Factors Explaining ICT Expenditure Behavior of Greek Firms During the Economic Crisis 2009–2014

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Abstract. The financial and economic crisis of 2008 affected negatively investment in general, and investment in ICT was not left unchanged, with negative consequences for firms' future performance and competitiveness. So this paper aims at investigating factors explaining firms' crisis behavior with respect to ICT investment and ICT operational expenditures, i.e. their crisis vulnerability of ICT expenditures, for the crisis period 2009–2014. To this end, we examine the effects of six groups of factors on firms' ICT investment and expenditure behavior during the crisis 2009–2014: three groups of *internal* factors and three groups of *external factors*. We focus our analysis on the internal ICT-related factors; we need all other factors in order to be able to appropriately specify two econometric models, one for ICT investment expenditures and a second one for ICT operational expenditures, and avoid omitted variable bias. The analysis of the factors that may influence the likelihood of a reduction of ICT investment and operating expenditure as a consequence of the crisis is primarily explorative, thus driven by available data and economic intuition. Our study is based on Greek firm data from the manufacturing, construction and services sector that have been collected in 2015/2016. We find that all six groups of variables contribute significantly to the explanation of both ICT investment and ICT operational expenditures during the crisis period 2009–2014, even if not to the same extent and not for each of the two dependent variables.

Keywords: ICT investment · ICT operational expenditures · ICT technologies · Economic crisis

1 Introduction

The financial and economic crisis of 2008 affected negatively investment in general, and investment in ICT was not left unchanged, with negative consequences for firms' future performance and competitiveness (Rojko et al. 2011; Keeley and Love 2010; OECD 2009). World ICT spending fell by around 4% in 2009 (OECD 2010). Nevertheless, the decrease of ICT investment has been lower than that of GDP worldwide

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so that the ratio of ICT investment to GDP has increased. The 2009 decline of world spending in ICT is not as large in current US dollars as in 2001-02, owing to growth in non-OECD economies and the introduction of new products (OECD 2010), two factors that helped compensate part of the reduction of expenditures in the OECD economies, particularly in the 'old' industries. Worldwide, about 57% of the 2009 ICT spending was on communication services and hardware, 21% on computer services, 13% on computer hardware and 9% on software.

The theoretical expectation for the impact of crisis on ICT investment is qualitatively the same as for all other kinds of investment. The main idea is that independent of the source of financing the general investment propensity decreases in periods of economic recession. Firms are confronted with demand uncertainty that makes investment more risky than in 'normal' or boom periods. Demand uncertainty forces firms to a pro-cyclical behavior. However, particularly in the innovation literature, an alternative approach is discussed that leads to an anti-cyclical investment behavior. According to the opportunity costs approach, in a booming economy it is expected that costs for labor and other input factors for R&D activities are high, while in recessions these costs are low (Rafferty and Funk 2004). Hence, opportunity costs are lower in recessions and firms would benefit if they could shift resources to R&D activities. It is then an empirical issue which situation for which investment type prevails.

So it is interesting and useful to investigate factors explaining firms' crisis behavior with respect to ICT investment and operational expenditures, i.e. their crisis vulnerability of ICT expenditures as shown by the extent of reduction of ICT investment and operational expenditures during the crisis period 2009–2014. This research can contribute to a better understanding of this negative phenomenon, which constitutes one of the most negative consequences of such crises, and also provide a basis for the design of appropriate interventions at firm level, in order to reduce the negative impact of such economic crises on firms' investment and expenditure for these highly important technologies. To this end, we distinguish six groups of factors that might affect ICT expenditure behavior during the crisis 2009–2014: three groups of internal factors, namely ICT-related resource endowment, ICT-related capabilities, and factors indicating overall internal problems such as over-investment in equipment and insufficient cost control, etc.; and also three groups of external factors: competition conditions in a firm's production market, conditions in a firm's broader economic environment, and macroeconomic conditions. We focus our analysis on the internal ICT-related factors. We need all other factors in order to be able to appropriately specify two econometric models, one for ICT investment expenditures and a second one for ICT operational expenditures, and to avoid omitted variable bias. The analysis of the factors that may influence the likelihood of a reduction of ICT investment and operating expenditures as a consequence of the crisis is primarily explorative, thus driven by available data and economic intuition.

Our study is based on Greek firm data from the manufacturing, construction and services sector that have been collected in 2015/2016. We find that all six groups of variables contribute significantly to the explanation of both ICT investment and ICT operational expenditures during the crisis period 2009–2014, even if not to the same extent and not for each of the two dependent variables. To our knowledge, there is no

other study investigating these topics, so our paper has also the character of an explorative study in a new and highly important for management practice research field[1].

The paper is structured as follows: Sect. 2 presents the conceptual background and related literature. Section 3 discusses the data. In Sect. 4 presents the specification of the models and the research hypotheses. In Sect. 5 econometric issues and the results are presented and discussed. Section 6 concludes the paper.

2 Conceptual Background

The theoretical expectation for the impact on ICT investment is qualitatively the same as for all other kinds of investment. The main idea is that independent of the source of financing the general investment propensity decreases in periods of economic recession. Firms are confronted with demand uncertainty that makes investment more risky than in 'normal' or boom periods. Decreasing demand limits also internal financing of investment by past revenues. Uncertain economic perspectives reduce also the willingness of banks and other financial intermediaries to finance firms' investment projects. Of course, not all kinds of investment bear the same risk, with innovation projects being considered as quite risky and buildings being seen as much less risky than other investment categories (see, e.g., Kahle and Stulz 2012; Gerner and Stegmaier 2013; Geroski and Gregg 1997). Further, not all types of firms bear the same risk, with small firms being confronted with more difficulties to finance investments in recession than large firms, due to credit rationing, i.e. limited access to external funding by financial intermediates (for the theoretical background see, e.g., Stiglitz and Weiss 1981 for investment in general; Goodacre and Tonks 1995 for investment in innovation). So in general, we expect that economic crisis negatively affects ICT investment. To our knowledge, there are no studies dealing with the question of the impact of economic crisis on ICT investment and factors that affect it.[2]

As a consequence, it is not a priori clear which components of ICT-related resource endowment, e.g., such as ICT applications (ERP, CRM. SCM, etc.), Cloud Computing, or which of a series of ICT-related capabilities (see Sect. 4) might explain a firm's ICT-related behavior in an economic crisis. The analysis of the ICT-related characteristics (ICT-related resource endowment and ICT-related capabilities) that may influence the likelihood of having reduced ICT investment as a consequence of the crisis is primarily explorative, thus driven by available data and economic intuition.

We can nevertheless deduce from the analogous case of overall investment and particularly R&D investment, which overall external factors, e.g., such as competition pressure at product markets, crisis-caused unfavorable behavior of creditors, suppliers

[1] Some hints about ICT characteristics at firm level that are correlated with ICT-related 2008 crisis vulnerability are found in Arvanitis and Loukis (2015) for a sample of firms from the glass/ceramics/cement industry in six European countries.

[2] However, there is a paper which is worth-mentioning: In a case study, Leidner et al. (2003) found based on interviews with 20 CIOs that firms reacted both pro- and anti-cyclically to the crisis of 2000-02 depending on their short-term or long-term time-horizon.

and customers as well as unfavorable macroeconomic conditions, might affect negatively investment in ICT. There is some theoretical consent (see, e.g., Barlevy 2007) and some empirical evidence (see, e.g., Quyang 2011a and Guellec and Ioannidis 1999) that R&D investment expenditures of firms, the most important input for innovation, are pro-cyclical, i.e. they are increasing in the business upswing and they are decreasing in the business downturn. However, there are also some theoretical arguments as well as some anecdotic evidence that firms show an anti-cyclical R&D investment behaviour. In order to explain pro- or anti-cyclical R&D behaviour we have to take into account two diverging forces, the demand aspect (see Filippetti and Archibugi 2011) and the opportunity costs aspect (Rafferty and Funk 2004). Since R&D investment and analogously ICT investment are predominantly financed through the cash-flow of a firm, which is expected to fluctuate pro-cyclically with demand, we would expect a pro-cyclical R&D – and analogously – ICT investment behaviour as well. Since empirical evidence supports mostly pro-cyclical behaviour we concentrate here on the hypothesis of pro-cyclical behaviour with respect to ICT investment (see hypothesis 4).

3 Data

3.1 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 service enterprise) of 6429 firms. To our knowledge, there is no other source for firm data in Greece that is publicly available. Our intermediate sample was constructed based on the composition by industry of the original sample reduced by reducing by about 50% the total number of firms; the firms for each industry sub-sample were chosen randomly out of the original sample. The questionnaire was sent to 3308 firms of the intermediate sample, 363 valid answers have been received, i.e. the response rate is about 11%.

Already the original sample is not representative of the composition of Greek firms by industry. The Greek economy contains thousands of small and very small enterprises in trade, particularly retail trade, tourism, particularly in catering, and in construction. The ICAP sample concentrates in manufacturing (30.7% of all firms in sample) and 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). As a consequence, also the intermediate sample contains similar proportions of firms from different industries. For the response sample we (further) concentrate in manufacturing (40.2% of all firms in sample) and modern services (27.4%). This structure corresponds to the technologically most developed part of the Greek economy to which we focus in this study. Our particular interest refers to the ICT-related crisis vulnerability of this part of the Greek economy, which is also most promising with respect to a recovery from the crisis.

3.2 ICT-Related Crisis Vulnerability

Table 1 shows how frequent each of the six possible values of our two dependent variables, the change of ICT investment expenditures and the change of ICT operational expenditure, have been reported by the firms of our sample: 58.4% of them reported 'small decrease' up to 'very large decrease' of ICT investment, while 62.8% 'small decrease' up to 'very large decrease' of ICT operational expenditures. More than one fifth reported large or very large decrease in both expenditure categories. These figures reflect clearly the impact of the crisis (pro-cyclical behaviour), but it is remarkable that still 41.6% (for ICT investment) and 37.7% (for ICT operational expenditures) reported 'no impact' or even increase. This could be interpreted as a hint that a considerable portion of firms in the sample showed significant robustness of behaviour and refrained from reducing their ICT budgets. An increase of expenditures is found only for 1.6% (investment) and 8.2% (operational expenditures). Only a small minority of firms could afford anti-cyclical behaviour during such a long-enduring crisis.

Table 1. Impact of crisis 2009–2014 on ICT investment and operational expenditures; percentage of all firms

Impact	Investment expenditures	Operational expenditures
Increase	11.6	8.2
No impact	30.0	29.5
Small decrease	15.5	21.3
Medium decrease	20.7	18.8
Large decrease	15.5	16.1
Very large decrease	6.7	6.1

4 Model Specification and Research Hypotheses

4.1 Model Specification

As dependent variable we use a six-level ordinal variable that measures the extent of change of ICT investment (for model 1) and the extent of change of ICT operational expenditures (for model 2) during the long crisis period 2009–2014. This variable is considered to measure crisis vulnerability: the stronger the decrease of ICT investment and/or ICT operational expenditures due to crisis, the higher is a firm's ICT-related crisis vulnerability.

We distinguish six groups of factors that might affect ICT investment and operating expenditure behavior during the crisis 2009–2014: three groups of *internal* factors: ICT-related *resource endowment* (six variables), ICT-related *capabilities* (six variables), and factors indicating overall internal problems such as over-investment in equipment and insufficient cost control, etc. (one composite variable); and also three groups of *external factors*: one referring to the *competition conditions* in a firm's production market (three variables), a second one covering conditions in a firm's

broader economic environment such as such as *behavior of banks, providers, competitors and customers* (one composite variable) and a third one related to *macroeconomic conditions* (overall development of domestic and foreign demand, price reduction, etc.; one composite variable).

ICT-related endowment. Besides the use of a series of ICT applications (ERP, CRM, SCM, Business Intelligence/Business Analytics Systems, and Collaboration Support Systems) and the share of ICT personnel belong to ICT-related resource endowment, even if indirectly, also the overall employee qualification level (as measured by the share of employees with tertiary-level education), the existence of R&D (as measure of innovation capability), which is closely positively associated to ICT use (see, e.g., Arvanitis et al. 2016), and new forms of workplace organization, particularly decentralization of decision-making, which correlates strongly with the existence of high-qualified personnel (see, e.g., Arvanitis 2005).

ICT-related capabilities. In accordance to relevant information systems literature firms in order to exploit ICT for supporting their activities develop not only their ICT resources endowment, but also relevant ICT capabilities, enabling them to fully exploit their ICT resources (Ravichandran and Lertwongsatien 2005; Gu and Jung 2013). So we also examine the effects of six important and widely cited in relevant literature ICT capabilities on firms' ICT investment and ICT operating expenses vulnerability: for rapid implementation of changes of existing applications or information systems to cover specific firm needs; rapid development of new ICT applications to cover specific firm needs; rapid realization of interconnection and integration of existing ICT applications inside the firm; good cooperation and information exchange between ICT personnel and ICT users inside the firm; good cooperation and information exchange with ICT providers of hardware, software and networks; development of ICT plans that are connected with overall firm strategy. We expect that they might decrease ICT investment and ICT operating expenses vulnerability.

Overall internal problems. Insufficient control of costs, over-investment in equipment, buildings and/or storage capacity as well as over-expansion due to takeovers and mergers (before the observed crisis period) might increase a firm's overall crisis vulnerability and as a consequence also its vulnerability as to ICT investment and ICT operational expenditures.

Competition conditions. Depending on the specific firm behaviour the relationship between ICT investment and competition pressure would be positive during a crisis, if a firm reacts anti-cyclical to crisis, which is mostly the case, or negative, if the firm reacts pro-cyclical (see Arvanitis and Woerter 2014). Thus, for the assumed pro-cyclical behaviour we expect that increased (price and non-price) competition pressure would increase crisis vulnerability with respect to ICT investment and ICT operational expenditures.

Broad economic environment. Decrease of credit limits by banks and suppliers as well as decrease of paying willingness of customers and increased competition pressure at the product market are typical crisis phenomena that are supposed to affect negatively also ICT investment and ICT operational expenditures.

Macroeconomic conditions. Decrease of overall domestic private or public demand and/or foreign demand is constitutive to the notion of economic crisis. Also decrease of prices is often result of decreasing overall demand. We expect decrease of demand to affect negatively also ICT investment and ICT operational expenditures.

We estimated Model 1 (for ICT investment expenditures) and Model 2 (for ICT operational expenditures), which are identically specified and are formally expressed as follows – in the Appendix we can see all variables definitions:

$$ICT\_CRISIS_i = \alpha_0 + \alpha_1 R\&D_i + \alpha_2 HQUAL_i + \alpha_3 ICT\_PERS_i + \alpha_4 ICT\_TECHN_i + \alpha_5 CLOUD_i + \alpha_6 ORG_i + \alpha_7 ICT\_CAP\_NEW_i + \alpha_8 ICT\_DEVELOP_i + \alpha_9 ICT\_CAP\_INTERCON_i + \alpha_{10} ICT\_CAP\_COOP\_INT_i + \alpha_{11} ICT\_CAP\_COOP\_EXT_i + \alpha_{12} ICT\_CAP\_ICT\_PLANS_i + \alpha_{13} INTERNAL_i + \alpha_{14} P\_COMPET_i + \alpha_{15} NP\_COMPET_i + \alpha_{16} OBSOLESCENCE_i + \alpha_{17} MARKET_i + \alpha_{18} MACRO_i + \alpha_{19} LAGE_i + \alpha_{20} Medium\text{-}sized_i + \alpha_{21} Large_i + industry\ controls + e_i$$

4.2 Research Hypotheses

Based on the discussion of literature in Sect. 2 and in this section, we postulate a series of hypotheses:

Hypothesis 1: The six components of ICT-related resource endowment as specified for both models 1 and 2 are jointly negatively correlated with ICT-related crisis vulnerability.

Hypothesis 2: The six components of ICT-related capabilities as specified for both models 1 and 2 are jointly negatively correlated with ICT-related crisis vulnerability.

Hypothesis 3: The composite variable for overall internal factors as specified for both models 1 and 2 is positively correlated with ICT-related crisis vulnerability.

Hypothesis 4: The variables for competition conditions as specified for both models 1 and 2 are jointly positively correlated with ICT-related crisis vulnerability, given pro-cyclical investment behavior.

Hypothesis 5: The composite variable for conditions of a firm's broad economic environment as specified for both models 1 and 2 is positively correlated with ICT-related crisis vulnerability.

Hypothesis 6: The composite variable for macroeconomic conditions as specified for both models 1 and 2 is positively correlated with ICT-related crisis vulnerability.

5 Results

5.1 Econometric Issues

The dependent variable is a six-level ordinal variable. The dependent variable refers to the extent of the change of ICT investment and ICT operational expenditures for the long period 2009–2014. Given the nature of the dependent variable, the appropriate estimation method is ordered probit regression ('oprobit' procedure of STATA).

The independent variables that refer to internal factors are measured either for 2014 (metric variables) or for the period 2012–2014 (ordinal variables), with the exception of overall internal problems that are explicitly related to the time before 2009 (see Appendix). Thus, they reflect a firm's condition at the end and not at the beginning of the observed crisis period. Thus, they could have been affected by the crisis and could reflect a firm's adaptation to the crisis. In this sense they are endogenous. Nevertheless, we have good reasons to consider them as structural factors that would have not changed considerably during the crisis, just because they are factors that could be expected to reduce crisis vulnerability (e.g., ICT capabilities, ICT and human capital endowment, existence of R&D activities).

We also have good reasons to assume that competition conditions at the product market are also of structural nature. We cannot exclude that the overall competition pressure became stronger during the crisis period, but with only small shifts as to the relative strength of competition pressure at different markets.[3]

The endogeneity issue is less a problem in the case of the external factors, 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 (see Appendix), thus reflecting factors that could have directly affected crisis vulnerability with respect to ICT investment and ICT operational expenditures.

The problem of possible observed heterogeneity still remains, even if we control extensively for many possible explaining factors as well as for 10 digit industries and 3 firm size classes. 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 with our research hypotheses.

5.2 Estimates for ICT Investment Expenditures

The estimates for the change of ICT investment expenditures (model 1) are presented in Table 2. The six estimated equations show values of Pseudo R^2 between 0.127 and 0.133 that are rather low but still satisfactory for cross-section micro data analysis. Moreover, the high significance of Wald chi2 statistics demonstrates the overall statistical validity of the estimates.

Resource endowment. The existence of R&D activities, the (overall or ICT specific) personnel qualification, and the use of standard ICT applications such as ERP, SCM, CRM, Business Analytics, and Collaboration Support Systems do not seem to be significantly correlated with crisis vulnerability. Negatively correlated with crisis vulnerability appear to be two further components of resource endowment, namely the use of new forms of workplace organization (such as teamwork and decentralization) and the use of Cloud Computing. Obviously these two resources increase a firm's flexibility to react to crisis, given the level of personnel qualification and of use of standard ICT applications, reducing the negative impacts of the crisis on it.

[3] There is no information about significant structural changes of the Greek economy as a whole. For single markets, e.g., retail trade and construction, the high number of bankruptcies in the last years indicates a concentration process that rather enhances competition pressure.

Table 2. Factors explaining crisis behavior with respect to ICT investment expenditures

	(1)	(2)	(3)	(4)	(5)	(6)
R&D	0.032	0.031	0.044	0.066	0.033	0.042
	(0.141)	(0.141)	(0.141)	(0.140)	(0.142)	(0.143)
HQUAL	0.455	0.446	0.459	0.495*	0.451	0.494*
	(0.297)	(0.299)	(0.294)	(0.290)	(0.297)	(0.297)
ICT_PERS	−0.114	−0.159	−0.044	−0.057	−0.155	−0.104
	(0.434)	(0.444)	(0.438)	(0.435)	(0.440)	(0.443)
ORG	−0.269**	−0.274**	−0.281**	−0.287**	−0.283**	−0.253*
	(0.137)	(0.138)	(0.135)	(0.135)	(0.136)	(0.136)
ICT_TECHN	−0.058	−0.075	−0.050	−0.038	−0.069	−0.028
	(0.067)	(0.069)	(0.067)	(0.067)	(0.069)	(0.073)
CLOUD	−0.339**	−0.346**	−0.335**	−0.311**	−0.337**	−0.348**
	(0.156)	(0.158)	(0.156)	(0.157)	(0.157)	(0.156)
ICT_CAP_NEW	−0.073					
	(0.061)					
ICT_CAP_DEVELOP		−0.029				
		(0.060)				
ICT_CAP_INTERCON			−0.099*			
			(0.060)			
ICT_CAP_COOP_INT				−0.157**		
				(0.064)		
ICT_CAP_COOP_EXT					−0.042	
					(0.062)	
ICT_CAP_ICT_PLANS						−0.117*
						(0.052)
P_COMPET	−0.040	−0.040	−0.039	−0.047	−0.042	−0.060
	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)	(0.069)
NP_COMPET	0.030	0.035	0.028	0.020	0.035	0.042
	(0.075)	(0.074)	(0.074)	(0.076)	(0.075)	(0.075)
OBSOLESCENCE	0.150**	0.153**	0.156**	0.138**	0.149**	0.141**
	(0.067)	(0.067)	(0.068)	(0.068)	(0.068)	(0.068)
INTERNAL	0.049	0.049	0.057	0.045	0.040	0.040
	(0.082)	(0.082)	(0.083)	(0.083)	(0.082)	(0.082)
MARKET	0.317***	0.316***	0.314***	0.326***	0.318***	0.308***
	(0.091)	(0.092)	(0.090)	(0.091)	(0.092)	(0.091)
MACRO	0.488***	0.488***	0.481***	0.471***	0.487***	0.497***
	(0.093)	(0.092)	(0.092)	(0.092)	(0.093)	(0.093)
LAGE	−3.483	−3.064	−3.431	−3.339	−3.345	−3.012
	(5.447)	(5.363)	(5.458)	(5.311)	(5.317)	(5.327)
Medium-sized	0.132	0.101	0.142	0.182	0.104	0.157
	(0.145)	(0.145)	(0.147)	(0.148)	(0.147)	(0.145)

(*continued*)

Table 2. (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
Large	0.482*	0.432*	0.480*	0.568**	0.447*	0.531**
	(0.265)	(0.261)	(0.261)	(0.269)	(0.267)	(0.260)
Industry dummies (9)	Yes	Yes	Yes	Yes	Yes	Yes
N	292	292	292	292	292	292
Pseudo R^2	0.128	0.127	0.130	0.133	0.127	0.130
Wald Chi2	175.8	179.0	176.4	184.6	174.0	173.3
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Log pseudolikelihood	−431.9	−432.5	−431.1	−429.4	−432.5	−431.0

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

Furthermore, these new forms of workplace organization enable the generation of more value from firm's ICT investment; the same holds for the use of Cloud Computing, which enables some standardized and commoditized ICT components to be accessed through external cloud computing services, so that ICT investment can focus on some highly valuable firm-specific as well as operation critical components. This decreases a firm's propensity to reduce ICT investment as a response to the crisis. Thus, the introduction of new forms of workplace organization and Cloud Computing contribute to a weaker ICT-related impact of crisis, i.e. to a reduction of ICT-related crisis vulnerability. The joint effect of all components of resource endowment is significantly negative, even if this effect is traced back to only two single factors. Thus, *hypothesis 1* is confirmed.

Capabilities: Weakening of the crisis effect is achieved through capabilities for high interconnection/integration of the used ICT-systems, intensive cooperation internally, and existence of a comprehensive ICT strategy (ICT plans). These capabilities contribute to a higher flexibility of firm activities, which is particularly relevant in order to be able to react adequately to crisis, and reduce its negative impact on the firm. Furthermore, the above ICT capabilities enable the generation of more value from firm's ICT investment, so they decrease firm's propensity to reduce ICT investment as a response to the crisis. Also in this case the joint effect of all capabilities is significantly negative, thus *hypothesis 2* receives empirical support.

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 ICT-related crisis vulnerability. *Hypothesis 3* is not confirmed.

Competition conditions: No effect of price or non-price pressure is found. Competition pressure is in general low in most sectors of the Greek economy (see, e.g., Arvanitis and Loukis 2009). There is a weakening effect of crisis in case of high obsolescence rate of products/services and/or their technologies: if firm's products,

services and/or their technologies become quickly obsolete, the firm has to maintain some level of ICT investment for supporting their renewal. Once more the joint effect shows in the expected direction. *Hypothesis 4* is also confirmed.

As expected, macroeconomic effects, but also effects of other market actors (behavior due to crisis of suppliers, financing agencies, competitors, customers, etc.), enhance crisis vulnerability. Overall unfavorable economic conditions and unfavorable behavior of market environment are factors that affect negatively investment behavior of firms in general, even if not all firms to the same extent. Thus, *hypothesis 5* and *hypothesis 6* are confirmed. Finally, large firms seem to be more crisis-vulnerable than medium-sized and small firms, presumably due to higher operation flexibility of smaller firms.

5.3 Estimates for ICT Operational Expenditures

The estimates for the change of ICT operational expenditures (model 2) are presented in Table 3. The six estimated equations show values of Pseudo R^2 between 0.115 and 0.121 are somewhat lower than in the estimates in Table 2, but still satisfactory for cross-section micro data analysis. Moreover, the high significance of Wald chi2 statistics demonstrates the overall statistical validity of the estimates.

Table 3. Factors explaining crisis behavior with respect ICT operational expenditures

	(1)	(2)	(3)	(4)	(5)	(6)
R&D	0.006	0.008	0.018	0.039	0.011	0.015
	(0.138)	(0.138)	(0.138)	(0.137)	(0.140)	(0.142)
HQUAL	0.406	0.383	0.404	0.432	0.392	0.434
	(0.280)	(0.281)	(0.279)	(0.277)	(0.281)	(0.283)
ICT_PERS	−0.081	−0.159	−0.095	−0.106	−0.159	−0.163
	(0.419)	(0.425)	(0.426)	(0.435)	(0.429)	(0.434)
ORG	−0.287**	−0.291**	−0.311**	−0.318**	−0.317**	−0.283**
	(0.134)	(0.135)	(0.132)	(0.131)	(0.133)	(0.133)
ICT_TECHN	−0.030	−0.063	−0.046	−0.036	−0.049	−0.028
	(0.064)	(0.064)	(0.064)	(0.064)	(0.066)	(0.071)
CLOUD	−0.326**	−0.337**	−0.332**	−0.308*	−0.314**	−0.345**
	(0.157)	(0.159)	(0.157)	(0.159)	(0.159)	(0.157)
ICT_CAP_NEW	−0.157***					
	(0.061)					
ICT_CAP_DEVELOP		−0.082				
		(0.057)				
ICT_CAP_INTERCON			−0.106*			
			(0.060)			
ICT_CAP_COOP_INT				−0.162***		
				(0.061)		
ICT_CAP_COOP_EXT					−0.106	
					(0.067)	

(*continued*)

Table 3. (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
ICT_CAP_ICT_PLANS						−0.112*
						(0.067)
INTERNAL	0.266***	0.266***	0.268***	0.255***	0.243***	0.250***
	(0.083)	(0.084)	(0.085)	(0.084)	(0.083)	(0.084)
P_COMPET	−0.120*	−0.121*	−0.119*	−0.128*	−0.126*	−0.139**
	(0.069)	(0.070)	(0.070)	(0.070)	(0.069)	(0.068)
NP_COMPET	0.005	0.005	−0.001	−0.010	0.004	0.013
	(0.073)	(0.072)	(0.073)	(0.075)	(0.075)	(0.073)
OBSOLESCENCE	0.082	0.090	0.070	0.072	0.079	0.074
	(0.071)	(0.070)	(0.090)	(0.069)	(0.069)	(0.070)
MARKET	0.056	0.052	0.056	0.068	0.060	0.051
	(0.089)	(0.092)	(0.089)	(0.091)	(0.091)	(0.090)
MACRO	0.540***	0.536***	0.526***	0.516***	0.534***	0.542***
	(0.094)	(0.093)	(0.093)	(0.093)	(0.095)	(0.095)
LAGE	−3.399	-4.140	-4.076	−4.262	-3.511	-4.502
	(5.881)	(5.729)	(5.821)	(5.607)	(5.705)	(5.662)
Medium-sized	0.038	−0.014	−0.002	0.036	−0.013	0.001
	(0.148)	(0.146)	(0.149)	(0.148)	(0.147)	(0.146)
Large	0.415*	0.321	0.336	0.420*	0.355	0.378*
	(0.225)	(0.220)	(0.221)	(0.226)	(0.228)	(0.217)
Industry dummies (9)	Yes	Yes	Yes	Yes	Yes	Yes
N	292	292	292	292	292	292
Pseudo R^2	0.121	0.115	0.117	0.120	0.116	0.116
Wald Chi2	143.5	142.4	141.6	152.2	133.3	133.4
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Log pseudolikelihood	−429.7	−432.4	−431.7	−429.9	−432.0	−431.9

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

We concentrate here on the differences as compared with the results presented in 5.2:

Resources: There are no differences from these results for the change of ICT investment expenditure. *Hypothesis 1* is confirmed.

Capabilities. In addition to the ability for interconnection/integration of ICT-systems, for internal cooperation and for a comprehensive ICT strategy, also the capability for development of new ICT-applications contributes to a smoothening of crisis **vulnerability** with respect to ICT operational expenditures. *Hypothesis 2* is also confirmed.

Overall internal problems. Insufficient cost controls, over-investment in equipment, buildings or storage capacity and/or over-expansion by takeovers or mergers are positively correlated **with** ICT-related crisis vulnerability. This means that over-investment,

over-expansion and/or insufficient cost control increase crisis vulnerability with respect to operational ICT expenditures. *Hypothesis 3* is confirmed in this case.

Competition conditions: Price competition matters, the more price competition a firm is exposed, the **lower** is its ICT crisis vulnerability, which is contrary to our theoretical expectation (see hypothesis 4); a possible explanation is that price competition puts a pressure for reducing overall operating costs, and this does not allow reductions in ICT operating costs that contribute significantly to this (e.g., through automation or support of important activities or business processes). Obsolescence does not matter for operational costs. *Hypothesis 4* is not confirmed in this case.

The behavior of other market partners is – contrary to the results for ICT investment – not relevant for operational costs. Unfavorable behavior of other market actors do not affect crisis vulnerability with respect to operational ICT costs. Thus, *hypothesis 5* is not confirmed. Macroeconomic conditions are also for operational costs relevant, i.e. they increase crisis vulnerability. As a consequence only *hypothesis 6* is confirmed.

Large firms seem to be more crisis-vulnerable than smaller firms also with respect to ICT operational expenditures, but to a smaller extent than investment expenditures.

All in all, for both ICT investment and operational expenditures resource endowment seems to be less important with respect to crisis vulnerability than ICT capabilities and general environment factors.

6 Summary and Conclusions

It is interesting and useful to investigate factors explaining crisis behavior with respect to ICT investment and operational expenditures, i.e. crisis vulnerability of ICT expenditures as shown by the extent of reduction of ICT investment and operational expenditures during the crisis period 2009–2014. To this end, we distinguish six groups of factors that might affect ICT expenditure behavior during the crisis 2009–2014: three groups of *internal* factors, namely ICT-related *resource endowment*, ICT-related *capabilities*, and factors indicating overall internal problems, such as over-investment in equipment and insufficient cost control, etc.; and three groups of *external factors: competition conditions* in a firm's production market, conditions in a firm's *broader economic environment*, and *macroeconomic conditions*. We focus our analysis on the internal ICT-related factors. We need all other factors in order to be able to appropriately specify two econometric models, one for ICT investment expenditures and a second one for ICT operational expenditures, and avoid omitted variable bias.

We have found for ICT investment expenditures that the use of new forms of workplace organization and the use of Cloud Computing as ICT-related *resources* contribute to a weaker impact of crisis, i.e. to a reduction of ICT-related crisis vulnerability by increasing a firm's flexibility to react to crisis, given the level of personnel qualification and of use of standard ICT applications, reducing the negative impacts of the crisis on the firm. The joint effect of all components of resource endowment is significantly negative, even if this effect is traced back to only two single factors. Thus, *hypothesis 1* is confirmed. This hypothesis is also confirmed for ICT operational expenditures.

Further, weakening of the crisis effect is achieved through a firm's high capabilities for interconnection/integration of the used ICT-systems, intensive cooperation and information exchange internally, and the existence of a comprehensive ICT strategy (ICT plans). These capabilities also contribute to a higher flexibility of firm activities, which is particularly relevant in order to be able to react adequately to crisis, and reduce the negative impact of it. Furthermore, these ICT capabilities enable the generation of more value from firm's ICT investment, so they decrease firm's propensity to reduce it as a response to the crisis. For ICT operational expenditures an additional effect is found for the capability to develop new ICT-applications. Also in this case the joint effect of all capabilities is significantly negative, thus *hypothesis 2* receives empirical support also for ICT operational expenditures. *Hypothesis 3* referring to insufficient cost control, over-investment and/or over-expansion before 2009 is not confirmed for ICT investment expenditures, but confirmed for ICT operational expenditures.

The effect of competition conditions is ambiguous. Obsolescence of products and services is positively correlated with crisis vulnerability with respect to ICT investment but not with respect to ICT operational expenditures. Price competition pressure is negatively correlated with vulnerability for ICT operational expenditures but not for ICT investment. Thus, *hypothesis 4* is only partly confirmed.

Hypothesis 5 is confirmed for ICT investment but not for operational expenditures; *hypothesis 6* is confirmed for both expenditure categories.

On the whole, our analysis yields some new insights, first, about the firm characteristics, particularly ICT-related characteristics, and, second, about the characteristics of a firm' s economic environment that contribute to a weakening or enhancing of a firm's crisis vulnerability concerning ICT expenditures. Given that ICT constitute a growth-determining factor of increasing importance and that economic crises are an inevitable trait of market-based economies, it is not only for Greek firms relevant to know which factors could enable them to become more resistant to crisis, when the next crisis comes.

Appendix. Definition of Variables

Variable	Definition
Dependent variables	
Impact of crisis 2009–2014 on ICT *investment* expenditures	Six-level ordinal variable; 1: 'increase'; 6: 'very large decrease'; see also Table 2
Impact of crisis 2009–2014 on ICT *operational* expenditures	Six-level ordinal variable; 1: 'increase'; 6: 'very large decrease'; see also Table 2
Independent variables	
ICT-related 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

(*continued*)

(*continued*)

Variable	Definition
ICT_PERS	Share of ICT-specialized personnel 2014
ORG	Use of new forms of workplace organization such as teams, job rotation, decentralization of decision making, etc.
ICT_TECHN	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 five-point Likert scale (1: 'no use'; 5: 'very intensive use')
CLOUD	Use of cloud computing: yes/no; binary variable
ICT-related capabilities	
ICT_CAP_NEW	Rapid implementation of changes of the applications of existing information systems to cover specific firm needs
ICT_CAP_DEVELOP	Rapid development of new ICT applications to cover specific firm needs
ICT_CAP_INTERCON	Rapid realization of interconnection and integration of existing ICT applications inside the firm
ICT_CAP_COOP_INT	Good cooperation and information exchange between ICT personnel and ICT users inside the firm
ICT_CAP_COOP_EXT	Good cooperation and information exchange with ICT providers of hardware, software and networks)
ICT_CAP_ICT_PLANS	Existence of ICT plans that are connected with overall firm strategy (ICT business alignment)
Overall internal problems	
INTERNAL	Average of the scores on a five-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.
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'
OBSOLESCENCE	Average of the scores on a five-point Likert scale of the two single factors concerning the extent to which firm's products and services quickly become obsolete/outdated, and also their technologies change quickly

(*continued*)

(*continued*)

Variable	Definition
Broad economic environment	
MARKET	Average of the scores on a five-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 credit limits by banks; by providers; decrease of paying willingness of customers; increase of competition pressure at the product market (1: 'not relevant; 5: 'very relevant')
Macroeconomic conditions	
MACRO	Average of the scores on a five-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')
LAGE	Natural logarithm of firm age (2015 minus foundation year)
Medium-sized	50 to 149 employees; binary variable
Large	250 and more variables

Note: The capability variables ICT_CAP_NEW to ICT_CAP_ICT_PLANS are ordinal variables measured on five-point Likert scale (1: '(available) to a very small extent/not at all'; 5: '(available) to a very large extent').

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