realising the intention of increasing their R&D investment. In this section, we examine whether or not the firms realised their R&D strategy and search for explanatory factors for the observed outcome. Thus, a proactive R&D strategy often leads to increasing R&D investment, but not in all cases. However, a regression analysis shows that the intended there is still a significant correlation between the R&D strategy and the actual development in firms' R&D investments.

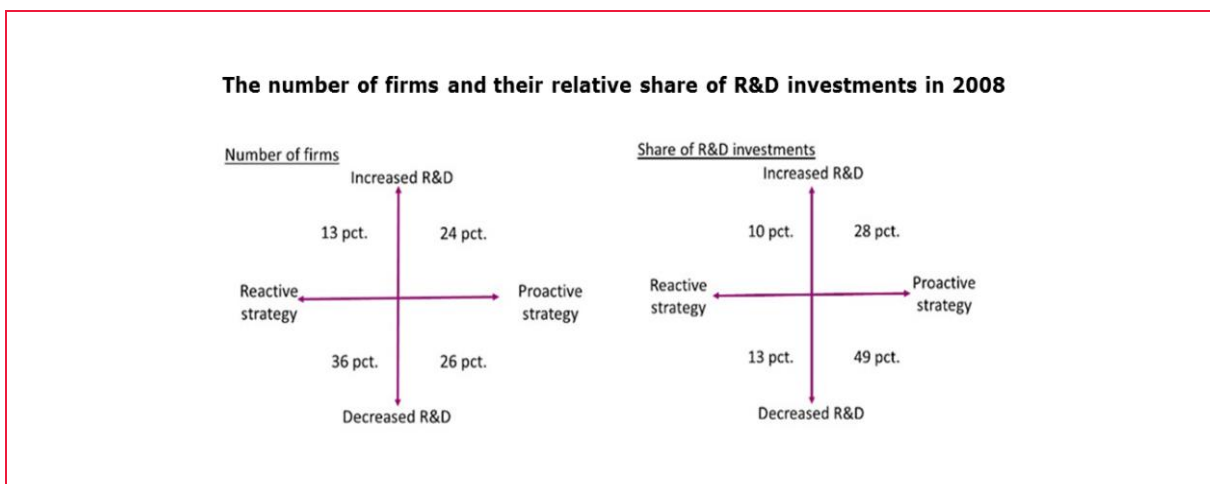
5.1. Accomplishment of the R&D investment strategy

This section covers hypothesis 3: *Economic uncertainty in the wake of the economic crisis made it difficult for firms to forecast their R&D investments in the years following the economic crisis.*

Uncertainty and financing opportunities can be challenging making it difficult for firms to realise the intended R&D investment level in the years following the economic crisis. Generally, many Danish did not realise their intentions to increase their R&D investment immediately after the economic crisis. The firms may have been affected differently than expected by the economic situation characterised by a high degree of uncertainty. Therefore, it is likely that a number of firms changed R&D strategies during the years following the economic crisis. How the firms realised their intended R&D strategy is shown in Figure 5.1.

Figure 5.1: Intended R&D strategy and realised R&D investments from 2008-2010

The number of firms and their relative share of R&D investments in 2008



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the research and innovation database FUI). N=163.

Note: Due to round-off the percentage of firms does not add up to 100.

Note: In Annex 2 key economic figures for the four group of firms.

The majority of firms experienced decreasing R&D investments in the wake of the crisis. This is the case for the proactive firms as well as the reactive firms, and this could indicate that the economic crisis was deeper than expected and generally had a negative impact on the R&D investments among Danish firms. When we compare the numbers, it is obvious that a larger share of the proactive firms increased their R&D investments compared to the firms that intended to follow a reactive research and development strategy in 2009. Based on the above statistics there is clear tendency that firms with a proactive R&D strategy more often increased their R&D investments than the firms that pursued a reactive strategy. However, it is remarkable that 52 pct. of the firms intending a proactive R&D strategy actually had decreasing investments in R&D after 2009.

The firms intending a proactive R&D strategy but had decreasing R&D investments accounted for almost half of the overall R&D investments although they only accounted for a quarter of the firms. In total, the proactive firms accounted for more than three quarters (77 pct.) of the R&D investments in 2008

5.2. Factors correlated with the realised development in R&D investments

This section covers hypothesis 4: *The R&D investment strategy itself was an important driver for realising the intended R&D strategy in the years following the economic crisis.*

One thing is to set out a R&D strategy; another thing is to realise the intentions in the strategy. So which factors were correlated with, whether the firms in the study realised their R&D investments following the economic crisis? We examine the effects of different factors in order to examine whether the intended R&D strategy itself was a significant factor for the realised development in R&D investments in the years following the economic crisis. Before continuing the analysis, we have split the firms into the four groups above to investigate whether there are large differences among the firms realising their intended strategy and those not realising, see figure in Annex 2. The figure shows that the firms increasing their R&D irrespective of the intended strategy in general were larger and had a higher export share.

The rest of the analysis of hypothesis 4 examines the factors that affect firms R&D investment level in the years following the economic crisis. Again, this is done using logistic regression with decrease in R&D as the reference category.

Figure 5.2 shows Odds Ratios (likelihood) for achieving an 'Increase in R&D' over a 'Decrease in R&D'. An Odds Ratio of 1 indicates that the variable does not affect the likelihood of achieving an increase rather than a decrease in R&D all other variables being equal. An Odds Ratio value above 1 imply improved odds (a positive effect, and higher Odds Ratios values indicate increasing impact.) while a value below 1 indicates decreased odds (a negative impact).

The intended R&D strategy in itself is positive correlated with the realised development in firms' R&D investments, as the variable for R&D investment strategy is still significant all other variables being equal. In other words, firms with an intended proactive strategy had significantly higher odds (likelihood) of realising an increase in R&D investments. The only

confounding variables with a borderline significant effect are low tech and the export share. The latter indicates that a higher export share increases the likelihood of increasing R&D investments. An argument for this may be that doing business on an international market probably implies a higher competitive pressure forcing the firm to focus on R&D to be more innovative when developing new products and services. The variables measuring firm size and educational level had the expected sign, but were statistically insignificant.

Figure 5.2: Logistic regression for the realised level of R&D investments

The dependent variable is a binary variable for firms' realised R&D investment with increasing R&D investment as 1, and decreasing R&D investment as 0. The cells contain the Odds Ratios for increasing R&D investment over decreasing R&D investment. Odds Ratios over 1 indicate increased Odds for the increasing R&D investment, while Odds Ratios values at 1 or below 1 indicates no or negative impact on the realised R&D investment strategy.

	Parameter estimates	Standard error	Significants	Odds ratio
	B	S.E.	Sig.	Exp(B)
Export share	,987	,579	,089*	2,683
Proactive R&D investment strategy	,923	,379	,015**	2,516
Educational level	,794	1,920	,679	2,213
Size	,381	,419	,363	1,464
Solidity	,095	,322	,769	1,099
Previous growth in employment	-,001	,008	,887	,999
R&D Intensity	-1,522	1,219	,212	,218
(Constant)	-2,163	1,194	,070*	,115
Low-tech manufacturing	-,898	,475	,058*	,407
Trade	,314	,803	,695	1,370
Knowledge services	-,177	,789	,823	,838
Other sectors	-,632	,691	,360	,532

Source: Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM, the R&D database FUI and the educational database UDD). N=163.

*** Indicates p-levels<0.01, ** Indicates p-levels<0.05, * Indicates p-levels<0.1.

Note: Previous growth indicates the growth rates for employment from 2006 to 2008.

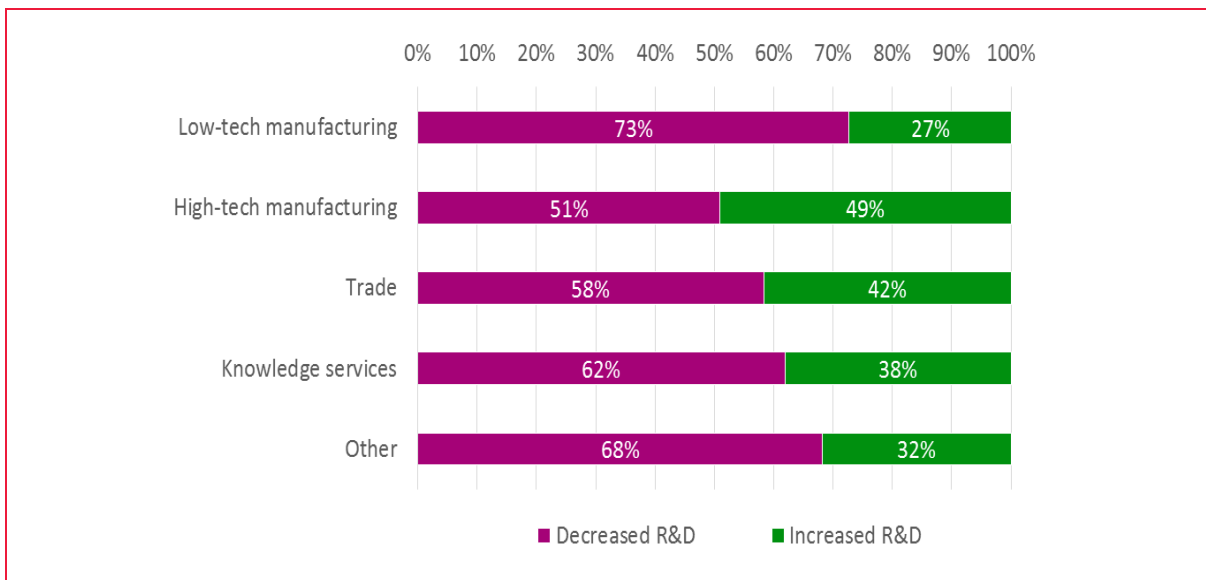
5.3. Individual firm characteristics correlation with the realised development in R&D investments

The above logistic regression analyses the possible correlation of realised R&D investments and the different factors all other factors being equal. The significance level in the odd-ratio analysis above is influenced by the relatively small sample size. To get a better understanding of the relationships it is worth examining the bivariate relations between the respective factors and the realised R&D investment level. The following sections cover a variety of crosstabs with these variables.

The main findings are that there is a positive and significant correlation between export share and educational level on the one hand, and, on the other hand, firms' realization of increasing R&D investment. Other factors such as number of employees, R&D-intensity and solidity are not significantly correlated with the observed increases in R&D investment. All the examined confounding variables are presented below.

Firms' realised increase in their R&D investments differs by business sector (see Figure 5.3). 'High-tech manufacturing' has the highest share of firms that increased their R&D in the years following the economic crisis followed by 'Trade' and 'Knowledge services'. 'Low-tech manufacturing' and other sectors have the lowest share of firms that increased R&D. None of the differences are statistically significant.

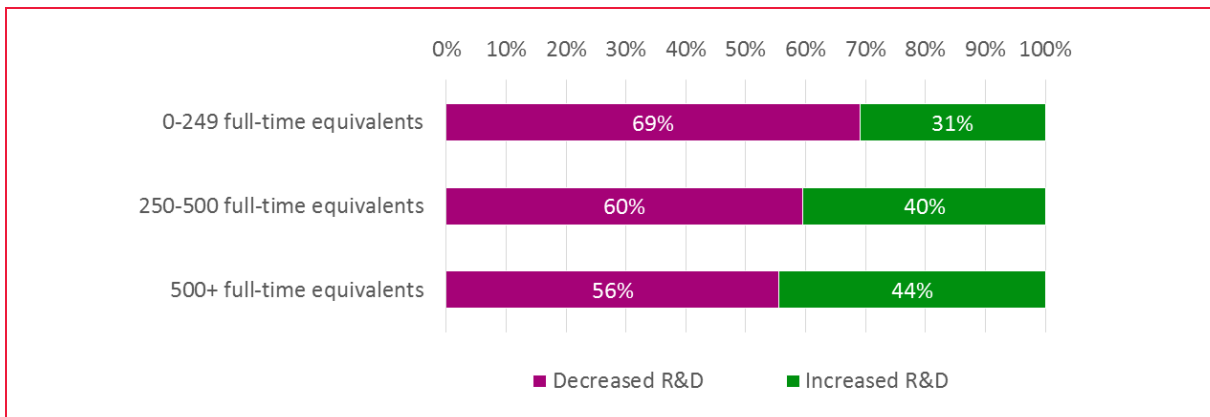
Figure 5.3: Realised R&D investments by business sector, increase in 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=163 (Low-tech manufacturing=55, high-tech manufacturing=53, trade=12, knowledge services=21, other=22). The R&D investment strategy does not differ significantly (Chi-square-test, p=0.209).

Firm size seems to affect firms' development in their R&D investments (see Figure 5.4). 31 pct. of the small firms increased their R&D investment, while 44 pct. of the large firms increased their R&D. None of the differences are statistically significant.

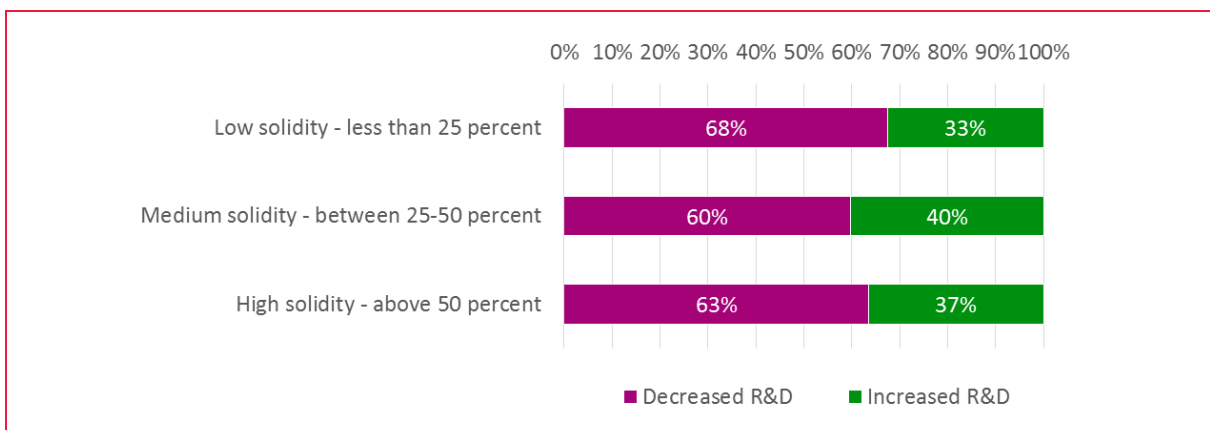
Figure 5.4: Realised R&D investments by firm size, increase in 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=163 (0-249 full-time equivalents=71, 250-500 full-time equivalents=47, 500+ full-time equivalents=45). The R&D investment strategy does not differ significantly (ANOVA-test, $p=0.124$).

We expected that the differences in the financial position of the firms would be of major importance for their increase in R&D investments. However, the financial solidity does not seem to correlate significantly with the increase in R&D investments (see Figure 5.5). The share of firms that increased their R&D investments only ranges from 33 pct. to 40 pct. and this is not statistically significant.

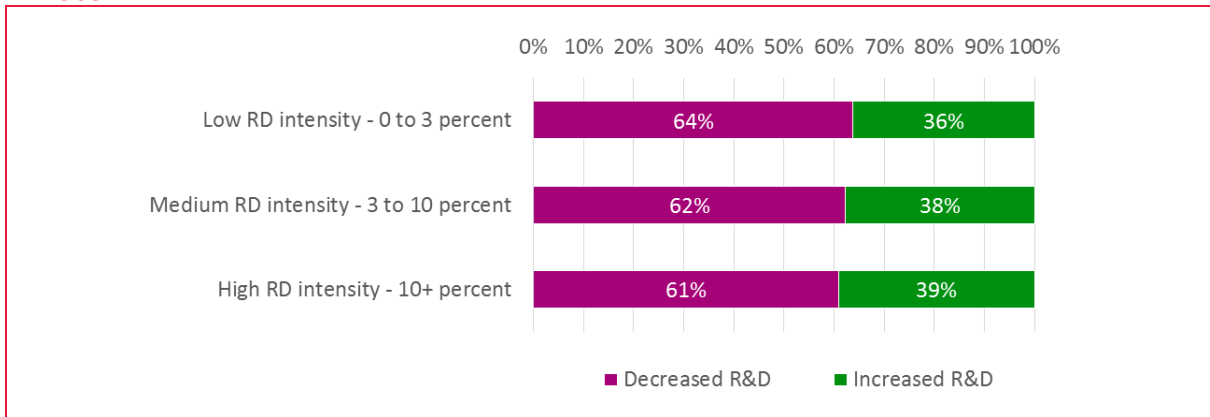
Figure 5.5: Realised R&D investments by solidity, increase in 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=163 (low solidity=40, medium solidity=82, high solidity=41). The R&D investment strategy does not differ significantly ($p=0.706$).

The existing level of the firms' R&D intensity does not seem to affect the increase in R&D (see Figure 5.6). The share of firms with increased R&D only ranges from 36 pct. to 39 pct. between the different groups of R&D intensity.

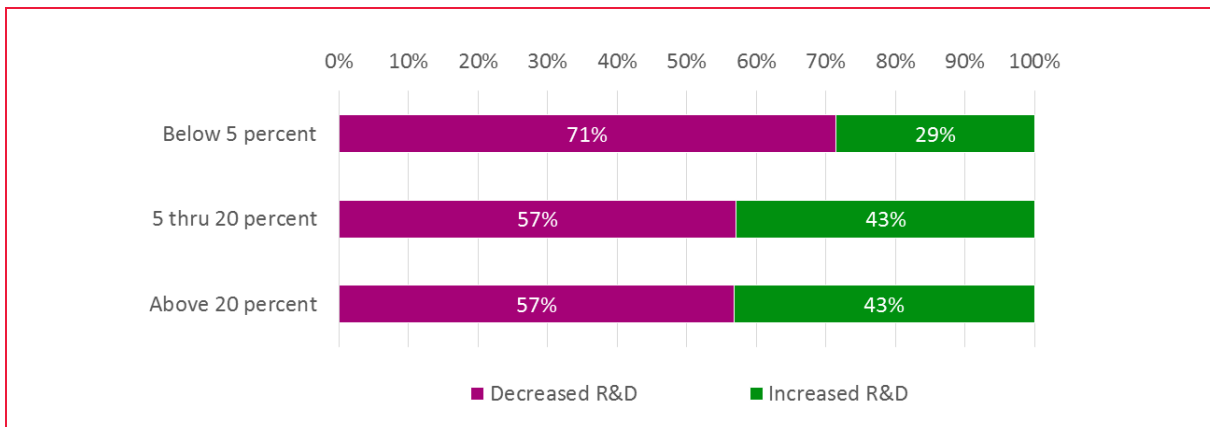
Figure 5.6: Realised R&D investments by R&D intensity (share of R&D personnel), increase in 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM and the R&D database FUI). N=149 (low R&D intensity=58, medium R&D intensity=45, high R&D intensity=46). The R&D investment strategy does not differ significantly ($p=0.759$).

The educational level of the employees in the firms affects their change in R&D (see Figure 5.7). Firms with a medium or high educational level increased their R&D investments to a higher extent than firms with a low educational level did.

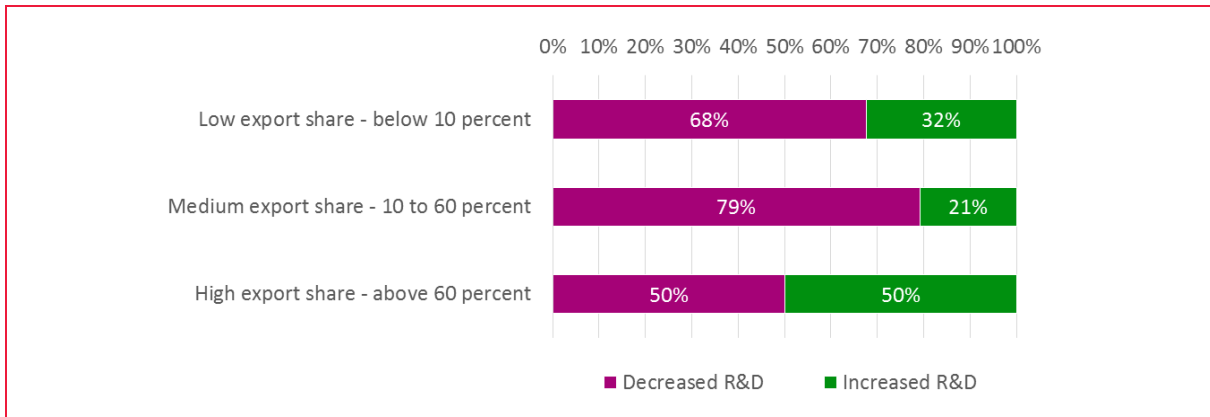
Figure 5.7: Realised R&D investments by educational level, share of employees with higher education, increase in 2009



Source: Survey data from the Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM and the educational database UDD). The crisis strategy do not differ significantly ($p>0.1$).

Firms with a high export share increased their R&D investment more than firms with a low or medium export share (see Figure 5.8).

Figure 5.8: Realised R&D investments by export share, increase in 2009



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=165 (low export share=37, medium export share=48 high export share=78). The R&D investment strategy differ significantly ($p=0.009$).

6. Economic performance

In the previous chapters, we have analysed factors that could have an impact on the intended R&D investment strategy or could impact the realised development in R&D investments. In this chapter, we look for factors that correlate with the economic performance of the firms including tests of any correlation between the intended and realised R&D investment strategy and the economic performance.

The overall result is that firms with an intended proactive R&D investment strategy generally performed better than the reactive firms in terms of growth in turnover, exports and value added per employee in the years following the economic crisis. Moreover, there is a tendency to converging performance. Furthermore, applying and realise a proactive R&D investment strategy is a main predictive factor for achieving growth in turnover and employment, whereas other characteristics of the firms, such as economic capacity, do not seem to be strong predictive factors for firm performance.

6.1. Development in economic performance

This section covers hypothesis 5: *Firms intending to pursue a proactive strategy performed economically better than firms intending to pursue a reactive strategy in the years following the economic crisis.*

Based on the findings in chapter 5, it is interesting to analyse how the firms intending to pursue a proactive strategy performed in the years following the economic crisis compared to firms intending to pursue a reactive strategy. We assume that firms with an intended proactive strategy performed better economically than reactive firms in the years following the economic crisis.

In order to analyse how firms with different R&D investment strategies performed over time, we selected four performance indicators: growth in turnover, number of employees, exports, and value added.

In chapter 4 we saw that the mean and the median for the economic characteristics of the typical proactive and reactive firms deviated substantially on some of the important firm characteristics. Therefore, the development on the four performance indicators is presented in terms of both the average value and the median value.

Figure 6.1 shows that firms with an intended proactive strategy had substantially higher turnover in 2009 than firms with a reactive R&D investment strategy. This tendency became even clearer in the following years, as the firms with a proactive strategy experienced an increase in turnover, whereas the turnover in reactive firms stagnated. From 2009 to 2012, the average turnover in the proactive firms increased from DKK 1,311 million in 2009 to DKK 1,601 million in 2012, while the average turnover in the reactive firms decreased from DKK 720 million on average in 2009 to DKK 696 million in 2012.

In the years leading up to 2009, proactive and reactive firms had almost equal performance. The relative difference between the two groups was almost unchanged. After the economic crisis, the difference increased markedly.

Figure 6.1: Average turnovers for proactive and reactive firms

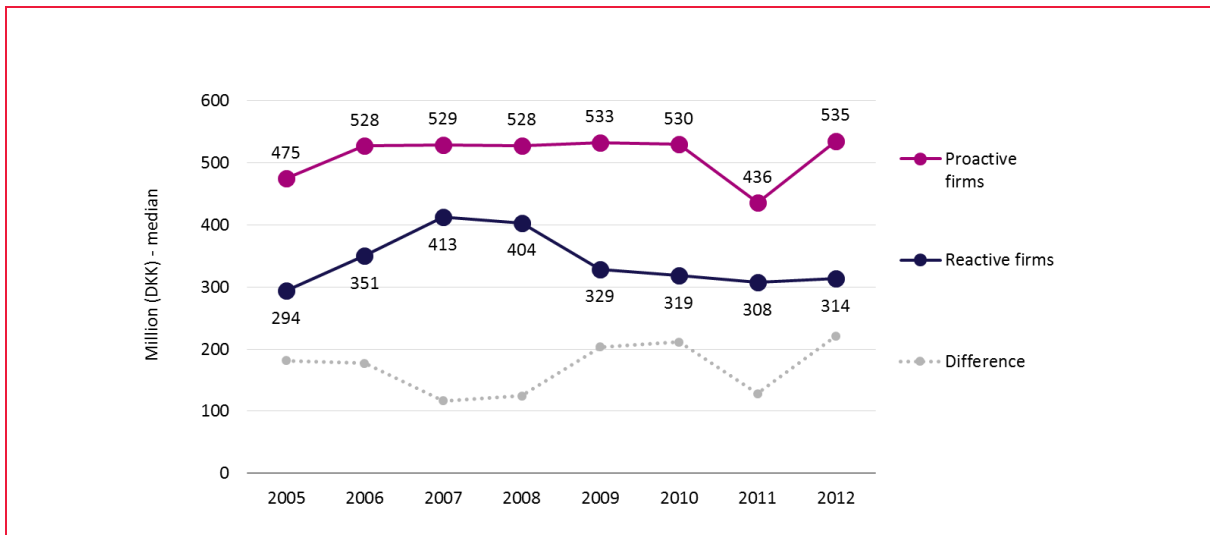


Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). Turnover significantly differs in 2011 and 2012 ($p < 0.1$). $N = 163$.

If we look at the development in median turnover, we see another development leading up to the economic crisis (see Figure 6.2). The median for the intended proactive firms was almost constant in the period from 2006 to 2012 (disregarding the strange data in 2011), while reactive firms increased until 2007 then decreased and stagnated from 2009 to 2012 following a more pro-cyclical path. Seen over the entire period there is no clear evidence that the proactive perform better, but they have a more resilient development during the crisis. The difference between development in the mean and the development in the median can probably be explained by a group of proactive firms performing very well.

Figure 6.2: Median of the turnover for proactive and reactive firms

Number of Employees is measured as the number of full-time equivalents.



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=163.

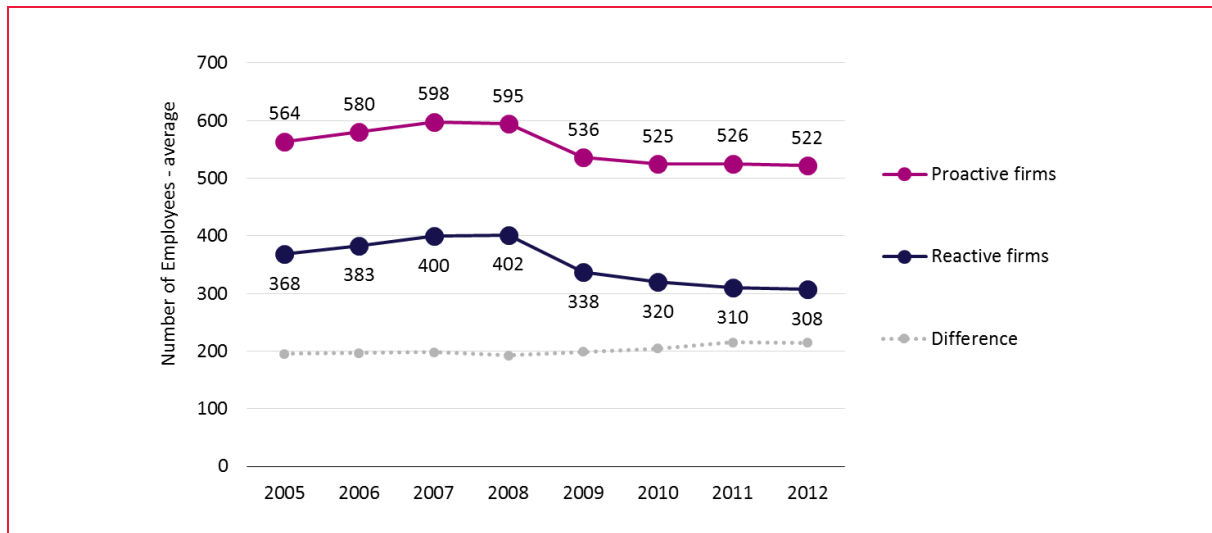
Note: An explanation to the large drop in 2011 has not been found and is disregarded in the interpretation.

The development in average number of employees indicates that that the proactive and reactive firms followed a nearly parallel path.

The proactive firms experienced a drop from 536 employees on average in 2009 to an average of 522 employees in 2012 (see Figure 6.3). The reactive firms experienced a similar drop in the number of employees from 338 employees on average in 2009 to 308 in 2012. The difference between the two groups is almost constant over the entire period from 2005 to 2012.

Figure 6.3: Average number of employees for proactive and reactive firms

Number of Employees is measured as the number of full-time equivalents.

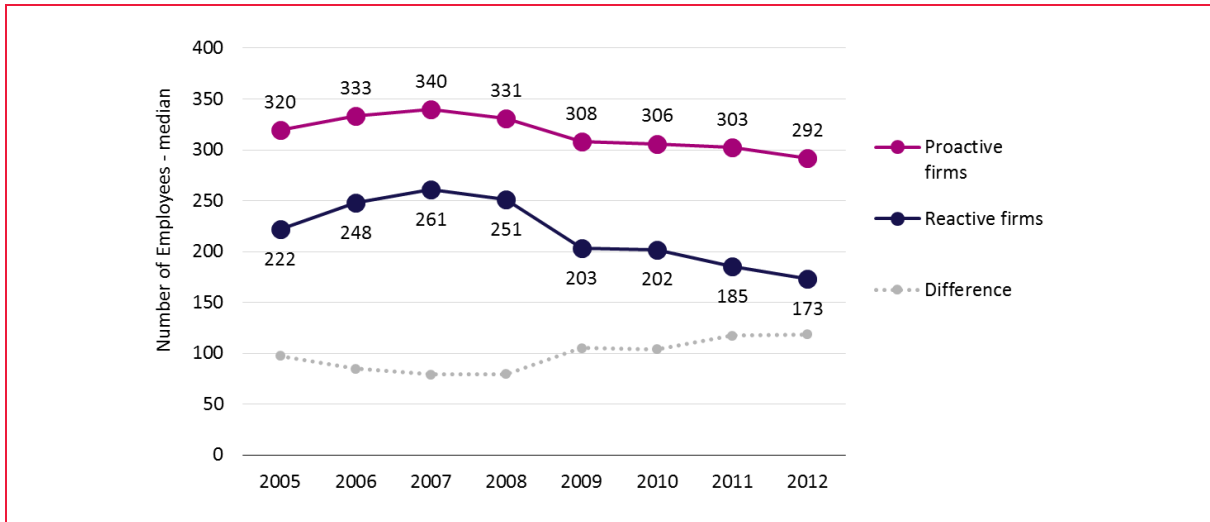


Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). The average number of employees differ significantly in 2009, 2010, 2011 and 2012 ($p > 0.1$). $N = 163$.

If we look at the median number of employees, a different development for proactive firms and reactive firms stands out. The median number of employees converged in the years up until 2008, but the difference between the two groups increased (divergence) from 2008 to 2012. In other words, the 'typical' proactive firm experienced a smaller drop in number of employees following the economic crisis compared to the reactive firms (see Figure 6.4).

Figure 6.4: Median number of employees for proactive and reactive firms

Number of Employees is measured as the number of full-time equivalents.

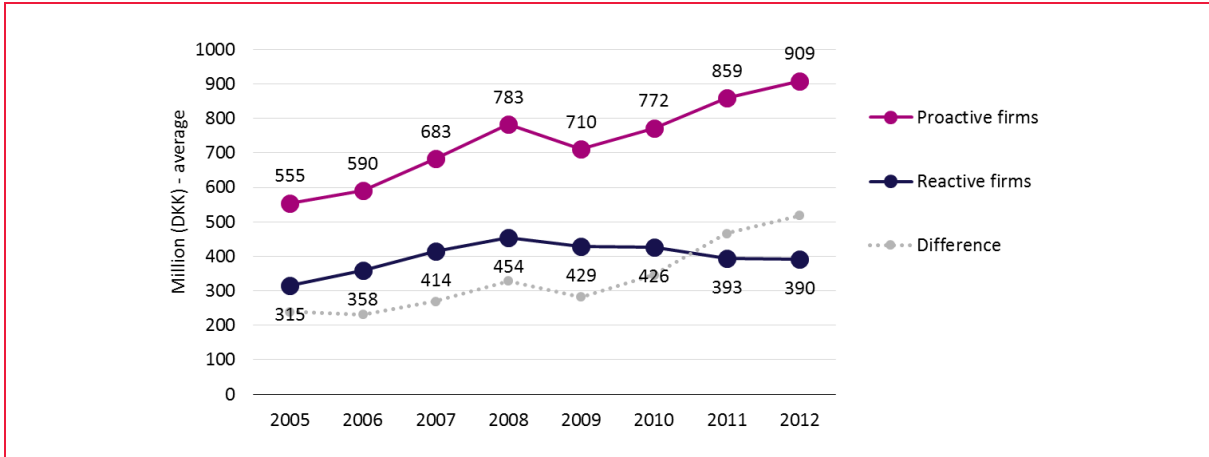


Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). N=163.

The third performance indicator selected to compare the performance of intended proactive and reactive firms is the average turnover from exported goods. As shown in Figure 6.1, firms with a proactive R&D investment strategy had on average a little higher export share in 2009 compared to firms with a reactive R&D investment strategy. The exports of proactive firms increased during the economic crisis, as the firms with a proactive strategy experienced higher turnover from exports, while exports in the reactive firms decreased (see Figure 6.5).

From 2009 to 2012, the average proactive firm increased its export turnover from 710 million DKK to 909 million DKK (29 pct. increase), while the reactive firms experienced a decrease from 429 million DKK in 2009 to 390 million DKK (9 pct. decrease). Based on these statistics, the proactive firms obviously performed better measured on the increase in export of goods.

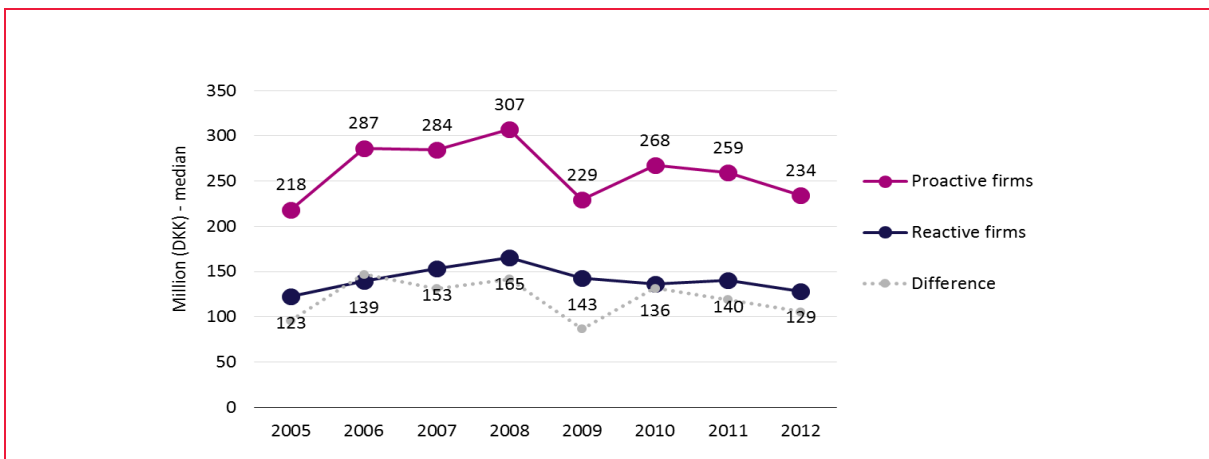
Figure 6.5: Average turnover from exported goods for proactive and reactive firms



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). Export significantly differs in 2005 ($p=0.094$). $N=163$.

The median turnover from exported goods shows a less clear picture (see Figure 6.6). The median export turnover for proactive firms decreased drastically from 2008 to 2009, and then increased again from 2009 to 2010. Since then the two groups' median exports have converged. This indicates that among the proactive firms there is a group of companies, which performed very well.

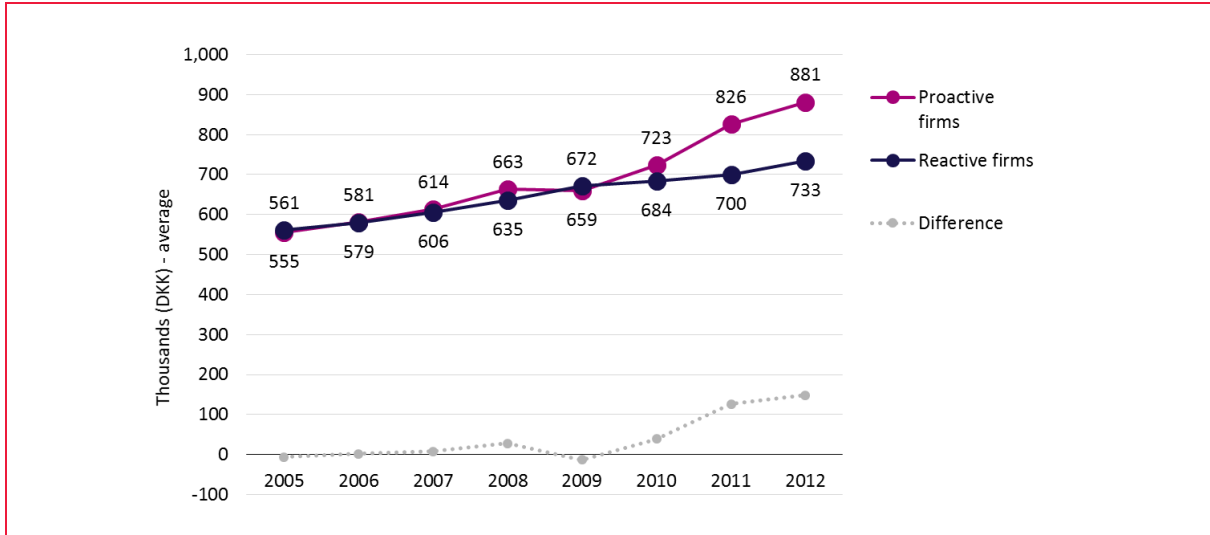
Figure 6.6: Median turnover from exported goods for proactive and reactive firms



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). $N=163$.

The fourth performance indicator selected to compare the performance of intended proactive and reactive firms is the average value added per employee (see Figure 6.7). Until 2009, the two groups had almost the same level and experienced a similar development. However, from 2009 to 2012 the proactive firms had a higher increase in value added per employee than reactive firms. Proactive firms increased from 659 thousands DKK in 2009 to 881 thousands DKK in 2012 (34 pct. increase), while reactive firms increased from 672 thousands DKK in 2009 to 733 thousands DKK (8 pct. increase) in 2012.

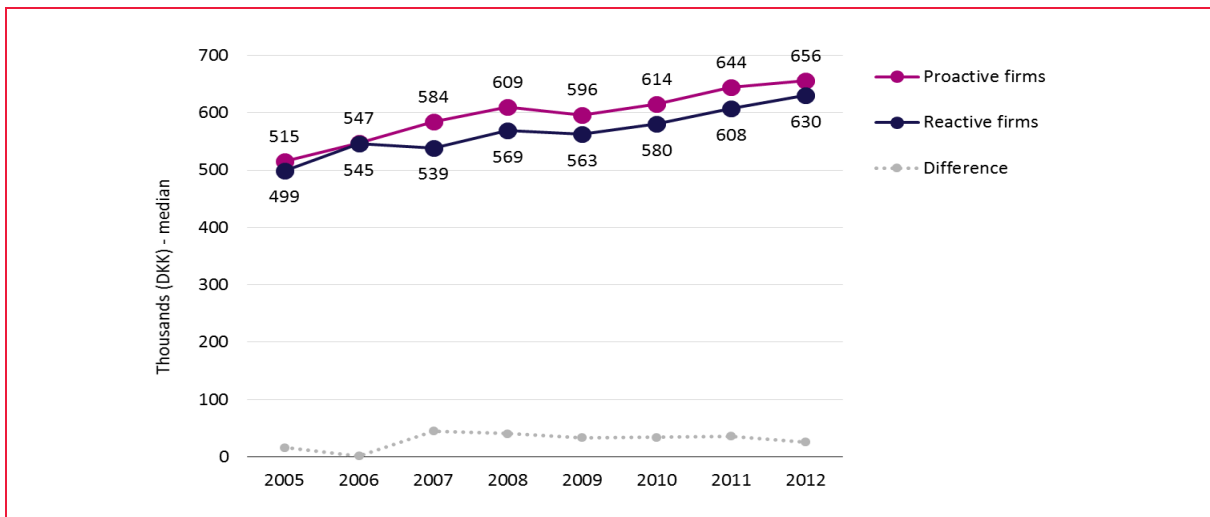
Figure 6.7: Average value added per employee for proactive and reactive firms



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). The average value added do not differ significantly ($p > 0.1$). $N = 163$.

When we look at the median value added per employee instead of the average, intended proactive and reactive firms had an almost similar development (see Figure 6.8). The two groups diverged from 2006 to 2007, but then the difference between the two groups remained constant.

Figure 6.8: Median value added per employee for proactive and reactive firms



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). $N = 163$.

6.2. Factors determining the economic outcome

This section covers hypothesis 6: *The realisation of a proactive strategy was important for firms' economic performance in the years following the economic crisis.*

The section above describes how intended proactive firms performed economically compared to intended reactive firms on some performance parameters. However, the economic development can be influenced by both firm characteristics and the realisation of the intended R&D investment strategy. This section tests the hypothesis that the firms in the sample who realised an intended proactive strategy performed better in the years following the economic crises.

The analysis isolates correlation of realising the R&D investment strategy and economic outcome through a multiple linear OLS-regression. The three following sections isolate the correlation on turnover, employment and value added per employee respectively.

The cells in the tables for the OLS-regressions contain values for the unstandardized Beta-coefficients for the relative development on the given economic parameter (measured in percentages). A positive value indicates that the variable has a positive correlation with the development all other variables being equal.

To analyse how firms with different intended R&D investment strategy and realisation of this strategy performed, we have defined three binary variables for respectively firms with a proactive strategy in 2009 that increased R&D and proactive firms that did not, and reactive firms that increased their R&D spending. Reactive firms that did not increase their R&D serve as a reference group in the overall model. While testing the economic performance, 'business sectors' are presented as binary variables with high-tech manufacturing as the reference category. Thereby, the unstandardised Beta-coefficients contain the difference between the given sector and high tech industry.

6.2.1. Firm characteristics and growth in turnover

The realisation of the R&D investment strategy of the firms in the study was significantly correlated the firms' turnover development in the years following the crisis when we take into account potential confounding variables. Proactive firms that realised their strategy had a significantly higher growth rate in turnover than reactive firms that fulfilled their strategy (see Figure 6.9). However, this possible impact did not come through in year one, but it appeared later in the period and lasted for both 2008-2010, 2008-2011 and 2008-2012. Firms that intended to pursue a proactive strategy following the economic crisis, but ended up decreasing their R&D investments did perform significantly better than reactive firms that decreased their R&D investments as well, but not as well as proactive firms that fulfilled their strategy.

The only significant confounding variables are R&D intensity and business sector. The R&D intensity seems to have had a huge positive impact in the first year, but then it lost its impact in the later years. The business sector seems to have had a higher impact in the initial years as well. Firms in 'Knowledge services' and other sectors had significantly higher relative growth in turnover than firms in the 'High-tech industry' in year 1 and 2, and year

1 respectively. Firms in 'Low-tech manufacturing' performed significantly better than 'High-tech manufacturing' in year 1, but significantly worse in year 3 and 4.

Figure 6.9: Multiple linear OLS-regressions for growth in turnover

The cells contain the unstandardized Beta-coefficients for the growth in turnover in the given period (measured in percentages).

Firms' R&D investment strategy and realised increase R&D investment are binary variables in this model. 'Proactive strategy – increased R&D', 'Proactive strategy – decreased R&D' and 'Reactive strategy – increased R&D' all have 'Reactive strategy – decreased R&D' as a reference category. Therefore, the unstandardized Beta-coefficients show the effect from having one of this strategies rather than a reactive strategy with decreased R&D.

	2008-2009	2008-2010	2008-2011	2008-2012
(Constant)	-27.9***	-51.7***	-30.2*	-26.9
Proactive strategy - increased R&D	3.0	15.8***	20.8***	26.2***
Proactive strategy - decreased R&D	-3.2	9.5*	8.7	20.4***
Reactive strategy - increased R&D	-2.1	12.8**	8.2	18.6**
Low-tech manufacturing	8.6**	2.1	-12.5*	-18.8**
Trade	-1.5	-1.6	-14.1	-4.8
Knowledge services	32.0***	23.3***	8.1	-4.4
Other sectors	18.9***	8.1	-3.6	-6.8
Size	3.7	8.1*	7.4	5.8
R&D Intensity	45.3***	6.7	3.4	6.9
Export share	3.5	10.2	0.9	-0.8
Educational level	-11.6	1.2	-9.8	6.6
Solidity	-3.8	2.6	2.9	2.3
Previous growth in turnover	-0.13***	-0.07	-0.14**	-0.06
R Square	0.34	0.21	0.15	0.16
Sig.	0.000 ^a	0.002 ^a	0.040 ^a	0.027 ^a

Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM, the R&D database FUJ and the educational database UDD).

*** Indicates p-levels<0.01, ** Indicates p-levels<0.05, * Indicates p-levels<0.1. N=149.

Note: High tech manufacturing is reference for "business sector".

6.2.2. Firm characteristics and growth in employment

The intended strategies of the firms in the study and realisation of these, in the years of the economic crisis seem to be correlated with the relative growth in number of employees in the firms (see Figure 6.10). Intended proactive firms with increasing R&D had growth rates in employment that were significantly higher than reactive firms with decreasing R&D all else being equal. This correlation increased over the period with growth rates that were 8.3, 17.1, 24.8, and 27.0 pct. points higher respectively during the periods 2008-2009, 2008-2010, 2008-2011 and 2008-2012 when controlling for confounding variables. Proactive firms that decreased their R&D also had higher relative growth rates in employment than reactive firms that decreased their R&D, but the difference is only marginally significant in the last period of 2008-2012.

As with turnover, the business sector seems to have had a significant impact on employment growth as well. Firms in 'Knowledge services' and other sectors had significantly higher relative growth in employment than firms in the High tech industry in respective year 1 and 2, and year 1 did, while firms in 'Low-tech manufacturing' performed significantly worse than 'High-tech manufacturing' in years 2, 3 and 4.

Somewhat surprisingly, factors for economic capacity such as size and solidity do not appear to correlate with the growth in employment significantly, because one would expect that stronger companies would perform better during the crisis.

Figure 6.10: Multiple linear OLS-regressions for growth in number of employees

The cells contain the unstandardized Beta-coefficients for the growth in fulltime employee equivalents in the given period (measured in percentages). Firms' R&D investment strategy and realised increase R&D investment are binary variables in this model. 'Proactive strategy – increased R&D', 'Proactive strategy – decreased R&D' and 'Reactive strategy – increased R&D' all have 'Reactive strategy – decreased R&D' as a reference category. Therefore, the unstandardized Beta-coefficients show the effect from going from a reactive strategy with decreased R&D to one of the other strategies.

	2008-2009	2008-2010	2008-2011	2008-2012
(Constant)	-19.5***	-30.0***	-15.8	-21.0
Proactive strategy - increased R&D	8.3***	17.1***	24.8***	27.0***
Proactive strategy - decreased R&D	0.0	6.6	8.4	11.2*
Reactive strategy - increased R&D	3.9	6.8	6.8	6.3
Low-tech manufacturing	1.6	-8.7**	-14.4***	-16.1**
Trade	7.1	0.6	-3.5	-0.7
Knowledge services	14.9***	12.9*	8.8	8.6
Other sectors	12.1***	3.1	3.3	8.5
Size	1.7	4.9	0.1	1.4
R&D Intensity	16.1***	-11.9	-11.1	-19.4
Export share	-1.5	-3.7	-6.6	-6.8
Educational level	-4.7	-6.9	-14.1	-2.4
Solidity	-3.9**	-0.1	0.0	0.0
Previous growth in employment	-0.06	-0.11*	-0.05	-0.03
R Square	0.26	0.21	0.23	0.20
Sig.	,000 ^a	,000 ^a	,001 ^a	,003 ^a

Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM, the R&D database FUI and the educational database UDD).

*** Indicates p-levels<0.01, ** Indicates p-levels<0.05, * Indicates p-levels<0.1. N=149.

Note: High tech manufacturing is reference for "business sector"

6.2.3. Firm characteristics and growth in value added per employee

The firms' strategy in the years of the economic crisis does not seem to have a significant correlate with their relative growth in value added per employee (see Figure 6.11). It is worth noting that the overall multiple linear OLS-regressions do not appear to encapsulate the statistical variance sufficiently as two of the overall models are statistically insignificant. The only consistent factor appears to be the export share; the higher the export share, the higher the growth rates for value added per employee.

Figure 6.11: Multiple linear OLS-regressions for growth in value added per employee

The cells contain the unstandardized Beta-coefficients for the growth in value added per fulltime employee equivalents in the given period (measured in percentages). Firms' R&D investment strategy and realised increase R&D investment are binary variables in this model. 'Proactive strategy - increased R&D', 'Proactive strategy - decreased R&D' and 'Reactive strategy - increased R&D' all have 'Reactive strategy - decreased R&D' as a reference category. Therefore, the unstandardized Beta-coefficients show the effect from going from a reactive strategy with decreased R&D to one of the other strategies.

	2008-2009	2008-2010	2008-2011	2008-2012
(Constant)	-6.7	-20.0	1.5	13.0
Proactive strategy - increased R&D	-0.3	1.8	-1.3	3.3
Proactive strategy - decreased R&D	-2.4	15.2**	6.9	8.4
Reactive strategy - increased R&D	-0.1	5.0	-9.0	3.3
Low-, and med.-low tech manufacturing	8.4	9.0	0.9	-6.1
High-, and med.-high tech manufacturing	12.2	11.5	-0.7	2.6
Knowledge services	12.8	7.4	-9.6	-15.6
Other	19.6	22.4***	3.5	-7.0
Size	1.0	6.3	6.2	-0.5
R&D Intensity	-3.0	-2.1	-3.2	15.3
Export share	15.1**	24.8***	21.7**	12.6
Educational level	-0.3	-9.5	-7.2	3.7
Solidity	-5.5	-6.9**	-8.9	-2.1
Previous growth in value added per employee	-0.05	-0.15***	-0.13**	-0.09
R Square	0.07	0.25	0.14	0.07
Sig.	0.746 ^a	0.000 ^a	0.095 ^a	0.704 ^a

Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM, the R&D database FUI and the educational database UDD).

Note: Business sector are binary variables in this model, and High Tech Industry serve as a reference category for Low, and med.-low tech manufacturing, high-, and med.-high tech manufacturing, trade, knowledge services and other.

*** Indicates p-levels<0.01, ** Indicates p-levels<0.05, * Indicates p-levels<0.1. N=149.

Note: High tech manufacturing is reference for "business sector".

7. Other approaches

7.1. Other ways to approach proactive/reactive R&D strategies

The analysis above covers only strategies that entirely focus on change in R&D investments. However, a proactive strategy aimed at growth may take different forms. Below we make a short presentation of two other approaches not directly related to changes in R&D investments. Hence, this chapter is based on the same survey of Danish firms as the rest of this analysis, but the analysis itself is not directly related to the rest of the analysis.

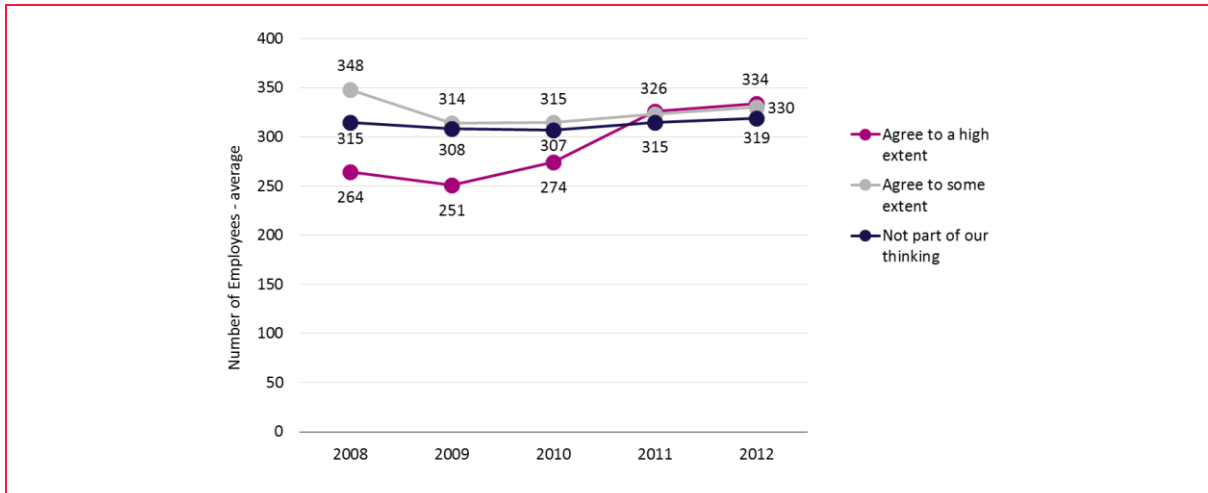
One way for firms to realise a proactive strategy can be to increase their external collaboration. The following textbox shows how the firms that increased their focus on external collaborations had a substantially higher increase in number of employees in the following years. Note that this approach uses a different population from the other analyses in this report and it is therefore shown in a separate text box.

Increased external collaboration were a tool for progress

Some firms responded to the economic crisis by focusing more on external collaboration than they did before the crisis. Ten percent of the firms agreed to the statement that they focused on external collaboration after the economic crisis to a higher degree. However, it should be noted that this accounts for a small absolute number of firms with this strategy (n=40). It should also be noted that the question does not take account of the absolute level of external collaboration but only the ambition to focus more on external collaboration.

The firms that agreed to the statement that they focused more on their external collaboration following the economic crisis experienced a substantial increase in the number of employees in the following years. These firms' average number of employees dropped from 2008 to 2009 but increased substantially afterwards. The same thing happened to a lesser extent for companies that agreed to some extent, while firms that did not consider an increase in external collaborations remained constant over the entire period.

Figure 7.1: Development in number of employees by strategies for external collaboration
 To what extent it is part of your thinking, to focus more on external collaboration?



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). The population for this question differs from the rest of this paper. Only firms that answered the question concerning new development activities are part of this analysis.

N=388 (agree to a high extent=40, agree to some extent=201 and not part of our thinking=147).

Note: The category 'Agree to some extent' includes firms that answered 'Agree either to some degree' or 'Agree to a low degree'.

Another proactive course of action can be to hire skilled labour that has become available due to the crisis. The following textbox shows how the firms that took advantage of the easier access to skilled labour had a higher increase in number of employees in the following years. This example is based on a different population from the rest of the analyses. Therefore, it is shown separate text box.

The crisis led to new growth opportunities for some

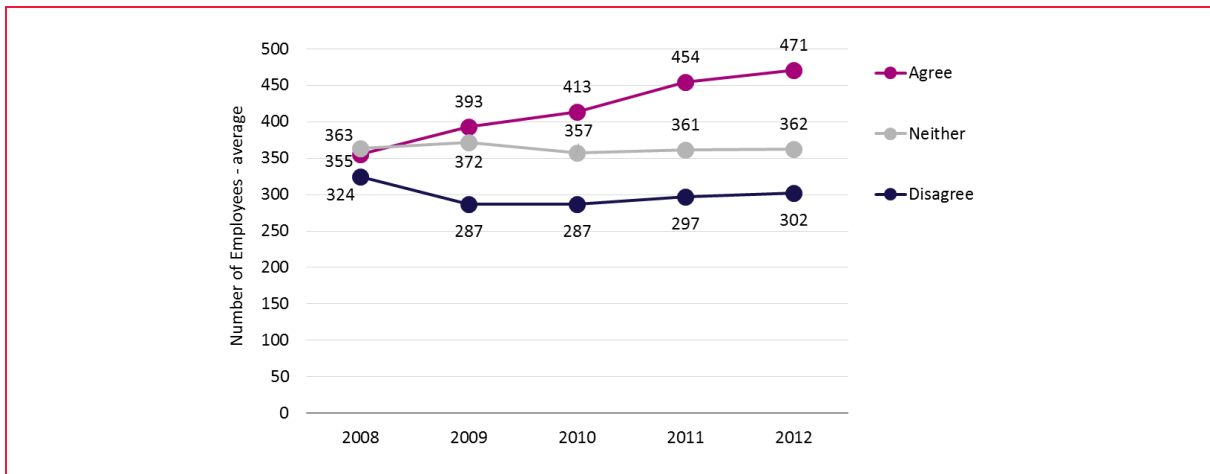
Some firms took advantage of the improved availability of skilled labour following the economic crisis. These firms started new development activities, because of the improved access to skilled labour caused by the economic crisis. Eleven percent of the firms agreed to the statement that they would use this new opening on the job market to initiate new development activities. However, it should be noted that this accounts for a small absolute number of firms with this strategy (n=44).

The firms that agreed that they would exploit the improved supply of skilled labour experienced a pronounced and continuous growth in the number of employees in the following years. In 2008, their average number of employees was 355, and it grew to 471 in 2012. Firms that did not agree to the statement that they would initiate new employment strategies because of the improved access to skilled labour caused by the economic crisis experienced a drop in the average number of employees, from 324 in 2008 to 287 in 2009. Subsequently, their number of employees grew steadily and reached 302 in 2012. However, this is still below the 2008 level. In other words, firms that initiated new employment strategies caused by the new supply of skilled labour had a substantially larger increase in

the number of employees in the following years than firms that did not use the labour supply to initiate new development activities.

Figure 7.2: Development in number of employees by strategies for hiring skilled labour

We have started new development activities because we caused by the economic crisis have greater access to skilled labour?



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the firm-level database FIRM). The population for this question differs from the rest of this paper. Only firms that answered the question on new development activities are part of this analysis.

N=394 (agree=44, neither=45 and disagree=305).

Annex 1: Data and method

Data

In the period from 2009 to 2014, Danish Technological Institute and the Danish Agency for Science, Technology and Innovation have made annual projections of Danish firms' R&D investment levels based on annual surveys of approx. 1,000 Danish firms.¹² In 2009, the survey emphasised the firms' strategic responses regarding their R&D investment to the ongoing economic crisis.

The **population** consists of the firms that:

- 1) Were active from 2009 to 2012
- 2) Shared their research and development strategy in the 2009 survey
- 3) Reported their R&D investment for at least two years to the R&D databases in Statistics Denmark (in Danish: FUI databases); and
- 4) Had R&D investments of at least DKK 100,000 in 2008

Some firms have been **excluded** using the following criteria:

- 5) Financial firms have been excluded (NACE rev. 2 group 64: Financial service activities, except insurance and pension funding)
- 6) Firms with no data on solidity in 2008 have been excluded (15 firms)

We supplement this survey on R&D investment strategies with firm level data from Statistics Denmark. Thus, we have had access to unique time series data with data merged from the survey data and firm level data from Statistics Denmark.

The survey data are merged with firm level data from statistics Denmark, meaning that the population consists of firms that were active throughout the period from 2009 to 2012.

Statistics Denmark measures Danish firms' R&D activities and investments in a given year. Thus, the R&D-database holds data for the realised level of R&D investments of firms for the period 2007-2012. The data collection is survey-based. Consequently, there is not a full overlap between respondents across different years. However, in case of panel overlaps it is possible to merge data on the firms' R&D investment strategies with their realised R&D activities and investments in the following period.

Statistic Denmark also holds information on all Danish firms' economic performance in their FIRM-database. We have merged the survey responses on R&D investment strategy with the firms' key economic figures throughout the period and measured the historic developments on a number of relevant indicators for the firms' economic performance over time, including turnover, export, number of employees and value added. This way we can calculate the economic effect of different R&D investment strategies.

¹² The surveys followed the sampling procedure as the Community Innovation Survey (CIS) set out in OECD's Frascati manual.

Finally, the UDD-database contains data on the educational level at an individual level by measuring the highest level of education completed. We use this information to calculate an indicator for the educational level within a given firm.

Table 7.1: Data sources

	R&D survey	FUI	FIRM	UDD
Origin	Survey by Danish Technological Institute and Jysk Analyse	Statistics Denmark database (survey-based)	Statistics Denmark database	Statistics Denmark database
Indicator	R&D investment strategy	Level of R&D investments	Economic performance at firm level	Educational level at individual level
Timeframe	2009	2007-2012	2001-2012	2001-2012
Variables	Expected percentage change in R&D investments	Investment in own R&D (in DKK)	Turnover (in DKK)	Highest level of education completed
		Number of R&D personnel (full-time equivalents)	Value added (in DKK)	
			Export (in DKK)	
			Number of Employees (full-time equivalents)	
			Business sector	
			Equity (in DKK)	
			Assets (in DKK)	

Table 7.2: List of variables

Variable name	Definition	Construction of the variable	Scale/interpretation
Low-tech manufacturing	<p>The following aggregation of the manufacturing industry is based on Eurostat's³³ aggregates for high-technology, medium high-technology, medium low-technology and low-technology.</p> <p>This category encapsulates medium low-technology and low-technology manufacturing.</p> <p>These aggregates are based on NACE Rev. 2 codes.</p>	<p>This category contains the following NACE Rev. 2 codes:</p> <p>18.2 Reproduction of recorded media 19 Manufacture of coke and refined petroleum products 22 to 24 Manufacture of rubber and plastic products, Manufacture of other non-metallic mineral products, Manufacture of basic metals 25 Manufacture of fabricated metal products, except machinery and equipment excluding 25.4 Manufacture of weapons and ammunition 30.1 Building of ships and boats 33 Repair and installation of machinery and equipment 10 to 17 Manufacture of food products, beverages, tobacco products, textiles, wearing apparel, leather and related products, wood and of products of wood, paper and paper products 18 Printing and reproduction of recorded media excluding 18.2 Reproduction of recorded media 31 Manufacture of furniture 32 Other manufacturing excluding 32.5 Manufacture of medical and dental instruments and supplies</p>	<p>Measured as a dummy: 1 indicates that the firm relates to this category and 0 indicates that it does not.</p> <p>High-tech manufacturing serves as a reference category. In other words, the coefficients for 'Low-tech manufacturing' measures how 'Low-tech manufacturing' differs from 'High-tech manufacturing'.</p>
High-tech manufacturing	<p>The following aggregation of the manufacturing industry is based on Eurostat's³⁴ aggregates for high-technology, medium high-technology, medium low-technology and low-technology.</p> <p>This category encapsulates medium high-technology and high-technology manufacturing.</p> <p>These aggregates are based on NACE Rev. 2 codes.</p>	<p>This category contains the following NACE Rev. 2 codes:</p> <p>21 Manufacture of basic pharmaceutical products and pharmaceutical preparations 26 Manufacture of computer, electronic and optical products 30.3 Manufacture of air and spacecraft and related machinery 20 Manufacture of chemicals and chemical products 25.4 Manufacture of weapons and ammunition 27 to 29 Manufacture of electrical equipment, Manufacture of machinery and equipment n.e.c., Manufacture of motor vehicles, trailers and semi-trailers 30 Manufacture of other transport equipment excluding 30.1 Building of ships and boats, and excluding 30.3 Manufacture of air and spacecraft and related machinery 32.5 Manufacture of medical and dental instruments and supplies.</p>	<p>'High-tech manufacturing' serves as a reference category for the other business sector categories</p>

Trade	Contains both retail and wholesale. Based on NACE Rev. 2 codes.	This category contains the following NACE Rev. 2 codes: 44 to 47 Trade.	Measured as a dummy : 1 indicates that the firm relates to this category and 0 indicates that it does not. 'High-tech manufacturing' serves as a reference category. In other words, the coefficients for 'Trade' measures how 'Trade' differs from 'High-tech manufacturing'.
Knowledge Services	Business sectors that delivers knowledge-based services.	This category contains the following NACE Rev. 2 codes: 69 Legal and accounting activities 70.2 Management consultancy activities 71 Architectural and engineering activities; technical testing and analysis 72 Research and development 73 Advertising and market research.	Measured as a dummy : 1 indicates that the firm relates to this category and 0 indicates that it does not. 'High-tech manufacturing' serves as a reference category. In other words, the coefficients for Knowledge services measures how 'Knowledge services' differ from 'High-tech manufacturing'.
Other sectors	Contains the sectors not covered by the other business sector categories.	This category contains the following NACE Rev. 2 codes: 1 to 3 Agriculture, forestry and fishing 6 to 9 Mining and quarrying 35 Electricity, gas, steam and air conditioning supply 36 to 39 Water supply; sewerage, waste management and remediation activities 41 to 43 Construction 49 to 53 Transport 55 to 56 Accommodation and food service activities 58 to 53 Information and communication 64 to 66 Financial and insurance activities (excluded from the analysis) 68 Real estate activities.	Measured as a dummy : 1 indicates that the firm relates to this category and 0 indicates that it does not. 'High-tech manufacturing' serves as a reference category. In other words, the coefficients for 'Other sectors' measures how 'Other sectors' differs from 'High-tech manufacturing'.
Size	Number of Employees measured as full-time equivalents.	The variable is log-transformed .	Measured as LOG(size)
R&D-intensity	The firms' share of R&D personnel.	The share of R&D-personnel in 2008 (measured as full-time equivalents) as a percentage of the firms total number of full-time equivalents in 2008.	Measured as a share from 0 (no R&D intensity) to 1 (full R&D intensity)
Export share	Export as share of total turnover.	Export in 2008 (in 1.000 DKK) divided by total turnover in 2008 (in 1.000 DKK).	Measured as a share from 0 (no export) to 1 (turnover is solely based on export)

¹³ Eurostat (2014): 'Aggregations of manufacturing based on NACE Rev. 2', Eurostat indicators of High-tech industry and knowledge - intensive services, January 2014

¹⁴ Eurostat (2014): 'Aggregations of manufacturing based on NACE Rev. 2', Eurostat indicators of High-tech industry and knowledge - intensive services, January 2014

Solidity	<p>Firms' solidity (assets/equity) compared to the median solidity for firms in the same business sector.</p> <p>This measure takes account of sectorial differences in solidity.</p>	<p>Firms' solidity is measured as their assets in 2008 (in 1.000 DKK) divided by their equity in 2008 (in 1.000 DKK).</p> <p>Sector solidity is measured as the median of firms' solidity within the sector.</p> <p>Solidity is calculated as the firms solidity divided by firms solidity.</p>	<p>Measured at a scale from 0 to infinite.</p> <p>1 indicates that the firms solidity is at level within their business sector</p> <p>Numbers below 1 indicate that firms' solidity are below the level within their business sector.</p> <p>Numbers above 1 indicate that firms' solidity are above the level within their business sector.</p>
Previous growth – Employment	<p>The previous development in the employment level.</p>	<p>The relative change in employment from 2006 to 2008 (measured as full-time equivalents).</p>	<p>0 indicates no change in employment level.</p> <p>Positive values indicate a positive growth rate, while negative values indicate a negative growth rate.</p>
Previous growth – Turnover	<p>The previous development in turnover.</p>	<p>The relative change in turnover from 2006 to 2008 (measured in 1.000 DKK).</p>	<p>0 indicates no change.</p> <p>Positive values indicate a positive growth rate, while negative values indicate a negative growth rate.</p>
Previous growth – productivity	<p>The previous development in productivity.</p>	<p>The relative change in productivity from 2006 to 2008. Productivity is measured as value added (in DKK) pr. full-time equivalents.</p>	<p>0 indicates no change in productivity.</p> <p>Positive values indicate a positive growth rate, while negative values indicate a negative growth rate.</p>
R&D investment strategy	<p>The strategy for R&D investment in light of the economic crisis set out in 2009.</p>	<p>Based on survey responses from 2009 regarding firms' strategy for R&D investments over a 2-year period following the economic crisis.</p>	<p>1 indicates a proactive strategy.</p> <p>0 indicates a reactive strategy.</p>
Proactive strategy – increased R&D	<p>Firms' that followed a proactive strategy following the economic crisis and increased R&D investment in the period.</p>	<p>Firms' that followed a proactive strategy (see R&D investment strategy) and had an unchanged or increased R&D investment level from 2009 to 2011.</p>	<p>Measured as a dummy: 1 indicates that the firm relates to this category and 0 indicates that it does not.</p> <p>'Reactive firms with decreased R&D' serves as a reference category. In other words, the coefficients for 'Proactive strategy – increased R&D' measures how 'Proactive strategy – increased R&D' differs from 'Reactive firms with decreased R&D'.</p>
Proactive strategy – decreased R&D	<p>Firms' that followed a proactive strategy following the economic crisis, but decreased R&D in the period.</p>	<p>Firms' that followed a proactive strategy (see R&D investment strategy) and had a decreased R&D investment level from 2009 to 2011.</p>	<p>Measured as a dummy: 1 indicates that the firm relates to this category and 0 indicates that it does not.</p> <p>'Reactive firms with decreased R&D' serves as a reference category. In other words, the coefficients for 'Proactive strategy – decreased R&D' measures how</p>

			'Proactive strategy – decreased R&D' differs from 'Reactive firms with decreased R&D'.
Reactive strategy – increased R&D	Firms' that followed a reactive strategy following the economic crisis, but increased R&D in the period.	Firms' that followed a reactive strategy (see R&D investment strategy) and had an unchanged or increased R&D investment level from 2009 to 2011.	Measured as a dummy : 1 indicates that the firm relates to this category and 0 indicates that it does not. 'Reactive firms with decreased R&D' serves as a reference category. In other words, the coefficients for 'Reactive strategy – increased R&D' measures how 'Reactive strategy – increased R&D' differs from 'Reactive firms with decreased R&D'.
Reactive strategy – decreased R&D	Firms' that followed a reactive strategy following the economic crisis and decreased R&D in the period.	Firms' that followed a reactive strategy (see R&D investment strategy) and had a decreased R&D investment level from 2009 to 2011.	'Reactive firms with decreased R&D' serves as a reference category for 'Proactive strategy – increased R&D', 'Proactive strategy – decreased R&D' and 'Reactive strategy – increased R&D'.

Method

Using data from the annual surveys of Danish firms' R&D investment level combined with firm level data from Statistics Denmark, this study is based on unique time series data set from 2009 to 2012. The time series data allow us to investigate the R&D activities among Danish firms during the economic crisis and estimate the isolated economic effects of firms' R&D investment strategies using a set of OLS-regressions (Ordinary Least Squares regressions). The methodology to examine firms' intended R&D investment strategy and their realised change in R&D investments uses a logistic regression.

Confounding variables

To ensure the best possible control of third variables it is essential to examine the economic effect of firms' realisation of a proactive R&D investment strategy. We take into account a variety of characteristics of the firms to ensure control for confounding variables, see Table 2 above for a complete list of variables and the construction of these.

Problem with data gaps in time series

For many of the firms, there is no available data for all years in the period. Survey-based registries, such as the FUI-databases, will not have a full overlap in the surveyed firms. Firm level economic data from the FIRM-database will be fully adequate for all years in the period.

Firms closed in the period

During the examined period, some of the firms closed. However, we do not include the missing values in average calculations for economic indicators (e.g. turnover) as this would affect the estimates for the remaining firms negatively.

Time lag effects

Since we analyse effects of R&D investment strategies in the following years, it is important to be aware of potential time lag effects. In relation to potential lag effects, it is especially important to be aware of two particular situations. First, that R&D investment preceding the economic crisis may affect firms' economic performance if the effects of long-term investments are not realised until many years after the development projects started. In other words, a boost in economic performance may be the result of investments preceding the crisis and not the R&D investment strategy itself. However, there is a data shift in the FUI statistics from 2006 to 2007, which makes analysis across this period unreliable. Therefore, we cannot adequately account for previous developments in R&D investments. Second, the effects of corporate crisis strategies may not have occurred yet. If so, it will be difficult to find a significant effect in the short term. Regarding the second problem, we estimate the effects of all available years after the crisis to uncover trends in the possible impact of corporate strategies. This approach will unveil whether the effects appear in the short term but disappear in the long term, or whether the effects grow in the years up to 2013 and are therefore likely to be even stronger in the following years.

Finally, it should be noted that the potential association between strategy and past performance might be a base of bidirectional causality. The strategy may affect the performance, but the economic performance may also affect the choice of strategy.

Outliers

The presence of extreme observations can distort effects and weaken the reliability of the calculation of effects. This particularly applies in cases where extreme observations are caused by typing errors or wrong registration of the firms' data, or mergers, acquisitions, spin-offs etc. To overcome this problem, we follow the procedure in the Danish Agency for Science, Technology and Innovation's study 'Economic effects of industry research collaboration with public knowledge institutions' and exclude firms from the analysis if their values deviate too much from one year to another. A value is considered an outlier to be excluded if a firm's value on an economic performance indicator from one year to another either 1) more than triples the value or 2) drops more than 50 pct.

Annex 2: Key economic figures for four group of firms



Source: Survey data from Danish Technological Institute performed by Jysk Analyse and register data from Statistics Denmark (the re-search and innovation database FUI). N=163.