A Lasting Crisis affects R&D decisions of smaller firms: the Greek experience

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Abstract

We use the Greek crisis of 2008 onwards as a case study to understand how a lasting economic shock affects the innovation strategies of firms in economies with moderate innovation activities. Adopting the 3-stage CDM model, we explore the link between R&D, innovation, and productivity for different size groups of Greek manufacturing firms. At the first stage, we find that the continuation of the crisis is harmful for the R&D engagement of smaller firms while it increased the willingness for R&D activities among the larger ones. At the second stage, among smaller firms the knowledge production remains unaffected by R&D investments, while among larger firms the R&D decision is positively correlated with the probability of producing innovation, albeit the relationship is weakened as the crisis continues. At the third stage, innovation output benefits only larger firms in terms of labor productivity, while the innovation-productivity nexus is insignificant for smaller firms.

Keywords: Small firms; Large firms; R&D; Innovation; Productivity; Crisis

JEL codes: L25; L60; O31; O33

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1. Introduction

Pursuing innovative strategies is a key way to improve a firm's output through increased productivity. What seems already important in normal times (see *inter alia* Griffith et al. 2006, Hall et al. 2010; Huergo and Moreno 2011; Baumann and Kritikos 2016; Kancs and Siliverstovs 2016; Lööf et al. 2017) might become crucial in times of crisis: developing a sustainable and dynamic recovery path through an innovation strategy (Filippetti and Archibugi 2011; Archibugi et al. 2013), when firms are confronted with sharp reductions in sales. However, when sales collapse, firms put R&D expenditures at the top of the list for cutting. Additionally, public R&D investment is often dropping in such times in economies with moderate innovation activities, like Greece or other southern or eastern European economies (see Cruz-Castro et al. 2018; Pellens et al. 2020). We use the Geek economic crisis to investigate how firms react in a situation of a deep and prolonged downturn. It is a fact that the financial crisis of 2008 created a turbulent environment for the Greek economy, being particularly harmful for the economic performance and viability of a large number of Greek firms (Williams and Vorley 2015; Giotopoulos et al. 2017). In this research note we analyze what kind of innovation strategies the Greek manufacturing sector, separated into small and large firms, practiced as the crisis continued unabated and how the respective strategies influenced their productivity.

The long-term economic crisis in Greece offers a unique case study to explore how strong exogenous shocks to an economy affect small and large firms and their innovative behavior. Although the crisis of 2008-2013 differs from the COVID-19 pandemic crisis with respect to its sources and other aspects, it shares two significant similarities. As Roper and Turner (2020) point out, both were sharp exogenous shocks rather than business-cycle fluctuations. Furthermore, they both have affected firms through strongly reduced liquidity, either through a substantial reduction in the availability of commercial finance (economic crisis) or extensively reduced turnover (COVID-19 crisis) (see Fairlie 2013, 2020). Hence the effects on business performance and the relevant business decisions may share common characteristics and, consequently, could offer important insights for fine-tuning policy measures in the post-COVID era, especially in moderate innovation economies. In both cases, financial stringency will force firms to make rapid strategic decisions regarding spending and potential savings.

Using a unique Greek data set from a two-wave survey of 524 Greek manufacturing firms during the crisis period (2011 and 2013), we employ the well-established model of Crepon et al (1998) to investigate how firms in different size groups reacted as the crisis continued to trouble the economy. We find that, for the first stage of our analysis, the continuation of the crisis appears to be harmful for the R&D engagement of smaller firms while it increased the willingness for R&D activities among the larger ones. At the second stage, among smaller firms the knowledge production remains unaffected by R&D investments - among larger firms the predicted R&D decision is positively correlated with the probability of producing innovation output. At the third stage, we observe that innovation output benefits only larger firms since it significantly improves their labor productivity.

With our analysis, we contribute to the literature on the effect of lasting economic shocks on R&D investments. We provide a systematic analysis on potential effect heterogeneities in R&D-innovation-productivity linkages for different firm size groups and we consider - to the best of our knowledge for the first time - how a *lasting* shock causes large economic imbalances in moderate innovator economies. This adds to the analysis on the effects of unique shocks like the general financial crisis of 2008 (as considered in Archibugi et al. 2013). In that sense, our research is relevant in designing policy instruments intended to increase the resilience of firms across different size groups under turbulent economic conditions.

2. Theoretical Background, Data and Crisis Measurement

2.1 Theoretical Background

Investments in R&D and innovation activities are in normal times risky decisions aiming at increasing the productivity performance of firms. To analyze this relationship, Griliches (1979) has introduced a knowledge production function according to which investments into R&D increase the stock of knowledge, leading to innovation and ultimately to higher productivity. At the same time such investments bear the risk of failure as it might not be possible to realize positive returns on such investments (see inter alia Peters et al 2017). There is extensive research that empirically investigates – based on the Griliches (1979) knowledge production function and making use of the so called CDM model, a structural model introduced by Crepon et al. (1998) - the relationship between R&D, innovation, and labor productivity (see Hall, 2011, and Lööf, et al., 2017 for surveys).

Earlier research has also focused on the question to what extent smaller firms are similarly able of managing R&D efforts to improve their stock of knowledge and to transfer this improved knowledge into higher productivity. Reasons for firm size differences are the two conditions driving this R&D decision: opportunity and appropriability (Cohen and Klepper, 1996). From related empirical research, we know that firm size is indeed positively associated with the decision to invest in R&D, but that smaller firms do still substantially engage in R&D activities (see Hall et al. 2009; Baumann and Kritikos, 2016).

In this contribution, we investigate how the triad relationship between innovation input, innovation output, and productivity develops in an economic crisis. Smaller businesses tend to be more vulnerable compared to their larger counterparts when major exogenous shocks jeopardize markets due to lack of resources known as liability of smallness (Eggers 2020). In a lasting crisis, smaller firms may be reluctant to invest their limited resources into innovative projects with an uncertain outcome (Lee et al. 2015) or other activities that will increase their financial risks (Thorgren and Williams 2020). This holds even more so if firms will be challenged by managing high levels of debt. Therefore, we aim to find out whether smaller firms tend to refrain from investing in innovation activities during a lasting crisis.

2.2 Data and Crisis Measurement

The data used to empirically investigate our main research question stem from an extensive field survey conducted through CATI method. The first wave took place in 2011, the second in 2013, with the same group of firms being surveyed. The final sample used in this paper contains 524 Greek manufacturing firms that participated in both survey waves. Table 1 describes in detail the examined variables and presents per wave their frequency distributions for binary and 5-point Likert scale variables as well as some summary statistics for the continuous variables.

<Insert Table 1 about here>

As shown in Table 1, about 67% of the manufacturing firms of the sample have introduced a product or process innovation within the last two years of wave 1 (2011), whereas this rate falls to 58% in wave 2 (2013). About 25% of the sample indicated the existence of in-house R&D activities in 2011, which increased to 31% in 2013. Employee training is widely used, reaching 73% of the firms in both waves. Training costs seem to be unaffected and are not reduced despite the sharp increase in liquidity constraints. Liquidity constraints are substantial as the crisis continues and the percentage of firms that indicate a very high degree of bank credit difficulties, as it doubles between the two waves (from approximately 20% to 40%). Finally, the average values of labor productivity and capital investment remain almost stable in both waves.

<Insert Table 2 about here>

In this analysis, the crisis continuation variable is formulated with the value of 0 for the responses of 2011 and the value of 1 for the responses of 2013, the latter incorporating the peak of the Greek economic crisis. As a matter of fact, the recessionary cycle of the Greek economy began in 2008, along with the burst of the global economic crisis, when a first negative growth rate in the GDP was recorded (-0.3%). By the end of 2011, the accumulative recession was -18% of the Greek GDP, while at the end of 2013 Greece had lost 26.4% of its GDP. 2013 was the year when the Greek GDP was at its lowest level (measured in constant prices of 2015) since the outbreak of the crisis in 2008, thus representing the trough of the Greek experience. This is why we consider 2013 as a crucial milestone representing the worst moment of the Greek economic crisis (European Commission 2017). The other important factor in this context is that over the following years (from 2014 onward) the Greek economy grew only slightly, if at all. Thus, after five years of strongly negative signs, the economy did not recover, rather it remained at a low level in economic stagnation before dropping by another 9% in 2020 in the wake of the pandemic.

3. Empirical Strategy

To explore the relationship between a firm's decision to invest in R&D, its innovation output and productivity, we apply the well-established three-stage CDM model (Crepon et al. 1998) by a variant developed by Mairesse et al. (2005). The general benefits of this framework are extensively described in various approaches (see Lööf et al. 2017), while the benefits of the variant by Mairesse et al. with respect to selection bias and endogeneity issues are discussed in Audretsch et al. (2020). For the sake of brevity, we keep the model description short.

In the first stage, we use a bivariate probit model to estimate the innovation input; i.e., the probability of undertaking R&D activities (as suggested by Mairesse et al. 2005). The decision of firm i to invest in R&D (r_i^*) can be specified as follows:

$$r_i = \begin{cases} 1, if\ r_i^* = X_i'a + e_i > \hat{c} \\ 0, if\ r_i^* = X_i'a + e_i \leq \hat{c} \end{cases} \qquad (1)$$

where r_i represents the observed binary variable for the R&D decision, r_i^* denotes an unobserved latent variable that captures the probability of undertaking R&D activities, X_i' is a vector of possible factors influencing the decision of firms to engage in R&D, and e_i is the error term. When the unobserved latent variable exceeds a certain threshold level $\hat{c}$, then the observed r_i takes the value of 1, and 0 otherwise.

In the second stage, the specification of the knowledge production focuses on the link between innovation input and innovation output. We use a probit model to estimate the probability of introducing an innovation output, where product and process innovation are merged to one variable of innovation output (Hall 2011), by including the predicted R&D decision obtained from stage 1 as the explanatory variable. To this end, knowledge production is modeled as:

$$i_i = \begin{cases} 1, if\ i_i^* = r_i^*\beta + Z_i'\delta + u_i > \hat{c} \\ 0, if\ i_i^* = r_i^*\beta + Z_i'\delta + u_i \leq \hat{c} \end{cases} \qquad (2)$$

where the observed binary variable for innovation output is denoted by i_i and the latent R&D decision predicted in the first stage is represented by r_i^*. Z_i' is a vector of factors that may influence the innovation output and u_i is the error term.

The third stage of the CDM approach makes use of a productivity function including the predicted innovation output derived from stage two as the explanatory variable, as a proxy for knowledge input. To estimate the productivity, we use a Cobb-Douglas production function extended with the use of knowledge stock (Griliches 1979). The equation of the OLS estimation is expressed in logs as follows:

$$y_i = \alpha_1 + a_2 k_i + a_3 i_i^* + a_4 W_i + v_i \qquad (3)$$

where the dependent variable y_i denotes the labor productivity measured in sales per employees in logs. The explanatory variables of primary interest in the production function are the knowledge input (i_i^*) derived from the estimated innovation output in stage 2, and the capital input (k_i) measured by the investment intensity in logs. Finally, W_i is a vector of control variables, and v_i is the observed error term.

4. Results

4.1 First stage: R&D engagement

We estimate the panel probit model expressed by equation (1) for the full sample and separately for the size groups, as defined above. Table 3 presents the marginal effects of the explanatory variables on the probability of firms' engagement in R&D activities.

<Insert Table 3 about here>

Focusing on the total sample (Column 1), we find that micro and small firms are less likely to engage in R&D activities than the reference group of large-sized firms (confirming earlier findings of Hall et al. 2009 and Baumann and Kritikos 2016).

To further explore whether the examined factors influence in a different way the R&D engagement of micro and small firms, as compared to their larger counterparts, we discuss the empirical results for the two size groups separately (Columns 2 and 3). In particular, the continuation of the crisis has a negative effect (significant at the 5% level) on the probability of micro and small firms engaging in R&D activities, while a positive and strong association (at the 1% level of significance) emerges in the case of larger firms. The coefficients' values obtained from the marginal effects indicate that the continuation of the crisis is associated with an 8 pp decrease in the probability of smaller firms to become involve in R&D activities, while it is correlated with a 20% increase in the probability of larger firms to engage in R&D.

4.2 Second stage: Knowledge production

Table 4 presents the results from the second stage on the full sample and on the two examined size groups. For the full sample, we reveal a strong link between the predicted R&D (obtained from the previous stage) and innovation output in terms of probability (based on coefficients' values) and significance level. Moreover, employee training is positively correlated with the probability of firms to innovate, while the continuation of the crisis and liquidity constraints are harmful for the firms' innovativeness.

<Insert Table 4 about here>

Looking at the size groups, a strong link exists between R&D and innovation output for larger firms, while among smaller firms there is no such link. Additionally, training only unfolds a positive influence on innovation among larger firms, increasing the probability to innovate by 17 pp, while it has no effect on the innovativeness of smaller firms. However, the continuation of the crisis also decreases the probability of large firms to innovate by 9 pp. Last, but not least, among larger firms, it is particularly younger firms that are more likely to turn R&D into innovation output; among smaller firms this appears true at least for the middle-aged firms.

4.3 Third stage: Labor productivity

Table 5 presents the results for the third stage of the CDM model to reveal whether innovation activities affect the labor productivity of firms. Our findings for the full sample indicate that the productivity level of innovative firms is significantly higher compared to firms that do not innovate. Differentiating between firm size groups reveals that large firms are able to improve their labor productivity from innovation output, while the innovation-productivity nexus is insignificant for smaller firms. This finding raises similar concerns as those expressed in some empirical studies on manufacturing SMEs according to which product and process innovations may not necessarily foster firm productivity due to increased production costs associated with innovation investments (Jaumandreu and Mairesse 2016; Exposito and Sanchis-Llopis 2018).

<Insert Table 5 about here>

5. Discussion and Conclusion

We use the CDM model and data on 524 Greek manufacturing firms to explore how the continuation of the Greek economic crisis from 2008 onwards links to the triad relationship between R&D, innovation output, and productivity. Important firm size differences emerge confirming our expectations with respect to smaller firms. For smaller firms an R&D decision has become less likely, while larger firms are even more likely to engage in R&D. These results imply different strategic responses to the crisis between smaller and larger firms. Small and micro ventures might be constrained by a lack of resources due to the liabilities of smallness, where the continuation of the financial crisis might have led to a severe "funding gap" (Block and Sandner 2009), which is why they may have reduced R&D expenditures and innovation efforts (Edeh and Acedo 2021). By contrast, the crisis seems to have pushed large firms, which typically have better access to finance and other resources to withstand the economic downturn, to continue investing in R&D activities in order to create or further support a new competitive advantage either in the local market or in cross border markets (Geroski and Walters 1995; Nickell et al. 2001). An additional aspect may be related to the fact that larger firms have already made some large investments in R&D in either tangible or intangibles assets (see Mañez and Love 2020).

This has consequences for the later stages of our analysis: in the knowledge production function, a positive association between R&D and innovation output can only be found for larger firms, but not for smaller ones. Still, the continuation of the crisis also has negative effects for larger firms, as it reduces the probability of introducing an innovation among them.

Hence, it seems that although larger firms are more likely to invest in R&D during turbulent economic times, diminishing returns may appear, taking the form of decreased innovation performance – this particularly holds true for older firms among the larger grouping. These diminishing returns might be explained on the grounds of path dependencies of the past and organizational inertia (Nieto and Santamaría 2010; Thrane et al. 2010), implying a limited agility of larger firms when significant changes emerge in the external environment, like those observed in adverse economic conditions.

Finally, innovation improves labor productivity only in larger firms, but the corresponding effect is not significant for smaller firms. The crucial link between R&D, innovation, and productivity that also exists for smaller firms in normal times, is distorted during crises, making them more vulnerable, and worsening their recovery from the shock (Castellani et al. 2019). When economic conditions worsen, smaller firms seem to reduce whatever R&D budget they had in place, affecting their innovative performance and their productivity. As a result of this, larger firms might have better survival and success probabilities, as they are able to continue their innovation processes throughout a lasting crisis. This diverging result may lead to cleansing processes with smaller firms closing more often than larger ones – an outcome observed in the Greek manufacturing sector in subsequent years (see Kritikos et al. 2018).

The Greek governments remained passive during these times of the Greek economic crisis with the consequence that there was no economic recovery in Greece, rather low-level economic stagnation persisted from 2014 through 2019 (resembling to an "L-shaped recovery"). This calls for a more active role at the policy level in order to overcome such a crisis which may also become relevant in the context of the ongoing economic crisis following the COVID-19 pandemic.

In this context, we should emphasize that the economic shock due to the COVID-19 crisis is resembling in some parts to what Greece experienced during the 2008-2013 period in terms of some macroeconomic indicators. These two crises share common features, such as nearly double-digit GDP losses in economies with moderate innovation activities, increasing unemployment rates, negative inflation rates, as well as significant increases in public debt (European Commission 2020). Moreover, in both cases, the regulatory frameworks, institutions, and investors were unprepared for the magnitude and the persistent consequences of the crises (Lustig and Mariscal 2020). Both crises also appear to have devastating effects on business activity, resulting in business exits, supply chain disruptions, redundancies, and loss of key customers (Fairlie and Fossen 2021, Belitski et al. 2021). And there are already visible signs for diverging funding pattern at the first stage of the relationship between R&D, innovation and productivity: smaller firms reduced their R&D investments during the first year of the COVID-19 crisis –in Germany (Infas et al. 2021).

In contrast to the passive role of the Greek government during the Greek economic crisis, under the COVID-19 crisis investments from the planned funds of the EU's Resiliency and Recovery Facility (RRF) may come in, which is the key instrument to mitigate the economic and social impact of the pandemic crisis. Basically, there are two options that may facilitate a quick recovery when making use of these funds. One option could be to secure additional support for small and micro firms during such turbulent times. Measures like extensive tax reductions on R&D expenses, over-depreciation rates on R&D equipment, an increase in public R&D funding, and swifter regulation for attracting researchers to contract-based research or collaborations with universities and other research institutions could offer some additional incentives for overcoming "R&D crunch" conditions among small and micro businesses. Any type of support in collaboration in R&D for smaller firms is beneficiary as these firms rely more on external sources of input to the innovation process and as smaller firms tend to receive greater benefit from such exchange. Overall, such a policy mix would support more small and micro firms to survive such long-lasting crisis and secure more growth afterwards. The other option could be to try and use the exit of some less efficient small and micro firms as an opportunity to increase the notoriously underrepresented number of large firms in such moderate innovation economies by removing regulatory obstacles that hinder the growth of the remaining smaller firms (Herrmann and Kritikos 2013), thus increasing labor productivity by supporting transitions from small to large firms.

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Table 1: ***Descriptive Statistics of the Examined Variables***

Variables	Description	2011 wave	2013 wave
In-house R&D	*Firms indicated whether they have organized or developed an R&D department during the last two years.*	**Frequency**	
	1. Yes	25.96%	31.48%
	0. No	74.04%	68.52%
Innovation Output	*Firms indicated whether they were engaged in new or significantly improved product or process innovations within the last two years.*	**Frequency**	
	1. Yes	67.37%	58.40%
	0. No	32.63%	41.60%
Training	*Firms indicated whether they provided external or internal training programs to their employees within the last two years.*	**Frequency**	
	1. Yes	73.85%	72.85%
	0. No	26.15%	27.15%
Liquidity Constraints	*Firms indicated (on a 1-5 Likert scale), the level of credit crunch conditions they face due to banks inability to provide loans*	**Frequency**	
	1. None credit difficulties	25.96%	11.95%
	2. Low degree of credit difficulties	18.27%	9.06%
	3. Moderate degree of credit difficulties	19.42%	15.99%
	4. Relatively high degree of credit difficulties	17.12%	22.16%
	5. Very high degree of credit difficulties	19.23%	40.85%
Metropolitan	*Firms indicated their location and based on this information a regional dummy was constructed referring to the two metropolitan areas of Greece, i.e. Athens and Thessaloniki*	**Frequency**	
	1. The firm is located in the metropolitan areas of Greece	37.02%	
	0. The firm is located in the rest regions of Greece (i.e. non-metropolitan areas)	62.98%	
Labor Productivity	*Sales per full time equivalent employees (in logs)*	**Summary Statistics**	
	Mean	11.873	11.807
	Std Dev	0.833	0.925
	Max	14.685	15.174
	Min	6.463	7.875
Investment intensity	*Capital investment per full time equivalent employees (in logs)*	**Summary Statistics**	
	Mean	9.383	9.061
	Std Dev	1.435	1.313
	Max	15.807	13.074
	Min	3.912	4.855

Table 2: ***Frequencies per Size Group***

Size Group	Micro Firms (firms that employ fewer than 10 persons)	Small Firms (firms that employ 10-49 persons)	Medium Firms (firms that employ 50-249 persons)	Large Firms (firms that employ 250 or more persons)
% of firms	6.58%	40.94%	42.18%	10.31%

Table 3: ***R&D Engagement***

Dependent Variable: In-house R&D	Full Sample	Micro and Small Firms <50 employees	Medium and Large Firms >=50 employees
50–249 employees	-0.058		
	(0.048)		
10-49 employees	-0.178***		
	(0.051)		
0–9 employees	-0.440***		
	(0.095)		
Age class (15–34 years)	-0.010	-0.043	0.052
	(0.036)	(0.042)	(0.061)
Age class (35 + years)	0.010	-0.012	0.037
	(0.042)	(0.055)	(0.065)
Exporting activity	0.027	0.033	0.041
	(0.037)	(0.044)	(0.059)
Metropolitan area	0.007	0.016	-0.006
	(0.033)	(0.053)	(0.045)
Crisis Deepening	0.054	-0.086**	0.199***
	(0.028)	(0.035)	(0.040)
Liquidity constraints	0.004	0.048	0.001
	(0.010)	(0.012)	(0.015)
Employees (ln)		0.073**	0.056**
		(0.031)	(0.025)
Industry dummies	Yes	Yes	Yes
Observations	1034	489	544

***Significance at p < .05 level; ***Significance at p < .01 level.*

The table reports the marginal effects of the panel probit regressions.

Reference groups for the firm size and age dummies: large firms (size group >=250 employees) and young firms (age group < 15 years).

The majority of the above variables are binary ones apart from Liquidity constraints (5-point Likert scale) and Employees (ln).

Table 4: ***Knowledge Production Function***

Dependent Variable: Innovation Output (Product or Process Innovation)	Full Sample	Micro and Small Firms <50 employees	Medium and Large Firms >=50 employees
50-249 employees	0.325***		
	(0.478)		
10-49 employees	0.874**		
	(1.328)		
0–9 employees	2.248***		
	(3.315)		
Age class (15–34 years)	0.140**	0.223***	-0.243**
	(0.222)	(0.283)	(0.501)
Age class (35 + years)	-0.045	0.178	-0.363***
	(0.218)	(0.320)	(0.539)
Training	0.127**	0.095	0.172**
	(0.204)	(0.282)	(0.340)
Investment intensity (in logs)	0.008	0.023	0.005
	(0.050)	(0.095)	(0.086)
In-house R&D (predicted)	1.630***	0.467	1.446***
	(2.241)	(1.432)	(2.254)
Metropolitan area	-0.022	-0.251	0.009
	(0.210)	(0.448)	(0.261)
Crisis Deepening	-0.368***	0.182	-0.964***
	(0.480)	(0.588)	(1.385)
Liquidity constraints	-0.031**	-0.017	0.005
	(0.057)	(0.084)	(0.076)
Employees (ln)		0.107	-0.012
		(0.188)	(0.144)
Industry dummies	Yes	Yes	Yes
Observations	694	275	404

***Significance at p < .05 level; ***Significance at p < .01 level. Bootstrap standard errors with 100 replications are reported in parentheses.*

The table reports the marginal effects of the panel probit regressions.

Reference groups for the firm size and age dummies: large firms (size group >=250 employees) and young firms (age group < 15 years).

Table 5: ***Production Function***

Dependent Variable: Labor Productivity	Full Sample	Micro and Small Firms <50 employees	Medium and Large Firms >=50 employees
Investment intensity (in logs)	0.198***	0.257***	0.179***
	(0.027)	(0.050)	(0.032)
Innovation Output (predicted)	0.311**	-0.404	0.349***
	(0.129)	(0.216)	(0.106)
Employees		-0.132	-0.028
		(0.140)	(0.043)
Crisis Deepening	0.125	0.008	0.156
	(0.075)	(0.122)	(0.084)
Industry dummies	Yes	Yes	Yes
Age group dummies	Yes	Yes	Yes
Size group dummies	Yes	No	No
Observations	557	207	350

***Significance at p < .05 level; ***Significance at p < .01 level. . Bootstrap standard errors with 100 replications are reported in parentheses.*

Reference groups for the firm size and age dummies: large firms (size group >=250 employees) and young firms (age group < 15 years).