MSc in Business Administration

Master thesis on topic:

The impact of the financial crisis on innovation activity of public technology companies: evidence from Germany

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Abstract

This thesis aimed to explore the impact impaired by financial crisis 2008-2009 on innovation activities of public technology firms in Germany. Specifically, the analysis focused on the change in R&D intensity due to the crisis with respect to firm-specific characteristics (size and age). The research also investigated the resulting influence of this change on firms' market-based performance. Through the longitudinal observation of a panel of 110 German public companies attributable to technology sector, the analysis rejected the suggestions of both pro-cyclicality in R&D investment and positive relationship between R&D intensity and firm value. The following findings were derived: 1) overall, public technology companies tend to persist their innovation investment in spite of the crisis; 2) younger and smaller firms in general are more R&D intensive that older and larger firms, in particular, smaller firms even increased their R&D intensity during the crisis; 3) there are found to be industrial differences in patterns of R&D investment; 4) market value is found to be negatively associated with R&D investment during the crisis. Limitations of the analysis and perspectives for future research are discussed.

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I. Introduction

1.1. The relevance of the research

Scholars have different opinions regarding the roots of the recent financial crisis 2008-2009 and the recession that followed it. Some possible reasons mentioned in the literature include: the collapse of the "financial bubble" as a part of a bigger structural phenomenon (Perez, 2009), intellectual monopolization of the economy as one of the reasons for the economic shock (Pagano & Rossi, 2009), the evidence of a middle-term business cycle (Alvarez-Ramirez & Rodriguez, 2011), financial innovations in competitieve banking system (Thakor, 2012). Regardless of cause, of major importance is the significant negative effect of the crisis on the global economy (OECD, Guellec et al., 2009).

Surprisingly, there is still a lack of theoretical and empirical research on the impact of the recent financial crisis on the innovation activity of firms (both in terms of investment in innovation and innovation performance). At the aggregated (national) level the investment in innovations tends to be rather cyclical. The literature provides some empirical evidence of this cyclicality from the US (Campello, Graham, & Harvey, 2010, p. 470), European Union (Archibugi & Filippetti, 2011, p. 1153), eight Latin American countries (Paunov, 2012a, p. 24). But at the firm-level there is mixed evidence of both cyclical and counter-cyclical behavior (e.g. Correa & Iootty, 2010; Filippetti & Archibugi, 2011; Laperche, Lefebvre, & Langlet, 2011; Archibugi, Filippetti, & Frenz, 2013). Moreover, the patterns of innovation performance seem to differ from the patterns of innovation investment. For example, in Latin America while the investment decreased significantly, introduced product innovations decreased in average by more than 1% and process innovations increased more than 10% (Paunov, 2012a, p. 26). Several works also analyze the particular strategies firms implement to respond to the crisis (Laperche et al., 2011; Mazzanti, Montresor, Antonioli, Bianchi, & Pini, 2011).

The present analysis aims to fill the existing research gap by providing the empirical evidence from German technology companies and contribute to the stream of research in this field.

The relevance of exploring the interconnection between the financial crisis and the innovation activity of firms naturally arises from the logic of economic development. As suggested by J. Schumpeter in his theory of business cycles (1939), major technological improvements are the drivers for the changes in long economical cycles (Schumpeter, 1939, p. 83). Through a dynamic process of “creative destruction” new technologies replace the old ones, shaping the economic development: “radical” innovations create major disruptive changes, whereas “incremental” innovations continuously advance the process of change (OECD/Eurostat, 2005, p. 30). Hence, innovation activity contributes to economic development and growth. Financial crises, on the other hand are believed to be the integral part of the business cycles (e.g. F. Allen & Gale, 1998, p. 1248). Thus, the impact of the financial crisis on innovation activity represents the feedback loop of innovations’ effects on the business cycle.

1.2. Research question and the structure of the work

The purpose of this thesis research is to investigate the impact impaired by financial crisis 2008-2009 on the innovation activities of public companies within a particular industrial sector (Technology) in Germany. Related literature suggests the existence of sectoral patterns of innovation (e.g. Malerba & Orsenigo, 1997; Pavitt, 1999), thus it is interesting to explore the similarities or dissimilarities in the way firms within one sector respond to the common exogenous shock. To the technology sector the technology-intensive industries as included: telecommunication, communication equipment, semiconductors, electrical engineering, mechanical/industrial engineering etc.[1] Technology sector is of particular interest since the mentioned industries are named to be the most research and innovation intensive in Germany alongside with automotive industry, pharmaceutics and biotechnology (Belitz, Clemens, & Cullmann, 2010, p. 13).

This analysis focuses on public companies, first of all, because of the availability of corporate data. Moreover, public companies are often of larger size and older age, thus the analysis might help to test the predictions of the theories dealing with the size advantage and incumbency in relation to innovation activities (see, for example, (e.g. Chandy & Tellis, 2000; Hill & Rothaermel, 2003). Germany is chosen because it is one of the leading European innovators (Archibugi & Filippetti, 2011, p. 1166).

The **central question** of the analysis is formulated as follows:

How did German public technology companies change the scope of their innovation activity in terms of R&D investment during the crisis 2008-2009?

More specifically, the following research questions needed to be addressed:

[1] Based on the data from http://www.research-in-germany.de/ (last accessed 23.05.2013); http://www.crmz.com/Directory/CountryDES.htm (last accessed 05.08.2013)

1) What was the change in innovation investment before-during-after the crisis?
2) How did those changes influence the firms' financial performance?

The thesis is organized as follows: Chapter II introduces the basic concepts for the analysis, namely: financial crisis, innovation activity and R&D investment. In Chapter III the author develops the theoretical framework for the analysis, exploring the theoretical and empirical evidence of financial crises' impact on firm performance and innovation activity (reflected in R&D investment). Moreover, the author identifies the general patterns of firms' response to the crisis, discuss the possible determinants for such a behavior and formulate the hypotheses for the empirical testing. Chapter IV presents the research design for the empirical study and argues on sampling and data collection procedure. Results of the empirical analysis are introduced in Chapter V. The research concludes with the discussion of results and suggestions for the further analysis in Chapter VI.

II. Background for the research: overview of basic concepts

2.1. Financial crises

2.1.1. Financial crisis: definition, characteristics, taxonomy

The analysis starts with a closer look at the phenomenon of financial crisis. Financial crises are defined as "systemic disturbances to the financial system that impede the system's ability to allocate financial capital and disrupt the economy's capacity to function" (Visano, 2006, p. 3), therefore leading to severe financial and economic distress. The term systemic refer to the collapse of the part or the whole financial structure (Lagunoff & Schreft, 2001, p. 221). The dysfunction is characterized by the unwillingness of investors to provide funding to the financial system (Thakor, 2012, p. 136) either directly or through financial intermediaries (e.g. banks). Sometimes in the literature the term "banking panic" is used as a synonymous to "financial crisis" (e.g. Gorton, 1988, p. 751; F. Allen & Gale, 1998, p. 1245), however, such a terminology emphasizes the focus on banks and other financial intermediaries and neglects the significance of, for example, financial markets in the process. To avoid this misleading interpretation in the current work the term "financial crisis" is used.

Financial crises usually develop as a two-stage process: during the first ("run-up") phase (Brunnermeier & Oehmke, 2012, p. 3) the so-called "bubble" inflates and the imbalances between the asset prices and their real values increase; after the bubble impodes, the stage of actual crisis begins, during which the effects of the bubble's burst spread to the other sectors and markets, often followed by a recession of the whole economy (Franklin Allen & Gale, 2000, p. 236; Kindleberger, 2005, p. 12; Brunnermeier & Oehmke, 2012, pp. 3–4). The term "bubble" defines here the situation of a sustained mispricing of the financial or real asset (usually, real estate or security), when the purchase of the assets are driven not by the expected rate of return on the investment, rather by the anticipation of high profit from the asset's resale due to the constant price increase (Kindleberger, 2005, p. 13; Brunnermeier & Oehmke, 2012, p. 12).

The general model of a financial crisis was described among the first by H. Minsky within the "financial-instability hypothesis" (Minsky, 1982, p. 13)[2]. According to this model, the potential crisis starts with the displacement (an exogenous shock such as technical innovation or change in financial regulation), which is strong enough to

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[2] The model is well-elaborated in (Kindleberger, 2005, pp. 25–33), which the author refers to in the further analysis.

create an optimism among investors and generate the expectations of profit opportunities and economic growth in a particular sector of economy (Kindleberger, 2005, pp. 25–26). This optimism leads to the expansion of the investment and credit and, consequently, to the increase in assets price, which accelerates over time (Brunnermeier & Oehmke, 2012, p. 12). Decoupling of the market prices from the real values of the underlying fundamentals signals the forming of the bubble (Perez, 2009, p. 784; Barnes, 2011, p. 424). A bubble can inflate in such a way over a long period of time - from 15 to 40 months (Kindleberger, 2005, p. 26). With the explosively growing prices for the asset, the number of trading speculations takes off, creating the situation of market euphoria, characterized by high interest rates and speed of payments (Kindleberger, 2005, p. 31; Brunnermeier & Oehmke, 2012, p. 12). Abnormally high profits attract new less sophisticated investors, thus spreading the euphoria to the other markets (also internationally). At this stage more sophisticated investors might get suspicious about the bubble nature of the boom and seek to reduce their positions by selling the assets to the newcomers and take the profits (Brunnermeier & Oehmke, 2012, p. 13). The demand for the asset is heated up by those new investors, however, the scope of the imbalances is too high at this stage, thus even a non-major (in respect to the whole economy) "unusual event" (e.g. failure of a firm or bank) is enough to trigger the burst of the bubble and catalyze the panic (Minsky, 1982, pp. 30–31; Kindleberger, 2005, p. 30). This turning point, a so-called "Minsky moment", changes the expectations of the market agents, first of all the borrowers of the investment capital, and leads to increased rates of returns for the increased risk, inabilities to meet the debt liabilities, defaults and insolvencies of both firms and banks (Kindleberger, 2005, pp. 31–33; Barnes, 2011, p. 424).

An important role in increasing and spreading the effects of the burst is attributed to the "amplification mechanisms", developed as the bubble builds up (Brunnermeier & Oehmke, 2012, pp. 4–5; Brunnermeier, 2009, p. 78). Direct amplification mechanisms (i.e. caused by direct contractual links between the agents) realize through domino effects within a network of interconnected financial institutions (e.g. interbank loans) or in "runs" of capital owners (e.g. massive withdrawing of deposits) (F. Allen & Gale, 1998, p. 1245; Brunnermeier & Oehmke, 2012, p. 5). Although the deposit insurance in modern banking almost liquidates the risk of "bank runs", other financial institutions, like hedge funds, are still vulnerable to them (Brunnermeier, 2009, p. 96). Indirect amplifications (i.e. caused by spillovers and externalities) realize through price mechanisms (Brunnermeier & Oehmke, 2012, p. 5). At the borrower's side, mutually reinforcing "liquidity spirals" ("loss spiral" and "margin/haircut spiral") take place (Brunnermeier, 2009, pp. 92–93). They are caused by investors' capital erosion due to the price drop and simultaneous tightening of lending standards and margins, and lead to fire-sales, pushing down prices and tightening funding even further (Brunnermeier, 2009, p. 78). At the credit side, the worsening financial situation of lenders, caused by the burst, leads to: a) the restriction of lending capital through the reduction of the quality monitoring of borrowers' investment decision ("moral hazard in monitoring"), and b) to the reservation of the funds for the own projects in anticipation of interim shocks ("precautionary hoarding") (Brunnermeier, 2009, p. 95). As many agents in financial system act as borrowers and lenders at same time, this gives rise to the network effects (Brunnermeier & Oehmke, 2012, p. 52). Concerns about the counterparty credit risk (which does not even necessarily exist) lead to the failure of multiple trading parties to cancel out offsetting positions, thus creating a so-called "gridlock" (Brunnermeier, 2009, p. 78). If the bubble formation was financed by credit, the amplification mechanisms are stronger due to the de-leveraging of investors, and turn the bubble's burst into the financial crisis (Brunnermeier & Oehmke, 2012, p. 5).

Although each crisis has its unique features, in the way they develop they tend to follow the above described general pattern (Kindleberger, 2005, p. 33). Some other characteristics that are common in advance of a crisis include: shifts in financial regulation; credit expansion and debt accumulation (Franklin Allen & Gale, 2000, p. 238; Davis, 2003, p. 15); increase in the number of financial innovations (Davis, 2003, p. 15; Perez, 2009, p. 791; Thakor, 2012, p. 144); easing of entry conditions to financial markets and concentration of risk (Davis, 2003, p. 15).

Different typologies are applied for the analysis of financial crises distinguish them according to a variety of grounds, such as: by sector (public, private or corporate); by object of speculation (financial or real assets); or by institutional spheres of finance (banks or financial markets) (Visano, 2006, p. 3). However, there is no dominating taxonomy. One of the approaches is to distinguish between banking crisis, currency crisis and twin crisis (e.g. Kaminsky & Reinhart, 1999, p. 473; Franklin Allen & Gale, 2007a, p. 24). Banking crisis refers to the simultaneous collapse of many banks (or in a broader sense – financial institutions); currency crisis describes the situation of devaluation or revaluation caused by the large volumes of trade in foreign exchange market (Franklin Allen & Gale, 2007a, p. 24). Twin crisis occurs when banking and currency crises happen simultaneously (Franklin Allen & Gale, 2007a, p. 9). From the perspective of decision-making of individual agents, Lagunoff & Schreft (2001) suggest to distinguish between situations, when agents do not foresee the possibility of contagious losses and get involved in "loss spirals" (Brunnermeier, 2009, p. 92) and situations when agents have perfect foresight, and strategically and simultaneously shift to less risky portfolios in anticipation of future losses (Lagunoff & Schreft, 2001, pp. 221–222). A very broad typology, suggested in (Davis, 2003, pp. 5–6), distinguishes between 3 generic types of financial instability: 1) bank failures; 2) market-price based; 3) market-liquidity based. Bank failures refer to the defaults of financial credit institutions due to the loan or trading losses, which lead to drying up of lending capital and wider economic disruption. Domestic and international facets are distinguished here. Market-based crises refer to the extreme volatility in market price due to the shift in expectations among the market agents; characterized by involvement of institutional investors as principals and their "herding" behavior. Market-liquidity crises are identified as "protracted collapses of market liquidity and issuance"; more typical for debt and derivative markets rather than equity of foreign exchange (Davis, 2003, pp. 5–6).

2.1.2. Origins of financial crises

One of the most intrguing questions about the phenomenon of crisis is what causes them. Minsky, the author of the general model of crisis described above, suggested that the internal mechanisms of "capitalist economy", reflected in the pro-cyclical supply of credit and speculative financing, generate the environment "conductive to instability" (Minsky, 1982, p. 36) and increase the likelihood of financial crisis, thus emphasizing the inherent fragility of the market economy itself (Lagunoff & Schreft, 2001, p. 221; Barnes, 2011, p. 426). Later works aimed to explore the nature of this fragility more systematically and explain the occurrence of crises. The literature provides three groups of theories, suggesting the following sources of financial crises (Gorton, 1988, pp. 223–224; Franklin Allen & Gale, 2007a, p. 20; Thakor, 2012):

1. Crises arise from panics that could be unrelated to fundamentals in real economy and are random events (Kindleberger, 1978, p. 14; Diamond & Dybvig, 1983, p. 416);
2. Crises arise from shocks to economic fundamentals and are systematic events (Gorton, 1988, p. 248; F. Allen & Gale, 1998, p. 1249);
3. Crises take place due to the interconnectedness of agents and the complexity of the financial system (Leitner, 2005, p. 2925; Caballero & Simsek, 2009, p. 1).

According to the first view, the crises occur as a result of the financial "mania" that have an episodic nature and don't explain the whole business cycle, rather *describe* (own emphasis) the turning point from "final upswing to initial downturn" (Kindleberger, 1978, p. 14). "Mania" is a typical situation of a bubble's inflation and is defined as a "frenzied pattern of purchases" (Kindleberger, 2005, p. 13), when investors thrust to buy the asset before the price increase further. The use of the term "mania" also emphasizes the irrationality of the investors' behavior, resulting from the "mob psychology" when most or all of the market participants change their view at the same time and move as a "herd" (Kindleberger, 1978, p. 28). Irrationality, thus, leads to the system's collapse: trigger event (as described in the general model) starts the panic, which then feeds on itself until the prices become low enough to attract investors again or until the policy regulation influences the situation (Kindleberger, 2005, p. 33). This view was developed by the multi-equilibrium model in (Diamond & Dybvig, 1983), where the panic is a self-fulfilling process, which occurs if all the participants anticipate (based on some exogenous event) the decrease in the value of their assets and try to withdraw their funds (or sell assets). However, if there is no common expectation of value decrease, only those who actually need the funds will withdraw them, hence, no panic will start (Franklin Allen & Gale, 2007a, p. 6). The model is random, because the exogenous event forming the expectations can be anything – "a bad earnings report, a commonly observed run at some other bank, a negative government forecast, or even sunspots" (Diamond & Dybvig, 1983, p. 410). Moreover, the authors argue that the panic can start even without a displacement (like risky technology or currency), described in the general model (Diamond & Dybvig, 1983, p. 416).

The alternative view in turn suggests the systematic component in crises origin and argues that crises arise in response to the "unfolding economic circumstances" and, hence, are integral part of the business cycle (F. Allen & Gale, 1998, p. 1248). According to Gorton (1988), panics (and subsequent crises) result from the changes in perceived risks estimated on the basis of prior information (Gorton, 1988, p. 248). Due to the information asymmetry between the market agents (e.g. banks and depositors), to assess their risks agents have to use some kind of aggregate information (Gorton, 1988, p. 224). Such aggregate information might be presented, for example, by the seasonal changes in short-term interest rates ("Seasonal Hypothesis"), unexpected capital losses due to the failure of a large financial institution ("Failure Hypothesis") or liabilities of failed nonfinancial business, signaling about the downturn phase of the business cycle ("Recession Hypothesis") (Gorton, 1988, p. 231). As empirically tested in (Gorton, 1988), the panics are systematic events, caused by the "consumption smoothing behavior on the part of cash-in-advance constrained agents", thus linked to the business cycle (Gorton, 1988, p. 248). In other words, when the market participants have reasons to believe that economic fundamentals soon are likely to loose their values due to the recession or depression (aggregate information), they will try to secure their positions by selling the stocks at the financial market or withdrawing their deposits from the banks (change in the perceived risk) (Franklin Allen & Gale, 2007a, p. 58). Mass sales at the stock markets lead to the sharp fall in price; bank "runs" threaten banks with insolvency. The resulting panic is similar to the "mania" view, however, the cause is principally different (Franklin Allen & Gale, 2007b, p. 6).

The most modern view takes into account the network perspective of financial systems and focuses on the interconnectedeness of agents and the inherent complexity of the system as the main source of crises. Due to the holding of diversified portfolios, financial positions of market agents are linked to each other in a way that return on an agent's portfolio depends on the portfolio allocations of other agents (Lagunoff & Schreft, 2001, p. 201). An initial shock to fundamentals in one sector or "region" (F. Allen & Gale, 2000, p. 2) of financial system generate losses to the individual portfolios of the agents of this particular sector, but due to the overlapping claims with the other agents, the losses spread across the network and become a "contagion" (F. Allen & Gale, 2000, p. 2; Lagunoff & Schreft, 2001, p. 250). The interconnectedness, however, not only generates fragility of the financial system, but also provides more sustainable agents with the opportunities to "bail out" their less lucky partners through the mutual insurance, even though the latter can not "pre-commit to making payments" (Leitner, 2005, p. 2925). The contagion view was developed by Simsek & Caballero (2009) who focus on the decision-making process of the financial institutions (Simsek & Caballero, 2009, p. 2). While in the usual situation it is enough for agents to collect the information only about their direct partners, when the shock hit some part of the network, to reduce the counterparty risk agents also have to increase their efforts, as well as the costs of information collection (Simsek & Caballero, 2009, pp. 1–2). Since agents have to understand more interlinkages, the complexity of the environments increases. With complexity rises perceived uncertainty, making even healthy agents pull back in order to protect themselves from the contagion cascade. This results in the erosion of market liquidity and exacerbates the financial crisis (Caballero & Simsek, 2009, p. 2). The last view focuses more on the reasons for the crisis development from panic, assuming the initial shock is already introduced to the system. However, the nature of the initial shock is less emphasized in those models.

2.1.3. Financial crisis 2007-2009[3]: overview and theoretical explication

The recent financial cirsis, originated in the U.S. and spread globaly, provided scholars with an outstanding opportunity to test the predictions of theoretical models. Before the author turns to the opinions, supporting the views described above, it is useful to trace the brief chronology of the turmoil.

From the late 90s, the U.S. and most other countries in the developed world experienced almost a decade of low interest rates (Perez, 2009, p. 796; Barnes, 2011, p. 425). Availability of cheap loans encouraged both individuals and firms to borrow freely. This also stimulated financial institutions sell off their existing mortgages to others, the process known as "securitisation" (Barnes, 2011, p. 425). Starting from the end of 2006, there appeared official statements from the world leading financial institutions (e.g. European Cenral Bank, HSBC), claiming the instability of the sub-prime mortgage market and world financial markets in general due to the overflood of financial derivatives (Dolmetsch, 2008; ECB, 2013). The trigger for the liquidity crisis was an increase in subprime mortgage defaults in the U.S., which was first noted in February 2007 (Brunnermeier, 2009, p. 82). During the summer of 2007 U.S. market experienced a full-scale crisis in the confidence of investors holding securitized mortgages, which lead to the collapse of the inter-bank lending. Banks became reluctant to lend because of the high risks of losses on subprime-related securities and their derivatives. Due to the globalization of inter-bank lending the liquidity crisis spread to other financial institutions in other countries (Barnes, 2011, p. 425). In September, 2008 heavily exposed to the sub-prime mortgage market American investment bank Lehman Brothers filed for bankruptcy, prompting worldwide financial panic (Kingsley, 2012). Despite the government-backed significant cash injections, the lack of liquidity, caused by mistrust among banks, had spread from loans into commodities, bonds, and equity markets (Chorafas, 2009, p. 260; Dolmetsch, 2008). *"On 18 October 2008 India's Sensex had fallen by 48.1 percent; Hong Kong's Hang Seng, 46.8 percent; Japan's Nikkei, 45.9 percent; Germany's Dax, 43.7 percent; France's CAC 40, 43.5 percent; and Britain's FTSE 100, 39.1 percent. Russia's equity index had beaten all others, falling by nearly 70 percent"* (Chorafas, 2009, p. 260). From the end of 2008 the G20 countries started to develop coordinated policy response to the spreading crisis, resulting in the stimulus package worth $5 tn introduced in April, 2009. In line with the

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[3] The time frame 2007-2009 refers to the U.S. chronology. In the following chapters the author refers to this crisis as "financial crisis 2008-2009", indicating that it fully spread to Europe with the start of the panic in the second half of 2008.

government fiscal expansion central banks gradually cut the interest rates (Kingsley, 2012; ECB, 2013). As a response to government intervention, the economy showed some expansion, which led International Monetary Fund to declare the start of recovery from the crisis (IMF, 2009, p. 1). However, by spring 2010 Greece officially claimed the need in the financial support, which signaled the start of Eurozone crisis and threw the crisis from the private sphere to public with a major issue of sovereign insolvency (Shambaugh, 2012, p. 157).

Scholars express different opinions regarding the financial crisis 2007-2009, providing support for each of the theoretical view presented in previous section. Some authors interpret the recent crisis as prove for a typical “bubble” and a following panic, unrelated to the economic fundamentals: *”…the bubble was brought about by excessive borrowing which led to the fragility of the financial system in which speculative and Ponzi financial structures, at both the individual and firm level, could not be sustained”* (Barnes, 2011, p. 431). Barnes (2011) also emphisizes the important role of the accounting information in the development of the panic, because understated provisions for bad and doubtful debts forced the misleading investment decisions (Barnes, 2011, p. 432).

Other works provide support to the business cycle view, proving that the initial U.S. subprime crisis had its origin in the “shock to fundamentals”, which led to the credit crisis, panic and recession in line with the general model of financial crisis (Gorton, 2009, p. 567). Perez (2009) connects the recent financial crisis (“easy-liquidity bubble”) with the precedent internet mania and crash of the 1990s (“major technology bubble”), arguing that those two episodes are structurally related and are endogenous to the way the technological revolutions develop (Perez, 2009, p. 779-780). Moreover, the empirical study of U.S. stock market dynamics found the evidence that financial crisis 2007-2009 coincides with the occurrence of a 22-year cycle in the Dow Jones index, also suggesting the connection with the long-term business cycles (Alvarez-Ramirez & Rodriguez, 2011, p. 1332).

Finally, in line with the financial interconnectedness view, Brunnermeier (2009) notes that although financial crisis 2007-2009 in its development has been very similar to a classical banking crisis, its distinctive features refer to the large extent of securitization, “which led to an opaque web of interconnected obligations" (Brunnermeier, 2009, p. 98).

The discussion about the origins of the recent financial crisis is ongoing and is undoubtedly important because of the significant damage crises impair on the real economy (Franklin Allen & Gale, 2007b, p. 9). The further analysis is therefore dedicated to the exploration of the impact of financial crisis on the economy from the perspective of innovations.

To sum up, Section 2.1. introduced the concept of financial crisis, provided the overview of the financial crisis 2008-2009 and briefly discussed its theoretical explications. The following section focuses on the other essential component for this analysis, namely: innovation activity reflected in R&D investment.

2.2. From innovation activity to R&D investment

2.2.1. R&D investment: Defining the terms

This section defines the concept of innovation activity and concentrates on R&D investment as a measure for it. According to the terminology, adopted by OECD, "innovation activities include all scientific, technological, organisational, financial and commercial steps which actually lead, or are intended to lead, to the implementation of technologically new or improved products and processes" (OECD, 2002, p. 18; OECD/Eurostat, 2005, p. 18). Innovation activities, thus, can include a very wide range of proceedings, such as: identification of new concepts for change and improvement; acquisition of technical information, know-how or intellectual property; purchasing or development of relevant skills; reorganization of business systems; introducing new methods of marketing and selling and others (OECD/Eurostat, 2005, p. 36).

An essential, although not exhaustive, part of innovation activity is research and development (R&D). The term is defined as "creative work undertaken on a systematic basis in order to increase the stock of knowledge [...] and the use of this stock of knowledge to devise new applications" (OECD, 2002, p. 30). The scope of R&D covers three types of activities, namely: basic research (experimental or theoretical acquiring of new knowledge "without any particular application or use in view"), applied research ("directed primarily towards a specific practical aim or objective") and experimental development ("systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed") (OECD, 2002, p. 31). In other words, R&D represents the key resource input for the process of creating innovations (Licht & Zoz, 1998, p. 331).

In order to measure the R&D efforts different indicators might be employed. As R&D refers to the process of knowledge creation and application, it is useful to distinguish between input and output measures. Input measures represent all kind of resources invested in the R&D activity, while output measures indicate the subsequent results (OECD, 2002, p. 17). The most common input indicators used in the literature are R&D expenditures and R&D personnel (e.g. Licht & Zoz, 1998, p. 330; OECD, 2002, p. 20; Wang, Lu, Huang, & Lee, 2013, p. 146). R&D expenditures reflect the spending on the research and development activities performed in-house and/or externally, representing the financial capital invested in the innovation activity (OECD, 2002, p. 20; Moncada-Paternò-Castello, Ciupagea, Smith, Tübke, & Tubbs, 2010, p. 523; Wang et al., 2013, p. 146). R&D personnel indicator counts the physical number of employees directly involved in the R&D activities (i.e. researchers, engineers etc.), representing the human capital invested (OECD, 2002, p. 20; Wang et al., 2013, p. 146). Other possible input indicators include facilities available for R&D, such as standardized equipment, laboratory space and facilities, journal subscriptions or standardized computer time. Those are, however, rarely used in the research (OECD, 2002, p. 22). Appropriate measuring of the R&D output is somewhat more challenging task, as the special technical knowledge acquired by the firm and the economical and social effects are not always quantifiable. The indicator of R&D output most commonly used in the literature is patent applications, which represent the protectable (if granted) result of successful research (e.g. Clark, Freeman, & Soete, 1981, p. 309; Licht & Zoz, 1998, p. 303; Wang et al., 2013, p. 145). Apart from patents the output might be measured using bibliometrics, analysis of trade data and technology balance of payments (OECD, 2002, p. 17).

The focus of this analysis is the innovation input represented in the financial capital invested in the R&D. In the literature the terms "R&D investment" and "R&D expenditures" are often used as synonymous (e.g. Moncada-Paternò-Castello et al., 2010, p. 524). However, taking into consideration the strategic importance of R&D efforts in developing and sustaining a competitive advantage for firms, it sounds more appropriate to go for the term "investment" (Ehie & Olibe, 2010, p. 128). Thus, in the further analysis to refer to the financial capital invested in research and development the name "R&D investment" is employed.

2.2.2. R&D investment: characteristics, sources of financing, effective measures

R&D investment differs from the other types of investment in a variety of ways. First of all, this investment is somehow embedded in the human capital of the organization, because in practice more than half of the R&D spending refer to the cost of high-qualified scientist and engineers (B. H. Hall & Lerner, 2010, p. 5). Through the intellectual efforts of those employees the organisation absorbs and creates intangible assets of firm-specific technological knowledge, which enables it to generate future profits (Hashai & Almor, 2008, p. 1023; B. H. Hall & Lerner, 2010, p. 5). However, due to the rather tacit nature of created knowledge, when the employee is gone, the knowledge asset (and consequently, the R&D investment) is lost (B. H. Hall & Lerner, 2010, p. 5). This fact implies the high adjustment costs of R&D investment, making it expensive for the firms to stop such investments (Paunov, 2012b, p. 27).

Secondly, the output of R&D investment is associated with high uncertainty, which is especially high at the early stages of the projects (B. H. Hall & Lerner, 2010, p. 6). This uncertainly gives rise to the issues of, first, sources of funding capital for R&D investment and, second, of its distribution among projects. The latter results in the notion, that the projects with low probablity of success might still be worth financing until their outcomes become more clear, thus R&D management requires rather dynamic framework of real-options than a traditional evaluation of margin profits (B. H. Hall & Lerner, 2010, p. 6; Paunov, 2012b, p. 27). The former referes to the problem of assymetric information about the possible success of the innovation between the idea owner and potential investor. Due to the strategic role of innovations, the disclosure of firm-specific technical knowledge to the marketplace is not desirable by firms in order to protect their ideas from imitation. This make it difficult for the potential investor (e.g. bank) to evaluate the funding project and leads to the obstacles in aquiring of the external financing for long-term highly uncertain R&D investment in comaprison with ordinary (non-innovative) investment (B. H. Hall & Lerner, 2010, p. 9-10).

The above discussion implies the exceptional relevance of internal financing for R&D investment. The major source for internal financing are positive cash flows (i.e. retained earnings); this kind of internal equity financing is especially typical for economies with well-developed financial markets and transparent ownership (such as "Anglo-Saxon") (B. H. Hall & Lerner, 2010, p. 23; Brown & Petersen, 2011, p. 659). Internal financing is particularly important for young firms in high-tech industries who have lower chances to get access to the debt capital due to the information problems, skewed and highly uncertain returns and lack of collateral value (Brown, Fazzari, & Petersen, 2009, p. 152). Alternative source of funding applicable for R&D investment is the external equity financing through the stock markets (i.e. public share issues) (Brown et al., 2009, p. 152). Due to the volatile nature of such funding sources, the exogenous changes in the supply of internal or external equity finance (e.g. financial crisis) should lead to the changes in R&D investment (Brown et al., 2009, p. 152).

Some characteristics of aggregated R&D investment are also worth mentioning. At industry-level the composition of R&D investment is argued to be not homogeneous, but rather follow "technological cycles" (Bhattacharjya, 1996, p. 445). Within those cycles, independent to the exogenous shocks, the periods of a particular focus on long-term oriented “research” activities are changed by the periods of short-term oriented “development” activities (Bhattacharjya, 1996, p. 448).

A common measure employed in empirical research for firm’s R&D investment is R&D intensity calculated as percentage of firm’s revenues expended on research and development (e.g. Lin, Lee, & Hung, 2006, p. 679; L. A. Hall & Bagchi-Sen, 2007, p. 5; Moncada-Paternò-Castello et al., 2010, p. 523). The relevance of this approach is supported by the strong associations of R&D intensity with the measures of innovation output, such as domestic and international patent applications and approvals (L. A. Hall & Bagchi-Sen, 2007, p. 5). However, in this regard it is important to note the existence of the time lag between the actual spending and the product revenue or profit generation (L. A. Hall & Bagchi-Sen, 2007, p. 5; Wang et al., 2013, p. 146). High levels of R&D intensity although not guarantee the generation of successful innovation, nevertheless signal about strategic importance of innovation to the firm (Lin et al., 2006, p. 680). An empirical study in biotechnology industry, for example, found significant relationships between high levels of R&D intensity and high levels of research-based innovation, and between low levels of R&D intensity and high levels of production-based innovation (L. A. Hall & Bagchi-Sen, 2007, p. 12).

Among the factors shaping R&D intensity scholars name size, capacity for rapid growth and a variety of “framework conditions”, such as entrepreneurial culture, IPR regime, high taxation, access to finance and to adequate skills, social security regimes, regulation of labor and capital markets etc. (Moncada-Paternò-Castello et al., 2010, p. 525). At the aggregated level, the research distinguishes between “intrinsic” and “structural” effects, where the former refer to R&D intensity within industries, and the latter concern the sector composition. Interestingly, EU is found to be inferior to the US in the aggregated R&D intensity, which is explained by the differences in the distribution of firms across sectors and company population. Despite its strong specialization in automotive industry EU yields in IT hardware, electronics and software. Moreover, in EU a relatively small number of companies perform larger volumes of R&D; while in the US and in Japan the levels of R&D intensity are distributed more broadly across many companies. (Moncada-Paternò-Castello et al., 2010, p. 524).

2.2.3. R&D investment and firm performance

Concluding the discussion of R&D investment as a measure for innovation activities, it is useful to trace the link between investment in research and development and the overall functioning of firms. The literature suggests the positive impact of R&D investment on firms' financial performance (e.g. Griliches, 1986, p. 23; Ehie & Olibe, 2010, p. 128; Wang et al., 2013, p. 145). The general line of argumentation is as follows: substantial investment in R&D is perceived as a risky strategy, therefore it is associated with higher returns and, consequentially, is more attractive for the shareholders in anticipation of better financial performance (Ehie & Olibe, 2010, p. 128). Three distinct streams of research focus on the following perspectives: 1) direct impact of R&D output (i.e. patents) on firm-level performance; 2) the overall impact of R&D activities (both input and output) on firms' productivity and growth; and 3) the contribution of the R&D investment to the market value of the firm (Toivanen, Stoneman, & Bosworth, 2002, p. 39; Wang et al., 2013, p. 145). The overview of related studies and major results are presented in (Wang et al., 2013, pp. 145–146).

The further discussion and empirical testing focuses on the latter perspective, analyzing the impact of R&D investment on market-based valuation of firms. Market value of assets is argued to be a useful approach in the assessment of private returns to innovation, since the latter, expressed in R&D investment, represent the intangible assets of the firms and, hence, are included in the bundle of total assets the firm possesses. Assuming that financial market correctly price the firm's assets (which is fair for EU and the U.S.), it is, hence, possible to derive the marginal value of intangible asset (innovation input) from the total firm value perceived by market (B. H. Hall, 1999, p. 4).

A commonly accepted measure of market-based firm performance in the empirical literature on R&D investment is Tobin's Q (e.g. B. H. Hall, 1999, p. 6; Toivanen et al., 2002, p. 40; Lin et al., 2006, p. 682). It is calculated as the ratio of market value of assets to their book value and indicates the replacement cost of firms' assets (Lev & Sougiannis, 1996, p. 109). Tobin's Q, therefore, reflects the market expectations of less quantifiable dimensions of performance, such as the portion of intangible capital, to which R&D investment contributes to (Lin et al., 2006, p. 682). By doing so, it allows to capture both short-term performance and long-term perspectives, which are necessary to consider due to the long-term nature of innovation investment (Lin et al., 2006, p. 682; Uotila, Maula, Keil, & Zahra, 2009, p. 247).

Empirical studies in general find significant positive relationship between R&D investment and market value (e.g. Ehie & Olibe, 2010, p. 132). The U.S. data for manufacturing firms shows that R&D investment is capitalized in the market value at high rates (centered at 5-6), moreover, this relationships differ among industries (B. H.

Hall, 1999, p. 10). The evidence from the UK for the period 1989-1995 also suggests that market positively values R&D investment, although this valuation doesn't't' show any consistent trend over time and varies in coefficients from 2,5 to 5 (Toivanen et al., 2002, p. 58). Surprisingly, the panel study of US technology firms for the period between 1985-1999 hasn't found the significant relationship between R&D intensity and Tobin's Q (Lin et al., 2006, p. 683). As a possible explanation for that the authors emphasized the important role of commercialization efforts, which together with R&D contribute to the value creation (Lin et al., 2006, p. 684).

However, the research of the R&D investment-market value link in the specific situation of unfavorable economic environment is rather rare. Thus, the empirical testing of this thesis might contribute to the better understanding of this relationship.

To sum up, Section 2.2. defined the term of innovation activity and the related concept of R&D investment, providing the theoretical outlook of its characteristics, measures and links to the firm performance. The following chapter aims to explore the interconnection of two discussed phenomena – financial crises and innovation activity reflected in R&D investment – and develops the theoretical framework for the further analysis.

III. Theoretical framework: Crisis and innovation

3.1. Major effects of financial crises on firm performance and economic growth

From now on the author moves to the main focus of the study, namely: the impact impaired by financial crises on firms' performance with a special focus on their innovation activity.

Financial markets and intermediaries function to facilitate the investment made by firms, thus promoting economic growth. Hence, financial turmoil has a negative impact on the firm performance, especially on those firms heavily dependent on debt capital (Kroszner, Laeven, & Klingebiel, 2007, p. 188). Major negative effects related to the financial collapse include: credit constraints, lack of liquidity, stock under pricing, drop in demand, suboptimal allocation of investment and, consequentially, the slowdown of economic growth.

First of all, financial shock either blocks completely or at least significantly hinders the access of firms to "credit channel" (Akbar, Rehman, & Ormrod, 2013, p. 68; Kroszner et al., 2007, p. 190). Increased real (or perceived) shortage of capital for lenders leads to unwillingness of capital owners to finance even healthy firms. The increased uncertainty about the riskiness of debt capital contributes to this reluctance (Kroszner et al., 2007, p. 190). In particular, high-risk firms and firms with low share of tangible assets are likely to be more sensitive to bank capital shocks (Popov & Udell, 2012, p. 160). Credit constraints refer to credit rationing in the capital markets (limited credit availability), higher cost of borrowing, difficulties in initiating or renewing a credit line (Campello et al., 2010, p. 471).

Credit constraints lead to the significant reducing of the costs. According to the survey of 1050 companies by the end of 2008, "the average constrained firm in the U.S. planned to dramatically reduce employment (by 11%), technology spending (by 22%), capital investment (by 9%), marketing expenditures (by 33%), and dividend payments (by 14%) in 2009" (Campello et al., 2010, p. 471). Decrease in employment, especialy on a permanent basis, was also noticed, for example, for Eastern Europe (Ramalho, Rodríguez-Meza, & Yang, 2009, p. 5). Other evidence of the credit constraints concerns the burn of cash and cutting of dividends (Campello et al., 2010, p. 486). Credit contrains (drastic decrease in new loans) also found to accelerate the withdrawal of funds from the outstanding credit lines caused by the anticipated restriction of access to them in the near future (Campello et al., 2010, p. 486; Popov & Udell, 2012, p. 159).

This is found to be true for firms with fewer internal funds, although such withdrwals imposed higher costs (Campello, Giambona, Graham, & Harvey, 2011, p. 1947). To hedge themselves from the negative impact of credit constraints, private firms tend to hold cash and issue equity (Akbar et al., 2013, p. 68).

The other important negative effect of financial crisis reveals itself on the downstream side of the firm performance in the significant drop in demand for products and services and, consequently, decrease in sales (Ramalho et al., 2009, p. 2). According to the survey among 1700 firms in Eastern Europe, more than 70% of the firms of both production and service industries declared the sharp demand decrease (Ramalho et al., 2009, p. 2).

Reduction of funds influence the amount of capital available for investment. Firms have to cancel interesting and valuable investment or extend the investment plans ex post, which affects firms' growth (Campello et al., 2010, p. 486; Fernández, González, & Suárez, 2013, p. 2419; Gaiotti, 2013, p. 226). The inability to borrow forces firms to search for other sources of financing. Possible alternatives include internally generated cash flows, cash reserves or asset sales (Campello et al., 2010, p. 472; Borisova & Brown, 2013, p. 171). However, those measures are not always optimal. For instance, fire sales of assets by the equity funds, who early had impared losses from the investment in financial sectors are found to cause significant underpricing of real stock (Hau & Lai, 2013, p. 393). Such a mispricing was found to have a significant negative effect on both investment and employment.

The negative impact of crisis realizes not only in difficulties in access to investment capital, but also in the composition of investments. Credit constraints contribute to the “the asset allocation effect”, decreasing the share of investment in intangible assets in favor of investment with high returns (Fernández et al., 2013, p. 2431). Moreover, the increased anticipated risk of liquidity shock due to the crisis, reduces the firms’ willingness to engage in long-term investment (Aghion, Angeletos, Banerjee, & Manova, 2010, p. 247).

Through the reduction of credit supply, decrease in intangible assets intensity and contracting share of long-term investment financial crises hinders economic growth and imposes higher volatility. (Aghion et al., 2010, p. 247; Fernández et al., 2013, p. 2420). Those negative effects were found to be more significant in countries “whose more financially developed system and better protection of property rights promote greater growth during normal periods” (Fernández et al., 2013, p. 2431).

3.2. Firms' response to the financial crisis: pro-cyclical versus counter-cyclical behavior in innovation investment

In response to the unfavorable economic environment firms have two major options: either to behave pro-cyclical (to cut costs, reduce and rationalize investment, including innovation spending) or to stand up against the stream and to remain or even increase the innovation activity, thus behaving counter-cyclical (Filippetti & Archibugi, 2011). The latter is explained by two opposite mechanisms, namely: creative accumulation and creative destruction (Archibugi et al., 2013a, p. 303). Creative accumulation refers to the process of continuous innovation on a regular basis of the firms following the chosen technological trajectories and experiencing the path-dependency (Nelson, 1982; Pavitt, 1999). Scholars argue that only few firms are able to perform persistency in innovations (Geroski, Van Reenen, & Walters, 1997, p. 97), however, such cumulative patterns are found to be greater "in those firms that (a) devote a substantial budget to R&D and innovation, (b) concentrate on product innovations, and (c) are large in terms of their size" (Archibugi et al., 2013; p. 304). The other mechanism is a Schumpeterian creative destruction that refers to the emergence of new innovators ('entrepreneurs') that might not be active before the crisis and who want to take advantage of the crisis turmoil and to contest the market shares of incumbent firms or to launch fresh markets (Francois & Lloyd-Ellis, 2003; Archibugi et al., 2013).

In general, R&D investment (and other long-term investment) tends to be rather pro-cyclical and decline during the recessions, which is especially notable for the firms facing tight credit constraints (Guellec et al., 2009, p. 6; Aghion, Askenazy, Berman, Cette, & Eymard, 2012, p. 1001). The reason for pro-cycliality is that R&D investment is financed mainly from the cash flows (as discussed in Section 2.2.2), which contracts in the downturns due to the shrinking demand (Guellec et al., 2009, p. 6; Paunov, 2012a, p. 27). Moreover, credit constrains typical for financial crises makes it difficult to get access to the external funding and, thus, also contributes to the decrease in R&D spending (Paunov, 2012a, p. 27). The dependence of R&D investment on financial constraints is found to be true also for the equity financing (i.e. issuing new stocks) (Brown, Martinsson, & Petersen, 2012, p. 1527). However the evidence from the recent crisis provides mixed support for both cyclical and counter-cyclical patterns. For example, the survey of 500 multinational firms in the world, conducted by McKinsey, indicates that 34% planned to spend less on R&D in 2009 while 21% planned instead to increase spending (Guellec et al., 2009, p. 6). In turn, according to the EU-wide study by Archibugi & Filippetti (2011) 65% of firms declared to have kept their innovation investment unchanged in spite of the crisis (Archibugi & Filippetti, 2011, p. 1157).

In order to be consistent with the general theoretical predictions, for the present empirical analysis the pro-cyclical hypothesis of R&D investment is formulated as follows:

H1: Public technology firms show a decrease in innovation investment during the crisis period in comparison to pre-crisis.

In line with the body of empirical research on R&D investment (as described in Section 2.2.2), for the testing of this and the following hypotheses we will employ R&D intensity as a measure of innovation investment.

Firms' motivation to follow cyclical or counter-cyclical behavior is determined by number of factors. Firm-specific factors influencing the firms' decision to invest in innovation regardless of the business cycle include: strategic orientation towards innovation – especially following the exploration strategy, learning capabilities, existence of in-house R&D facilities, network embeddings. Among industry-specific determinants scholars name path dependent nature of the technology, technological accumulation, dynamics of the demand and profit opportunities. Moreover, some influential characteristics of institutional settings, such as national systems of innovation play thier role (see Filippetti & Archibugi, (2011), Paunov, (2012), Archibugi et al., (2013)).

A distinct stream of research discusses the significance of size and age in R&D investment decisions during the economic downturn. There is some empirical evidence that younger and smaller firms were more affected by the financial constraints (Borisova & Brown, 2013, p. 171). Some recent studies of the crisis 2008-2009 provide the support that larger and older firms are less vulnerable in terms of innovation spending than the younger and smaller ones (Correa & Iootty, 2010, p. 20; Paunov, 2012, p. 32). In line with those findings the pro-cyclical hypothesis for R&D investment distinguishes between size and age of the firms as follows

H2a: Larger firms show a less significant decrease than smaller firms.

H2b: Younger firms show more significant decrease, than older firms.

As already mentioned, industry-specific factors might influence the cyclical or counter-cyclical behavior of firms (Archibugi, Filippetti, & Frenz, 2013b, p. 2). One of the reasons for within-industry similarities is empirically supported in (Malerba & Orsenigo, 1996, p. 470). By means of patent analysis across 49 technological classes the authors argue that there exist patterns of innovation activities, which differ among each other, but are systematically similar across countries for each class (Malerba & Orsenigo, 1996, p. 451). Although those findings are proved to be true for innovation output, it is interesting to explore whether the same logic is applicable to the innovation input (i.e. R&D investment). When extending this proposition to the situation of crisis, the following hypothesis is stated:

H3: The investment patterns during the crisis differ among industries.

Finally, it is useful to briefly discuss the impact of the crisis on the relationship between R&D investment and firm's market-based performance. Some empirical studies exploring the impact of the economic disturbances on R&D intensity-market value link showed the persistence of the positive relation although with lower influence in face of the crisis (Ehie & Olibe, 2010, p. 133). This evidence suggests that the market positively perceives the R&D efforts both in normal economic environment and in face of crisis. Guided with those findings and the previously discussed positive contribution of R&D investment to the firm's value (see Section 2.2.3), the positive relationship between them is anticipated with respect to the financial crisis. In line with the empirical literature on the R&D investment - firm financial performance link (see Section 2.2.3) Tobin's Q is chosen as a measure of market-based financial performance. The resulting hypothesis is developed as follows:

H4: Firms that increased their innovation investment during the crisis showed better financial performance (higher Q) compared to firms, that didn't change their innovation investment.

Thus, Chapter III outlined the theoretical framework for the empirical analysis by exploring the interactions among financial crises, firms' performance and their innovation activity. The following chapter presents the empirical framework of the research, arguing on the data and method for the analysis.

IV. Empirical analysis: Data and Method

4.1. Research design: panel study

The main purpose of this analysis is to explore the patterns of investment in R&D in response to the financial crisis 2008-2009 and compare them with pre-crisis and post-crisis behavior. With a special focus on firm-specific characteristic (size, age etc.) the author investigates the R&D spending across a panel of German public companies (AGs: Die Aktiongesellsschaften), operating in technology sector. Taking into account that financial crisis is not a single event, rather a developing process (as described in Chapter 1.1) the analysis aims to explore its impact on corporate innovation spending over a period time by employing the methods of longitudinal analysis (Menard, 2008, p. 3; Rindfleisch, Malter, Ganesan, & Moorman, 2008, p. 34). Longitudinal research design allows the measurement of change in phenomenon, and moreover it allows controlling for individual unobserved heterogeneity (Brüderl, 2005, p. 2; Menard, 2008, p. 3). This also differs this analysis from similar studies, that use cross-sectional approach (Paunov, 2012a; Archibugi et al., 2013a).

As in some similar research on the impact of recent financial crisis on innovation investment (Archibugi et al., 2013a, p. 306, e.g. 2013b, p. 4), the author starts the observation from 2006, referring to 2006-2007 as a pre-crisis period, and carry the investigation until 2012 in order to make use of the natural point of time the analysis is conducted. Following the timeline of the financial crisis (as described in Section 1.3.), the timeframe 2008-2009 refers to the actual period of crisis. Finally, the period from 2010 to 2012 refers to the post crisis period. The argument supporting this time frame is the notion by IMF in the late 2009 (IMF, 2009, p. 1), when the global economy showed some recovery from initial financial shock. However, as it further transformed in what is often called “Eurozone crisis” (e.g. The Economist, 2013; The Guardian, 2010), it would be more accurate to call this period a recession, following the 2008-2009 financial turmoil. The division of the time frame into the proposed also finds some support when looking at the macro economical indicator of real GDP growth[4] in Germany over the past 10 years (Figure 1). Until 2006 there is an increase in growth, slight decrease in 2007, then a significant drop in 2008-2009, followed by a sharp increase in 2010 (partial economic recovery) and a steady decrease up to 2013

[4] “Gross domestic product (GDP) is a measure of the economic activity, defined as the value of all goods and services produced less the value of any goods or services used in their creation. <…> For measuring the growth rate of GDP in terms of volumes, the GDP at current prices are valued in the prices of the previous year and the thus computed volume changes are imposed on the level of a reference year” (Eurostat, 2013).

(recession). To sum it up, the current analysis is designed as a longitudinal retrospective panel study with a time frame 2006-2012 (*T=7)* (Menard, 2008, p. 6).

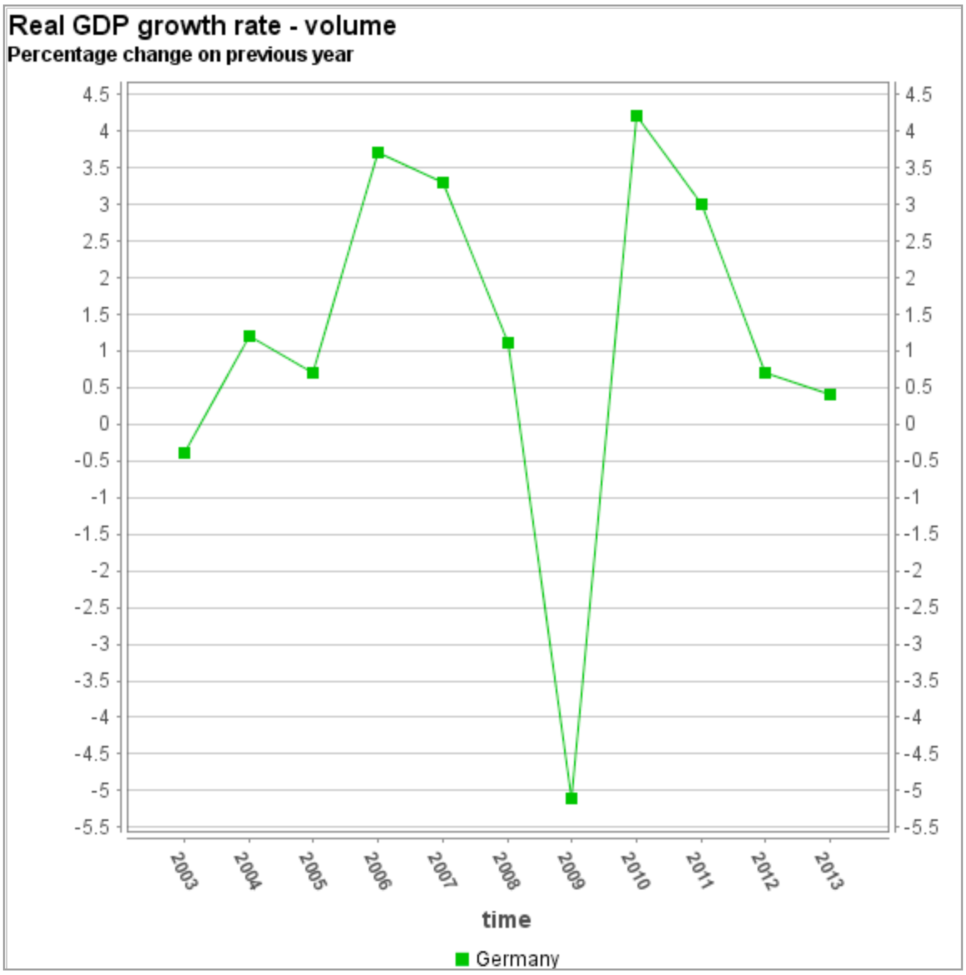

Figure 1. The real GDP growth in Germany for the period 2003-2013 *(Eurostat, 2013)*[5].

4.1.1. Sample

In order to define the panel for the study the purposive non-probability sampling approach was used (Babbie, 1998). This decision was made as the author seeked to explore all the available organizations of a particular type (public companies) in a particular industrial sector (Technology). The further adjustments to the size of chosen sample were driven by the previous research (e.g. extending the range of industries) and availability of data.

Preliminary population for the research consisted of 297 German public companies, mentioned in the Technology sector according to Worldwide Directory of Public Companies published by *Credit Risk Monitor*[6]. After a closer look at those

[5] ***http://epp.eurostat.ec.europa.eu/tgm/graph.do?tab=graph&plugin=1&language=en&pcode=tec00115&toolbox=typ*** (extracted on 05.08.2013)
[6] http://www.crmz.com/Directory/CountryDES.htm (last accessed on 05.08.2013)

companies, the ones representing Computer Services and Software & Programming were excluded from the sample, because they can hardly be further traced based on their innovation output[7]. Further, comparing the Worldwide Directory of Public Companies with a similar database[8], it was noticed that the companies corresponding with Mechanical Engineering industry, are mentioned in Capital Goods sector instead of Technology. Those 63 companies were also added to the sample. Next, considering the innovation intensity of ICT sector, 17 telecommunication companies (originally classified in Service sector) were added. Thus, the preliminary sample for the research counts 207 companies as illustrated in Table 1.

Table 1. Description of the preliminary sample based on the Credit Risk Monitor database.

Sector	*Industry*	*Number of Companies*	*Availability for Analysis*
	Communication Equipment	23	
	Computer Hardware	5	
	Computer Networks	6	
	Computer Peripheries	9	
	Computer Services	44	-
Technology	Computer Storage Devices	3	
	Electronic Instruments & Controls	27	
	Office Equipment	4	
	Scientific &Technical Instruments	13	
	Semiconductors	37	
	Software & Programming	121	-
Capital Goods	Misc. Capital Goods	63	
Services	Communication Services	17	
Total		372	207

Further, the careful investigation of the preliminary sample was undertaken by checking: first, the fact of existance and/or operation of each of 207 companies; second, the presence of financial information available for analysis on the corporate web-site. After this procedure, the panel of 110 companies was identified as follows (Table 2):

[7] The current research project is to be continued with the analysis of the innovation output of the same panel.
[8] http://www.research-in-germany.de/ (last accessed on 23.05.2013)

Table 2. Final panel of firms available for the analysis.

Sector	*Industry*	*Number of Companies*
	Communication Equipment	11
	Computer Hardware	1
	Computer Networks	3
	Computer Peripheries	6
Technology	Computer Storage Devices	1
	Electronic Instruments & Controls	16
	Office Equipment	1
	Scientific &Technical Instruments	10
	Semiconductors	22
Capital Goods	Misc. Capital Goods	30
Services	Communication Services	9
Total		**110**

4.1.2. Data collection

Yearly data was collected from corporate financial documents (annual reports) for the period 2006-2012. The market data (share price), when not reported, was gathered from the Frankfurt stock exchange data repositories[9]. The input data collected directly from reports included: number of employees, R&D expenditures, total revenues (sales), net income (profit), total assets, book common equity, deferred tax, number of common shares outstanding and the end-year price[10]. The data on firms' age was calculated as the difference between the year of foundation (acquired from the web-sites) and the current period of observation (2006, 2007 etc.). The complete set of variables is listed in Table 3.

Since R&D expenditures is the key input variable, it is important to explain more precisely how it was collected. The recognition of R&D expenditures is regulated by International accounting standard (IAS) 38 (intangible assets) (Regulation (EC) No 1126/2008, 2008), according to which the expenditures might be recognized as expenses or as intangible assets[11]: "IAS 38 requires an entity to recognise an intangible asset, whether purchased or self-created (at cost) if, and only if: [IAS 38.21] it is

[9] www.finanzen.net

[10] All the companies in the panel report under IFRS; all monetary amounts were converted into euros.

[11] http://www.iasplus.com/en/standards/ias38

probable that the future economic benefits that are attributable to the asset will flow to the entity; and the cost of the asset can be measured reliably". In case the described recognition criteria are not met, "IAS 38 requires the expenditure on this item to be recognised as an expense when it is incurred. [IAS 38.68]". Moreover, "initial recognition of research and development costs is prescribed as follows: charge all research cost to expense [IAS 38.54]; development costs are capitalised only after technical and commercial feasibility of the asset for sale or use have been established. This means that the entity must intend and be able to complete the intangible asset and either use it or sell it and be able to demonstrate how the asset will generate future economic benefits. [IAS 38.57]". For the purpose of the current research the author considers *the total amount of R&D expenditures* reported, namely: the amount recognized as expenses to the income plus net capitalized development costs for the period. This approach is consistent with the Frascati Manual (OECD, 2002) and some other research on R&D investment (e.g. Moncada-Paternò-Castello et al., 2010, p. 527).

Such a manual data collection is time-consuming, however, it provides higher reliability of results due to the access to the primary source of data, it also allows to use the specific set of indicators customized to the research questions and, moreover, contributes to the data consistency. Alternatives to such a manual data collection might be using the data from existing databases. For example, in case of similar research authors use datasets from Community Innovation Survey (CIS), conducted by Comission (Archibugi et al., 2013a, p. 306) or Innobarometer Survey, organized by European Comission (Archibugi et al., 2013b, p. 4). The limitations of CIS are that it is conducted not on the annual basis (every 2 years), besides the access to it is problematic. Innobarometer is somewhat an aggregated dataset for the whole EU. Due to its ex post nature the analysis has to exploit data obtained from completed survey and, thus, can not select the data in accordance with the research objectives. It would be useful for this analysis to use *Compustat* database[12] because of the standardized financial data ("one-stop-shopping"), unfortunately, there was no access to it.

Finally, the recognized limitations of data collection have to be mentioned. There is a measurement error for 15 companies since they adapt different fiscal years (other than January, 1 – December, 31) in their accounting policy. Out of 112 companies in the sample 9 - report on September, 30; 4 on March, 31; 1 - on June, 30; and 1 - on May, 31. The data on those companies is included in the analysis as follows: fiscal year April,

12 https://www.capitaliq.com/home/what-we-offer/information-you-need/financials-valuation/compustat-financials.aspx (last accessed 27.08.2013)

1 20xx – March, 31 $20xx_{+1}$ refers to the same fiscal year as January, 1 20xx – December, 1 20xx. However, October, 1 20xx- September, 30 $20xx_{+1}$ refers to the fiscal year January, 1 $20xx_{+1}$ – December, 31 $20xx_{+1}$.

4.2. Variables

The major independent variable of interest is R&D investment measured in R&D intensity as the ratio of R&D expenditures to total sales (Hall & Bagchi-Sen, 2007; Ehie & Olibe, 2010). Additionally, R&D expenditures in ablosulte values are observed for the purposes of specific tests. Dependent variable is the Tobin's Q (Bebchuk, Cohen, & Ferrell, 2009), measured as the ratio of market value of assets to their book value (Kaplan & Zingales, 1997), (Gompers, Ishii, & Metrick, 2003), (Bebchuk et al., 2009). The calculation of Tobin's Q components is adapted from the *Compustat* data base items (Gompers et al., 2003), (Standard & Poor's Compustat Services, 2000). As an alternative dependent variable, reflecting the firm performance, the ROA is examined. In line with the hypotheses, the control variables for the testing models are Age (in logs) (Bebchuk et al., 2009), Size expressed in Number of Employees and Total Revenues (both in logs) (Ehie & Olibe, 2010) and Leverage as a proxy for financial risk (Kroszner et al., 2007, p. 221). Moreover, industry incorporation and inclusion into one of the German stock index (DAX, TecDAX or CDAX[13]) is observed (Gompers et al., 2003). In the Table 3 the detailed description of all the variables is provided.

Table 3. Variables and their description.

Variable Name	*Variable Type*	*Construct*	*Description*
Dummies			
ID	Independent		The dummy code created to distinguish the cases (companies).
Sector	Independent		The dummy code created based on the companies' sector classification: 1=Capital Goods, 2= Services, 3= Technology
Industry	Independent	Industry Control	The dummy code created based on the companies' industry classification: 1 - Communications Equipment; 2 - Communications Services; 3 - Computer

[13] DAX (Deutscher Aktienindex) - market index, tracking the price development of the 30 largest and most actively traded German equities; TecDAX – index, reflecting the price development of the 30 largest technology shares in Prime Standard below DAX; CDAX (Composite DAX) - index that reflects the price development of all German shares across Prime Standard and General Standard (Deutsche Börse, 2013).

			Hardware; 4 - Computer Networks; 5 - Computer Peripherals; 6 - Computer Storage Devices; 7 - Electronic Instruments & Controls; 8 Misc. Capital Goods; 9 - Office Equipment; 10 - Scientific & Technical Instruments; 11 Semiconductors
Market Index	Independent	Control	The dummies representing the inclusion of the company into the Market Index (0=CDAX, 1=DAX, 2=TecDAX)
Input data			
Year Founded	Interim		The year of the enterprise foundation; used for the calculating age at each observed period
Number of Employees	Independent	Size control/Model	The size of the company reflected in the average number of employees for the period (in logs).
R&D Expenditures	Independent	Model	R&D Expenditures expressed in absolute values (in thousands EUR) in logs.
Total Revenue	Independent	Size control/Model	The amount of total revenues reported in absolute values (thousands EUR) in logs.
Net Income	Interim		The net income (profit) expressed in absolute values (in thousands EUR)
Total Number of Common Shares	Interim		The amount of the total outstanding shares of common stock.
Share price for Common Stock	Independent	Control	The market price for one share of common stock (end year price at XETRA) in absolute values (EUR).
Total Book Assets	Interim		The amount of company's assets expressed in absolute values (thousands EUR)
Book Common Equity	Interim		The book common equity (shareholder's equity less preferred equity) expressed in absolute values (thousands EUR).
DefferedTax	Interim		Balance sheet deferred taxes expressed in absolute values (thousands EUR).
Computed data			

Age	Independent	Age control/Model	The age of the company in years at each observed period (in logs).
R&D Intensity	Independent	Model	R&D intensity expressed as the ratio of R&D Expenditures to Total Revenues
Leverage	Independent	Control	Financial leverage (Debt-to-Equity) calculated as a ratio of total book assets less common equity to common equity
Book Value of Equity	Interim		Book value of common equity (the sum of Book common equity and deferred taxes) expressed in absolute values (thousands EUR).
Market Capitalization	Interim		The market value of common stock expressed as the market share price times the total amount of shares outstanding (in logs).
Market Assets	Interim		Market value of assets, where market value is a book value of assets plus market value of common stock less the book value of common equity, expressed in absolute values (thousands EUR).
ROA	Dependent	Model	Return on the company assets expressed as the ratio of Net income to total assets.
Q	Dependent	Model	Tobin's Q expressed as a ratio of market value of assets to book value of assets.

4.3. Methodology

To test the hypotheses *H1-H3* the author employs the method of unobtrusive research by descriptive analysis of the available statistics on the panel over the course of *T=7* (Babbie, 1998, p. 322). To test the *H4* regression analysis is implemented.

Table 4 describes the research methods to be implemented to answer the research questions stated in hypotheses above (see Section 3.2.) together with the key measures and sources of data.

Table 4. Summary of the research methods and their links to hypotheses.

Hypothesis	*Method*	*Measures*
H1: public technology firms decrease innovation investment during the crisis. *H2a:* larger firms show less decrease than smaller firms. *H2b:* younger firms show more significant decrease,	Longitudinal panel observation	*Independent variables:* R&D expenses (as absolute value) R&D intensity (as relative to company's revenue for the period) *Control variables*: Age, Size, Industry

than older firms. *H3:* investment patterns differ across industries. *H4:* innovation investment during the crisis positively influences firm performance.	Regression Analysis	*Independent Variables*: R&D Intensity, Change in R&D intensity *Dependent Variables*: Firm performance (expressed as Tobin's Q and ROA)

Thus, Chapter IV introduced the empirical framework for the analysis, argued on research design, data, sample and methods employed. The following chapter presents and discusses the results of the empirical testing over the panel in order to support the hypotheses developed within the theoretical framework.

V. Empirical analysis: Results

5.1. Exploring the data

In the following section the author moves to the empirical analysis of the panel of German technology companies (*n=110, T=7*). For the longitudinal panel analysis Stata software is used with implementation of the insturments of xtset analysis (StataCorp., 2011).

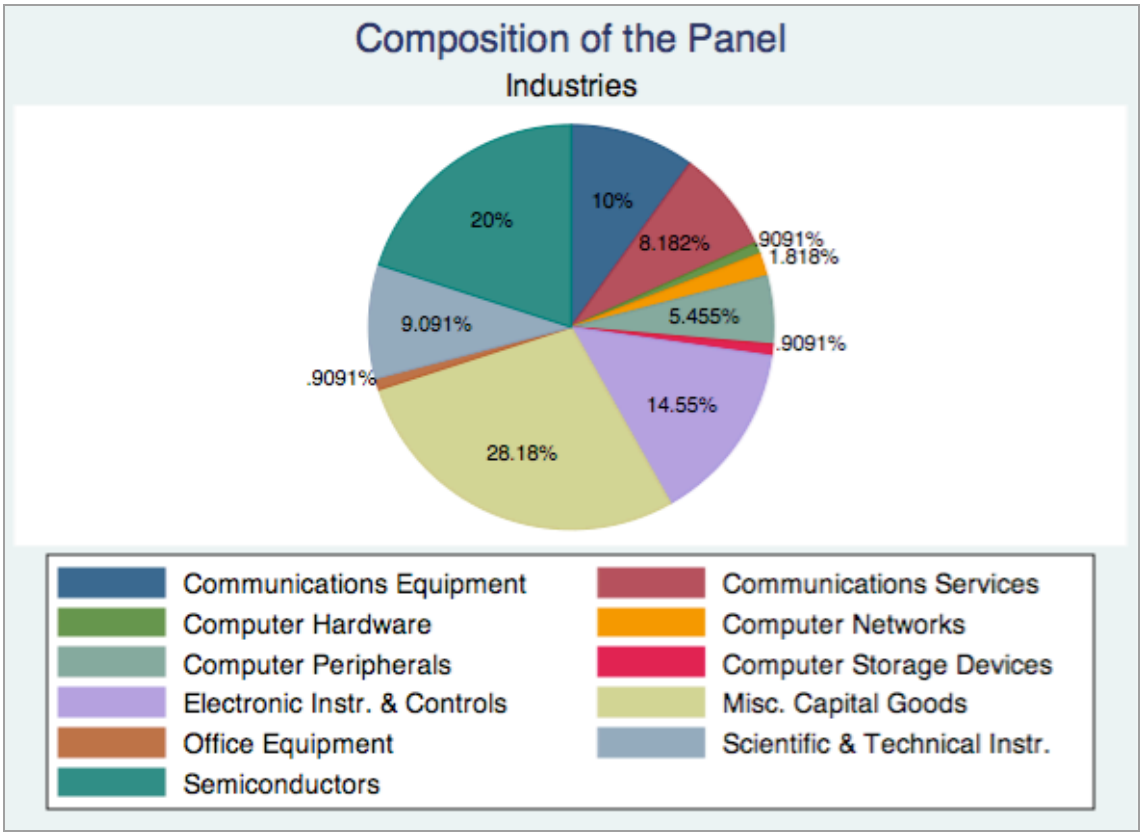

Figure 2. Industrial composition of the panel.

Figure 2 and 3 present the overview of the panel structure from the perspectives of industrial and sub-sectoral composition and firm's distribution across market indices. Out of 11 industries represented in the panel, the majority of firms are concentrated in 7: Misc.Capital Goods (i.e. Industrial Engeneering – 28%), Semiconductors – 20%, Electronic Instruments & Controls – 14,5%, Communication Equipment – 10%, Scientific & Technical Instruments – 9%, Communication Services – 8% and Computer Perophericals – 5%. Those attract the primary attention of the analysis. Interestingly, the panel is dominated by CDAX firms, while DAX and TecDAX companies together have less than 15%. That means that most of the firms are of small and medium size and are not that actively traded at the stock market.

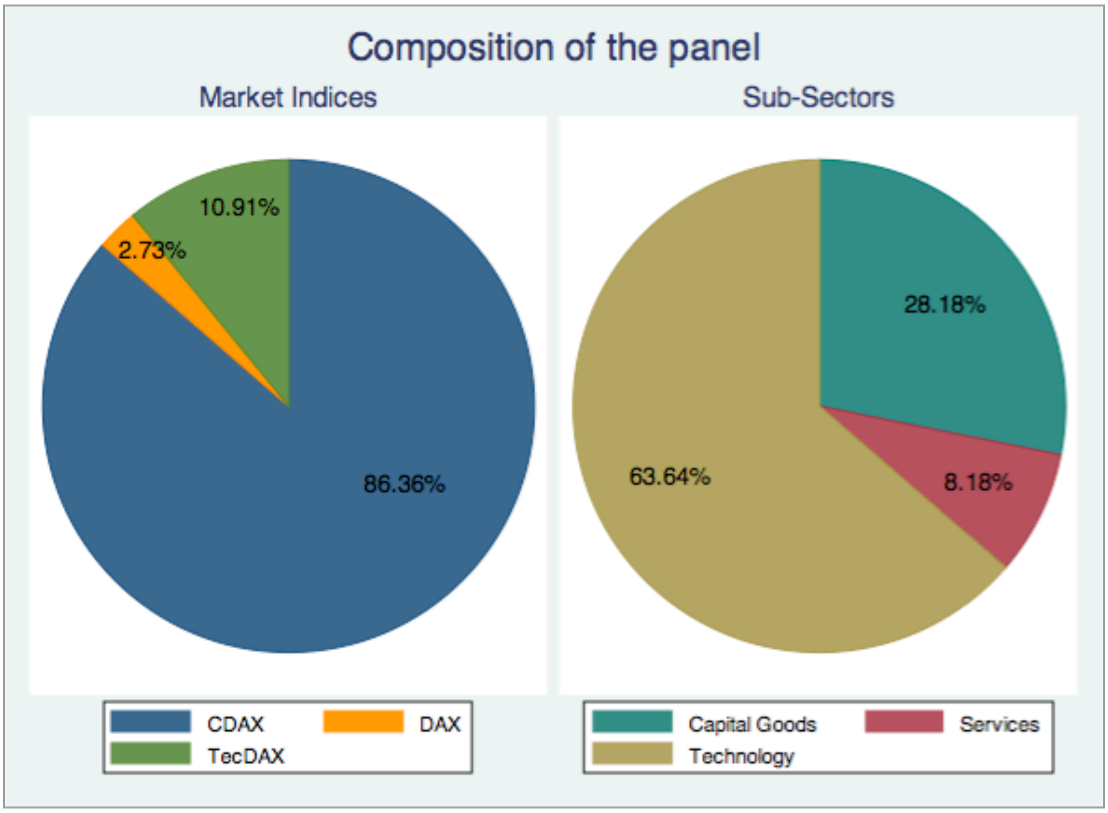

Figure 3. Distribution of the panel across Sub-sectors and Market Indices.

The author starts the analysis by looking at the descriptive statistics of the data (Table 5). Summarized descriptive statistics for longitudinal panel decompose the mean variable $\mathbf{x}_{it}$ into a between ($\mathbf{x}_i$) and within ($\mathbf{x}_{it} = \mathbf{x}_i + \mathbf{x}$, the global mean $\mathbf{x}$ being added back in order to make the results comparable). The overall and within are calculated over N firms-years of data. The between is calculated over n firms, where N refer to firms-years, n – to firms, T – average number of years the variable was observed (StataCorp., 2011).

Table 5. Descriptive statistics of key variables over the panel.

Variable		*Mean*	*Std. Dev.*	*Min*	*Max*	*Observations*
Age	overall	50.47	61.98	-4.00	443.00	N = 770
	between		62.19	-1.00	440.00	n = 110
	within		2.00	47.47	53.47	T = 7
Number of Employees	overall	9 766.04	48 306.35	0.00	472 500.00	N = 695
	between		46 473.29	39 950.00	416 621.40	n = 108
	within		3 094.62	-20 655.39	65 644.61	T-bar = 6.43
Total Revenue	overall	1 919 616.00	9 707 548.00	0.00	87 300 000.00	N = 709
	between		9 347 547.00	700.50	77 300 000.00	n = 110
	within		577 244.60	-2 960 956.00	11 900 000.00	T-bar = 6.45

R&D Expenditure	overall	91 289.97	487 549.10	0.00	5 024 000.00	N =	565
	between		442 616.50	59.00	4 338 571.00	n =	98
	within		53 352.05	-452 376.70	776 623.30	T-bar =	5.77
R&D Intensity	overall	0.06	0.06	0.00	0.49	N =	563
	between		0.07	0.00	0.35	n =	98
	within		0.03	-0.13	0.25	T-bar =	5.74
Financial Leverage	overall	1.79	6.05	-40.32	135.01	N =	696
	between		2.54	-2.23	19.67	n =	110
	within		5.50	-37.59	117.13	T-bar =	6.34
Share Price	overall	14.05	20.00	0.24	257.10	N =	657
	between		15.04	0.38	73.92	n =	107
	within		12.63	-35.73	209.08	T-bar =	6.14
Market Cap	overall	1 567 025.00	8 525 041.00	810.06	88 100 000.00	N =	657
	between		7 906 744.00	2 104.22	67 000 000.00	n =	107
	within		1 493 085.00	-9 048 611.00	22 700 000.00	T-bar =	6.14
Book-to-Market	overall	0.86	0.88	-2.13	11.98	N =	654
	between		0.63	-1.08	3.72	n =	107
	within		0.67	-1.27	10.36	T-bar =	6.11
ROA	overall	-0.02	0.32	-5.88	0.69	N =	706
	between		0.19	-1.16	0.19	n =	110
	within		0.26	-4.73	1.16	T-bar =	6.42
Tobin's Q	overall	1.43	0.84	0.13	7.48	N =	654
	between		0.62	0.46	3.71	n =	107
	within		0.56	-1.03	6.79	T-bar =	6.11

The values of some variables (Age, Number of Employees, Total Revenue, R&D Expenditure and Market capitalisation) are not normally distributed, thus it is useful to use the median as a cenrtality measure for them rather than mean. For the further analysis they are taken in logs. It's is also interesting to decompose the data across the structural components and compare the results with the overall panel. Figures 4-8 illustrate the industiral differences of the companies on the key variables.

Firms show significant difference of Age across the industries. While Misc.Capital Goods (i.e. industrial engineering) and Office Equipment are close to the panel mean, most of the other industries vary in the range from 10 to 20 year (Scientific Instruments are a decade older). This is in line with the nature of the technological development: IT-related industries raised much later than industrial engineering.

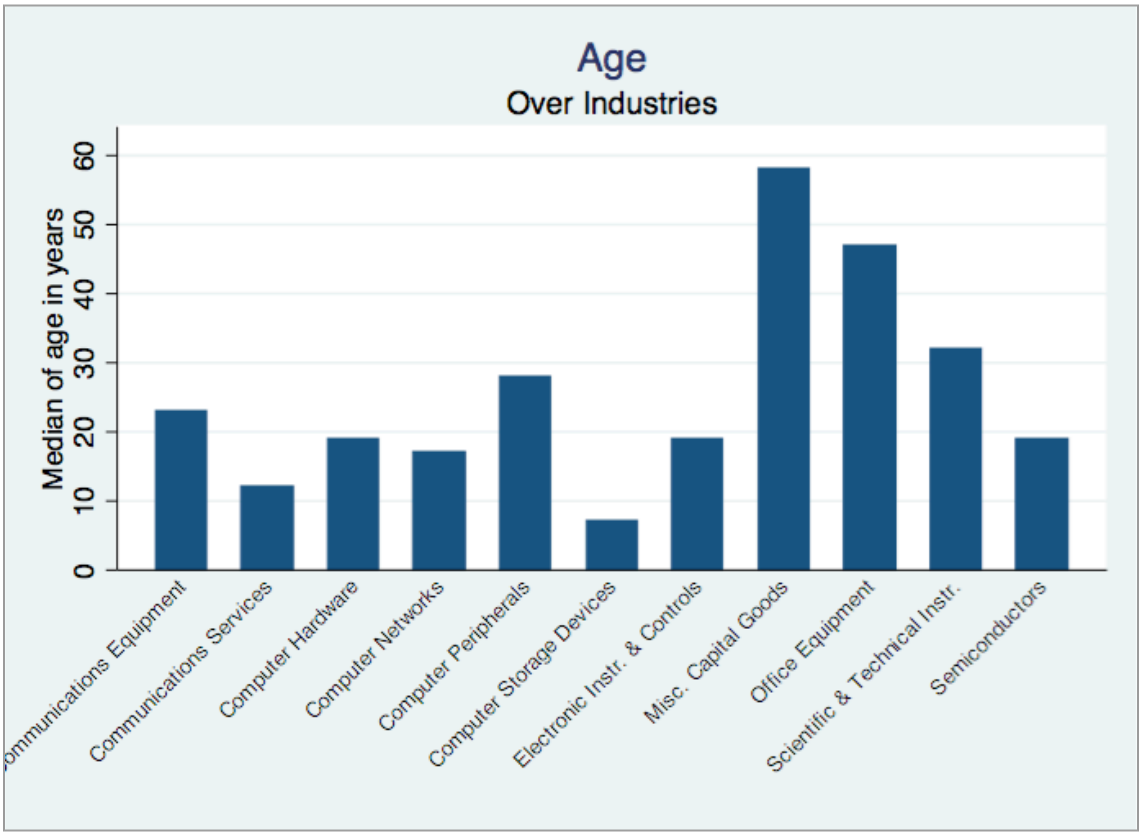

Figure 4. Age characterisitcs across industries.

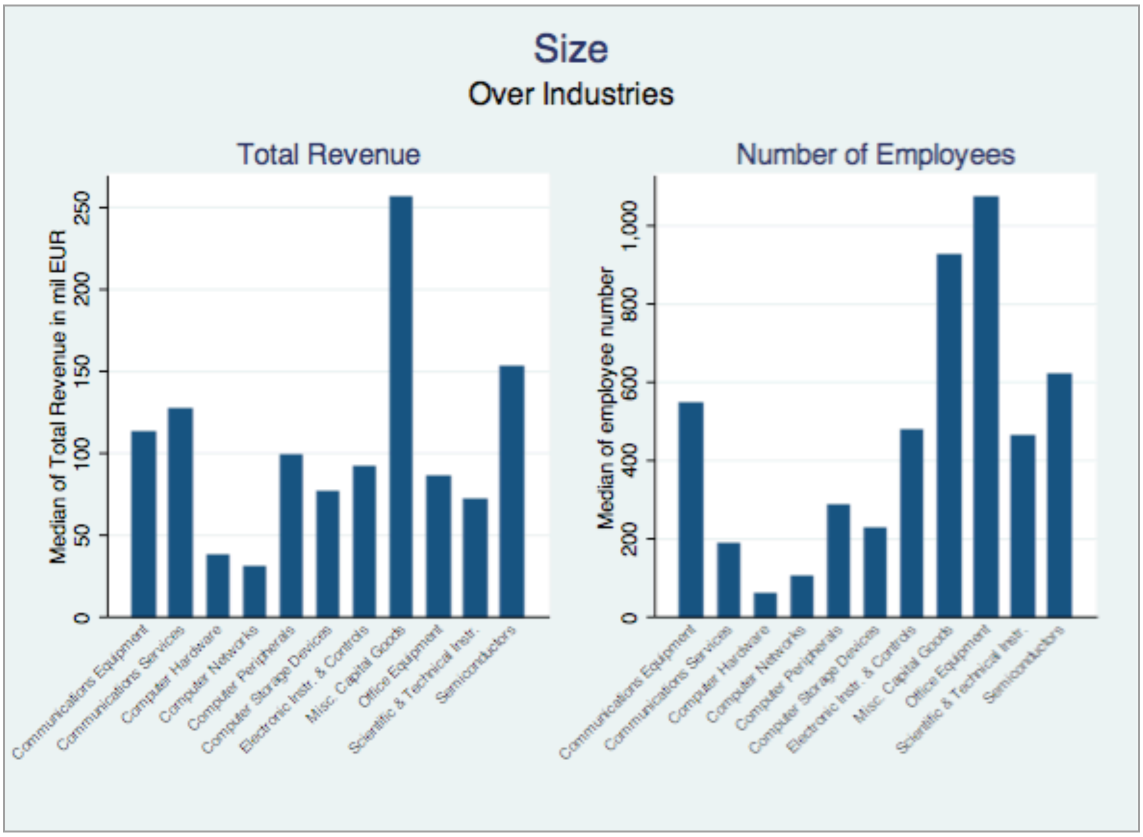

Figure 5. Size characterisitcs across industries.

Both size characteristic across industries are generally consistent with each other and in line with the Age: younger industries (e.g. Computer Hardware or Computer Networks) are respectively have less revenues and employees and the other way around (e.g. Industrial Engineering). Interestingly, Communication Services being smaller in headcount show unproportionally high revenues. Office Equipment show the inverse pattern, however, due to the very little representation in the panel, this is not much informative.

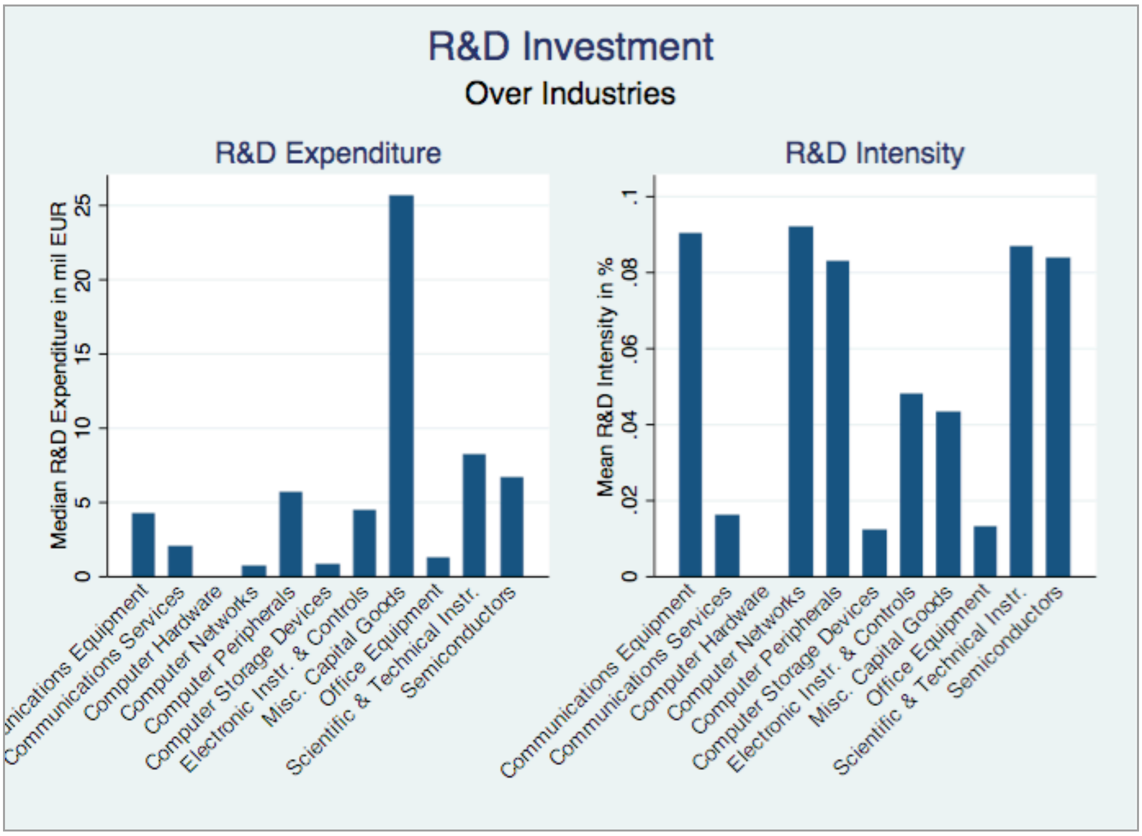

Figure 6. Characterisitcs of R&D across over industries.

R&D related indicators show interesting behaviour. While in absolute values R&D expenditures are low or moderate (e.g. Computer Networks, Communication Equipment, Semiconductors), in terms of R&D Intensity those firms show the highest values (8-9%). In turn, Misc.Capital Goods, that shows high volumes of R&D investments has only moderate intensity (4%). This fact proves the relevance of using the R&D intensity as a measure of engagement in innovation activity.

Table 6. Descriptive statistics of R&D intensity across industries.

	Industry	Variable	Mean	Std. Dev.	Min	Max	Observations
1	Communication Equipment	overall	0.09	0.08	0.00	0.34	N = 58
		between		0.10	0.03	0.30	n = 10
		within		0.02	0.03	0.17	T-bar = 5.8
2	Communication Services	overall	0.01	0.02	0.00	0.11	N=34
		between		0.02	0.00	0.05	n=7
		within		0.01	0.00	0.07	T-bar = 4.86
3	Computer Hardware	overall	0.00	0.00	0.00	0.00	N=2
		between		.	0.00	0.00	n=1
		within		0.00	0.00	0.00	T=2
4	Computer Networks	overall	0.09	0.09	0.00	0.18	N=4
		between		0.08	0.00	0.12	n=2
		within		0.06	0.00	0.15	T=2
5	Computer Peripherals	overall	0.08	0.10	0.01	0.49	N=33
		between		0.12	0.02	0.35	n=6
		within		0.04	-0.06	0.22	T-bar = 5.5
6	Computer Storage Devices	overall	0.01	0.01	0.01	0.03	N=5
		between		.	0.01	0.01	n=1
		within		0.01	0.01	0.03	T=5
7	Electronic Instr. & Controls	overall	0.05	0.04	0.00	0.18	N=78
		between		0.04	0.01	0.15	n=14
		within		0.01	-0.01	0.10	T-bar = 5.57
8	Misc. Capital Goods	overall	0.04	0.04	0.00	0.24	N=150
		between		0.04	0.00	0.15	n=25
		within		0.01	-0.02	0.13	T=6
9	Office Equipment	overall	0.01	0.00	0.01	0.02	N=7
		between		.	0.01	0.01	n=1
		within		0.00	0.01	0.02	T=7
10	Scientific & Technical Instr.	overall	0.09	0.06	0.01	0.24	N=59
		between		0.06	0.02	0.20	n=10
		within		0.02	0.04	0.13	T-bar = 5.9
11	Semiconductors	overall	0.08	0.07	0.00	0.36	N=133
		between		0.06	0.00	0.20	n=21
		within		0.04	-0.11	0.27	T-bar = 6.33

The benchmark study of the 1000 most R&D intensive EU and non-EU companies (Moncada-Paternò-Castello et al., 2010, p. 527) suggests to distinguish between high-intensive (more than 5%), medium-high (2-5%), medium low (1-2%) and low intensity (below 1%) industries. High R&D intensity industries comprise pharmaceuticals & biotechnology, health-care equipment & services, technology hardware & equipment, software & computer services and leisure goods. Medium-high include automobiles & parts, aerospace & defence, electronics & electrical equipment, industrial engineering & machinery, chemicals, personal goods, household goods, general industrials, support services and travel & leisure. Medium-low R&D intensity: food producers, media, oil equipment, general retailers, tobacco, mobile and fixed line telecommunications. Low R&D intensity: as oil & gas, industrial metals, banks, construction &materials, food & drug retailers, beverages, industrial transportation, mining, electricity and multiutilities (Moncada-Paternò-Castello et al., 2010, p. 527). As seen from the Table 6, the results over the panel are absolutely consistent with the suggested benchmark classification.

From the perspective of market performance, the most valued industries in terms of share prices are Computer Peripherals, Electronic Instruments & Controls, Industrial Engineering and Semiconductors. At the same time only the latter two show consistent pattern of market capitalization.

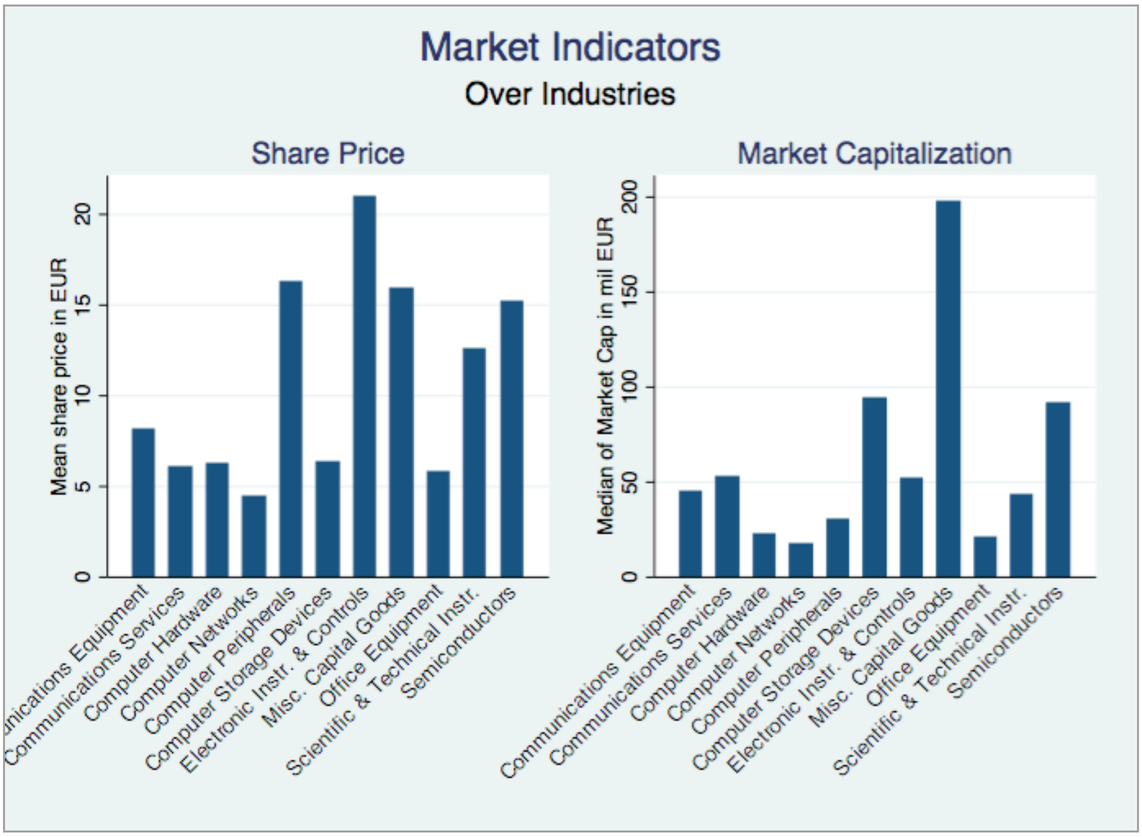

Figure 7. Market indicators across industries.

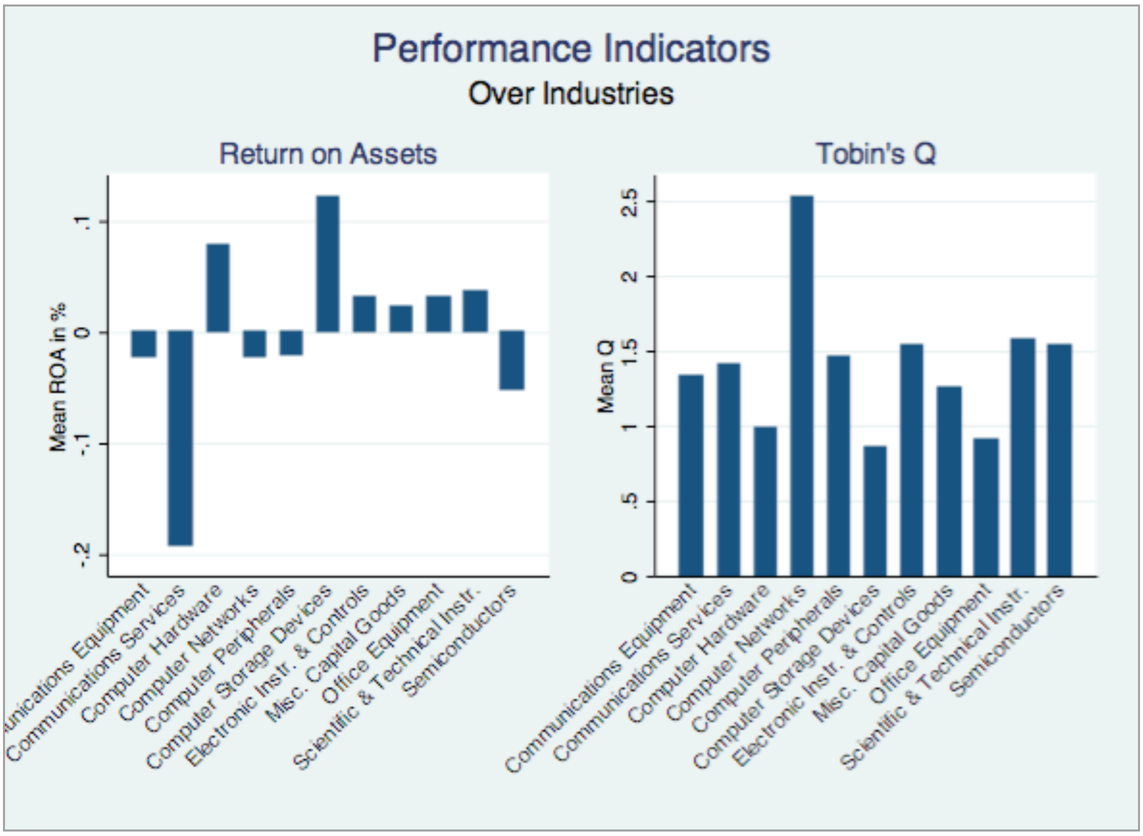

Figure 8. Performance indicators across industries.

Lastly, the group of performance indicators provide some interesting insights. Such, ROA of virtually half of the panel is negative, which is logically might be explained as a impact of crisis on financial performance (negative profits). Even in case of positive returns, the values are still low (less than 5%). Computer Hardware and Computer Storage Devices show comparatively much better results, although, as mentioned earlier, due to the low representation their results might be not reliable. Tobin's Q is distributed mostly equally among the industries with an exception of highly overvalued Computer Networks. Most of the other industries show the value consistent with the panel's mean of 1,43, which reflects in general positive attitude of the market towards the technology intensive firms.

To make one step further in understanding the panel it is neccessary to look at the correlations existing among the key variables as described in Table 7 (for the full correlation matrix see Appendix A). Strong correlation between Number of Employees and Total Revenues supports the choice of both as size controls. As it was noticed, Age and Size correlate with each other, in particular Age and Number of Employees. Moreover, R&D Expenditures show significant positive correlation with the size controls, while R&D Intensity reveals negative correlation with age. Interesting relations shows the share price, correlating with both age and size and, besides, with

R&D Expenditure. Tobin's Q correlation with the share price might be explained by the market component of the ratio.

Table 7. Pairwise correlations of the key variables.

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1	Age	1.00									
2	Number of Employees	0.26*	1.00								
3	Total revenue	0.19*	0.99*	1.00							
4	Industry		-0.09	-0.10*	1.00						
5	Market Index		0.16*	0.18*		1.00					
6	R&D Expenditure	0.20*	0.89*	0.82*		0.16*	1.00				
7	R&D Intensity	-0.18*		-0.08		0.18*		1.00			
8	Leverage							-0.13*	1.00		
9	Share price	0.22*	0.27*	0.25*	0.13*		0.30*	-0.13*		1.00	
10	ROA	0.09						-0.22*		0.14*	1.00
11	Tobin's Q	-0.12*				0.09				0.35*	-0.10

*Results printed for $p > .05$, * - for $p > .01$*

5.2. Longitudinal analysis: R&D Intensity hypotheses

Descriptive statistics provide somehow a snapshot of the data. To make use of the longitudinal research design and to answer the research question, we should look at the data over time. Analysis of longitudinal data typically concentrates on the changes in mean values over the given time period and on relation of those changes to the covariates (Menard, 2008, p. 204). Thus, to test the first hypothesis (*H1*) we trace the change of panel's mean R&D intensity over the course of 7 years (2006-2012). Figure 9 illustrates that.

The mean R&D intensity indeed shows a decline in 2008 (when the crisis occurred), generally supporting the predictions of *H1*. Interestingly, in 2009, which refers to the crisis period in our definition, it also has a sligh increase, followed by the decrease until 2011, which is in line with the recession period. However, the overall fluctuations of R&D intensity are in range of less than 1% and, therefore, might be not very significant. As R&D intensity depend on R&D Expenditures and Total Revenue, it's useful to track their behavior as well (Figure 10). Both variables (in logs) don't show any significant change in spite of crisis. According to this visualization, firms in the panel seem to remain the intensity unchanged, which contradicts the expectations of *H1*.

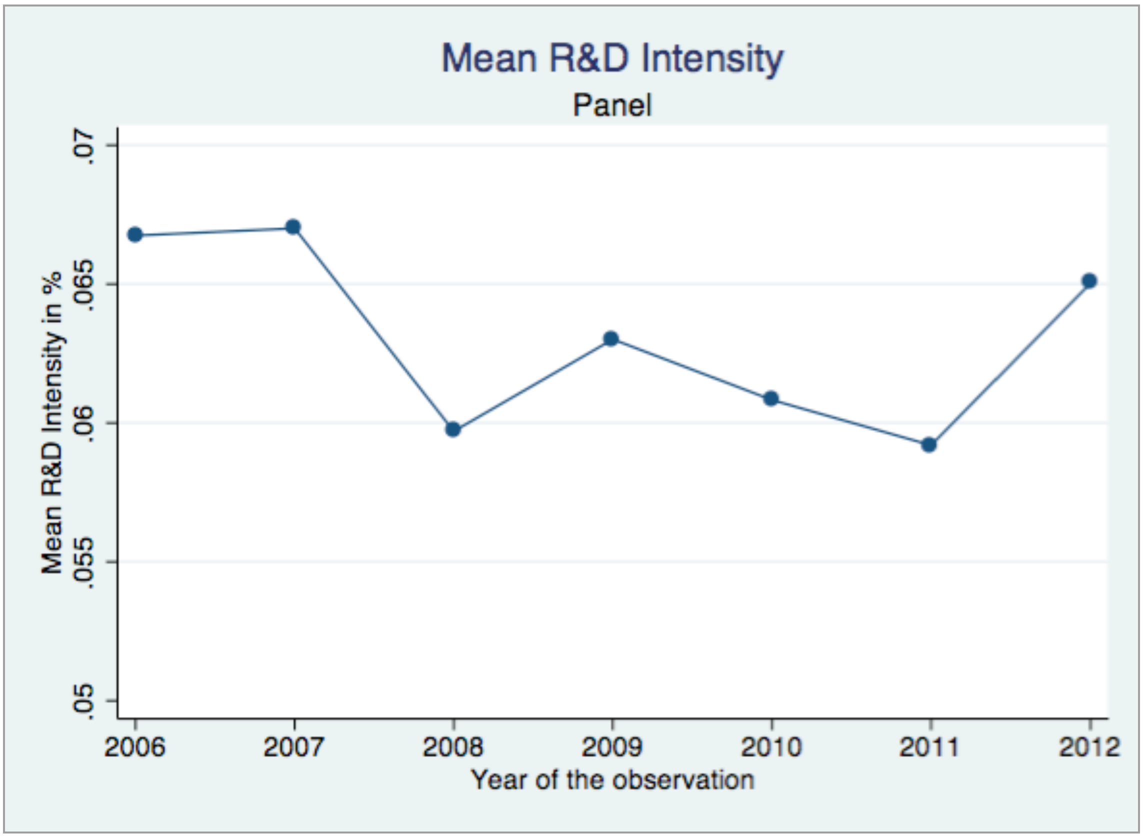

Figure 9. The movement of the mean R&D intensity in the panel over time.

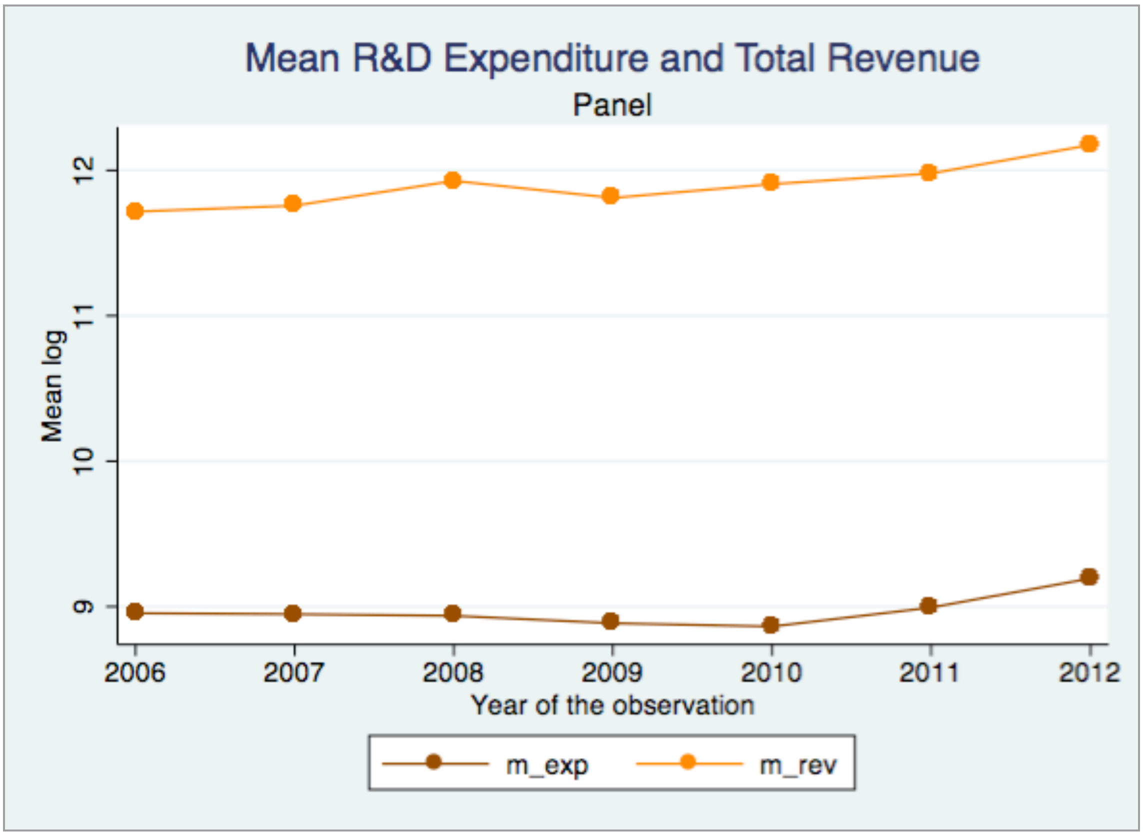

Figure 10. The movement of the mean R&D Expenditure and Total Revenue in the panel over time.

To test the decrease in R&D intensity during the crisis period the author implements the two-sample *t*-test, distinguishing between the period before the crisis (2006-2007) and period during (and after) the crisis (2008-2012) (Hamilton, 2006, p. 148). There is no significant differences in the mean intensity for pre-crisis period (M=0.07, SD=0.07) and during and after crisis (M=0.06, SD=0.06); t (561)=0.91, p = 0.363[14]. The result is also robust for the unequal variances t (232)=0.82, p = 0.41. The p is high, therefore there is no reason to reject null hypothesis. Similarly, there are no significant differences in the means of R&D expenditures and Total Revenues: (M=8.95, SD= 2.08) before the crisis and (M=8.97, SD= 2.18) during and after the crisis; t (560)= -0.81, p=0.94 for R&D Expenditures and (M=11.74, SD= 2.14) for pre-crisis versus (M=11.95, SD= 2.07) during and after crisis; t (705)= -1.22, p=0.22 for Total Revenues. These results suggest that the technology firms in the panel didn't decrease their R&D intensity in spite of crisis. Thus, the *H1* is not supported.

Further, Hypotheses 2a and 2b seek to test the impact of size and age effects on R&D intensity with regard to the crisis. To test *H2a* we distinguish between larger and smaller firms, based on the EU-definition of small and medium enterprises (EC, 2003, p. 39). Firms with a headcount less than 250 employees and an annual turnover less than 50 millions euro, are considered as small in the panel. Respectively, those with more than 250 employees and 50 million euro revenues are considered as large. Figure 11 illustrates the movement in mean R&D intensity over period of study with respect to the joint size effect of both Number of Employees and Total Revenue. Lager firms are very similar in their pattern to the mean over the panel, showing almost no change in R&D intensity in spite of crisis. Smaller firms have much more curious pattern: first, they are on average more research intensive (2% difference); second, they show only a slight decrease by the 2008 year (comparable on speed with larger firms in 2007-2008), but then showing a significant 3% increase up to the 2010 (i.e. during the crisis). This behavior is very interesting and contradicts the expectations of the *H2a.*

At the same time, mean R&D Expenditure doesn't show any notable responce to the crisis circumstances when controling for size (Firgure 12). Both larger and smaller firms behave similar to the panel's mean, smaller firms just show a little more persistent decline.

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[14] Here and further the results are reported at 95% confidence level, unless the different is stated.

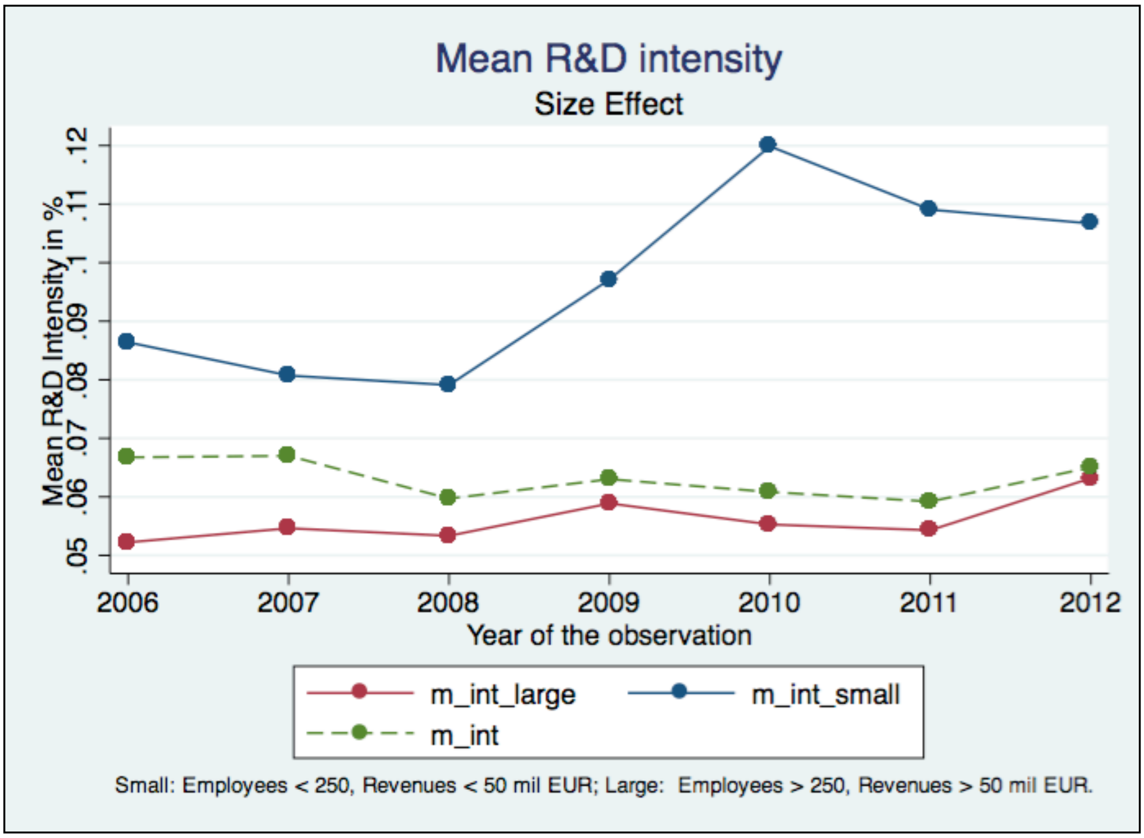

Figure 11. The movement of the mean R&D intensity in the panel with respect to size effect.

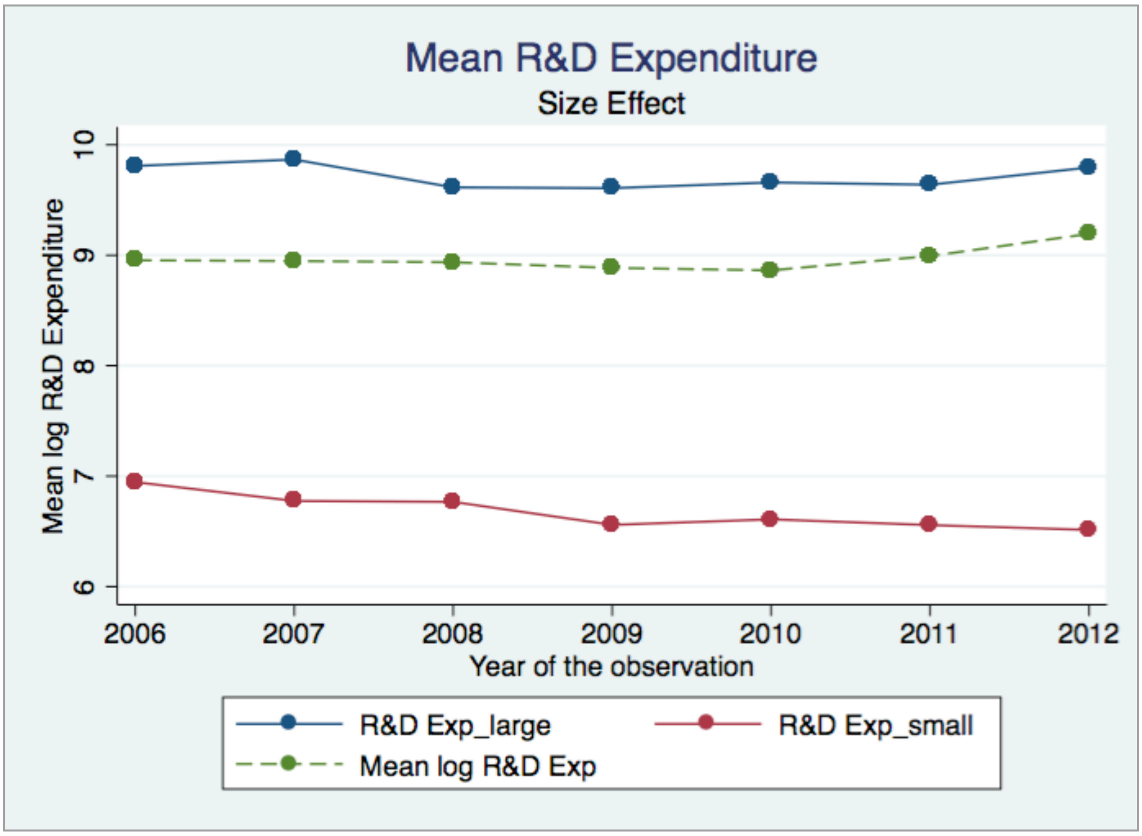

Figure 12. The movement of the mean R&D Expenditure in the panel with respect to size effect.

To check the robustness of the size effect the author looks at the impact of each size control separately (Figure 13). While larger firms tend to present the same intensity pattern, which is still close to the overall panel mean, smaller firms are more sensitive to the size controls. When distinguished by the headcount, the pattern follows the cumulative one, just somehow smothely and less extreme. However, when controling for size by means of log revenues, the pattern looks differently. That might be explained by the difference in the volatility level of revenues and employment, when the former might change faster than the latter, although they are strongly connected as proved by the pairwise correlation.

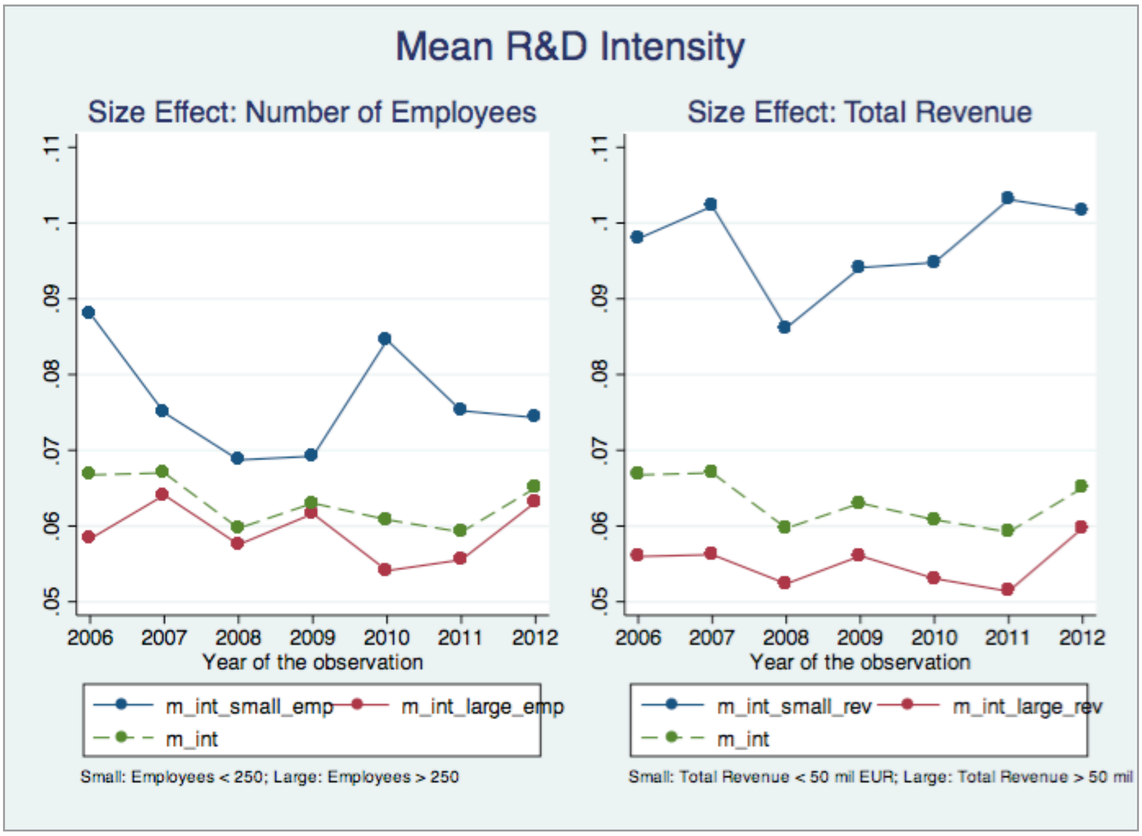

Figure 13. Decomposing the size effect on mean R&D intensity in the panel.

In order to test the significance of size effect on R&D intensity, we again employ the analaysis of variances. First of all, we look at the separate effects of each control on overall R&D intensity by implementing a two-sample *t*-test. Depending on the number of employees, larger and smaller firms indeed differ in their mean R&D intensity, in particular smaller firms are more R&D intensive than larger ones: (M=0.08, SD=0.08) for smaller firms versus (M=0.06, SD=0.06) for larger at t (561)=2.78, p = 0.006. When taking the Total Revenue as a measure for size, the results are consistent and even more notable in case of smaller firms: (M=0.10, SD=0.09) for smaller firms versus (M=0.05, SD=0.05) for larger at t (561)=2.78, $p < 0.001$. To test the effects of size differences with regard to the crisis, two-way ANOVA test is used, by looking at the interaction of each size control with the crisis variable (before and during/after) (Hamilton, 2006, p. 152). The results yielded again the significant main effect for both size controls (F (1, 559)=6.81, p=0.01 for Number of Employees and F (1, 559)=36.29, p <0.001 for Total Revenues), while the main effect of crisis was not significant (F (1, 559)=0.40, p=0.53 and F (1, 559)=0.25, p=0.62 for Number of Employees and Total Revenues respectively). Moreover, the interaction effect was not significant in both cases (F (1, 559)=0.04, p=0.85 and F (1, 559)=0.06, p=0.80 for Number of Employees and Total Revenues, respectively). This indicates that when controlling for number of employees and total revenues separately, R&D intensity of firms differs with respect to size characteristic. Specifically, smaller firms are more intensive than larger and the impact of difference in total revenues is more notable. However, in this case the crisis doesn't seem to cause significant disproportions in mean R&D intensity among the groups of larger and smaller firms.

The next step is to test the joint effect of the both size controls on the R&D intensity and its response to the crisis. By implementing two-way ANOVA we model the effect of number of employees, total revenues and their interaction on intensity. Variance test yields the significant main effect of total revenues as a size control (F (1, 559)=34.24, p <0.001), while the impact of number of employees in the joint model is smoothened and doesn't have a significant main effect on intensity (F (1, 559)=1.32, p =0.25). Furthermore, the interaction effect of both controls is insignificant on overall intensity (F (1, 559)=0.15, p =0.70. Finally, we add the crisis variable into the model and test for the significance of interaction effect of the joint size control and the crisis. Interestingly, the joint model provides now the support for the crisis effect (F (1, 555)=9.41, p =0.02) on intensity, indicating that mean R&D intensity differs before and after the crisis with respect to size. Moreover, the results yield the significant effect of interaction between number of employees and total revenues (F (1, 555)=14.98, p <0.001), indicating the difference in R&D intensity between large and small firms. Lastly, there is found a significant main effect of interaction between both size controls and the crisis variable (F (1, 555)=6.12, p < 0.001). These results suggest that with respect to the joint size controls, financial crisis matters for the differences in R&D intensity among small and large firms. Specifically, firms with lower headcound and smaller revenues show increase in R&D intensity during the crisis (*M=0.08, SD=0.08* before the crisis versus *M=0.10, SD=0.09* after the crisis*)*, which is larger than for firms with more employees and higher revenues (*M=0.05, SD=0.05* versus *M=0.06, SD=0.05* before and after the crisis, respectively*)*. These results contradict the propositions of *H2a,* which although predicted the difference in responce to the crisis depending on firm's size, but expected the other direction of change in R&D intensity. Thus, *H2a* is rejected.

In order to test *H2b,* the analysis distinguishes between older and younger firms based on the mean log age in the panel. Firms, whose log age is smaller than the mean log age, are considered as younger; firms with log age larger than the mean log age, are considered as older. Figure 14 illustrates the impact of age effect on the mean R&D intensity over time; Figure 15 presents the same effect on R&D expenditure.

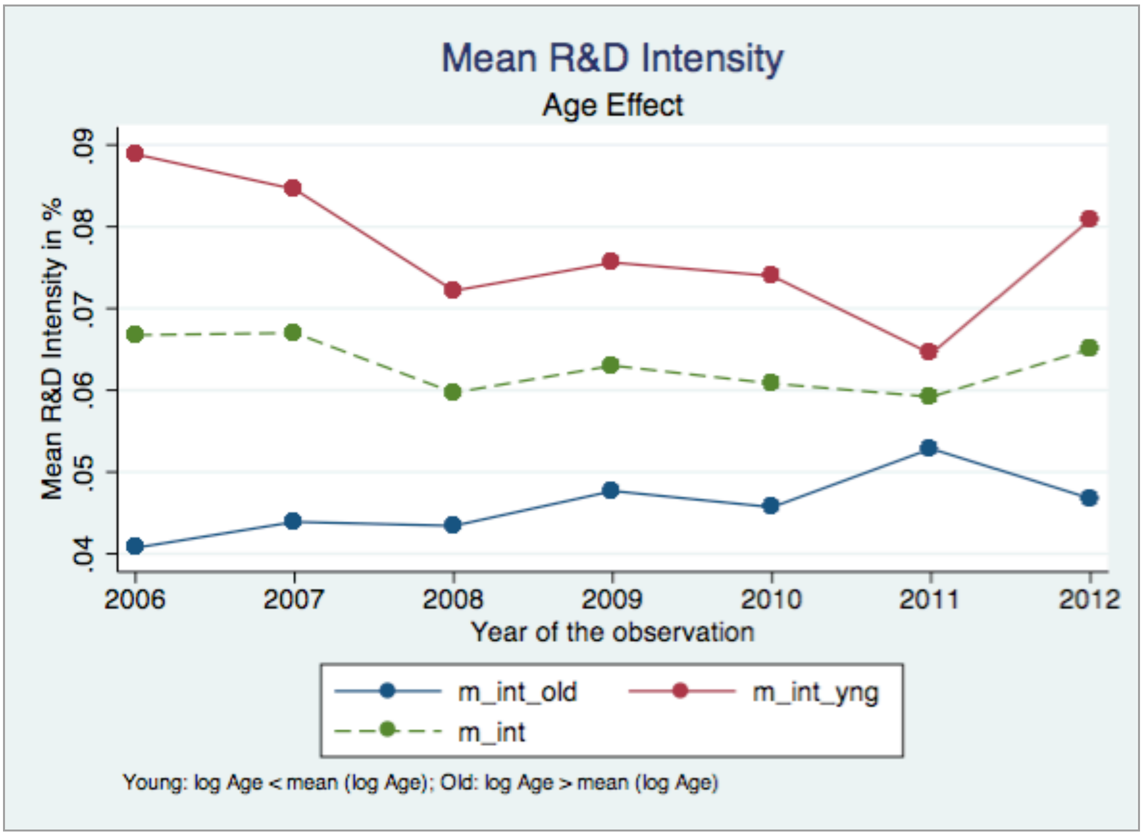

Figure 14. The movement of mean R&D intensity with respect to age effect.

According to the mean behavior on the graph, younger firms indeed decrease the R&D intensity more sharply in the period 2006-2011 – in 2,5%, slowing down during the crisis (2008-2009). Older firms, in turn, steadily increase the intensity rate by 1% over the same period.

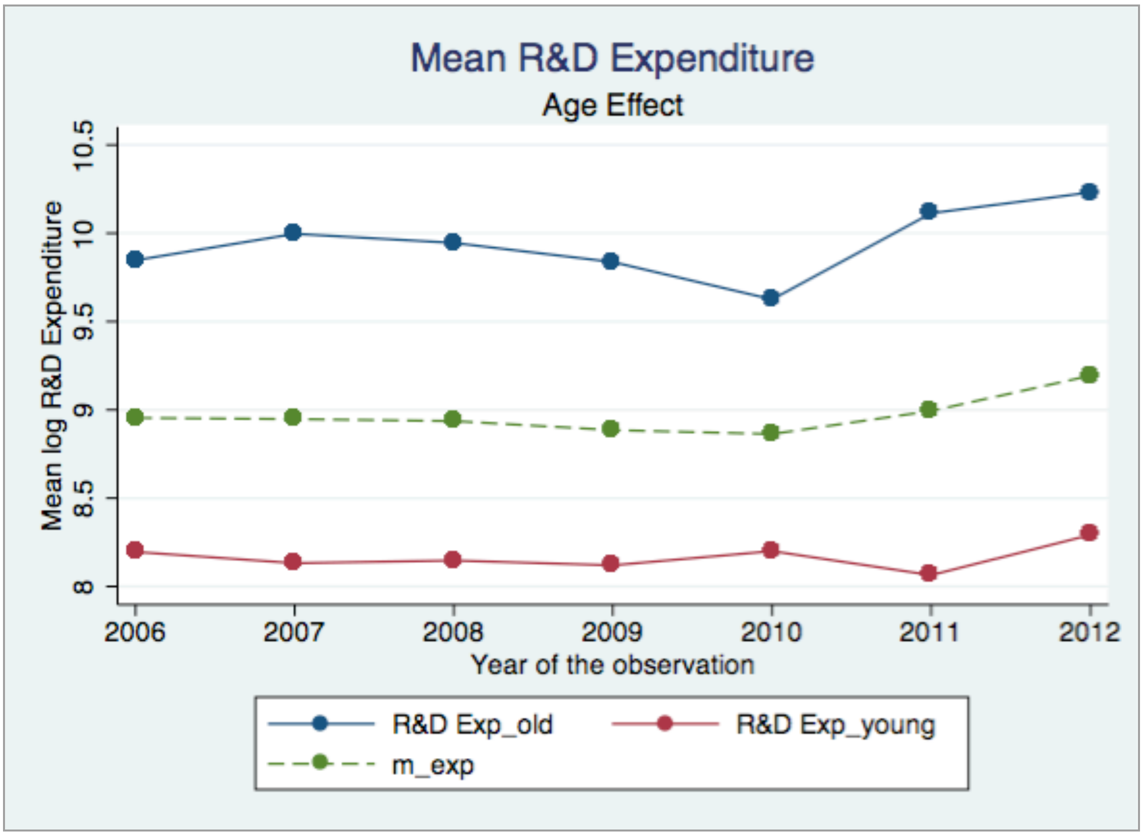

Figure 15. The movement of mean R&D Expenditure (log) with respect to age effect.

Similarily to the size effect, the author tests the significance of this hypothesis by, first, comparing the age differences over the panel and, secondly, evaluating the impact of the crisis. The results of the *t*-test support the significant differences in mean R&D intensity among younger and older firms, indicating that younger firms are more intensive: (M=0.08, SD=0.08) for smaller firms versus (M=0.05, SD=0.05) for larger at t (561)=5.90, p < 0.001. When introducing the crisis variable in the two-way ANOVA, we yield the significant main effect of age (*F* (1, 559)=35.77, *p* <0.001), but, again, not significant main effect of both crisis and their interaction (*F* (1, 559)= 0.52, *p* =0.47 and *F* (1, 559)= 2.49, *p* =0.11 respectively). In other words, although younger and older firms do significantly differ in their R&D intensity, those differences are not getting more notable during the crisis. Thus, the *H2b* is not supported.

In accordance with *H3* the existense of industrial patterns in R&D intensity is expected. Figure 16 provides the overview of the industrial patterns of R&D intensity in the panel. One can notice that the patterns are not identical in line with the *H3*, however it is not clear how the R&D intensity moves over time. To track its development it's is useful to have a closer look at the mean values over time (Figure 17).

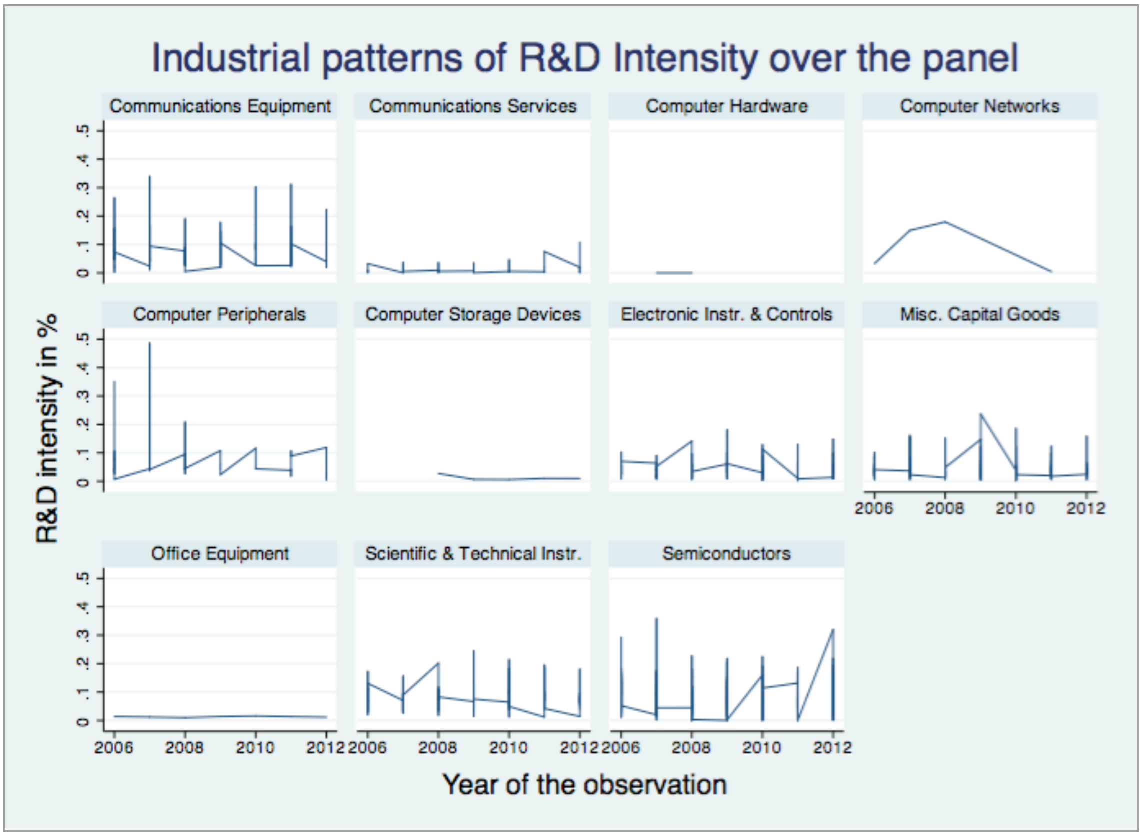

Figure 16. Overview of industrial patterns of R&D intensity in the panel over time.

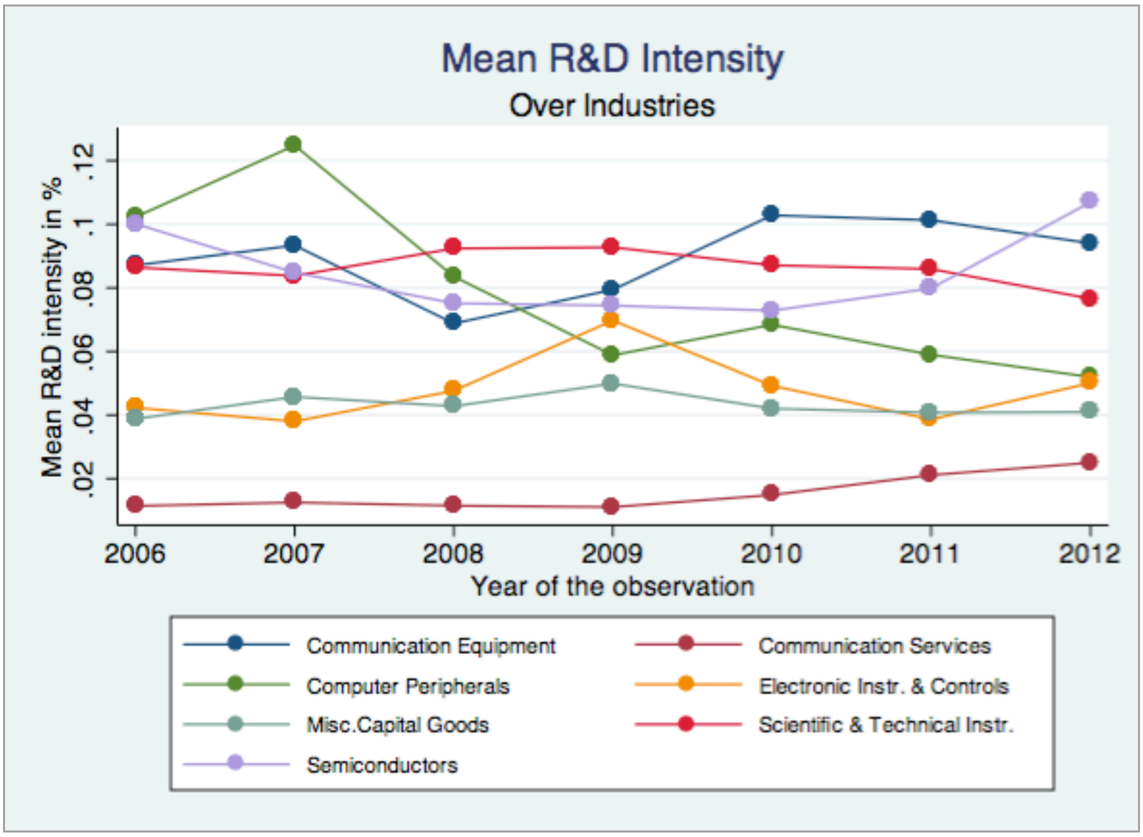

Figure 17. The movement of the mean R&D intensity over industries.

Looking at the means across industries[15] it is possible to identify 3 generic types of behavior: decrease, increase or no change in R&D intensity during the crisis period in comparisons to the pre-crisis. Computer Peripherals, Communication Equipment and Semiconductors show a decrease in 2008-2009 in comparison with the levels of 2006-2007, although Communication Equipment demonstrate faster recovery by 2010. In contrast, R&D intensity levels within Electronic Instruments & Controls and Scientific &Technical Instruments even increases in crisis period when compared to pre-crisis. Finally, Communication Services and Misc.Captial Goods, both with comparatevely low intensity levels, don't show any significant movements.

In order to test the significance of this hypothesis we implement one-way ANOVA test (Hamilton, 2006, p. 150). Ananlysis of variances shows that the effect of industry involvement on the mean R&D intensity is significant, $F\,(10, 552) = 9.67$, $p < 0.001$. In particular, Scheffé multiple-comparison test indicates the significant contrast between Communication Equipment (M=0.09, SD=0.08) and Communication Services (M=0.02, SD=0.02), $p < 0.001$ and Misc. Capital Goods (M=0.04, SD=0.04), $p = 0.004$. Scientific & Technical Instruments (M=0.09, SD=0.06) and Semiconductors (M=0.08, SD=0.07) both have a significant variance from Communication Services (M=0.02, SD=0.02) and from Misc. Capital Goods (M=0.04, SD=0.04), $p = 0.001$ and $p < 0.001$ respectively. Lastly, Computer Peripherals (M=0.08, SD=0.10) differs significantly from Communication Services (M=0.02, SD=0.02), p =0.02. Hence, we have different groups of industries based on their R&D intensity, thus *H3* is supported.

5.3. Regression analysis: R&D intensity-Firm performance hypothesis

In order to test the final hypothesis *H4* concerning the impact of the R&D investment on firm performance in the face of crisis environment, we build a refression model over the panel. First of all, it's useful to model the overall impact of R&D intensity on the firm 's financial performance, using the two proxies for it – Tobin's Q and ROA. Based on the Hausman test (StataCorp., 2011, p. 720), the coefficients for both Q and ROA regressions are systemic, thus a fixed-effects (within) model describes them better than a random-effect model. Table 8 presents the results of the regression.

[15] The graphs are not informative for the Computer Hardware, Computer Networks, Computer Storage Devices and Office Equipment industries, therefore they will be ignored in the further illustration.

Table 8. Fixed-effects regression results for Tobin's Q over the panel.

Tobin's Q	1		2		3		4	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Constant	2.28 (0.52)	4.38	4.29 (1.11)	3.89	5.99 (1.20)	5.00	5.64 (1.19)	4.74
R&D Intensity	-3.69* (1.10)	-3.34	-4.77* (1.44)	-3.30	-4.18* (1.44)	-2.91	-4.23* (1.41)	-3.00
Log R&D Expenditures	-0.07 (0.06)	-1.15	0.18* (0.07)	2.37	0.17* (0.07)	2.34	0.15* (0.07)	2.03
Log Number of Employees			-0.78* (0.12)	-6.66	-0.72* (0.12)	-6.19	-0.71* (0.11)	-6.20
Log Total Revenue			0.10 (0.14)	0.76	0.17 (0.14)	1.25	0.15 (0.13)	1.14
Log Age					-0.83* (0.24)	-3.42	-0.63* (0.24)	-2.59
Leverage							0.01 (0.01)	-0.89
R^2 (within)	0.04		0.18		0.20		0.20	
R^2 (between)	0.00		0.06		0.05		0.06	
R^2 (overall)	0.00		0.07		0.05		0.05	
No. observations	532		524		524		520	
No. groups	95		93		93		93	

*Standard errors are reported in parentheses. * - indicates the significance at the 95% level.*

The regression is built in 4 steps (Models 1-4), where first only the R&D investment is considered (1), then the size controls introduced (2), next – the age control (3) and finally – the leverage control (4). Based on the goodness of fit, R^2, models (3) and (4) have the best explanatory power out of all, although still only 20% of Tobin's Q are explained. Since it is a panel, similarly to the descriptive statistics (see Table 5 in 5.1) we distinguish between within, between and overall effects. For the fixed-effects regression R^2 within is an ordinary R^2, while the others are just correlations squared, thus we concern R^2 within the most (StataCorp., 2011, p. 456). Further, for the within regression the relevant is Number of observations, representing the total amount of firm-years, not the Number of groups (actual number of firms involved in the regression). It seen from the Table 8, that R&D intensity has a robust significant negative impact on market-based firm performance. Other significant factors, that determines Tobin's Q are R&D Expenditure, Number of Employees and Age.

To test the impact of R&D investment on the alternative measure of performance, we run the similar regression for Return of Assets (Table 9).

Table 9. Fixed-effects regression results for the Return on Assets.

Return on Assets (ROA)	*1*		*2*		*3*		*4*	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Constant	0.55 (0.24)	2.33						
R&D Intensity	-2.12* (0.51)	-4.19	-2.01* (0.04)	-2.84	-1.66* (0.71)	-2.34	-1.64* (0.71)	-2.31
Log R&D Expenditures	-0.05 (0.03)	-1.76	-0.02 (0.04)	-0.67	0.03 (0.04)	-0.81	-0.02 (0.04)	-0.64
Log Number of Employees			-0.13* (0.06)	-2.25	-0.11 (0.06)	-1.66	-0.11 (0.06)	-1.86
Log Total Revenue			0.07 (0.07)	1.03	0.11 (0.07)	1.65	0.11 (0.07)	1.64
Log Age					-0.39* (0.12)	-3.29	-0.40* (0.12)	-3.37
Leverage							-0.01 (0.00)	-1.70
R^2 (within)	0.07		0.08		0.10		0.11	
R^2 (between)	0.02		0.00		0.03		0.03	
R^2 (overall)	0.01		0.00		0.01		0.01	
No. observations	558		550		549		545	
No. groups	97		95		95		95	

*Standard errors are reported in parentheses. * - indicates the significance at the 95% level*

The explanation power of this model is rather weak (only 11% at best), but since it's just an alternative measure, it is not the focus of the analysis. What's more important is that it also demonstrates a significant persistent impact of R&D intensity and a weaker influence of Age as well. The major conclusion of the performed regressions is as follows: R&D investment, measured as R&D intensity, has a significant negative impact on firm performance: the increase in R&D intensity leads to the decrease in returns.

To reflect the influence of R&D investment on firm performance in face of crisis as stated in the *H4*, the author models the change in intensity for the 3 respective time periods: "before" (the change between 2007 and 2006), "crisis" (the change between 2008 and 2007) and "after" (the change between 2009 and 2008)[16]. Taking in the account the lagged nature of R&D investment, the author models the impact of the

[16] This distinguishing attempts to grasp the impact of change in R&D ininvestment for the each point of time in the crisis time frame; in line with the research design, the «after» period refers to the general crisis period, however, the term «after» aims to reflect the fact that this period happened after the intial shock in the economic environment, which we call here «crisis» and mark as the difference between 2008 and 2007.

change in intensity on the Tobin's Q for the last three years of the study (Q2010, Q2011 and Q2012, respectively). Table 10 presents the descriptive statistics for these variables.

Table 10. Descriptive statistics for the measures of change in R&D intensity in face of crisis and Tobin's Q.

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
Independent					
before	73	0.007	0.032	-0.128	0.135
crisis	79	-0.003	0.038	-0.278	0.075
after	78	0.006	0.035	-0.213	0.099
Dependent					
Q2010	100	1.43	0.79	0.70	5.94
Q2011	101	1.28	0.67	0.13	4.68
Q2012	84	1.36	0.68	0.42	4.71

As already proved by the *H1*, there is only a very small insignificant descrease in R&D intensity during the crisis (the difference between 2008 and 2007 is negative). However, of the interest for the analysis is the impact of this change on the firm performance. To test it, we build a regression model. Tables 11 and 12 show the regressions for Q2010 and Q2011, since they had more obsevations and higher R^2 (for the full regression see Appendix B).

Table 11. Regression results for Tobin's Q in 2010.

Tobin's Q	*2010*							
	1		*2*		*3*		*4*	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Constant	1.44 (0.11)	13.50	1.45 (0.10)	14.75	1.54 (0.08)	18.76	1.54 (0.09)	17.10
before	5.88 (3.35)	1.76					-8.64 (4.65)	-1.86
crisis			-5.73* (2.58)	-2.22			-11.28 (6.37)	-1.77
after					-14.43* (2.30)	-6.28	-12.14* (3.29)	-3.69
R^2	0.04		0.06		0.35		0.41	
Adjusted R^2	0.03		0.05		0.34		0.38	
No. Observations	69		76		75		66	

*Standard errors are reported in parentheses. * - indicates the significance at the 95% level*

Table 12. Regression results for Tobin's Q in 2011.

Tobin's Q	*2011*							
	1		*2*		*3*		*4*	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Constant	1.18 (0.07)	17.52	1.20 (0.06)	18.64	1.28 (0.06)	20.68	1.25 (0.06)	21.23
before	4.20* (2.09)	2.01					-4.28 (3.01)	-1.42
crisis			-5.90* (1.66)	-3.55			-2.75 (4.27)	-0.64
after					-8.46* (1.72)	-4.94	-8.20* (2.15)	-3.81
R^2	0.06		0.15		0.26		0.36	
Adjusted R^2	0.04		0.14		0.25		0.33	
No. Observations	66		73		73		63	

*Standard errors are reported in parentheses. * - indicates the significance at the 95% level*

Models (1) – (3) in each table show the individual impact of change in intensity on the respective Q, while Model (4) demonstrates the joint impact. For both years (2010 and 2011) the change in R&D intensity after the shock (2009-2008) has a significant negative effect on firm performance reflected in Tobin's Q. Interesting results are yielded for 2011: the change in R&D before the crisis is positively assosiated with firm performance, while when the shock occurs, the influence becomes negtive and increases with time. However, this relationship is not robust and disappears in the joint model. To sum up, the increase in R&D spending in face of crisis leads to worse performance. That contradicts the expectations of *H4,* which is therefore rejected.

Chapter V dealt with the empirical testing of the developed theoretical propositions within the suggested research design. Out of 5 formulated hypotheses, only *H3* is fully supported with statistical testing, while *H1, H2a, H2b* and *H4* have to be rejected. In particular, for *H2a* the theoretical predictions about factors of change in R&D intenstity (size) were true, while the direction of change (decrease) was proved to be reverse. In the following chapter the results of the conducted theoretical and emprical analysis are summarized and discussed and the concluding comments are derived.

VI. Summary and Conclusion

This thesis reseach aimed to explore the effect that the recent financial crisis 2008-2008 impaired on the innovation activity of public technology firms and related financial performance. Built on the theoretical body of knowledge about the financial crises, innovation activity and R&D investment as a measure for it, the author attempted to develop the theoretical framework which might possibly explain the nature of the relationshiop between cirisis and innovation. More specifically, she hypothesized how financial crisis hinders private investment in R&D and what are the possible effects of it on firm's market value. In oder to test empirically the propositions of the theoretical framework, the author collected financial data on the panel of German public firms attributable to the technology sector. The results of the empirical analysis are more than surprising.

First of all, the main hypothesis predicting the pro-cyclical behavior of R&D investment in face of crisis didn't find empricial support. The analysis showed that firms in the panel didn't significantly decrease their R&D intensity during the period of financial crisis in comparison with the level of R&D intensity before the crisis. This result is very interesting and provides a support for the “creative accumulation” view (e.g. Archibugi et al., 2013a). It shows that technology firms, for whom the specific technological knowledge is a strategically valuable asset, are more likely to be persistent in their innovation activity in spite of the economical fluctuations. In this way the conducted analysis contributes to the stream of reseatch on persistency of innovations (e.g. Geroski et al., 1997; Archibugi et al., 2013b).

Next, the longitudinal panel analysis allowed to derive valuable insights about the impact of firm-specific characterstics on innvation. The empirical findings over the panel showed the evidence that size and age matter for R&D intensity. More specifically, it was statistically proved that younger and smaller firms are more intensive in their R&D invesment than older and bigger firms. As the impact of crisis didn't find significan support over the panel, it is reasonable to conclude that these differences preserve even in case of unfavorable economic environment (financial crisis in our research). Moreover, when controlling for both factors of size (number of employees and total revenues) smaller firms even showed the increase in R&D intensity. It was also found that in general the effect of revenues as a factor for size is more significant than the number of employees. These results contribute to the literature exploring the influence of size and age on innovation activity (e.g. Cohen & Klepper, 1996; Chandy & Tellis, 2000; Hill & Rothaermel, 2003). In line with the theoretical predictions the panel analysis also proved the industiral differences in R&D intensity, which is found to be significant over time.

Even more interesting results were derived for the relationship between R&D investment and market value of firms. Market-beased performance was found to be strongly negatively assosiated with R&D intensity over the panel. In other words, the increase in R&D leads to descrease in market percived value. The same is true for return on assets, although with comparatively lower impact. Firm performance is also assosiated with size and age in the following way: yonger and smaller (in terms of headcount) show better market-based performance (regression coefficients are negative), while in the ROA story only age matters. Interestingly, financial leverage as a proxy for financial rist didn't show any significant influence on the performance for both Tobin's Q and ROA. Furthermore, the change in R&D intensity is significantly negatively associated with market-based performance during the crisis: firms who increase their research and development intensity, experience worse market performance. These findings are in contrast with the empirical evidence in the literature, arguing for the positive relation between R&D and market value (e.g. B. H. Hall, 1999; Toivanen et al., 2002). In this was this analysis provides the new insights that the crisis situation seems to inverse the relationship between R&D investment and market evaluation of the firm.

Thus, the major conclusion of the conducted analysis is as follows: in spite of the financial crisis technology firms in Germany tend to persist their innovation activity as reflected in R&D investment even if the financial market doesn't support it.

With regard to the generalization and implications of the results the author is mindful about the subjective sampling as a limitation of the study. As a possible improvement the robustness check testing for the adjustments in the industry involvement might be useful.

To conclude, this thesis has focused only on the input dimension of the innovation activity affected by crisis, namely on R&D investment and its intensity. In order to complete the analysis of the financial crisis' impact on the innovation activity of German public technology firms it would be also be beneficial to consider innovation output. The author intends to pursue further research on this topic by investigating the patent activity of the firms in the chosen sample during the same period.

Appendix A

Table 13. Correlation matrix of variables.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Market Index	1.00																	
2	Sector	-0.09	1.00																
3	Industry	-0.06	-0.01	1.00															
4	Age	-0.10	-0.25	-0.09	1.00														
5	Employees	0.16	0.03	-0.12	0.25	1.00													
6	R&D Exp	0.15	0.07	-0.02	0.19	0.89	1.00												
7	R&D Intensity	0.13	0.20	0.05	-0.17	-0.06	0.00	1.00											
8	Total Revenue	0.17	0.01	-0.13	0.19	0.99	0.83	-0.07	1.00										
9	Net Income	0.11	0.04	-0.04	0.17	0.73	0.79	-0.03	0.68	1.00									
10	Share number	0.18	-0.03	-0.16	0.04	0.65	0.28	-0.07	0.75	0.22	1.00								
11	Share price	-0.02	0.03	0.02	-0.01	-0.01	-0.01	-0.03	-0.01	0.00	-0.01	1.00							
12	Market cap	0.18	0.03	-0.11	0.16	0.97	0.84	-0.06	0.98	0.72	0.71	-0.01	1.00						
13	Total Assets	0.17	0.00	-0.16	0.14	0.92	0.68	-0.08	0.97	0.58	0.87	-0.01	0.94	1.00					
14	BV Equity	0.17	-0.01	-0.16	0.12	0.87	0.60	-0.08	0.93	0.55	0.91	-0.01	0.92	0.99	1.00				
15	Leverage	-0.06	-0.04	-0.02	0.11	0.05	0.04	-0.12	0.05	-0.02	0.04	0.00	0.04	0.05	0.04	1.00			
16	Book/Market	-0.03	-0.04	-0.08	0.02	-0.04	-0.05	0.04	-0.03	-0.05	-0.02	0.07	-0.06	-0.03	-0.02	0.03	1.00		
17	Market Assets	0.18	0.02	-0.13	0.15	0.97	0.78	-0.07	0.99	0.66	0.79	-0.01	0.98	0.99	0.96	0.05	-0.04	1.00	
18	ROA	0.06	-0.03	0.06	0.08	0.03	0.02	-0.07	0.02	0.12	0.01	0.01	0.03	0.02	0.02	-0.08	0.05	0.02	1.00
19	Tobin's Q	0.12	0.11	0.07	-0.12	-0.05	-0.02	0.02	-0.05	0.01	-0.05	-0.03	-0.02	-0.05	-0.05	-0.05	-0.48	-0.04	-0.03

Appendix B

Table 14. Regression results for the Tobin's Q in 2010, 2011 and 2012 with respect to the change in the R&D intensity.

	Q2010								*Q2011*								*Q2012*							
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Constant	1,44	13,50	1,45	14,75	1,54	18,76	1,54	17,10	1,18	17,52	1,20	18,64	1,28	20,68	1,25	21,23	1,22	21,67	1,29	18,70	1,29	20,47	1,22	23,70
	(0,11)		(0,10)		(0,08)		(0,09)		(0,07)		(0,06)		(0,06)		(0,06)		(0,06)		(0,07)		(0,06)		(0,05)	
before	5,88	1,76					-8,64	-1,86	4,20*	2,01					-4,28	-1,42	3,18	1,63					-5,66*	-2,18
	(3,35)						(4,65)		(2,09)						(3,01)		(1,95)						(2,59)	
crisis			-5,73*	-2,22			-11,28	-1,77			-5,90*	-3,55			-2,75	-0,64			-0,89	-0,29			-5,45	-1,43
			(2,58)				(6,37)				(1,66)				(4,27)				(3,08)				(3,82)	
after					-14,43*	-6,28	-12,14*	-3,69					-8,46*	-4,94	-8,20*	-3,81					-3,68*	-2,19	-2,48	-1,31
					(2,30)		(3,29)						(1,72)		(2,15)						(1,68)		(1,89)	
R^2	0,04		0,06		0,35		0,41		0,06		0,15		0,26		0,36		0,05		0,00		0,07		0,20	
Adjusted R^2	0,03		0,05		0,34		0,38		0,04		0,14		0,25		0,33		0,03		-0,02		0,06		0,15	
No. observations	69,00		76,00		75,00		66,00		66,00		73,00		73,00		63,00		56,00		60,00		62,00		54,00	

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