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Factors Explaining Firm Economic Vulnerability During the 2008 Crisis

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Abstract
The economic crises constitute the most important disruptions in firms' external environment, which have quite negative economic consequences for them, leading to significant reductions of their activities. However, the negative impacts differ significantly among firms, so it is important to identify factors that affect their magnitude at firm level, as they would provide to firms a useful basis for developing strategies for increasing their resilience to crisis. In this study, based on the resource-based view (RBV) of the firm as well as the dynamic-capability view (DCV) as theoretical foundations, we develop a set of research hypotheses concerning the effects of a series of factors on firm overall crisis economic vulnerability as well as crisis vulnerability with respect to several investment categories. We test these hypotheses using Greek firm data for the crisis period 2009–2014. We find evidence for a vulnerability reducing effect of new forms of "organic" workplace organization and human capital endowment, the latter effect particularly for investment in R&D and innovation, a stabilizing effect of a series of dynamic capabilities, a stabilizing effect of export activities, a de-stabilizing role of crisis-induced liquidity restrictions, and a de-stabilizing effect of crisis-induced decrease of overall private and public demand.

Keywords Economic crisis · Vulnerability · Investment · Resource-based view · Dynamic-capability view

JEL Classification D21 · L22 · L25

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1 Introduction

The economic crises, which repeatedly appear in market-based economies, constitute the most important disruptions in firms' external environment and have quite negative economic consequences for them, leading to significant reductions of their activities and even closure of many firms (Knoop 2015; Bo et al. 2014; Allen 2016; Bouncken et al. 2022). During the last 100 years, we have experienced many economic crises (a review of them is provided in Knoop 2015). One of them has been the 2008 global economic crisis, which has caused big economic and social problems in many countries all over the world. More recently, the COVID-19 pandemic has given rise to one more economic crisis, and also the Ukraine war is expected to spark another economic crisis triggered by the war-induced huge increases in the prices of oil, gas, wheat, and other goods.

In this study, we particularly focus on the crisis behavior of Greek firms. The Greek economy was strongly hurt by the economic crisis that begun in 2008, so it is a very interesting context for investigating factors affecting firm's crisis economic vulnerability because no other European country has gone through a depression of such a magnitude. Real income per capita declined every single year between 2008 and 2014, resulting to a cumulated drop of about 25%; the unemployment rate was 7.8% in 2018 and rose to 26.6% in 2014 (Gourinchas et al. 2017; Meghir et al. (2017)). The corporate investment decreased from 10.3% of GDP on average in the period 2001–2008 to 7.7% of a significant smaller GDP on average of the period 2009–2014 (Gourinchas et al. 2017).[1]

However, the crisis-induced negative economic impacts differ significantly among firms, so it is important to identify factors that affect their magnitude at firm level, as they would provide to firms a useful basis for developing strategies for increasing their resilience to crisis.

Studies focusing on micro-economic aspects of the effects of the economic crisis 2008 on investment behavior at firm level can be classified in two main groups. A first group contains studies that investigate primarily the impact of crisis-induced reduction of external financing, mostly in form of bank credit supply, on corporate investment (see, e.g., Duchin et al. 2010; Kahle and Stulz 2013 referring to US firms). Nguyen et al. (2015), also dealing with US firms, emphasize the role of corporate governance in alleviating adverse consequences of lack of external finance for investment. Further studies include Akbar et al. (2013) for UK firms; Zubair et al. (2020) for NL firms, particularly focusing on the relationship between external and internal financing channel and their impact on investment during the economic crisis of 2008; and Bo et al. (2014) investigate corporate investment during this crisis for Chinese corporations.[2] Further, Knudsen and Lien (2014) analyze in a literature survey how two key aspects of economic crises, demand reduction and reduction in credit availability, affect three different types of investment: physical capital, R&D and innovation, and human and organizational capital.

A second group of studies are focusing on factors influencing investment in innovation (see, e.g., Arvanitis et al. 2014 for Swiss firms and several investment categories; Archibugi et al. 2013a for European firms; Archibugi et al. 2013b for UK firms; Rammer 2011

[1] Comparable data for three European countries that have also been also strongly hurt by the 2008 crisis show that the negative effect on corporate investment in Greece has been of similar magnitude as in Portugal but considerably stronger than in Spain and Ireland: Spain: from 13.9 to 12.0% of GDP; Portugal: 12.9 to 10.8%; Ireland: 11.4 to 11.0% (Grourinchas et al. 2017).

[2] For a survey of literature that studied SMEs in previous crises and proposes ways to overcome economic downturns in finance and strategy see Eggers (2020).

and Trunschke et al. 2023 for German firms, all of them investigating crisis impact on innovation investment). Further, Giebel and Kraft (2019) examine for German firms the crisis impact on capital investments of innovative firms. Also, in a paper based on patent data, Brem et al. (2020) analyze the crisis effect on innovation outcomes, focusing on the development of innovative products that become "dominant designs," for European firms. Further, Aghion et al. (2012) investigate for French firms the relationship between credit constraints and firms' R&D behavior over the business cycle. Finally, Döner (2017) and Brem et al. (2023) present surveys of literature on the impact of economic crises on innovation activities.

Three further papers deal with specific factors moderating crisis-induced business failure, reduction of investment or firm performance, namely, R&D human capital and vertical cooperation (Martinez Garcia et al. 2019 for Spanish firms), managerial ability (Andreou et al. 2017 for North American firms), dynamic capabilities (Makkonen et al. 2014 for Finnish firms), and board of directors' characteristics (Ferrero-Ferrero et al. 2012 for US firms).

These studies examine single factors that influence overall corporate investment or innovation investment behavior during crisis, but do not conduct a conceptually systematic investigation of a series of possible impact factors affecting crisis-induced economic vulnerability, which is the main goal of the present study.

In this study, we develop and test a set of research hypotheses concerning the effects of a series of factors on firms' overall crisis economic vulnerability as well as crisis vulnerability with respect to investment during the 2008 crisis period. Our theoretical foundations are the resource-based view (RBV) of the firm as well as the dynamic-capability view (DCV). As dependent variables, we use several ordinal variables that measure various dimensions of crisis economic vulnerability. One variable measures the overall negative impact of the crisis on a firm's economic activities, which is considered as a close proxy to overall crisis economic vulnerability. Eight further variables measure the extent of crisis-induced reduction of eight investment categories during the period 2009–2014 (investment in equipment, ICT, buildings, training, marketing R&D, product, and process innovation). These variables are considered as measures of investment-related crisis vulnerability: the stronger the decrease of investment expenditures due to crisis, the higher is a firm's investment-related crisis vulnerability.

We distinguish five groups of factors that might have affected firm behavior, particularly investment behavior, during the crisis 2009–2014, which are used as independent variables. These five groups refer directly to our research hypotheses. We consider two groups of internal factors: measures for overall resource endowment and measures for firm dynamic capabilities. Further, we examine three groups of external factors: one referring to the competition conditions in a firm's product market, a second one covering liquidity conditions with respect to transaction partners (such as banks, customers, and providers), and a third one related to macroeconomic conditions (overall development of domestic and foreign demand). We are testing these research hypotheses using Greek firm-level data for the long economic crisis period 2009–2014.

We find evidence for a vulnerability reducing effect of new forms of "organic" workplace organization and of human capital endowment, the latter effect being valid particularly for investment in R&D and innovation, a stabilizing effect of a series of firm dynamic capabilities, a stabilizing effect of export activities, a de-stabilizing role of crisis-induced liquidity restrictions, and a de-stabilizing effect of crisis-induced decrease of private and public demand. Further, we find that firms operating in polypolistic markets (many competitors) are more vulnerable than firms operating in oligopolistic markets with few

competitors. Finally, firms that are exposed to international competition are less vulnerable than firms that operate only in a small home economy.

We expect that the results of our investigation of the factors that influence positively (thus stabilizing) or negatively (de-stabilizing) firms' economic behavior in a crisis period our findings will be particularly interesting and useful both for corporate management and public policy.

The structure of the paper is follows. Section 2 presents the conceptual background and the research hypotheses. Section 3 refers to the data; Sect. 4 presents the model specifications. Section 5 discusses econometric issues, Sect. 6 the econometric results, and Sect. 7 contains a summary and conclusions.

2 Conceptual Background and Research Hypotheses

2.1 Firm Vulnerability and Resilience During an Economic Crisis

Under economic vulnerability at firm level, we understand here the extent to which external shocks (such as the troughs of business cycles or more severe economic crises) impact negatively on relevant economic quantities that determine firm performance, particularly various investment categories. Briguglio et al. (2009) developed a concept for measuring the extent of adverse shocks on an economy at country level, which we slightly modify to adapt to the case of corporations. According to this concept, the effective degree of vulnerability (or net vulnerability) is the difference between gross vulnerability (degree of exposure to external shocks) and resilience (ability of coping with external shocks). Thus, the factors that decrease gross vulnerability or increase resilience contribute to a lower effective degree of vulnerability.

Extant economic literature refers mostly to resilience and the factors determining resilience at country level (see Caldera-Sanchez et al. 2016 for an overview; see also Hallegate 2014). Organizational resilience is the subject of a review article of Ruiz-Martin et al. (2018). The authors distinguish four types of assessment of firm resilience: first, measurement based on indicators measuring factors such as situation awareness, management of keystone vulnerabilities, resilience ethos, and adaptive capacity (McManus et al. 2007); second, based on fuzzy methods (fuzzy cognitive maps and fuzzy sets); third, based on the organizational recovery (how the organization recovers from failure); and fourth, based on organizational outcomes (e.g., operating income to sales (Watanabe et al. 2004); return on equity (Markman and Venzin 2014)). In this paper, we also concentrate on organizational outcomes.

With respect to the factors determining resilience at firm level, there is no generally accepted concept. For example, Watanabe et al. (2004) specify in a study—based on 54 large high-technology Japanese firms—sales entropy, technology elasticity to sales, ratio of actual to carrying capacity, and functionality development as factors determining resilience. Further, Markman and Venzin (2014) assess firm size, home-market solidity, and product and market complexity as the three main factors that explain resilience for 29 international banks. A more general approach pursues Pal et al. (2014): these authors define possible "enablers of resilience" and distinguish three main groups of such enablers, namely, assets and resources, dynamic competitiveness, and learning and culture. A recent

study by Miceli et al. (2021) concludes that agility and digitization are the most critical determinants of organizational resilience.

Aim of the study at hand is the identification and empirical testing of factors determining effective economic vulnerability, using data from a sample of Greek firms, which have been exposed to the severe economic crisis of this economy in the period 2009–2014. We intend to measure net vulnerability based on effective outcomes, covering overall economic activity and particularly investment, which is a crucial quantity for a firm's development. As vulnerability indicators, we use the extent of negative impact of the crisis on overall economic activities as well as the extent of reduction of five main investment categories (see section 6.1).

2.2 Factors Explaining Economic Vulnerability

2.2.1 Firm-Related Factors

Resourced-Based View of the Firm For the identification of relevant firm-level determinants of firm economic vulnerability due to economic crisis, we refer to the "resource-based view" (RBV) of the firm (Penrose 1959; Wernerfelt 1984; Barney 1991, 2001; Amit and Schoemaker 1993). According to this theoretical approach, critical determinants of a firm's performance are its resources (e.g., assets, human resources, etc.), as well as its capabilities for deploying and utilizing these resources in order to perform important tasks, so that performance differences among firms operating in the same environment are mainly created by differences among them with respect to available resources and capabilities.

Barney (1991) initially gave a wide definition of a firm's resources as "all assets, capabilities, organisational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive and implement strategies that improve its efficiency and effectiveness" (p. 101). Assets could be tangible (e.g., human resources, equipment, ICT hardware and software applications) or intangible (e.g., organizational routines or practices, know-how; see, e.g., Lev 2001). Capabilities are defined as "a special type of resource, specifically an organizationally embedded non-transferable firm-specific resource whose purpose is to improve the productivity of the other resource possessed by the firm" (Makadok 2001, p. 389).

There are some important differences between "assets" and "capabilities." First, capabilities are firm-specific in the sense that "ownership of capabilities cannot be transferred from one organisation to another without also transferring ownership of the organisation itself" (Makadok 2001, p. 388), while this does not need to be the case for assets. Second, and more important, capabilities serve primarily to enhance the productivity of assets (Makadok 2001, p. 389). Subsequently, a narrower definition of resources has been proposed and widely adopted, which differentiates them from capabilities: resources are stocks of available production factors that are owned or controlled by the firm, while capabilities refer to a firm's capacity to deploy resources using organizational processes in order to perform important firm tasks (Grant 1991). In this study, we adopt this latter definition of and distinction between resources and capabilities.

Summarizing, the central idea of the resource-based view is that resource allocations and organizational differences in capabilities for deploying and exploiting them explain performance variation of firms (Grant 1991). Consequently, we expect that the profile of a

firm's resources and capabilities would be reflected in its economic behavior, particularly its investment behavior, during an economic crisis. High levels of these (or some of these) resources and capabilities are expected to enable the firm to manage effectively the crisis, take the appropriate adaptation actions, and reduce its negative consequences, thus demonstrating high resilience (Ruiz-Martin et al. 2018).

Resource Endowment In economic literature, human capital, organizational capital, ICT, and knowledge capital are considered, besides the standard inputs labor and physical capital, as the most important components of firm resources according to the "new firm model" (Milgrom and Roberts 1995; Lindbeck and Snower 2000). The relative relevance of these factors varies strongly significantly among sectors and countries. Particularly the role of ICT has been the subject of a huge, primarily empirical literature (Aral and Weill 2007; Bartel et al. 2007; Arvanitis et al. 2013).

High-quality human resources and the use of new non-hierarchical organic forms of organization, such as teamwork, job rotation, and decentralization of decision-making, enable the firm to cope better with the crisis, reducing the needs for decrease of its activities and particularly all kinds of investment. Especially teamwork facilitates and enhances information/knowledge exchange among employees from different functional units as well as the coordination and cooperation among these units, which are highly important for successfully responding to the crisis (Black and Lynch 2004; Black and Lynch 2005; Bresnahan et al. 2002; Sherehiy et al. 2007; Arvanitis et al. 2016).

Also, the decentralization of decision-making improves the effectiveness of the extensive information/knowledge processing required for handling the crisis, by transferring part of it from the top management to the middle and lower management levels (Acemoglu et al. 2007). In a recent paper based on two large firm datasets on firm decentralization from 11 OECD countries (including USA), the authors find that firms that have delegated competencies from central headquarters to local plant managers already before the 2008 crisis performed better during the crisis than firms that remained centralized (Aghion et al. 2017).

Finally, R&D increases knowledge capital and enables the firm to make appropriate innovations in its products and services (e.g., develop some simpler and less expensive versions of them), and also in its processes (e.g., for reducing their costs) in order to cope better with the crisis, thus reducing the needs for a decrease of overall economic activities, particularly respective investment expenditures. We expect that these resources will be important for handling effectively the crisis and reducing its negative consequences.

Based on the above discussion, we formulate the following general hypothesis:

Hypothesis 1: Overall firm resource endowment (human capital, organizational capital, ICT, and knowledge capital) contributes to a reduction of crisis-induced economic vulnerability; thus, we expect that variables measuring these resources would correlate jointly negatively with measures of crisis-induced firm economic vulnerability.

Firm Capabilities Helfat (2018) emphasizes that two most important economic firm concepts converge to a similar definition of organizational capabilities (see also Jacobides and Winter 2012). Representing the resource-based view, Amit and Schoemaker (1993) define

a firm capability as "a capacity to deploy resources, usually in combination, using organizational processes, to effect a desired end. They are information-based, tangible or intangible processes that are firm-specific and are developed over time […] based on developing, carrying and exchanging information through the firm's human capital" (p. 35). Thus, the application of capabilities implies the combined use of ICT resources, organizational processes, and human capital. Representing the perspective of evolutionary economics, Winter (2000) defines an organizational capability as "a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type" (p. 983). To our opinion, the two approaches not only converge to a similar concept of firm capability but also complement each other. Combining the two approaches, we can consider capabilities as consisting of routines, i.e., behavioral rules that involve patterned behavior in "normal" times, but also in the face of external shocks such as economic crises (Helfat 2018).

For an empirical study, it is necessary to specify the kind of capabilities to be investigated in the respective firm and market context. An important issue thereof is the distinction between operational and dynamic capabilities as it currently used in strategic management research. As Helfat and Winter (2011) write: "We understand operational capabilities to be those that enable a firm to make a living in the present. … In contrast, a dynamic capability is one that enables a firm to alter how it currently makes its living" (p. 1244). In this direction, the "dynamic-capability view" (DCV) of the firm has been developed as the most important extension of the RBV for volatile external environments. According to it, a firm's dynamic capabilities, defined as its abilities to build, integrate, and reconfigure internal and external resources in order to cope with volatile environments, are highly important for its competitiveness and performance in such environments (Teece et al. 1997; Teece 2007, 2014; Drnevich and Kriauciunas 2011; Dejardin et al. 2023).

There has been empirical evidence of the importance of the dynamic capabilities for a firm's performance in highly volatile environments (e.g., Wu 2010; Drnevich and Kriauciunas 2011; Lin and Wu 2014; Dejardin et al. 2023), and especially in financial crisis conditions (Makkonen et al. 2014). So, we expect that a firm's dynamic capabilities will be quite helpful during economic crisis periods, in which there are rapid and unpredictable changes in the external environment, for making the required adaptation and renewal of a firm's internal and external resources, in order to keep a high level of activities, thus showing a low level of economic vulnerability.

The research that has been conducted on the DCV has identified some specific dynamic capabilities that refer to a firm's "organizational agility," i.e., its ability to anticipate changes in its external environment and respond to them rapidly and effectively. The external changes may refer to changes in customers' preferences, actions of competitors, economic shifts, technological advancements, and regulatory/legal changes, and firms may respond to such changes by adapting products/services mix, modifying existing products/services or/and introducing new ones, changing pricing policies, adopting new technologies, changing its partners' and suppliers' network, expanding to new markets, etc. (Overby et al. 2006; Lu and Ramamurthy 2011; Felipe et al. 2016; Ravichandran 2018; Brand et al. 2012; Walter 2012).

All or some of the above-mentioned types of changes in firms' external environment may appear in periods of economic crisis and firms may have to take all or some of the

above types of response actions that is why we expect that firms' "organizational agility" could be highly important for exhibiting during the crisis a high level of economic activities, particularly concerning investment, thus a low level of vulnerability.

Based on the above discussion, we formulate the following hypothesis:

Hypothesis 2: Firm dynamic capabilities concerning "organizational agility" contribute to a reduction of crisis-induced economic vulnerability; thus, we expect that variables measuring dynamic capabilities ("organizational agility") would correlate jointly negatively with measures of crisis-induced firm economic vulnerability.

2.2.2 Sectoral Factors

In this sub-section, we focus on the relationship between competition and investment behavior because investment is a particularly important economic activity for developing high resilience during an economic crisis and therefore for exhibiting low overall economic vulnerability. The relationship between competition and investment is rather complicated and theoretically not unambiguous. For example, Aghion et al. (2005) argue theoretically (also based on empirical evidence) for a reverse U-shaped relationship between market structure as measure of competition and R&D investment; Sacco and Schmutzler (2011) present a theoretical model (also based on evidence from an experiment) for a direct (non-inverted) U-relation between competition and investment. In view of the inconclusiveness of theoretical discussion, Schmutzler (2013) proposes a series of factors such as characteristics of firms, technologies, markets, and institutions as well as the applied notion of competition as possible determinants of this relationship that could be theoretically as well as empirically investigated (see also Delbono and Albertini 2022 and Peneder et al. 2020). Furthermore, in a literature survey, Mathis and Sand-Zantman (2014) conclude that effect of competition on investment depends—among other things—on the type of investment that is considered.

We conclude from the above discussion that the relationship might possibly be non-linear, but we prefer to remain agnostic given the fact that we investigate eight different types of investment. Under these conditions, it is not possible to formulate an overall hypothesis for the competition effect on firm crisis-induced economic vulnerability and expect that this issue could be empirically resolved. For this study, we use three variables (one structural and two rather behavior-related variables) for measuring competition (intensity of price competition, intensity of non-price competition, number of competitors). Further, eight types of investment are taken into consideration.

Further, firm vulnerability depends also on characteristics of the industry, in which the main firm activities take place. Dependent on technological factors or their character as producers of consumer goods, intermediate products or capital goods industries—and as a consequence firms belonging to these industries—react differently to external shocks. Thus, we have to control extensively for industry affiliation in the empirical part of the study.

2.2.3 Macroeconomic Factors

Finally, we develop two research hypotheses concerning the effects on crisis-induced overall economic vulnerability of two groups of macro-environment factors, which constitute the main manifestations of economic crises: reduction of demand and liquidity constraints. Market-based economies show the tendency to periodical fluctuations of economic activities

(Knoop 2015; Fagerberg and Srholec 2016). Such fluctuations affect seriously overall economic activity and particularly investment in general. There are reasons for firms to react usually pro-cyclically, decreasing overall economic activity and particularly investment in periods of economic recession, though sometimes firms might react anti-cyclically (or "neutral"), thus maintaining or even increasing overall activities and particularly investment.

Given the importance of investment for high resilience and low vulnerability, we focus here on investment. Given the cumulative character of investment, pro-cyclical behavior causes considerable losses of assets (incl. knowledge) that cannot be easily compensated. So, understanding the motives of anti-cyclical behavior would enable policy to try to promote and enhance such behavior, thus smoothening investment (and economic activity in general) along time and in this way avoiding damaging fluctuations.

We expect that in general investment would decrease during a recession period due to the demand uncertainty that makes investment more risky. Decreasing demand limits also internal financing of investment by past revenues. Such liquidity constraints further constrain firms' space for investment (Himmelberg and Petersen 1994; Hall et al. 1998). Furthermore, due to the above economic uncertainties, banks and other financial intermediaries have a lower propensity to finance firms' investment projects during economic crises periods, which further increases liquidity constraints. Of course, the risk differs among different kinds of investment, with innovation projects being considered as quite risky and buildings being seen as less risky than other investment categories (see, e.g., Gerner and Stegmaier 2013; Geroski and Gregg 1997). Further, larger firms are considered by banks and financial intermediaries as less risky than smaller ones. So small firms have more difficulties to finance investments in recession than large firms, due to credit rationing, i.e., limited access to external funding by financial intermediaries (for the theoretical background see, e.g., Stiglitz and Weiss 1981 for investment in general). Thus, we expect that all kinds of investment—even if not to the same extent—would fluctuate pro-cyclically with overall domestic and foreign demand of the economy. As a consequence, crisis-induced demand reduction would be a crucial determinant of firm economic vulnerability.

Furthermore, difficulties of financing investment, beyond the ones caused by this demand reduction, are also caused by liquidity constraints due to the behavior during the crisis of external players, such as financial intermediaries, suppliers, and customers. So, we expect that liquidity constraints caused by the crisis-induced decrease of credit limits by banks and by suppliers, as well as the decrease of paying willingness of customers due to the economic crisis, would be positively correlated with crisis economic vulnerability. Based on the above discussion, we formulate the following two hypotheses:

Hypothesis 3: Reduction of domestic and foreign demand due to overall contraction of economic activities in the economic crisis correlates positively with measures of crisis-induced firm economic vulnerability.

Hypothesis 4: Liquidity constraints at firm level due to an overall economic crisis correlate positively with measures of crisis-induced firm economic vulnerability.

Our research model is shown in Fig. 1.

3 Sampling

The "universe" of Greek firms as conceived in this study is given by the original sample of ICAP (a well-known large Greek business information and services enterprise, which is regarded as the largest and most reliable source for firm data in Greece), which includes

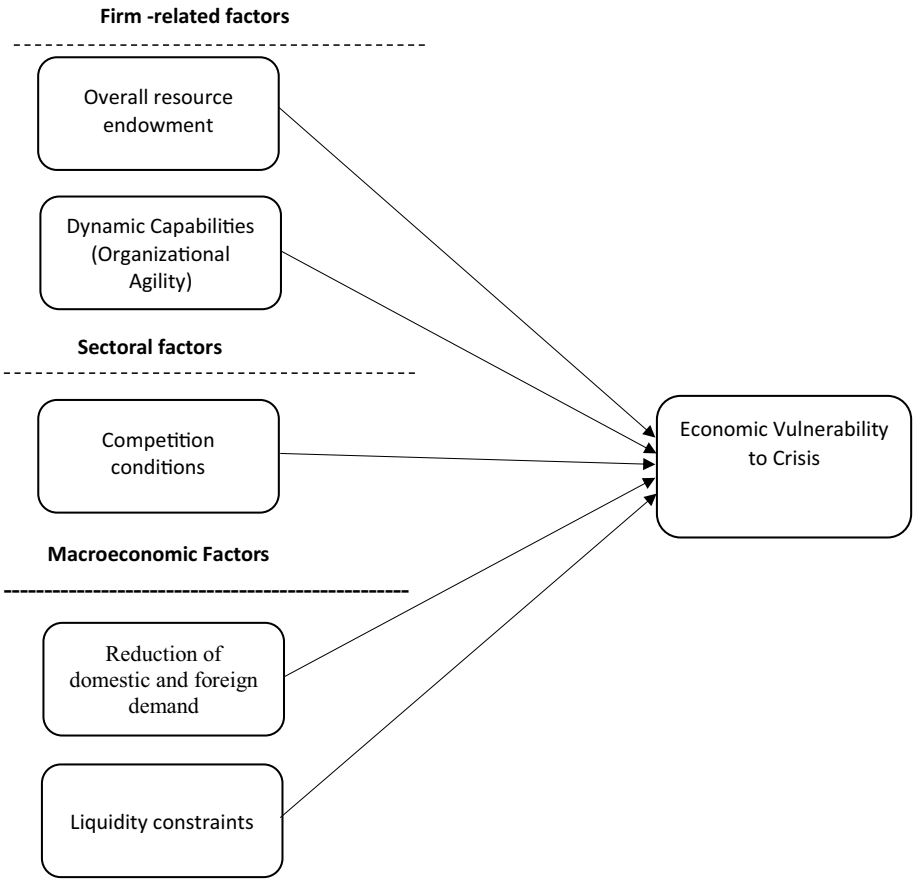

Fig. 1 Research model

6429 firms (see column 1 in Table 7 for the composition by industry of the original sample). This original sample has been the data basis out of which an intermediate sample of 3308 firms was constructed with the same composition by industry and size as the original sample; the firms for each industry sub-sample were chosen randomly out of the original sample (Table 7, column 2). A questionnaire (the questions it included are described in Sect. 4) was sent to the 3308 firms of the intermediate sample and we received 363 valid (response rate 11%). Table 8 in the Appendix shows the composition of the respondent firms' sample we used in our study by industry and firm class size. Due to missing values for some variables, only 298 observations could be used in the econometric analysis.

The existence of non-response bias was assessed using the method proposed by Rogelberg and Stanton (2007). A sub-sample of early respondent firms, a sub-sample of late respondent firms, and a random sample of non-respondent firms were compared with respect to number of employees, age as well as all dependent variables (see Table 9 of the Appendix); we found no statistically significant differences at the significance level of 5%.

It should be mentioned that already the original sample is not representative of the composition of Greek firms by industry. The Greek economy contains a very large number of

Table 1 Impact of crisis 2009–2014 on overall firm activities; percentage of all firms reporting one of the following effects

Impact	
No impact/very small negative impact	22.1
Medium negative impact	26.8
Large negative impact	29.6
Very large negative impact	21.5
Total	100.0

small and very small firms, mainly in trade, particularly retail trade, tourism, particularly catering, and construction. The ICAP data basis focuses on manufacturing (30.7% of all firms in the original sample), and also on some modern service industries (computer services, business services, and transport/communication (21.5% of service firms)), still keeping a high percentage of trade and tourism firms (78.5% of service firms). The response sample is further concentrated in manufacturing (40.2% of all firms in sample) and modern services (27.4%). This structure of the response sample corresponds to the technologically most developed part of the Greek economy on which we focus in this study. Of course, no claims can be made that the results of our study are representative for the entire Greek economy; nevertheless, they show characteristics of the crisis behavior of the technologically more developed part of the Greek economy.

4 Model Specification

Aim of the study at hand is the identification and empirical testing of factors determining effective economic vulnerability, using data from a sample of Greek firms, which have been exposed to the severe economic crisis of this economy in the period 2009–2014. We intend to measure net vulnerability based on effective outcomes, covering overall economic activity and particularly investment, which is a crucial quantity for a firm's development. As vulnerability indicators, we use the extent of negative impact of the crisis on overall economic activities as well as the extent of reduction of five main investment categories.

As dependent variables, we use several ordinal variables that measure various dimensions of economic vulnerability to crisis. One four-level variable measures the overall negative impact of the crisis on a firm's economic activities (VULN_ALL), which is considered as a close proxy to overall crisis economic vulnerability (see also Table 1). Eight further five-level variables measure the extent of crisis-induced reduction of eight main investment categories during the long Greek crisis period 2009–2014 (investment in equipment, ICT, buildings, training, marketing R&D, product, and process innovation; see Table 2 and Table 9 in the Appendix for the definition of all variables). These variables are considered as measures of investment-related crisis vulnerability: the stronger the decrease of investment expenditures due to crisis, the higher is a firm's investment-related crisis vulnerability.

We distinguish five groups of factors that might have affected firm economic behavior, particularly investment behavior, during the crisis 2009–2014. These five groups refer directly to our research hypotheses. We consider two groups of internal factors: measures for overall resource endowment (four variables) and measures for firm dynamic capabilities—organizational agility (eight variables). Further, we examine three groups of external factors: one referring to the competition conditions in a firm's product market (three

Table 2 Impact of crisis 2009–2014 on different kinds of ICT investment; percentage of all firms reporting one of the following effects

Impact	Equipment	ICT	Buildings	Training	Marketing	R&D	Product innovation	Process innovation
No impact/very small impact	24.4	41.6	37.0	33.0	25.8	41.5	36.5	38.2
Small decrease	21.0	15.5	18.7	18.4	16.5	13.8	21.9	21.5
Medium decrease	26.9	20.7	14.1	26.0	22.9	19.6	24.0	23.7
Large decrease	19.2	15.5	17.4	17.1	22.0	14.4	11.7	11.4
Very large decrease	8.5	6.7	12.8	5.5	12.8	10.7	5.9	5.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

variables), a second (composite) one covering liquidity conditions with respect to transaction partners (such as banks, customers, and providers), and a third (composite) one related to macroeconomic conditions (overall development of domestic and foreign demand, etc.).

4.1 Resource Endowment

Overall resource endowment (see hypothesis 1) is proxied by one variable for knowledge capital (variable R&D; existence of R&D activities), one for human capital (HQUAL; share of employees with tertiary-level education), one for the ICT infrastructure (ICT_INFRA; average use intensity of five important ICT enterprise applications (ERP, CRM, SCM, business intelligence/business analytics system, collaboration support system; see Table 9 in the Appendix)), and one for organizational capital (ORG; use of teams, job rotation, decentralization of decision-making, etc.).

4.2 Firm Dynamic Capabilities

We also examine the effects of eight important firm dynamic capabilities on crisis economic vulnerability based on previous relevant literature (CAP1 to CAP8; see research hypothesis 2). These refer, first, to the ability to rapidly react to changes of demand conditions (four variables), such as changes of demand for a certain product, adaption of products to customers' specific needs, necessity of decrease or increase of product diversity, and price changes of competitors. Second, they are related to the ability of taking action in the direction of product or process innovation (three variables), either through rapidly reacting to the introduction from competitors of new products, expanding to new domestic and/or foreign markets, or introducing new technologies for reduction of production costs and/or increase of product quality. Third, these capabilities also include the ability to rapidly change suppliers (one variable) for lower costs and/or higher quality, etc.

4.3 Competition Conditions

Competition conditions at the product market are measured by three variables: one variable for the intensity of price competition (P_COMPET), a second one for the intensity

of non-price competition (competition with respect to quality, technology, etc.; NP_COMPET), and a third one for the number of worldwide competitors at the product market (N_COMP). The first two variables refer to market behavior, the third one to structural market characteristics, which themselves imply a certain but not always non-arbitrary behavior.

4.4 Macroeconomic Conditions

For measuring macroeconomic conditions (see hypothesis 3), we use, first, a composite variable (MACRO), based on measures of the extent of crisis-induced decrease of private domestic and foreign demand, as well as of demand of the public sector, and also a measure of the extent of decrease of product and service prices during the crisis. Second, we also investigate separately the effects of the four underlying single variables (MACRO1 to MACRO4; see Table 9 in the Appendix), in order to determine the contribution of each single variable to the effects of the composite variable.

4.5 Liquidity Conditions

For measuring the effects of possible crisis-induced liquidity constraints (see hypothesis 4), we use a composite variable (LIQUIDITY), based on measures of the extent of decrease of credit limits of providers and banks, as well as the decrease of the paying willingness of customers. Also, in this case we also investigate separately the effects of the three constituent single variables (LIQUID1 to LIQUID3; see Table 9 in the Appendix), in order to determine the contribution of each single variable to the effects of the composite variable.

4.6 Other Variables

We control for possible internal problems before the crisis (insufficient control of costs, over-investment in equipment, buildings and/or storage capacity, as well as over-expansion due to takeovers and mergers; these individual variables are used to construct the composite variable INTER_PRO), which might increase a firm's overall crisis economic vulnerability. Further, we control for exporting activities, firm age, firm size, and industry affiliation.

We estimated the following model initially for the dependent variable VULN_ALL (Table 10 in the Appendix shows descriptive statistics of the variables of the model, Table 11 the correlations among the model variables):

$$\begin{aligned} VULN\_ALL_i = {} & \alpha_0 + \alpha_1 R\&D_i + \alpha_2 HQUAL_i + \alpha_3 ICT\_INFRA_i + \alpha_4 ORG_i + \alpha_5 CAP1_i + \cdots + \alpha_{12} CAP8_i \\ & + \alpha_{13} INTER\_PRO_i + \alpha_{14} P\_COMPET_i + \alpha_{15} NP\_COMPET_i + a_{16} NCOMP_i \\ & + \alpha_{17} LIQUIDITY_i + \alpha_{18} MACRO_i + a_{19} EXPORT_i + \alpha_{20} LAGE_i + \alpha_{21} FSIZE_i \\ & + industry\ controls + e_i \end{aligned} \tag{1}$$

for firm i.

We also estimated the same model for each of the abovementioned eight main investment categories.

In order to avoid multicollinearity problems, we also estimated the above equation separately for each single dynamic capability. For the eight investment reduction variables, we substituted the single dynamic capability variables by the average of the values of the single dynamic capability variables (CAP_AV).

5 Econometric Issues

The dependent variables are four- or five-level ordinal variables, which refer (a) to the overall impact of crisis on a firm's economic activities and (b) to the extent of the change of several categories of firm's investment expenditures during the long crisis period 2009–2014. Given the ordinal character of the dependent variables, the appropriate estimation method is Ordered Probit regression (using the "oprobit" procedure of STATA).

The independent variables that refer to internal factors are measured either for 2014 (metric variables) or for the period 2009–2014 (ordinal variables; only one is for 2012–2014), with the exception of the variable for overall internal problems that are explicitly related to the time before 2009 (see Table 9 in the Appendix). Thus, the independent variables reflect firms' condition at the end and not at the beginning of the observed crisis period. As a consequence, they could have been affected by the crisis and could reflect a firm's adaptation to the crisis. In this sense, they are endogenous. Logically, there exist the following three possibilities. First, these factors have changed so that they could have influenced positively crisis vulnerability or, vice versa, crisis vulnerability could have affected these factors positively. Second, these factors have changed so that they could have influenced negatively crisis vulnerability or, the other way around, crisis vulnerability could have affected these factors negatively. Third, they have remained as structural factors more or less unchanged during the crisis period contributing either to an increase or decrease of vulnerability. We cannot identify which effect of such possible interactions between dependent and independent variables (reverse causality) is dominant, but we get in the estimates the net effect for each of these factors independent of which kind of effects has been at work. Thus, we get knowledge of what has happened at the end of the process, i.e., which factors correlate positively or negatively with crisis vulnerability at the end of the day, under the assumption that only the magnitude but not the sign of possible effects could have changed during the observed crisis period. This would (still) be an important insight.

For some factors, we have good reasons to consider them as structural factors that would not have changed considerably during the crisis, just because they are factors that could be expected to reduce crisis vulnerability, thus to act anti-cyclically (e.g., capabilities, ICT and human capital endowment, existence of R&D activities).

The endogeneity issue is less a problem in the case of the external factors such as decrease of overall and crisis-induced liquidity constrains, which are explicitly reported in the survey as factors that could have affected a firm's economic activities before or during the observed crisis period, thus reflecting factors that could have directly affected crisis vulnerability with respect to investment.

The problem of possible unobserved, particularly time-variant, heterogeneity still remains, even though we control extensively for many possible explaining factors as well as for 20 two-digit industries and firm size, thus reducing to some extent the possibility of time-invariant heterogeneity. For these reasons, no claims are made for causality effects, but only for conditional correlation effects that might yield useful insights for possible causality effects in accordance to our research hypotheses.

With the exception of the eight capability variables, multicollinearity is not an issue in our estimations as shown in the correlation matrix in Table 11 in the Appendix. As already mentioned, we also estimated our model separately for each single capability variable, in order to be able to assess the relative relevance of these variables. Marginal effects were not calculated because most of the 21 right-hand variables in Eq. (1) are 5-level ordinal variables or binary variables; only 3 of them are metric variables. As a consequence, we refrain from a quantitative interpretation of the estimated coefficients of the empirical models.

Finally, there exists a certain survivor bias due to the fact that the crisis also caused many exits by the presumably less resilient companies. That they cannot be observed in the survey makes likely an underestimation of the true effects.

6 Results

6.1 Impact of Crisis on Overall Firm Activities and on Different Categories of Investment

Tables 1 and 2 respectively show the firm assessments of the impact of the crisis 2009–2014 on overall economic activities as well as on eight different categories of investment. About 78% of firms reported at least a medium-sized negative impact of crisis on overall firm economic activity (Table 1). Of these firms, about 27% reported a medium negative impact, 30% a large negative impact, and 21% a very large negative impact on overall economic activity.

The firm reaction to the crisis with respect to investment seems to diverge relatively strongly among different investment categories (Table 2). The percentage of firms that reported at least a small decrease of investment expenditures vary between 58.5% for investment in R&D and 75.6% for investment in equipment. This means that about 42% of firms could avoid a reduction of R&D, while the respective percentage in the case of investment in equipment amounted to only 24%. The percentage for the other six investment types lies somewhere between the extreme values for R&D and equipment. Very large decrease reported about 13% of firms for buildings and marketing, while the lowest firm shares with very large decrease are found for investment in process innovation (5.2%) and training (5.5%). It is an interesting feature of the reaction pattern that firms tried to maintain innovation on investment, thus showing to some extent an anti-cyclical behavior.

6.2 Estimates for the Overall Vulnerability Variable

The estimates for the overall crisis vulnerability variable (VULN_ALL) that measures the overall negative impact of the crisis on a firm's economic activities are presented in Table 3. The high significance of Wald chi2 statistics in the ten estimated equations demonstrates the overall statistical validity of the estimates.[3]

[3] The Wald chi-squared test is a parametric statistical measure to confirm whether a set of independent variables are jointly statistically significant for a model or not.

Table 3 Dependent variable: VULN_ALL; factors explaining crisis behavior—part I

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Resources										
R&D	0.120	0.112	0.118	0.120	0.104	0.115	0.138	0.119	0.119	0.130
	(0.155)	(0.153)	(0.154)	(0.156)	(0.153)	(0.152)	(0.155)	(0.156)	(0.159)	(0.157)
HQUAL	0.399	0.447*	0.413*	0.422*	0.419*	0.432*	0.458*	0.387	0.391	0.423*
	(0.250)	(0.252)	(0.250)	(0.253)	(0.249)	(0.247)	(0.249)	(0.247)	(0.257)	(0.250)
ICT_INFRA	0.068	0.061	0.060	0.063	0.056	0.035	0.048	0.038	0.061	0.078
	(0.066)	(0.063)	(0.063)	(0.064)	(0.064)	(0.064)	(0.063)	(0.064)	(0.066)	(0.065)
ORGAN	−0.240	−0.251*	−0.243	−0.221	−0.230	−0.272*	−0.227	−0.245	−0.279*	−0.183
	(0.157)	(0.151)	(0.157)	(0.159)	(0.160)	(0.161)	(0.160)	(0.157)	(0.165)	(0.159)
Capabilities										
CAP1	−0.179***								−0.103	
	(0.070)								(0.086)	
CAP2		−0.248***							−0.259***	
		(0.073)							(0.101)	
CAP3			−0.169*						0.169	
			(0.088)						(0.130)	
CAP4				−0.171**					−0.114	
				(0.073)					(0.083)	
CAP5					−0.099				0.010	
					(0.077)				(0.089)	
CAP6						0.005			0.130*	
						(0.066)			(0.071)	
CAP7							−0.112*		0.022	
							(0.064)		(0.084)	

Table 3 (continued)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CAP8								−0.220***	−0.188***	
								(0.064)	(0.070)	
AV_CAP										−0.367***
										(0.116)
INTERNAL	−0.046	−0.092	−0.074	−0.068	−0.053	−0.062	−0.045	−0.045	−0.067	−0.057
	(0.085)	(0.085)	(0.086)	(0.085)	(0.086)	(0.086)	(0.086)	(0.086)	(0.085)	(0.085)
Market environment										
IPC	0.072	0.087	0.085	0.074	0.063	0.070	0.062	0.067	0.083	0.076
	(0.073)	(0.073)	(0.075)	(0.072)	(0.072)	(0.072)	(0.071)	(0.073)	(0.076)	(0.073)
INPC	−0.105	−0.132*	−0.111	−0.096	−0.099	−0.090	−0.087	−0.086	−0.125*	−0.105
	(0.071)	(0.074)	(0.072)	(0.071)	(0.071)	(0.071)	(0.070)	(0.072)	(0.075)	(0.071)
N_COMP	0.005*	0.006*	0.005*	0.005*	0.005*	0.004	0.004	0.004	0.004	0.005*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
LIQUIDITY	0.275**	0.297***	0.288***	0.285***	0.299***	0.297***	0.295***	0.290***	0.291***	0.285***
	(0.074)	(0.073)	(0.073)	(0.073)	(0.073)	(0.073)	(0.073)	(0.074)	(0.075)	(0.073)
MACRO	0.449***	0.457***	0.452***	0.450***	0.452***	0.444***	0.432***	0.457***	0.460***	0.451***
	(0.098)	(0.098)	(0.098)	(0.099)	(0.098)	(0.097)	(0.098)	(0.100)	(0.099)	(0.099)
Other characteristics										
EXPORT	−0.467***	−0.454***	−0.463***	−0.463***	−0.472***	−0.492***	−0.459*	−0.522***	−0.491***	−0.449***
	(0.167)	(0.168)	(0.167)	(0.169)	(0.167)	(0.165)	(0.168)	(0.172)	(0.174)	(0.172)
AGE	0.011***	0.011***	0.011****	0.011***	0.011***	0.011***	0.011***	0.010***	0.010***	0.011***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
LEMP	−0.139***	−0.142***	−0.153***	−0.139***	−0.147***	−0.149***	−0.147***	−0.131***	−0.110**	−0.139***
	(0.050)	(0.052)	(0.051)	(0.051)	(0.050)	(0.050)	(0.051)	(0.052)	(0.055)	(0.052)
Industry dummies (19)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 3 (continued)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Thresholds (3)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	298	298	298	298	298	298	298	298	298	298
Wald chi2	148.4	159.1	155.1	157.8	157.4	161.1	156.8	151.8	164.2	150.0
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.173	0.180	0.170	0.173	0.168	0.167	0.170	0.182	0.197	0.179
Log pseudolikelihood	− 331.7	− 329.1	− 333.0	− 331.9	− 334.0	− 335.9	− 334.4	− 329.7	− 322.1	− 329.5

Note: Ordered Probit estimates; five thresholds are not shown; heteroscedasticity-robust standard errors in brackets; *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-test level, respectively

6.2.1 Resource Endowment

The joint test for all components of resource endowment is not statistically significant (table 12 in the Appendix). Nevertheless, we find statistically a (partially) significant negative correlation for the use of new forms of organic workplace organization (such as teamwork, job rotation, and decentralization; variable ORGAN). These organizational forms seem to increase a firm's capacity to flexibly react to the crisis, thus, its capacity to keep low the negative impact of the crisis on its activities. This finding is in accordance with Aghion et al. (2017), also to previous management research, which shows that in unstable external environments "organic" organizational designs enhance a firm's ability to identify and understand better the external changes as well as to successfully respond to them (Donaldson 2001; Sherehiy et al. 2007).

However, the existence of R&D activities and the ICT infrastructure (intensity of use of standard ICT enterprise applications such as ERP, SCM, CRM, business analytics, and collaboration support systems) do not seem to be significantly correlated with crisis vulnerability.

Further, we find a positive correlation for the variable that measures human capital. Such a positive correlation means that the higher the share of employees with tertiary-level education the higher the crisis vulnerability, which is contrary to theoretical expectation and economic intuition. A more detailed investigation revealed that though we control for firm size this correlation is presumably determined by the fact that smaller firms, which have a significantly higher share of high-educated employees than larger firms and build the wide majority in our sample,[4] show a higher crisis vulnerability than larger firms (negative correlation of the variable LEMP in Table 3). In estimates not shown here, we interacted HQUAL with the employment variable and found a negative—even though not statistically significant—correlation of this interaction term, meaning that the larger a firm is, the lower is the correlation of HQUAL with the vulnerability variable.

All in all, hypothesis 1 is only partly confirmed for new forms of organic workplace organization.

6.2.2 Dynamic Capabilities

The joint effect of the dynamic capabilities that are related to organizational agility and are taken into consideration in this study is negative and statistically significant.[5] Because of rather high multicollinearity among the capability variables (see Table 12 in the Appendix and column 9 in Table 3), we also present in Table 3 estimates of Eq. (1) separately for each capability variable and also for the average of the eight capability variables. We find statistically significant negative correlations for six out of eight single dynamic capabilities as well as for the average. Only two capabilities—CAP5 (rapid reaction to changes of product diversity) and CAP6 (rapid adaption to price changes of competitors)—do not seem to contribute to the attenuation of crisis negative impact. These findings indicate that the existence of a series of dynamic capabilities (related to organizational agility) weakens the negative impact of the crisis, being more important from this perspective than resource endowment. Particularly, those capabilities that imply a high propensity to innovative as

[4] For firms with more than 250 employees is the average share of high-educated employees 28%, for firms with less than 250 employees 43%.

[5] See the results of the respective statistical test (based on the estimates in column 9 of Table 3 in Table 12 in the Appendix).

well as flexible behavior (CAP1: rapid reaction to the introduction from competitors of new products; CAP4: expansion to new markets; CAP7: introduction of new technologies) appear to be more effective for stabilizing firm activities during a crisis. On the whole, hypothesis 2 receives significant empirical support.

6.2.3 Overall Internal Problems

Insufficient cost controls, over-investment in equipment, buildings or storage capacity or over-expansion by takeovers or mergers are not significantly correlated with overall crisis economic vulnerability. The additional estimates for the three underlying variables INTERN1, INTER2, and INTER3 in column 3 in Table 4 show that also at the level of the single variables no significant effects are discernible.

6.2.4 Competition Conditions

We find no statistically significant effect of price or non-price pressure. This is probably because competition pressure is in general low in most sectors of the Greek economy (see, e.g., Arvanitis et al. 2013). We find a positive statistically significant effect of the number of competitors, the structural component of our competition measurement. Estimates not shown here, in which also a quadratic term for N_COMP is added to the model, yielded non-significant coefficients for both the linear and the quadratic term, thus no confirmation for a non-linear relationship. The finding of a positive linear relationship indicates that firms in rather polypolistic markets with many competitors are more vulnerable than firms in oligopolistic or monopolistic structured markets with few competitors.

6.2.5 Macroeconomic Conditions

As expected, macroeconomic effects (referring to the decrease of demand for a firm's products and services as well as of their prices due to the crisis; MACRO), also liquidity problems due to decrease of credit limits by banks and suppliers or decrease of the paying willingness of customers (LIQUIDITY), increase overall crisis economic vulnerability. Thus, hypothesis 3 and hypothesis 4 are confirmed.

Additional estimates for the three single variables that constitute LIQUIDITY in column 2 in Table 4 indicate that the main effect is traced back to the decrease of paying willingness of customers (LIQUID3), which obviously has been a more important problem than the reduction of credit limits by banks or suppliers. Further, the estimates in column 1 in Table 4 show that the reduction of domestic and—to a small extent—of foreign demand (variables MACRO1 and MACRO3) have been the main effects behind the composite variable MACRO, which contained also variables for the reduction of state demand and of product and service prices.

Export orientation (EXPORT) is a further characteristic that contributes to an attenuation of crisis economic vulnerability, presumably because the successful exposition to international competition enhances operation flexibility that is needed for effectively confronting an economic crisis. In addition, between 2008 and 2014 the economic crisis in Greece was more severe than in most of the countries to which exports are directed, so

Table 4 Dependent variable: VULN_ALL; factors explaining crisis behavior—part II

Variables	(1)	(2)	(3)
Resources			
R&D	0.078	0.131	0.130
	(0.158)	(0.160)	(0.158)
HQUAL	0.527***	0.380	0.408
	(0.258)	(0.252)	(0.251)
ICT_INFRA	0.064	0.083	0.073
	(0.067)	(0.064)	(0.065)
ORGAN	−0.140	−0.178	−0.193
	(0.160)	(0.161)	(0.159)
Capabilities			
AV_CAP	−0.488***	−0.369***	−0.352***
	(0.180)	(0.115)	(0.115)
Internal problems			
INTERNAL	−0.019	−0.054	
	(0.087)	(0.085)	
INTERN1			−0.070
			(0.066)
INTERN2			0.148
			(0.095)
INTERN3			−0.125
			(0.090)
Market environment			
IPC	0.086	0.073	0.083
	(0.073)	(0.073)	(0.072)
INPC	−0.072	−0.105	−0.095
	(0.072)	(0.070)	(0.071)
N_COMP	0.005*	0.005*	0.005*
	(0.003)	(0.003)	(0.003)
Other external factors			
LIQUIDITY	0.294***		0.282***
	(0.075)		(0.074)
LIQUID1		0.090	
		(0.073)	
LIQUID2		0.056	
		(0.079)	
LIQUID3		0.152**	
		(0.067)	
Macroeconomic factors			
MACRO		0.447***	0.441***
		(0.099)	(0.099)
MACRO1	0.316***		
	(0.062)		
MACRO2	0.001		
	(0.052)		
MACRO3	0.147**		
	(0.062)		

Table 4 (continued)

Variables	(1)	(2)	(3)
MACRO4	−0.009		
	(0.069)		
Other characteristics			
EXPORT	−0.488***	−0.461***	−0.442***
	(0.180)	(0.172)	(0.173)
AGE	0.011***	0.011***	0.011***
	(0.004)	(0.004)	(0.004)
LEMP	−0.143***	−0.141***	−0.140***
	(0.054)	(0.052)	(0.052)
Industry dummies (19)	Yes	Yes	Yes
Thresholds (3)	Yes	Yes	Yes
N	298	298	298
Wald chi2	179.9	157.1	157.8
Prob > chi2	0.000	0.000	0.000
Pseudo R^2	0.198	0.180	0.183
Log pseudolikelihood	−322.0	−329.1	−327.9

Note: Ordered Probit estimates; five thresholds are not shown; heteroscedasticity-robust standard errors in brackets; *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-test level, respectively

firm's export orientation could help to reduce its overall economic vulnerability to the economic crisis.

Finally, larger firms seem to be less crisis-vulnerable than smaller firms, presumably due to higher operational flexibility compared to smaller firms. Even if there is a positive correlation between firm size and firm age ($r = 0.32$ in our sample), older firms seem to be more crisis-vulnerable than younger firms.[6]

6.3 Estimates for Different Investment Categories

The estimates for the eight investment variables are presented in Table 5. The high significance of Wald chi2 statistics in the eight estimated equations demonstrates the overall statistical validity of the estimates.

6.3.1 Resource Endowment

The joint test for all components of resource endowment is negative and statistically significant for the crisis-induced reduction of investment (i.e., vulnerability with respect to investment) in training, R&D, product, and process innovation (Table 12 in the Appendix). Seen from a complementary perspective this means that resource endowment is an important means of a firm's resilience primarily for the above-mentioned investment categories, which are the most "sophisticated" ones, associated with the increase of firm's

[6] Estimates containing either only the age or only the firm size variable showed that there is no multicollinearity effect.

Table 5 Factors explaining crisis behavior for different kinds of investment

Variables	(1) Equipment (without ICT)	(2) ICT	(3) Buildings	(4) Training	(5) Marketing	(6) R&D	(7) Product innovation	(8) Process innovation
Resources								
R&D	0.260*	0.253*	−0.149	−0.042	0.120	0.251	−0.052	−0.097
	(0.147)	(0.145)	(0.159)	(0.157)	(0.149)	(0.160)	(0.159)	(0.151)
HQUAL	−0.271	0.371	−0.147	−0.323	−0.080	−1.074***	−0.740***	−0.563**
	(0.286)	(0.280)	(0.262)	(0.266)	(0.252)	(0.285)	(0.284)	(0.286)
ICT_INFRA	−0.045	−0.029	0.005	−0.006	0.128**	−0.024	0.010	−0.007
	(0.062)	(0.064)	(0.064)	(0.067)	(0.063)	(0.071)	(0.070)	(0.071)
ORGAN	−0.457***	−0.242*	−0.044	−0.283**	−0.081	−0.019	0.031	−0.130
	(0.143)	(0.144)	(0.158)	(0.141)	(0.151)	(0.159)	(0.159)	(0.151)
Capabilities								
AV_CAP	−0.237**	−0.208**	0.005	−0.235**	−0.185*	−0.353***	−0.482***	−0.421***
	(0.112)	(0.107)	(0.104)	(0.108)	(0.111)	(0.101)	(0.111)	(0.104)
Internal problems								
INTERNAL	0.028	0.016	0.281***	0.235***	0.065	0.281***	0.326***	0.404***
	(0.086)	(0.084)	(0.092)	(0.079)	(0.089)	(0.078)	(0.079)	(0.076)
Market environment								
IPC	0.135**	−0.014	0.145*	0.037	0.055	0.016	0.082	0.116
	(0.069)	(0.072)	(0.076)	(0.078)	(0.074)	(0.077)	(0.075)	(0.076)
INPC	−0.038	0.017	−0.139*	−0.112	−0.141**	−0.112	−0.122*	−0.128
	(0.069)	(0.074)	(0.078)	(0.071)	(0.069)	(0.075)	(0.075)	(0.081)
N_COMP	0.005**	0.003*	0.007***	0.006***	0.004	0.008***	0.007***	0.007***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)
Other external factors								

Table 5 (continued)

Variables	(1) Equipment (without ICT)	(2) ICT	(3) Buildings	(4) Training	(5) Marketing	(6) R&D	(7) Product innovation	(8) Process innovation
LIQUIDITY	0.320***	0.359***	0.076	0.170**	0.156**	0.207***	0.255**	0.167**
	(0.071)	(0.075)	(0.073)	(0.070)	(0.074)	(0.079)	(0.082)	(0.082)
Macroeconomic factors								
MACRO	0.497***	0.511***	0.405***	0.494***	0.497***	0.501***	0.456***	0.436***
	(0.099)	(0.089)	(0.101)	(0.101)	(0.102)	(0.104)	(0.099)	(0.096)
Other characteristics								
EXPORT	−0.329*	−0.440***	−0.279	−0.120	−0.303*	−0.319*	−0.327*	−0.204
	(0.170)	(0.168)	(0.176)	(0.169)	(0.166)	(0.175)	(0.173)	(0.177)
AGE	−0.003	−0.000	−0.003	−0.006**	0.000	−0.011***	−0.001	−0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
LEMP	0.033	0.046	−0.005	0.019	−0.040	−0.120**	−0.069	−0.043
	(0.051)	(0.054)	(0.049)	(0.053)	(0.049)	(0.053)	(0.053)	(0.050)
Industry dummies (19)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Thresholds (4)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	298	298	298	298	298	298	298	298
Wald chi2	155.2	181.1	131.3	133.4	114.1	723.5	1194.3	1082.7
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.167	0.144	0.134	0.131	0.107	0.188	0.190	0.176
Log pseudolikelihood	−387.2	−434.2	−395.5	−387.3	−420.7	−357.0	−350.7	−354.6

Note: Ordered Probit estimates; five thresholds are not shown; heteroscedasticity-robust standard errors in brackets; *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-test level, respectively

knowledge base as well as its use for innovation, thus particularly relevant for the firm growth potential. Therefore, hypothesis 1 is fully confirmed for investment in training, R&D, product, and process innovation. However, from Table 5, we can see that not all resource components contribute to the same extent to the significant negative joint effect. For the innovation-related investment categories (in R&D, product, and process innovation), human capital (HQUAL) is the most important resource to which the joint effect can be traced back.[7] As they are highly "knowledge intensive" they rely on high-quality human capital, which can contribute to the identification of highly valuable opportunities for such investment, and also to their successful implementation and generation of business value, thus decreasing firms' propensity to reduce these investments during crisis. For investment in training is the existence of new forms of organic workplace organization (ORGAN) the main single resource that contributes to a reduction of crisis vulnerability.

On the contrary, the joint test for all components of resource endowment is not statistically significant for the crisis-induced reduction of investment in equipment, ICT, buildings, and marketing (Table 12 in the Appendix). However, the organic workplace organization variable is negatively correlated to crisis-induced decrease of investment in equipment and ICT vulnerability. Flexible and decentralized organizational forms enable the firm to utilize machines and ICT infrastructure more efficiently, which increases the value they generate for the firms for a certain investment volume, thus reducing a firm's propensity to decrease respective investment during the crisis. Therefore, for these two investment categories, hypothesis 1 holds only partly. For investment in buildings and in marketing, resource endowment is not relevant for the respective crisis-induced investment reduction. Investment in new buildings is the first activity to be postponed for after the crisis in times of limited financial means without severe consequences for the overall firm operations, independent of the level of resource endowment. Also, the decision as to the extent of reduction in marketing investment appears to be independent of resource endowment but not for the same reasons as in the case of buildings. Particularly during an economic crisis is often marketing crucial for the firm existence, thus not directly dependent on the level of overall resource endowment, which could explain the insignificant effect of resource endowment. For these two investment types, hypothesis 1 is not confirmed.

The significantly positive signs of the variable for R&D in the equations of vulnerability with respect to equipment and ICT investment could be interpreted as a hint of the existence of a trade-off between investment in R&D and investment in equipment and/or ICT. Such a trade-off could be traced back to different long-term perspectives of different investment types that might lead firms to prefer a type of investment over other types in times of limited financial means. Under such conditions, firms that want to maintain R&D activities because of their impact on long-term growth may find it better to reduce in the short term their investment in equipment and/or ICT stronger than firms without R&D. Presumably, this kind of trade-off does not occur for other investment categories, for instance for the investment in product and process innovations the investment in R&D is mostly a precondition.

[7] The adverse effect for this variable in the VULN_ALL-estimates disappears in the estimates for the eight investment categories.

6.3.2 Dynamic Capabilities

The variable for the average of the eight dynamic capability variables (AV_CAP) is negatively correlated for seven out of eight investment categories. With the exception of investment in buildings, the availability of a high level of dynamic capabilities (related to organizational agility) is a powerful means for coping better with the crisis and avoiding a reduction of investment, thus reducing investment vulnerability during an economic crisis. Therefore, hypothesis 2 receives strong confirmation for all investment categories (except for investment in buildings).

6.3.3 Internal Problems

Even if internal problems before the crisis do not seem to influence overall crisis vulnerability (see Tables 3 and 6), a more detailed analysis of the vulnerability with respect to single investment categories shows that this kind of problems may correlate positively with vulnerability with respect to five out of the eight investment categories examined in this paper; only investment in equipment, in ICT, and in marketing do not appear to be influenced by such internal problems.

6.3.4 Competition Conditions

We find a significantly positive correlation for the intensity of price competition for the investment in equipment and in buildings and a significantly negative correlation for the investment in buildings, in marketing, in product, and in process innovation. The positive correlations point to a vulnerability increase with respect to equipment and buildings under conditions of high price pressure. Contrary to this, firms that operate in markets with high non-price competition seem to be less vulnerable with respect to investment in buildings, marketing, and product innovation, as non-price competition drives firms to retain these investments as much as possible. The negative correlation of non-price equation in the equation for investment in product innovation is in accordance to earlier studies that show that strong non-price competition enhances product innovation.

Estimates of the equations for investment in equipment, ICT, training, buildings, product, and process innovation not shown here, in which also a quadratic term for N_COMP is added to the model, yielded insignificant coefficients for both the linear and the quadratic term, thus no confirmation for a non-linear relationship. For R&D and marketing, we find a significantly positive linear and a significantly negative quadratic term, corresponding to an inverse U-form. The former finding is in accordance to Aghion et al. (2005), while the latter is contrary to Sacco and Schmutzler (2011).

On the whole, the finding of a positive linear relationship in Table 5 (with the exception of marketing) indicates that firms in rather polypolistic markets with many competitors are more vulnerable than firms in oligopolistic or monopolistic structured markets with few competitors.

6.3.5 Macroeconomic Conditions

As expected, macroeconomic effects (referring to the decrease of demand for a firm's products and services as well as of their prices due to the crisis) and also liquidity problems due

Table 6 Summary of results

Variables	VULN_ALL	Equipment	ICT	Buildings	Training	Marketing	R&D	Product innovation	Process innovation
Resource endowment (hyp. 1)									
R&D	ns	+	+	ns	ns	ns	ns	ns	ns
HQUAL	+	ns	ns	ns	ns	ns	−	−	−
ICT_INFRA	ns	ns	ns	ns	ns	+	ns	ns	ns
ORGAN	(−)	−	−	ns	−	ns	ns	ns	ns
Capabilities (average) (hyp. 2)									
AV_CAP	−	−	−	ns	−	−	−	−	−
Market environment									
N_COMP	+	+	+	+	+	ns	**(non-lin.)**	**(non-lin.)**	+
Other external factors									
LIQUIDITY (hyp. 3)	+	+	+	ns	+	+	+	+	+
MACRO (hyp. 4)	+	+	+	+	+	+	+	+	+

Note: +: positive and statistically significant at the 10%-test level; −: negative and statistically significant at the 10%-test level; ns: statistically insignificant; non-lin.: non-linear relationship of N_COMP to the respective dependent variable

to decrease of credit limits by banks and suppliers or decrease of the paying willingness of customers during the crisis correlate positively with vulnerability with respect to all investment categories (with the exception of buildings). Therefore, overall unfavorable economic conditions and unfavorable behavior of important transaction partners affect negatively investment behavior of firms in general, even if not all firms to the same extent. Thus, hypothesis 3 and hypothesis 4 are confirmed.

Export orientation (EXPORT) is for most investment categories a further characteristic that contributes to an attenuation of crisis vulnerability, presumably because the exposition to international competition enhances operational flexibility that is needed for effectively confronting an economic crisis. In addition, as already mentioned, between 2008 and 2014 the economic crisis in Greece was more severe than in most of the countries to which exports are directed, so firm's export orientation could help to reduce its economic vulnerability to the economic crisis, and therefore the need to resort to investment reductions.

Finally firm size and firm age seem to be not relevant for vulnerability with respect to the most single investment categories.

7 Summary and Conclusions

Our study makes a contribution to a better understanding firms' behavior in an economic crisis by developing and testing a set of research hypotheses concerning the effects of a series of factors on firms' overall crisis economic vulnerability as well as vulnerability with respect to several different investment categories, including some highly "sophisticated" knowledge-intensity ones, such as investments in R&D, product innovation, and process innovation. The theoretical foundations of this study are the RBV view of the firm in combination with the DCV of the firm. As dependent variable, we use several ordinal variables that measure various dimensions of crisis economic vulnerability. One variable measures the overall negative impact of the crisis on a firm's economic activities, which is considered as a close proxy to overall crisis economic vulnerability. Eight further variables measure the extent of crisis-induced reduction of eight investment categories (investment in equipment, ICT, buildings, training, marketing, R&D, product, and process innovation). These variables are considered as measures of investment-related crisis vulnerability: the stronger the decrease of investment expenditures due to crisis, the higher is a firm's investment-related crisis vulnerability.

We distinguish five groups of factors that might have affected firm economic behavior, particularly investment behavior, during the crisis period 2009–2014. These five groups refer directly to our research hypotheses. We consider two groups of internal factors: measures for overall resource endowment (see hypothesis 1) and measures for firm dynamic capabilities (see hypothesis 2). Further, we examine three groups of external factors: one referring to the competition conditions in a firm's product market, a second one related to macroeconomic conditions (overall development of domestic and foreign demand, etc.; hypothesis 3), and a third one covering liquidity conditions with respect to transaction partners (such as banks, customers, and providers; hypothesis 4).

The above research hypotheses are tested using data from a national context that has been severely hit by economic crisis, so it is highly appropriate for such a study: we are using data for Greek firms for the crisis period 2009–2014. Table 6 summarizes the results of our econometric analysis. We find evidence for a partial confirmation of hypothesis 1 (vulnerability reducing effect of new forms of organic workplace organization and human

capital endowment, the latter effect particularly for investment in R&D and innovation), full confirmation of hypothesis 2 (stabilizing effect of a series of dynamic capabilities related to organizational agility), full confirmation of hypothesis 3 (de-stabilizing effect of crisis-induced private and public demand), and full confirmation of hypothesis 4 (de-stabilizing role of crisis-induced liquidity restrictions). Further, we find that firms operating in polypolistic markets (many competitors) are more vulnerable than firms operating in markets with few competitors. Finally, firms that are making exports and are therefore exposed to international competition are less vulnerable than firms that operate only in a small home economy.

On the whole, we conclude that it is not the level of resource endowment that makes the difference as to vulnerability level but the existence of dynamic capabilities, and especially organizational agility, that enable the firm to sense the important changes that appear in its external environment during an economic crisis and to respond to them rapidly and effectively.

Our study has interesting implications for both research and practice. From a research perspective, it makes a conceptually systematic investigation, based on a combination of the RBV and the DCV of the firm, of the effects of a series of internal and external factors on firms' economic vulnerability (with respect to both overall activity and several different investment categories) induced by economic crises. Furthermore, it opens up new directions of research concerning the determinants of various aspects of firms' vulnerability to economic crisis and provides useful theoretical foundation and research framework for this.

There are some implications of these findings for corporate management: the use of new forms of organic workplace organization (such as teams, job rotation, and decentralization of decision-making) and highly qualified personnel, as well as the development of series of dynamic capabilities related to organizational agility (such as rapid adaptation of products to customers' specific needs, efficiency-guided change of providers of inputs, rapid expansion of activities to new markets, and rapid reaction to the introduction of new products from competitors), are means through which firm management could reduce the negative impact on a firm's overall economic activity as well as investment of fluctuations of external economic activities.

The implications for public policy would be the need for stronger promotion of export activities, especially for small, open economies, and higher availability of human capital. Finally, the findings with respect to competition indicate that a high crisis-induced vulnerability can be expected for (presumably) small firms in markets with many competitors, for which specific policy measures (e.g., tax reduction) would be needed in order to avoid a strong employment decrease.

There are of course limitations of the present study, the most important are the cross-sectional character of the available data and the lack of data for the time before the crisis that do not allow us to make causal statements, so further research in this direction is required. A further limitation refers to the so-called survivor bias that can lead to an underestimation of the true effects due to the fact that the crisis caused many exits of the presumably less resilient companies that could not be observed in the survey. Another limitation is that our data are coming from a single country (which however experienced a severe economic crisis that makes it highly appropriate for such studies), so similar research is required for other countries that experienced economic crises of different levels of severity, and also having different levels of economic and technological development. Furthermore, this study has examined the effect of one type of dynamic capabilities on crisis-induced vulnerability, namely, those related to organizational agility, so it will be quite interesting to examine and compare the effects of other types of dynamic capabilities as well.

Appendix

Table 7 Sampling procedure: composition in % of original and intermediate sample resp. by industry

Industry	Original sample	Intermediate sample
Food, beverage, tobacco	37.1	34.3
Textiles, clothing, leather	8.6	11.3
Wood processing	1.0	0.9
Paper	3.8	4.4
Printing	5.2	5.1
Chemicals	8.3	11.1
Plastics, rubber	5.6	4.5
Glass, stone, clay	5.7	5.7
Metal, metal working	7.8	11.0
Machinery, vehicles	4.1	3.4
Electrical machinery, electronics	3.5	3.0
Other manufacturing (furniture, etc.)	5.9	1.4
Energy, water	3.4	3.8
Manufacturing	*30.7*	*27.7*
Construction	*5.7*	*11.2*
Trade	65.4	66.5
Hotels, catering	13.1	6.6
Transport, telecommunication	8.7	15.7
Computer services	2.1	2.0
Business services	10.7	9.5
Services	*63.6*	*61.1*
Total	*N* = *6429*	*N* = *3308*

Table 8 Composition of the used sample by industry and firm size class

Industry	*N*	%
Food, beverage, tobacco	46	12.7
Textiles, clothing, leather	7	1.9
Wood processing	3	0.8
Paper	8	2.2
Printing	6	1.7
Chemicals	19	5.2
Plastics, rubber	8	2.2
Glass, stone, clay	4	1.1
Metal, metal working	7	1.9
Machinery, vehicles	8	2.2
Electrical machinery, electronics	10	2.8
Other manufacturing (furniture, etc.)	12	3.3
Energy, water	8	2.2
Manufacturing	*146*	*40.2*
Construction	*34*	*9.4*
Trade	63	17.3
Hotels, catering	23	6.3
Transport, telecommunication	16	4.3
Computer services	21	5.8
Business services	60	16.5
Services	*183*	*50.4*
Small: up to 49 employees	191	52.6
Medium-sized: 50 to 249 employees	131	36.1
Large: 250 employees and more	41	11.3
Total	*363*	*100.0*

Table 9 Definition of variables

Variable	Definition
Dependent variables	
VULN_ALL	Impact of crisis 2009–2014 on overall firm activities (as compared with last 5 years before crisis); four-level ordinal variable; 1: "no impact/ weak negative impact"; 4: "very large negative impact"; see also Table 2
Equipment	Impact of crisis 2009–2014 on equipment investment expenditures (without ICT); five-level ordinal variable; 1: "increase"; 5: "very large decrease"; see also Table 2
ICT	Impact of crisis 2009–2014 on ICT investment expenditures; five-level ordinal variable; 1: "increase"; 5: "very large decrease"; see also Table 2
Buildings	Impact of crisis 2009–2014 on buildings investment expenditures; five-level ordinal variable; 1: "increase"; 5: "very large decrease"; see also Table 2
Training	Impact of crisis 2009–2014 on training expenditures; five-level ordinal variable; 1: "increase"; 5: "very large decrease"; see also Table 2
Marketing	Impact of crisis 2009–2014 on marketing expenditures; five-level ordinal variable; 1: "increase"; 5: "very large decrease"; see also Table 2
R&D	Impact of crisis 2009–2014 on R&D expenditures; five-level ordinal variable; 1: "increase"; 5: "very large decrease"; see also Table 2
Product innovation	Impact of crisis 2009–2014 on expenditures for product innovation; five-level ordinal variable; 1: "increase"; 5: "very large decrease"; see also Table 2
Process innovation	Impact of crisis 2009–2014 on expenditures for product innovation; five-level ordinal variable; 1: "increase"; 5: "very large decrease"; see also Table 2
Independent variables	
Resource endowment	
R&D	R&D activities in the period 2012–2014: yes/no; binary variable
HQUAL	Share of employees with tertiary-level education 2014
ORG	Use of new forms of workplace organization such as teams, job rotation, and decentralization of decision-making: yes/no; binary variable
ICT_INFRA	Average use intensity of the following ICT applications: ERP, CRM, SCM, business intelligence/business analytics system, collaboration support system; intensity use is measured on a 5-point Likert scale (1: "no use"; 5: "very intensive use")
Business capabilities	
CAP1	Rapid reaction to the introduction from competitors of new products/ services; five-level ordinal variable (1: "not available"; 5: "available to a very high degree")
CAP2	Rapid adaption of products/services to customers' specific needs; five-level ordinal variable (1: "not available"; 5: "available to a very high degree")
CAP3	Rapid reaction to changes of demand for a certain product/service; five-level ordinal variable (1: "not available"; 5: "available to a very high degree")
CAP4	Rapid expansion of activities to new domestic and foreign markets; five-level ordinal variable (1: "not available"; 5: "available to a very high degree")
CAP5	Rapid increase or decrease of product/service diversity; five-level ordinal variable (1: "not available"; 5: "available to a very high degree")

Table 9 (continued)

Variable	Definition
CAP6	Rapid adaption of prices as reaction to price changes of competitors; five-level ordinal variable (1: "not available"; 5: "available to a very high degree")
CAP7	Rapid introduction of new technologies for reduction of production costs and/or increase of product/service quality; five-level ordinal variable (1: "not available"; 5: "available to a very high degree")
CAP8	Rapid change of providers for lower procurement costs, higher quality, shorter delivery times, etc.; five-level ordinal variable (1: "not available"; 5: "available to a very high degree")
AV_CAP	Average of the scores on a 5-point Likert scale of the eight dynamic capabilities (see above)
Overall internal problems	
INTERNAL	Average of the scores on a 5-point Likert scale of the following three single factors that could be considered as sources/causes of firm problems in the period 2009–2014: insufficient cost control; over-investment in equipment, buildings and storage capacity; over-expansion by takeovers, mergers, etc
INTERN1	Insufficient cost control; five-level ordinal variable (1: "not important"; 5: "very important")
INTER2	Over-investment in equipment, buildings and storage capacity; five-level ordinal variable (1: "not important"; 5: "very important")
INTERN3	Over-expansion by takeovers, mergers, etc.; five-level ordinal variable (1: "not important"; 5: "very important")
Competition conditions	
P_COMPET	Intensity of price competition at the product market; five-level ordinal variable: 1: "very small"; 5: "very strong"
NP_COMPET	Intensity of non-price competition at the product market; five-level ordinal variable: 1: "very small"; 5: "very strong"
N_COMP	Number of worldwide competitors at the product market
Broad economic environment	
LIQUIDITY	Average of the scores on a 5-point Likert scale for the following three single factors that could be considered as sources/causes of firm problems in the period 2009–2014: decrease of credit limits by banks; by providers; decrease of paying willingness of customers
LIQUID1	Decrease of credit limits by banks; five-level ordinal variable (1: "not relevant"; 5: "very relevant")
LIQUID2	Decrease of credit limits by providers; five-level ordinal variable (1: "not relevant"; 5: "very relevant")
LIQUID3	Decrease of paying willingness of customers; five-level ordinal variable (1: "not relevant"; 5: "very relevant")
Macroeconomic conditions	
MACRO	Average of the scores on a 5-point Likert scale for the following four single factors that could be considered as sources/causes of firm problems in the period 2009–2014: decrease of domestic private demand; demand of the state; of foreign demand; decrease of product and service prices (1: "not relevant"; 5: "very relevant")
MACRO1	Decrease of domestic private demand; five-level ordinal variable (1: "not relevant"; 5: "very relevant")
MACRO2	Decrease of demand of the state; five-level ordinal variable (1: "not relevant"; 5: "very relevant")

Table 9 (continued)

Variable	Definition
MACRO3	Decrease of foreign private demand; five-level ordinal variable (1: "not relevant"; 5: "very relevant")
MACRO4	Decrease of prices of goods/services; five-level ordinal variable (1: "not relevant"; 5: "very relevant")
EXPORT	Exports yes/no; binary variable
AGE	Firm age (2015 minus foundation year)
LEMP	Natural logarithm of the number of employees

Note: The capability variables ICT_CAP_NEW to ICT_CAP_ICT_PLANS are ordinal variables measured on

Table 10 Descriptive statistics ($N = 298$)

Variable	Mean	Std. Dev	Min	Max
VULN_ALL	3.425	1.202	1	4
Equipment	2.665	1.270	1	5
ICT	3.815	1.471	1	6
Buildings	2.505	1.455	1	5
Training	2.437	1.259	1	5
Marketing	2.798	1.375	1	5
R&D	2.393	1.416	1	5
Product innovation	2.283	1.235	1	5
Process innovation	2.240	1.221	1	5
R&D	0.492	0.501	0	1
HQUAL	0.412	0.310	0	1
ORGAN	2.777	1.120	0	1
ICT infrastructure	0.511	0.401	0	1
CAP_1	3.579	0.964	1	5
CAP_2	4.025	0.953	1	5
CAP_3	3.997	0.784	1	5
CAP_4	3.376	1.009	1	5
CAP_5	3.530	0.938	1	5
CAP_6	3.579	1.024	1	5
CAP_7	3.257	1.101	1	5
CAP_8	3.528	1.139	1	5
AV_CAP	3.609	0.645	1	5
IPC	3.953	1.060	1	5
INPC	3.175	1.121	1	5
N_COMP	13.217	27.290	0	300
INTERNAL	1.899	0.906	1	5
INTERN1	2.227	1.195	1	5
INTER2	1.832	1.031	1	5
INTER3	1.634	1.033	1	5
LIQUIDITY	3.558	1.095	1	5
LIQUID1	3.511	1.419	1	5
LIQUID2	3.421	1.315	1	5
LIQUID3	3.744	1.169	1	5
MACRO	2.785	0.881	1	5
MACRO1	3.398	1.254	1	5
MACRO2	2.455	1.502	1	5
MACRO3	2.085	1.275	1	5
MACRO4	3.186	1.212	1	5
EXPORT	0.567	0.496	1	5
AGE	30.789	21.797	1	123
LEMP	3.866	1.511	0	9.473

Table 11 Correlation matrix ($N = 298$)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 R&D	1.000													
2 HQUAL	0.144	1.000												
3 ORGAN	0.222	0.048	1.000											
4 ICT infrastructure	0.283	0.186	0.198	1.000										
5 AV_CAP	0.140	0.022	0.225	0.260	1.000									
6 IPC	0.009	0.021	0.096	0.071	0.118	1.000								
7 INPC	0.066	0.005	0.203	0.159	0.046	0.355	1.000							
8 N_COMP	0.129	0.224	0.100	0.044	0.055	0.150	0.206	1.000						
9 INTERNAL	0.013	−0.060	0.078	−0.045	−0.057	0.085	0.159	0.017	1.000					
10 MACRO	−0.061	0.029	0.025	−0.015	−0.021	0.202	0.148	0.001	0.400	1.000				
11 LIQUIDITY	−0.020	−0.018	0.087	0.105	0.012	0.142	0.134	0.016	0.354	0.338	1.000			
12 EXPORT	0.308	0.002	0.052	0.177	0.164	0.096	0.093	0.119	0.057	−0.048	−0.087	1.000		
13 AGE	−0.001	−0.192	−0.073	0.057	0.031	0.044	0.095	0.136	−0.028	0.011	0.026	0.094	1.000	
14 LEMP	0.100	−0.267	0.137	0.230	0.173	0.103	0.097	0.102	−0.133	−0.099	−0.047	0.146	0.316	1.000

Table 12 Tests for joint effects

For equation in column (9) in Table 3 (VULN_ALL): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 0.86; Prob > chi2 = 0.353; Coeff(CAP_1) + … + coeff(CAP_8) = 0; Chi2 = 7.85; Prob > chi2 = 0.005
For equation in column (1) in Table 5 (Equipment): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 2.08; Prob > chi2 = 0.149
For equation in column (2) in Table 5 (ICT): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 1.28; Prob > chi2 = 0.258
For equation in column (3) in Table 5 (Buildings): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 1.27; Prob > chi2 = 0.260
For equation in column (4) in Table 5 (Training): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 3.87; Prob > chi2 = 0.049
For equation in column (5) in Table 5 (Marketing): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 0.09; Prob > chi2 = 0.766
For equation in column (6) in Table 5 (R&D): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 6.85; Prob > chi2 = 0.009
For equation in column (7) in Table 5 (Product innovation): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 4.56; Prob > chi2 = 0.033
For equation in column (8) in Table 5 (Process innovation): Coeff(R&D) + coeff(HQUAL) + coeff(ORG) + coeff(ICT_INFRA) = 0; Chi2 = 3.20; Prob > chi2 = 0.074

Note: coeff.: coefficients of the respective variables in Table 3 and 5, resp

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Declarations

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