Technological Forecasting & Social Change xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Technological Forecasting & Social Change

The impact of the economic crisis on innovation: Evidence from Europe

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ARTICLE INFO

Article history:
Received 3 April 2012
Accepted 9 May 2013
Available online xxxx

Keywords:
Economic crisis
Innovation investment
Firm-level analysis
Creative destruction

ABSTRACT

Economic crises cause companies to reduce their investment, including investment in innovation where returns are uncertain and long-term. This has been confirmed by the 2008 financial crisis, which has substantially reduced the willingness of firms to invest in innovation. However, the reduction in investment has not been uniform across companies and a few even increased their innovation expenditures. Through the analysis of a fresh European Survey, this paper compares drivers of innovation investment before, during and following on from the crisis, applying the Schumpeterian hypotheses of creative destruction and technological accumulation. Before the crisis, incumbent enterprises are more likely to expand their innovation investment, while after the crisis a few, small enterprises and new entrants are ready to "swim against the stream" by expanding their innovative related expenditures.

1. The effect of an economic shock on long-term investment

Major economic shocks, such as the 2008 financial crisis, make business opportunities less certain, and, in turn, companies become less willing to invest in long-term activities where returns are risky. Most companies react to a short- or medium-term adverse macroeconomic environment by downsizing expenditures, including expenditures on investment and innovation. However, economic crises also provide an opportunity for companies, industries and entire nations to restructure productive facilities and to explore new opportunities. Smart companies do perceive that an economic crisis will not last forever and that a recovery will sooner or later arrive. A new economic cycle, however, is also likely to bring structural changes in the composition of output and demand. In order to reap the opportunities of the new cycle, successful companies need to be prepared by providing new and improved goods and services.

As already predicted by Schumpeter and the Schumpeterian literature, while an economic crisis has an adverse impact on most of the economic agents, in the long-run it will not generate losers only. On the one hand, a few economic agents may emerge as winners and we assume that they will be found among those companies that understand earlier than others that the composition of output and relative prices to emerge from the crisis will be very different from the past. On the other hand, losers are more likely to be found among those firms that react not only just by reducing employment and productive capacity in general, but also downsizing their investment in innovation. Which are the key characteristics of the companies belonging to the two categories?

The 2008 economic crisis offers a unique opportunity to test two models of innovation originating from Schumpeter and the Schumpeterian economics and that can be labelled creative destruction and technological accumulation. In turn, these models may help us to identify what will be the typology of companies that will lead the recovery. Our paper is an attempt to test the interplay between the forces of creative destruction and accumulation in innovation before, during and after the financial crisis that started in the Fall of 2008. In fact, there was a substantial drop of innovative investment in Europe [1], and this leads us to wonder what

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0040-1625/$ – see front matter © 2013 Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.techfore.2013.05.005

are the best strategies that should be taken at the country level [2].

Our analysis is made possible thanks to a recent wave of the Innobarometer Survey designed and collected by the European Commission in 2009 [3]. Each year the Innobarometer introduces a different topic and the 2009 survey emphasises innovation related expenditure, including the effects on it of the economic downturn. Enterprises from the 27 EU member states, plus Norway and Switzerland responded to the survey.

The paper is structured as follows. Section 2 discusses the state of the art against which the paper is set. Section 3 develops the conceptual framework by providing a sketch of the two ideal type models of creative accumulation and creative destruction. Section 4 introduces the dataset and methodology. Section 5 presents the results that are discuss in the last section.

2. Innovation generated through technological accumulation and economic creative destruction

The young Schumpeter [4] looked at innovation as an event that could revolutionize economic life by bringing into the fore new entrepreneurs, new companies and new industries. The mature Schumpeter [5], on the contrary, observed and described the activities of large oligopolistic corporations, able to perform R&D and innovation as a routine by building on their previous competences. On the ground of these insights, the Schumpeterian tradition has further investigated the relative importance of the two processes (see [6–10]). Creative destruction is described as a result of a regime characterized by low cumulativeness and high technological opportunities, leading to an environment with greater dynamism in terms of technological ease of entry and exit, as well as a major role played by entrepreneurs and fierce competition. Creative accumulation is associated with a technological regime that is characterized by high cumulativeness and low technological opportunities, bringing about more stable environments in which the bulk of innovation is carried out by large and established firms incrementally, leading to a market structure with high entry barriers and oligopolistic competition.

There are arguments supporting the relevance of cumulativeness and of reinforcing patterns of technological development and innovation, and arguments lending support to a “destruction/discontinuous hypothesis”. Concerning the former, several studies suggest that learning processes that underlie innovation activities are both local and cumulative resulting in path-dependency (e.g. [11–13]). In addition, empirical evidence indicates that there is a degree of persistence in innovation and among innovators [14]. Concerning the latter, it has often been stressed that there are periods of turbulence associated with a change in the leading sectors and/or the emergence of new sectors, which brings about a decline of technological and profit opportunities in established industries [15]. This, in turn, might lead to a change in the knowledge and technological base for innovation and could substantially affect the hierarchy of innovators [16]. Other research has stressed the fact that firm-specific organisational routines and capabilities can bring about inertia and hamper the capacity of established firms to keep up with major discontinuities [17–19].

This should also be related to the “continuity” thesis advocated by Chandler [20] and his followers on the grounds of the fact that the population of incumbent, large firms has remained stable over the last decades. This thesis has been challenged by Simonetti [10], Freeman and Louca [21] and Louca and Mendonca [22], who claim that a stream of new firms has joined incumbent firms during periods of radical discontinuities. This can also be contingent to the specific knowledge base and technical skills attached to different industries. For example, while Klepper and Simons [23] show that firms established in making radios were successful in developing colour TVs, Holbrock et al. [24] illustrate that this pattern is not mirrored in the evolution of the semiconductor industry.

In this paper the emphasis is not on specific industries or technologies, but rather on how an external shock, represented by the financial crisis, is affecting companies' innovative strategies. As a result, we expect to find an array of different innovation drivers both before and in response to the crisis. These are examined in view of the changes at the macrolevel, as we aim to understand whether the crisis has led to some variation/discontinuity at the aggregate level as a result of a different composition among innovating firms.

3. An attempt to identify the core characteristics of creative destruction and technological accumulation

To guide the analysis we elaborate on the ideal type models of creative destruction and creative accumulation as two possible aggregate outcomes of microbehaviours. Creative destruction describes a dynamic environment in which new firms emerge as the most significant innovators as a result of a major discontinuity such as an economic downturn. Creative accumulation is underpinned by a more stable pattern of innovation which emphasises cumulativeness and persistency of innovative activities in response to the crisis. We make here an attempt to identify these two patterns in relation to firm behaviour rather than to the evolution of technological regimes. In this sense, our approach is complementary to the research pioneered by Malerba and Orsenigo [8] to identify Schumpeterian patterns of innovation with reference to various technological fields.

A sketch of the differences between the models of creative destruction and creative accumulation is given in Table 1 where four categories are singled out: i) characteristics of the innovating firm, ii) type of knowledge source dominant in the innovation process, iii) type of innovations, and iv) characteristics of the market.

In the empirical part of the paper some of these factors, those more directly associated to our data, will be used to test if the two ideal type models can be related to the patterns of innovation investment of firms.

3.1. Characteristics of the innovating firms

The creative accumulation model assumes that incumbent firms explore systematically technological opportunities. For them, to innovate is a routine, and it is one of the core things that the top management supervises. They have to upgrade periodically their products, often because they operate in concentrated oligopolistic industries. A stream of incremental innovation does not only guarantee that costs and prices are kept competitive, but also that products are differentiated and improved compared to those of the competition. This provides the possibility to accumulate knowledge and often not just in the

Table 1
Innovative firms' characteristics in the context of the ideal type creative accumulation and creative destruction models.
Source: Authors' elaboration.

Categories	Creative accumulation	Creative destruction
Characteristics of the innovating firms	Innovations are driven by large, incumbent firms that seek new solutions through formal research exploiting their pre-existing capability.	Small firms, new entrants are key drivers in the innovation process. They use innovations and exploit economic turbulences to acquire market share from incumbent firms or to open new markets.
Type of knowledge sources	High relevance of past innovations and accumulated knowledge. Importance of formal R&D, not only in-house, but also jointly performed, or externally acquired.	Higher relevance of collaborative arrangements leaning towards the applied knowledge base (other firms). Exploration of new markets and technological opportunities.
Type of innovations	The innovation process is dominated by a large number of incremental innovations. Organisational routines drive the generation of innovations.	The emphasis is on path-breaking innovations often able to create new industries. New organisational forms contribute to generating innovations.
Characteristics of the market	Barriers to entry are high due to relative importance of appropriation and cumulativeness of knowledge and high costs of innovation. Dominance of oligopolistic markets. Technological advancement based on path-dependent and cumulative technological trajectories.	Low barriers to entry into the newly emerging industries. A high rate of entry and exit leads to low levels of concentration and high competition. Discontinuous technologies are available that generate growing markets and new opportunities.

areas of their core products. When new technological opportunities are identified, these companies may also be quick in entering into new fields and industries, thanks to their wide, accumulated knowledge [25]. However, when firms diversify, they tend to do so along some kind of technological relatedness, defined as *coherence* [26,27]. Pavitt makes this point clear: "Given the increasingly specialized and professional nature of the knowledge on which they are based, manufacturing firms are path-dependent. […] it is difficult if not impossible to convert a traditional textile firm into one making semiconductors" [13, p. 95].

By contrast, the creative destruction model emphasises the role played by individual inventors and entrepreneurs. This model reflects a more uncertain landscape of early stages of new technologies. By anticipating or even creating technological opportunities, these far-sighted individuals manage to generate new firms and often new industries that substantially change the economic landscape. These individuals can not only be independent, e.g. setting up or owning their own business, but they can also be dependent and employed by an (sometimes large) organisation.

These individuals do not find the most conducive environment in existing organisations since learned and accumulated routine activities, organisational settings, and decision processes somehow discourage an entrepreneurial stance. Moreover, the larger the company, the greater might be a resistance to change by the company as a whole (see [28]). Thus, patterns linked to creative destruction are associated at the firm level with innovation driven by smaller size, and new entry into markets alongside established firms, as entrepreneurial activities might be greater due to lower inertia, greater flexibility and responsiveness to changes in demand conditions and technological discontinuities. This type of innovative behaviour could be found in spin-offs from established companies, universities or simply new businesses.

3.2. Type of knowledge sources

In creative accumulation routine-based research is more important as a key source in the innovation process than sudden insights. This favours the large firm that; i) has the capacity and the resources to set-up and maintain internal R&D laboratories, ii) can use interactions with others, and iii) has well-established internal functions (including design, production, and marketing). High-tech companies are also able to plug into the knowledge base of other companies, public institutions and countries. They are in the position to reduce the risks and costs associated with exploring new technological opportunities through strategic technological agreements, they have qualified personnel able to interact periodically with universities and public research centres, they can also establish intra-firm but international research networks through subsidiaries in other countries [25]. All these factors allow them to build on and add to their already existing competences.

Creative destruction on the contrary will be based on internal sources that in some occasions, and for limited periods of time, represent the bulk of the firm's economic activity, as it has happened for companies in emerging fields such as biotechnology and software. This will also be combined to the concentric exploration of new opportunities, to specific ventures with companies operating in other industries, or generating symbiotic contacts with university departments (see [7]). In the case of small or newly established firms, the development of new products, services or processes is likely to favour external collaborations and strategic alliances over and above than in the case for large corporations. Such set-ups help to overcome possible resource, finance and capability constraints within new and comparatively small firms.

3.3. Type of innovations

Creative destruction is linked to patterns of path-breaking innovations and radically new solutions that are incompatible with traditional solutions. Several scholars have argued that in this case innovations are more likely to be introduced by new firms, as existing firms can face problems in terms of a lack of the adequate new skills and competences [29,17,18], organisational adaptation [19], and difficulties in changing context [30,31].

Please cite this article as: D. Archibugi, et al., The impact of the economic crisis on innovation: Evidence from Europe, Technol. Forecast. Soc. Change (2013), http://dx.doi.org/10.1016/j.techfore.2013.05.005

Creative accumulation is linked with frequent, but more incremental innovation patterns. Accumulation or cumulativeness suggests that firm innovation activities are driven by past innovation activities. Current technologies build on past experience of production and innovation specific to the firm. Malerba and Orsenigo [8] and Breschi et al. [7] suggest that cumulativeness of technological change is high when; i) the firm is established and can build on a history of innovation success, and ii) there is a tradition of research carried out inside the firm.

Pavitt and his colleagues suggested that incumbents might have the resilience to survive and to adapt to major changes [11,9]. Methé et al. [32] present empirical evidence showing that established firms often are sources of major innovations, for example in telecommunications and medical instruments. In a similar vein, Iansiti and Levien [33] suggest that, despite the many predictions about incumbents' failures, technological transitions in the computer industry were survived by the overwhelming majority of firms. Studying a sample of large French firms, Laperche et al. [25] also show how they have quickly modified their innovative strategies to face the post-crisis context.

3.4. Characteristics of the market

In a Schumpeterian model, firms compete to become oligopolistic in their market. This allows them to gain extra profits through the appropriation of returns from their innovations. In a dynamic context, the oligopolistic structure is seen as a necessary evil to foster dynamic efficiency led by the continuous introduction of innovations [5,34]. Creative destruction has been associated with a market structure characterized by high dynamism and competition, as well as high rate of change in the hierarchy of innovators. On the contrary, creative accumulation patterns are linked to oligopolistic market structure with high entry barriers and high degree of stability of innovators.

Nelson and Winter [6] suggest that the market structure in a specific industry, the degree of concentration and rate of entry, are influenced by the degree to which technological opportunities arise and the ease with which innovations can be protected from imitation (i.e. the appropriability conditions). High technological opportunity together with low appropriability causes lower concentration in an industry and vice versa. These arguments are picked-up and empirically tested by Breschi et al. [7] and Malerba and Orsenigo [8] in their work on technological regimes and their role in the evolution of industrial structures, hierarchy of innovators and innovation activities. The following section operationalizes the concepts discussed in this section and summarized in Table 1.

4. Data and methodology

4.1. The data

The empirical part of the paper analyses the Innobarometer Survey 2009 that is designed and collected by the European Commission [3]. In each of the 27 EU member states, plus Norway and Switzerland, 200 enterprises with main activities in innovation intensive industry sectors and with 20 or more employees were sampled.[1] 5238 telephone interviews were completed between the 1st and 9th of April 2009. The sample is a random sample, stratified by country, enterprise size (5 size bands) and industry (2-digit industry codes).[2]

Since 2001 Innobarometer is conducted on a yearly basis. Each year the survey highlights a different issue/theme, which is picked up on in additional and specific questionnaire items over and above a core set of questions. The focus of the current, 2009 survey is on innovation related expenditures and the effects of the economic downturn on innovation related expenditures. It is in this section of the questionnaire from which our key variables are developed. In the remainder of this section we introduce our dependent and independent variables and discuss the methodology.

4.2. The dependent variables

Our dependent variables measure change in innovation related investment as it is reported by the firms themselves and with reference to different time periods (before, during and following on from the crisis). Innovation related investment is captured in a wide sense, incorporating not only expenditures on in-house R&D but also technology embodied in the purchase of machinery, equipment and software, licenced-in technology (patents or other know-how), training of staff in support of innovation, and expenditures on design of products, process and services. This broad definition (in line with the definition adopted in the Community Innovation Surveys) has advantages over a narrow definition, such as investment in R&D. R&D expenditures will not be able to capture short-term responses to the financial crisis on the grounds that R&D projects are typically commitments made for several years. Moreover, R&D is also concentrated in a few firms and sectors. In contrast, the wider definition of innovation related investments used in this paper that includes other innovation related expenditures over and above R&D, is better suited to capture short-term adjustments due to changes in the economic environment. Firms are quicker in cutting training for innovation, design budgets or purchases of software, than they are in adjusting R&D projects.

Our dependent variables are based on firms' responses to the following three questions.

(a) Before the crises: "compared to 2006 has the total amount spent by your firm on all innovation activities in 2008 increased, decreased or stayed approximately the same?",

[1] In the smallest EU countries, Cyprus, Malta, and Luxembourg, the sample consisted of 70 enterprises and in non-EU countries, Switzerland and Norway, the sample size was 100. The industry sectors included are: aerospace, defence, construction equipment, apparel, automotive, building fixtures, equipment, business services, chemical products, communications equipment, construction materials, distribution services, energy, entertainment, financial services, fishing products, footwear, furniture, heavy construction services, heavy machinery, hospitality and tourism, information technology, jewellery and precious metals, leather products, lighting and electrical equipment, lumber and wood manufacturers, medical devices, metal manufacturing, oil and gas products and services, paper, (bio)pharmaceuticals, plastics, power generation & transmission, processed food, publishing and printing, sport and child goods, textiles, transportation and logistics, and utility.

[2] A detailed description of the survey, including the sampling and data collection methods, can be found in a methodological report by the European Commission [3].

(b) During the crisis: "in the last six months[3] has your company taken one of the following actions as a direct result of the economic downturn; increased total amount of innovation expenditures, decreased […] or maintained […]?", and
(c) Following on from the beginning of the crisis: "compared to 2008, do you expect your company to increase, decrease or maintain the total amount of its innovation expenditure in 2009?".

The observations feeding into the empirical analysis are all those firms that were innovation active and, thus, firms that stated they increase, decrease or maintain their innovation investment in the three periods respectively. The weakness of our dependent variables – change in innovation related investment – is that the scales are categorical rather than continuous (e.g. three choices as opposed to the total amount spent on innovation); but the strength is that they provide a unique possibility to distinguish between three different time periods around the crisis.

Table 2 provides the descriptive statistics for the three dependent variables, including the number (frequency) and percent of enterprises that increased, maintained and decreased innovation investment under (a) time proxy for 'before the crisis' — we also refer to this as T1, (b) proxy for 'during the crisis' that we also refer to as T2 and (c) proxy for 'following on from the crisis' referred to as T3.[4]

Table 2 reveals two patterns. Firstly, 38% of enterprises reported that they increased innovation related investment in 2008 compared with their investment in 2006 (see Table 2 the "percent" column under T1); but, in T2 only 9% and in T3 13% of enterprises reported increased investment. Thus, there is a strong drop in the number of firms that increased innovation related investment during the crisis and following on from the crisis. This pattern is mirrored in a shift from few firms to many firms reporting decreased investment over the three time periods. In T1 only 9% of firms decreased their innovation related expenditures, but in the midst of the financial crisis – in T2 – 24% decreased investment and 30% planned to decrease investment in 2009 compared to investment levels in 2008. This might, at the aggregate level, point towards destruction. Secondly, a large share of firms (about half of all firms) reported that they maintained innovation related investment irrespectively of the crisis leaning towards an accumulation hypothesis.

In Table 3 we report the cross-tabulations and Chi^2 statistics between the dependent variables producing three cross-tabulations: before the crisis (T1) with during the crisis (T2); before the crisis (T1) with following on from the crisis (T3); and during the crisis (T2) with following on from the crisis (T3). We present the cross-tabulations to gain insight into the level continuity/discontinuity in innovation investment decisions. For example, are the firms that increased investment during the crisis also among the firms that increased investment before the crisis?

In the cross-tabulations we report frequencies and column percentages below the frequencies. In the first column total of the top cross-table we report that 438 firms increased investment during the crisis (T2), and, in the first cell of the first cross-tabulation, we report that, out of these 438 firms, 332 also increased investment before the crisis (T1). This is the same as stating that 76% of firms that increased investment during the crisis are firms that already increased investment before the crisis. These 76% or 332 firms indicate some consistency of investment patterns and may already point towards, despite of the crisis, a confirmation of the importance of technological accumulation.

But, out of the 438 firms that increased investment during the crisis (and 620 that increased investment following on from the crisis, see the middle cross-tabulations), 24% (and 42%) decreased or maintained investment before the crisis. And, it is among these firms that we could see a shift in firm characteristics and market conditions associated with increased innovation investment before, during and following on from the crisis.

From the information presented in Table 3 we also know that there is greater stability in the investment choices of firms between the two periods during (T2) and following on from (T3) the crisis, also resulting in the higher measure of association (Chi^2(4) = 1400; $p < 0.01$), compared with before the crisis (T1 and T2, T1 and T3).

To fully address our research question of who the firms are that increase investment (top row of Table 2) in the midst of the crisis – (a) the most dynamic ones that compete largely on continuous upgrading or (b) new players that could be newly established firms or firms less relevant in aggregate innovation – we use a set of measures capturing firm and market characteristics to which we now turn, and that we use to predict innovation related investment across T1, T2 and T3 in the Results section of the paper.

4.3. The independent variables

Table 4 contains an overview of the independent variables arranged by the categories introduced in Table 1. These categories are; i) characteristics of the innovating firms, ii) type of knowledge sources, iii) type of innovations and iv) market characteristics.

The first column in Table 4 gives the variable names of the independent variables and the second column the variable description. All our independent variables are dummy variables coded 1 if a characteristic is met and zero otherwise. We rely on dummies because of a lack of more detailed information. In the first category entitled 'characteristics of the firm', the first variable is called 'newly established' and this variable is coded 1 if a firm was established after 1 January 2001 and 0 if it was established earlier. This variable is used as a proxy to identify new entrants. The second set of variables is made of three dummies that we use to proxy firm size. Small firms (20 to 49 employees) are used as the base comparison group in the regressions. The final variable proxies the innovation intensity of firms or the stock/level of investment in innovation related

[3] The interviews were conducted between 1 and 9 April 2009, and, thus, the question relates to the period starting October 2008 ending with March 2009.

[4] The Innobarometer survey reports a lower number of non-innovation active firms compared with similar datasets, and specifically the Community Innovation Surveys. The following factors might contribute: (a) a difference in the industrial composition — "the enterprises interviewed in Innobarometer were sampled from sectors that are likely to be innovative" EC (2009), and (b) Innobarometer includes firms with 20 or more employees while the Community Innovation Survey includes enterprises with 10 and more employees.

Table 2
Investment in innovation related activities before, during and following on from the beginning of the crisis.
Source: Authors' elaboration on Innobarometer, European Commission (2009a).

Dependent variable: change in innovation related investment	Before the crisis		During the crisis		Following on from the beginning of the crisis	
	(T1)		(T2)		(T3)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Increase	1985	38	453	9	659	13
Decrease	472	9	1231	24	1560	30
Maintain	2207	42	2961	57	2452	47
Innovation active firms	4664	89	4645	90	4671	90
No innovation activities	328	6	457	9	343	7
Missing observations	242	5	132	3	220	4
Number of observations	5234	100	5234	100	5234	100

T1 refers to the change in innovation related investment in the calendar year 2008 compared to 2006; T2 refers to the change in innovation related investment in the six month period October 2008 to March 2009; T3 refers to the expected change in innovation related investment in 2009 compared with 2008.

activities with reference to the calendar year 2008. The variable 'high innovation intensity' takes a value of 1 if the enterprise invests at least 5% of turnover in innovation related activities.[5] It takes a value of zero if the enterprise invests less than 5% of turnover in innovation related activities.

Under the heading 'type of knowledge sources' are six variables; first, a variable that captures if the enterprise engaged in in-house R&D, second, if it engaged in extramural R&D. The remaining four variables relate to linkages or joint knowledge sources; specifically, collaboration on innovation with other businesses, collaboration on innovation with educational and other research institutions, collaborations with partners located abroad, and investment in companies located abroad. All variables are coded 1 for yes answers and zero for no answers.

Under 'type of innovations' or innovators we include four variables that are proxies for the strategic orientation of the firms with respect to their innovations: whether or not firms compete based on their innovations, based on improvements to existing products, based on a new business model, or based on cost savings. Competing on innovation might lean more closely to activities at the frontier and might be seen as more closely related to path-breaking developments vis-à-vis the remaining categories. While improvements lean towards incremental innovations, new business models might be indicative of a new service. Competing on cost might favour the upgrading of processes. There is, of course, much blurring and overlap across such categories when attempting to translate competitive orientation into 'type of innovations'.

Under the final heading 'characteristics of the market' are four variables. The first one captures the use of IPRs, specifically whether or not the firm applied for a patent or registered a design. The next two variables are used to capture the technological opportunities and market opportunities as assessed by the responding firms. 1 indicates that the firm perceived that there were opportunities (technological or market) and zero suggests a lack of opportunities. The final variable takes values of 1 if the enterprise operates in international markets and zero otherwise.

The dependent variables are observed for 4664 firms (out of 5234 observations in the initial database) in T1 (and 4645 and 4671 in T2 and 3 respectively). Table 5 presents descriptive statistics for the independent variables based on these 4664 observations. With respect to some of the independent variables we have missing observations where respondents stated that they did not know the answer. Only 4298 out of 4664 respondents provided a valid response with respect to their innovation intensity and so on. Because of missing values (and missing values not occurring systematically by appearing within the same observations) we have a final dataset of 3959 observations in T1 (3886 T2 and 3890 T3) that are used in the regressions. This dataset is the largest possible dataset that contains observations for all dependent and independent variables.

In Table 5, the column entitled 'mean' gives the mean value for our variables. Because these are all dummy variables, this column is the share of enterprises that engage in a specific activity, e.g. 0.08 or 8% of firms were newly established, 40% were small, and 50% of firms reported that they operated in international markets.

4.4. Methodology

We use regressions to analyse the relationships between our dependent and independent variables. Table 6 provides the zero order correlations between the dependent and independent variables, reporting polychoric correlations for the categorical dependent variables and tetrachoric correlations between the binary independent variables.

The correlations reveal, in line with our expectations and in line with the patterns reported in Table 3, that there is a higher association between the dependent variables 'investment during the crisis' and 'following on from the crisis', than with 'investment before the crisis' (both with respect to T2 and T3). Among the independent variables, the highest overlap exists between in-house R&D and bought-in R&D ($r = 0.63$; $p < 0.01$). Previous studies have shown that internal and bought-in R&D activities are complementing strategies, rather than substitutes [35]. A high overlap also exists between 'international

[5] The dataset has a fourth category – innovation related expenditure above 50% of turnover – but less than 1% of firms fell into this group and this is why we merged it with the next smaller band.

Table 3
Innovation investment before, during and following on from the crisis. Cross-tabulations of the dependent variables.
Source: As for Table 2.

			During the crisis (T2)			
			Increase	Decrease	Maintain	Total
Before the crisis (T1)	Increase	Frequencies	332	445	1124	1901
		Column percentages	76	38	40	43
	Decrease	Frequencies	18	255	167	440
		Column percentages	4	22	6	10
	Maintain	Frequencies	88	469	1538	2095
		Column percentages	20	40	54	47
Total		Frequencies	438	1169	2829	4436
		Column percentages	100	100	100	100
$Chi^2(4) = 463; p < 0.01$						
			Following on from the crisis (T3)			
			Increase	Decrease	Maintain	Total
Before the crisis (T1)	Increase	Frequencies	358	631	907	1896
		Column percentages	58	43	39	43
	Decrease	Frequencies	62	225	158	445
		Column percentages	10	15	7	10
	Maintain	Frequencies	200	625	1270	2095
		Column percentages	32	42	54	47
Total		Frequencies	620	1481	2335	4436
		Column percentages	100	100	100	100
$Chi^2(4) = 168; p < 0.01$						
			Following on from the crisis (T3)			
			Increase	Decrease	Maintain	Total
During the crisis (T2)	Increase	Frequencies	192	73	159	424
		Column percentages	32	5	7	10
	Decrease	Frequencies	61	812	256	1129
		Column percentages	10	57	11	26
	Maintain	Frequencies	350	544	1832	2726
		Column percentages	58	38	82	64
Total		Frequencies	603	1429	2247	4279
		Column percentages	100	100	100	100
$Chi^2(4) = 1400; p < 0.01$						

collaboration' and 'investing in companies located abroad' ($r = 0.65$; $p < 0.01$), and both these variables and 'operating in international markets' ($r = 0.54$; $p < 0.01$ and $r = 0.53$; $p < 0.01$ respectively), suggesting that these variables taken together might be indicative of an international orientation of firms.[6] The variables in the category 'type of innovations' are mutually exclusive groups and this is why the tetrachoric correlations return a value of −1. Competing on cost is our base comparison group in the regressions.

It is a limitation of our dependent variables that we do not have continuous data and, therefore, cannot use the classic linear model. The dependent variables are categorical variables that take the following categories: 1 = decrease in innovation related investment; 2 = innovation investment maintained; and 3 = increase in innovation related investment.

We report the results from two estimation models: a logistic regression model and a multinomial logistic regression model. The logistic regression predicting increased innovation investment compared to both the remaining outcomes taken together (decreased and maintained) is presented because the interpretation of the coefficients is easier; however, the model ignores that the firm is presented with three choices — to increase, decrease or maintain investment. The latter is picked up by the multinomial logistic regression. The logistic model is:

$$\Pr\left(y_j = 1\right) = \frac{\exp\left(x_j \mathrm{b}\right)}{1 + \exp\left(x_j \mathrm{b}\right)}$$

where x_j is the row vector of the values of the independent variables. The multinomial logistic that picks up the three choices is:

$$p_{ij} = \Pr\left(y_j = \mathrm{i}\right) = \begin{cases} \dfrac{1}{1 + \sum_{\mathrm{m}=2}^{k} \exp\left(x_j b_m\right)}, & \text{if } i = 1 \\ \dfrac{\exp\left(x_j b_i\right)}{1 + \sum_{\mathrm{m}=2}^{k} \exp\left(x_j b_m\right)}, & \text{if } i > 1 \end{cases}$$

where p_{ij} is the probability that the jth observation is equal to the ith outcome. 1 is assumed to be the base outcome, k is the number of categories (in our case 3), b_m is the coefficient for the outcome m (in our case either 2 or 3), and as before x_j is the

[6] In order to address an issue of multicollinearity between these variables, we have computed all regressions (a) without the variable international collaborations and (b) without the variable 'operating in international markets'. The findings remained unchanged. Results are not published, but are available upon request from the authors.

Please cite this article as: D. Archibugi, et al., The impact of the economic crisis on innovation: Evidence from Europe, Technol. Forecast. Soc. Change (2013), http://dx.doi.org/10.1016/j.techfore.2013.05.005

Table 4
Characteristics of the innovating firms, type of knowledge sources, type of innovations and characteristics of the market. Overview of the independent variables.

Characteristics of the innovating firms	
Newly established	The enterprise was established after 1 January 2001
Small enterprise	There are four dummies that we use to measure the size of the enterprise. Small enterprises here have 20–49 employees
Medium enterprise	The variable selects all enterprises with 50 to 249 employees
Large enterprises	The variables select all enterprises with more than 250 employees
Low innovation intensity	The enterprise invests less than 5% of turnover in innovation related activities in 2008
High innovation intensity	The enterprise invests at least 5% of turnover in innovation related activities
Type of knowledge sources	
In-house R&D	The enterprise had expenditures on in-house R&D since 2006
Bought-in R&D	The enterprise had expenditures on R&D performed for the company by other enterprises or by research organisations since 2006
Link with other firms	The enterprise developed strategic relationships in support of innovation with customers, suppliers or other companies since 2006
Link with the knowledge base	The enterprise developed strategic relationships in support of innovation with research institutes and educational institutions since 2006
International collaboration	The enterprise started or increased cooperation with local partners in other countries in support of innovation since 2006
Investment in companies abroad	The enterprise invested in companies located in other countries in support of innovation since 2006
Type of innovations	
Enterprise competes on innovations	The enterprise sees the main competitive advantage in new products, services and processes
Enterprise competes on improvements	The enterprise sees the main competitive advantage in the modification of existing products, services and processes
Enterprise competes on new business models	The enterprise sees the main competitive advantage in the developments of new business models or ways to market products and services
Enterprise competes on cost	The enterprise sees the main competitive advantage in reducing costs of existing products
Characteristics of the market	
IPRs	The enterprise applied for a patent or registered a design since 2006
Technological opportunities	New technologies emerged in the enterprise's market since 2006
Market opportunities	New opportunities to enter into new markets or expand sales in existing markets emerged since 2006
International market	The enterprise operates in international markets

row vector of the values of the independent variables. Based on one multinomial logistic regression, three sets of coefficients are reported: the first set of coefficients compares the choice to increase investment with maintained investment; the second set compares increase with decrease in investment; and the third set compares the effects of the independent variables on maintaining investment compared with decreasing investment. We now turn to the presentation of the empirical results in the next section.

5. Results

Two models are presented in this section. The first – logistic regression – reports coefficients that are indicative of the probability to increase innovation investment if the independent variables – all dummies – take a value of 1, i.e. the characteristic such as 'newly established' is met. It is reported in Table 7.

Before the crisis (column T1 in Table 7), and with respect to the characteristics of the innovating firms, the coefficients suggest that firms are more likely to increase innovation investment if they exhibit high innovation intensity (our proxy for stock of investment). The coefficient $b = 0.97$ ($p < 0.01$) is the largest coefficient in the column T1. Size and age are not significantly associated with increased investment, but the positive sign of the coefficients is in line with technological accumulation patterns (as per Table 1). During the crisis (T2), 'large size' is negatively associated with increased investment, meaning that small firms (our base group) are statistically more likely to increase investment compared with the group of large firms. The coefficient $b = -0.64$ ($p < 0.01$) is the most influential coefficient in the column T2. Following on from the crisis (T3) new entrants are more likely to increase investment ($b = 0.27$; $p < 0.10$). Both patterns, small firms in T2 and new entrants in T3, lean towards the creative destruction hypothesis (as per Table 1).

In relation to 'type of knowledge sources', our second category of independent variables, there are positive and significant coefficients for 'in-house R&D' and 'bought-in R&D' before the crisis supporting accumulation of technology before the crisis. But, 'in-house R&D' is not significant during the crisis but again positively associated with increased investment following on from the crisis, while 'bought-in R&D' is not significant in either T2 or T3 and the sign of the coefficients is negative. 'Link with other firms' as well as 'international collaboration' are significant throughout and irrespectively of the time period (T1, T2 or T3). We use 'link with other firms' as a proxy for access to applied knowledge that we thought less closely linked to accumulation compared with generic knowledge (proxied by 'links with universities and research institutes' that remains insignificant throughout). Thus, the collaboration variables do not suggest a change in pattern from before the crisis to during the crisis. Finally, firms that invested in companies abroad appear less likely to increase innovation investment following on from the crisis (no effect before then in columns T1 and T2). This variable, albeit restricted to the

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Table 5
Descriptive statistics of the independent variables.
Source: As for Table 2.

Independent variables	Number of observations	Mean	Standard deviation
Characteristics of the innovating firms			
Newly established	4664	0.08	0.28
Small enterprise (base group)	4664	0.40	0.49
Medium enterprise	4664	0.32	0.47
Large enterprise	4664	0.28	0.45
High innovation intensity	4298	0.32	0.47
Type of knowledge sources			
In-house R&D	4635	0.48	0.50
Bought-in R&D	4631	0.32	0.47
Link with other firms	4627	0.67	0.47
Links with the knowledge base	4628	0.38	0.49
International collaboration	4602	0.29	0.45
Investment in companies abroad	4620	0.11	0.31
Type of innovations			
Enterprise competes on innovations	4558	0.24	0.43
Enterprise competes on improvements	4558	0.23	0.42
Enterprise competes on business models	4558	0.16	0.37
Enterprise competes on cost (base group)	4558	0.34	0.47
Characteristics of the market			
IPRs	4613	0.15	0.36
Technological opportunities	4594	0.40	0.49
Market opportunities	4596	0.58	0.49
International market	4588	0.50	0.50

time period starting 2006, might capture if a firm was part of a larger, multinational company. Interpreted that way, the finding is closer to a destruction hypothesis. From our theoretical point of departure, the drop in significance of in-house and bought-in R&D during and following on from the crisis lends some support for the destruction hypothesis. But the findings in this category are less clear with respect to applied and generic knowledge sources as the coefficients are consistent across our three time periods.

Our proxies for types of innovations reveal that throughout the three periods, firms that increase investment in innovation are less likely to compete on cost, than they are to compete on innovations (confirming similar results previously reported by Bogliacino and Pianta, 2010). Firms competing on cost are also less likely to increase investment compared with firms that compete on improvements before and following on from the crisis, but not during the crisis. The size of the coefficients increases over the three time periods, which indicates that firms that compete on costs are increasingly less likely to increase innovation related investment, specifically in T3 where the coefficients (compete on innovation, improvements and business model contrasted with competing on costs) have the strongest impact in the regression model. The sole significance of 'competing on innovation' during the crisis, coupled with the increase in negative impact of 'competing on cost' is perhaps less indicative of accumulation as it is of destruction in T2 and T3.

With respect to the characteristics of the market, our final category of independent variables, the coefficients in Table 7 for IPRs are positive and significant both before and during the crisis (but not following on from the crisis T3). The coefficients for 'market opportunities', too, are positive and significant in T1 and increasing in terms of the size effect in T2 (during the crisis). 'Technological opportunities', however, are positively and significantly associated with increased investment only before the crisis. Strong 'IPRs' lean towards the accumulation hypothesis both before and during the crisis.

In Tables 8.a, 8.b, and 8.c, a pattern consistent with that in Table 7, but with greater detail with respect to the differences in the choices to maintain investment and decreasing investment is reported. Tables 8.a–8.c contain one regression model for T1, T2 and T3 respectively, but three sets of coefficients are reported: (a) the first set of coefficients contrasts increase in innovation investment against maintaining of investment; (b) contrasts increase in innovation investment against decrease in investment; and (c) maintaining in investment against decrease in investment.

One caveat that Tables 8.a, 8.b, and 8.c reveal, and that cannot be seen in Table 7, is that firms that maintain investment as opposed to both increase (Table 8.a) and decrease (Table 8.c), report lower innovation intensity during the crisis. Thus, reacting to the crisis by either increasing or decreasing innovation related investment are the two choices made by the more innovative firms.

Another caveat taken from Tables 8.a–8.c is related to large firms. Before the crisis, large firms are more likely to increase investment (as opposed to decrease investment — Table 8.b) and are more likely to maintain investment (as opposed to decrease investment — Table 8.c). In contrast, during the crisis large firms are less likely to increase investment as opposed to both the alternative choices — to maintain or decrease investment (Tables 8.a and 8.b). This, in line with the findings reported in Table 7, suggests that the role of small firms in innovation during the crisis is greater (a) than before the crisis and (b) compared with large firms during the crisis, supporting the destruction hypothesis.

Finally, comparing the choices increase and decrease in investment in the time period following on from the crisis, Table 8.b reports (as Table 7 before) newly established firms as more likely to increase investment. Among the remaining coefficients of the same set of coefficients, Table 8.b also reports that firms with low innovation intensity (stock) increase investment in T3. But, among the same set of coefficients, 'in-house R&D' and 'links with the knowledge base', as well as 'IPRs' are significant, providing a mixed picture with some characteristics closer to creative destruction ('newly established' and 'low innovation intensity') and others closer to accumulation ('in-house R&D', 'links with the knowledge base' and 'IPRs'). Thus, while we might have expected the patterns between T2 and T3 to be highly similar but different from T1, increased investment is not necessarily done by firms with the exact same characteristics and environments across T2 and T3, and some of the patterns dominant (significant coefficients) in T1 re-emerge in T3.

6. Discussion

The aim of this paper is to investigate whether the current economic downturn is significantly affecting the composition of innovating firms. During major recessions, the economic

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Table 6
Correlations between the dependent and independent variables.
Source: As for Table 2.

	Dependent variables	1	2	3
	Investment in innovation related activity			
1	Investment before the crisis	1.00		
2	During the crisis	0.28	1.00	
3	Following on from the crisis	0.21	0.44	1.00

	Independent variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Characteristics of the innovating firms																		
1	Newly established	1.00																	
2	Small enterprise (base group)	0.09	1.00																
3	Medium enterprise	0.02	−1.00	1.00															
4	Large enterprise	−0.13	−1.00	−1.00	1.00														
5	High innovation intensity	0.03	−0.05	0.02	0.05	1.00													
	Type of knowledge sources																		
6	In-house R&D	−0.03	−0.29	0.03	0.31	0.28	1.00												
7	Bought-in R&D	−0.02	−0.31	0.01	0.33	0.15	0.63	1.00											
8	Link with other firms	0.08	−0.15	−0.01	0.19	0.28	0.45	0.37	1.00										
9	Links with the knowledge base	0.02	−0.25	0.01	0.27	0.25	0.51	0.58	1.00										
10	International collaboration	−0.06	−0.19	−0.02	0.23	0.25	0.41	0.36	0.47	0.37	1.00								
11	Investment in companies abroad	−0.06	−0.25	−0.09	0.34	0.16	0.38	0.35	0.39	0.29	0.65	1.00							
	Type of innovations																		
12	Enterprise competes on innovations	−0.01	−0.02	0.01	0.02	0.20	0.21	0.18	0.18	0.17	0.13	0.13	1.00						
13	Competes on improvements	0.05	−0.06	0.03	0.04	−0.03	0.04	0.00	0.09	0.05	0.04	−0.07	−1.00	1.00					
14	Competes on business models	−0.04	0.01	−0.04	0.03	0.05	0.04	0.06	0.13	0.08	0.06	0.12	−1.00	−1.00	1.00				
15	Competes on cost (base group)	−0.02	0.02	0.00	−0.03	−0.14	−0.17	−0.15	−0.20	−0.20	−0.14	−0.11	−1.00	−1.00	−1.00	1.00			
	Characteristics of the market																		
16	IPRs	−0.05	−0.24	−0.06	0.31	0.26	0.53	0.44	0.37	0.39	0.38	0.36	0.19	0.05	0.00	−0.18	1.00		
17	Technological opportunities	0.00	−0.18	0.00	0.21	0.31	0.39	0.32	0.48	0.43	0.30	0.28	0.18	0.07	0.08	−0.19	0.31	1.00	
18	Market opportunities	0.03	−0.16	0.02	0.18	0.27	0.35	0.28	0.48	0.31	0.41	0.29	0.18	0.04	0.13	−0.16	0.33	0.50	1.00
19	International market	−0.02	−0.23	0.01	0.26	0.17	0.35	0.26	0.25	0.22	0.54	0.53	0.11	0.02	0.01	−0.05	0.36	0.22	0.37

Polychoric correlations between the dependent variables, and tetrachoric correlations between the independent variables, are reported. The variables compete on innovations, improvements, business models and cost that are mutually exclusive and thus yield a tetrachoric correlation of −1.

Table 7
Factors explaining the choice to increase innovation investment compared to maintaining or decreasing investment (combined) over time.
Source: As for Table 2.

Dependent variable: increase in innovation related investment	Before the crisis	During the crisis	Following on from the crisis
Estimation method: logistic	(T1)	(T2)	(T3)
Characteristics of the innovating firms			
Newly established	−0.19	−0.12	0.27*
	(0.13)	(0.20)	(0.16)
Medium enterprise	0.13	−0.13	0.10
	(0.08)	(0.13)	(0.11)
Large enterprise	0.12	−0.64***	−0.15
	(0.09)	(0.16)	(0.13)
High innovation intensity	0.97***	0.20*	0.01
	(0.08)	(0.12)	(0.10)
Type of knowledge sources			
In-house R&D	0.33***	0.21	0.20*
	(0.08)	(0.14)	(0.12)
Bought-in R&D	0.26***	−0.08	−0.07
	(0.09)	(0.13)	(0.11)
Link with other firms	0.36***	0.33**	0.23*
	(0.08)	(0.15)	(0.12)
Links with the knowledge base	0.07	0.15	0.15
	(0.08)	(0.13)	(0.11)
International collaboration	0.30***	0.38***	0.35***
	(0.09)	(0.13)	(0.11)
Investment in companies abroad	−0.02	−0.05	−0.33**
	(0.13)	(0.19)	(0.17)
Type of innovations			
Enterprise competes on innovations	0.29***	0.36**	0.58***
	(0.10)	(0.15)	(0.13)
Enterprise competes on improvements	0.24**	0.22	0.61***
	(0.10)	(0.16)	(0.13)
Enterprise competes on business models	0.14	0.15	0.52***
	(0.11)	(0.17)	(0.15)
Characteristics of the market			
IPRs	0.27**	0.32**	0.16
	(0.11)	(0.15)	(0.13)
Technological opportunities	0.20***	0.04	0.07
	(0.08)	(0.12)	(0.11)
Market opportunities	0.16**	0.40***	0.17
	(0.08)	(0.13)	(0.11)
International market	−0.16*	−0.02	0.00
	(0.08)	(0.13)	(0.11)
Industry dummies	Included	Included	Included
Country dummies	Included	Included	Included
Number of observations	3959	3886	3890
Wald Chi^2 (64)	524***	150***	179***
Pseudo R^2	0.11	0.07	0.06

Robust standard errors are reported in brackets under the logistic regression coefficients.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

Table 8.a
Factors explaining the discrete choices to increase, maintain, or decrease innovation related investment over time.
Source: As for Table 2.

Dependent variable: increase in innovation investment (base group: maintain)	Before the crisis	During the crisis	Following on from the crisis
Estimation method: multinomial logistic	(T1)	(T2)	(T3)
Characteristics of the innovating firms			
Newly established	−0.19	−0.14	0.22
	(0.15)	(0.50)	(0.19)
Medium enterprise	0.13	−0.18	0.06
	(0.15)	(0.17)	(0.60)
Large enterprise	0.06	−0.67***	−0.21
	(0.56)	(0.00)	(0.11)
High innovation intensity	0.99***	0.30**	0.15
	(0.00)	(0.02)	(0.16)
Type of knowledge sources			
In-house R&D	0.39***	0.23	0.18
	(0.00)	(0.10)	(0.14)
Bought-in R&D	0.23***	−0.09	−0.06
	(0.01)	(0.53)	(0.62)
Link with other firms	0.42***	0.37**	0.28**
	(0.00)	(0.01)	(0.02)
Links with the knowledge base	0.05	0.17	0.11
	(0.55)	(0.19)	(0.36)
International collaboration	0.33***	0.41***	0.36***
	(0.00)	(0.00)	(0.00)
Investment in companies abroad	−0.00	−0.04	−0.27
	(0.98)	(0.83)	(0.13)
Type of innovations			
Enterprise competes on innovations	0.25**	0.22	0.39***
	(0.01)	(0.16)	(0.00)
Enterprise competes on improvements	0.21**	0.07	0.47***
	(0.04)	(0.64)	(0.00)
Enterprise competes on business models	0.14	0.08	0.43***
	(0.19)	(0.65)	(0.00)
Characteristics of the market			
IPRs	0.32***	0.34**	0.11
	(0.00)	(0.03)	(0.43)
Technological opportunities	0.18**	0.07	0.10
	(0.03)	(0.57)	(0.35)
Market opportunities	0.13	0.39***	0.16
	(0.11)	(0.00)	(0.16)
International market	−0.15*	0.02	0.06
	(0.09)	(0.86)	(0.61)
Industry dummies	Included	Included	Included
Country dummies	Included	Included	Included
Number of observations	3959	3886	3890
Wald Chi2 (64)	652***	431***	419***
Pseudo R2	0.10	0.07	0.06

Robust standard errors are reported in brackets under the multinomial logistic regression coefficients.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

landscape is characterized by huge uncertainties about the direction of technological change, demand conditions, and new market opportunities. The first significant result at the aggregate level is that the crisis has substantially reduced the number of firms willing to increase their innovation investment, from 38% to 9%. No doubt that the crisis has brought, at least in its initial stage, "destruction" in innovation investment. But the anatomy of these 9% of firms that are still expanding their innovation investment can provide some insights to check if the gales of destruction are also bringing something creative.

We used two well-established, ideal type models – creative destruction and creative accumulation – to frame our results (as summarized in Table 1). For the purpose of developing the

Table 8.b
Factors explaining the choice to increase, maintain or decrease innovation investment over time.
Source: As for Table 2.

Dependent variable: increase in innovation investment (base group: decrease)	Before the crisis	During the crisis	Following on from the crisis
Estimation method: multinomial logistic	(T1)	(T2)	(T3)
Characteristics of the innovating firms			
Newly established	−0.16	−0.09	0.35**
	(0.43)	(0.68)	(0.05)
Medium enterprise	0.16	−0.01	0.16
	(0.23)	(0.95)	(0.20)
Large enterprise	0.40**	−0.54***	−0.04
	(0.01)	(0.00)	(0.79)
High innovation intensity	0.91***	−0.02	−0.22*
	(0.00)	(0.86)	(0.06)
Type of knowledge sources			
In-house R&D	0.04	0.15	0.25*
	(0.79)	(0.33)	(0.05)
Bought-in R&D	0.34**	−0.07	−0.09
	(0.02)	(0.66)	(0.45)
Link with other firms	0.10	0.23	0.14
	(0.45)	(0.15)	(0.29)
Links with the knowledge base	0.13	0.10	0.21*
	(0.35)	(0.51)	(0.09)
International collaboration	0.21	0.32**	0.33***
	(0.14)	(0.04)	(0.01)
Investment in companies abroad	−0.11	−0.06	−0.43**
	(0.58)	(0.77)	(0.02)
Type of innovations			
Enterprise competes on innovations	0.45***	0.71***	0.89***
	(0.00)	(0.00)	(0.00)
Enterprise competes on improvements	0.36**	0.55***	0.83***
	(0.02)	(0.00)	(0.00)
Enterprise competes on business models	0.11	0.29	0.63***
	(0.51)	(0.13)	(0.00)
Characteristics of the market			
IPRs	0.05	0.28*	0.26*
	(0.76)	(0.10)	(0.08)
Technological opportunities	0.31**	−0.04	−0.00
	(0.02)	(0.79)	(1.00)
Market opportunities	0.27**	0.45***	0.20
	(0.04)	(0.00)	(0.10)
International market	−0.22*	−0.15	−0.10
	(0.09)	(0.30)	(0.41)
Industry dummies	Included	Included	Included
Country dummies	Included	Included	Included
Number of observations	3959	3886	3890
Wald Chi2 (64)	652***	431***	419***
Pseudo R2	0.10	0.07	0.06

Robust standard errors are reported in brackets under the multinomial logistic regression coefficients.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

Table 8.c
Factors explaining the choice to increase, maintain or decrease innovation investment over time.
Source: As for Table 2.

Dependent variable: maintained innovation investment (base group: decrease)	Before the crisis	During the crisis	Following on from the crisis
Estimation method: multinomial logistic	(T1)	(T2)	(T3)
Characteristics of the innovating firms			
Newly established	0.03	0.05	0.13
	(0.88)	(0.74)	(0.32)
Medium enterprise	0.03	0.17*	0.10
	(0.80)	(0.07)	(0.26)
Large enterprise	0.34**	0.13	0.18*
	(0.02)	(0.21)	(0.07)
High innovation intensity	−0.08	−0.32***	−0.37***
	(0.55)	(0.00)	(0.00)
Type of knowledge sources			
In-house R&D	−0.36***	−0.08	0.07
	(0.01)	(0.40)	(0.42)
Bought-in R&D	0.11	0.02	−0.04
	(0.44)	(0.84)	(0.70)
Link with other firms	−0.31**	−0.13	−0.14
	(0.02)	(0.16)	(0.11)
Links with the knowledge base	0.08	−0.08	0.11
	(0.56)	(0.42)	(0.23)
International collaboration	−0.12	−0.09	−0.03
	(0.40)	(0.40)	(0.78)
Investment in companies abroad	−0.11	−0.02	−0.16
	(0.59)	(0.88)	(0.23)
Type of innovations			
Enterprise competes on innovations	0.20	0.50***	0.50***
	(0.20)	(0.00)	(0.00)
Enterprise competes on improvements	0.15	0.48***	0.36***
	(0.33)	(0.00)	(0.00)
Enterprise competes on business models	−0.03	0.21*	0.19*
	(0.83)	(0.07)	(0.08)
Characteristics of the market			
IPRs	−0.27	−0.05	0.15
	(0.13)	(0.66)	(0.20)
Technological opportunities	0.12	−0.11	−0.10
	(0.33)	(0.23)	(0.22)
Market opportunities	0.14	0.06	0.04
	(0.26)	(0.53)	(0.62)
International market	−0.07	−0.17*	−0.16*
	(0.58)	(0.06)	(0.06)
Industry dummies	Included	Included	Included
Country dummies	Included	Included	Included
Number of observations	3959	3886	3890
Wald Chi2 (64)	652***	431***	419***
Pseudo R2	0.10	0.07	0.06

Robust standard errors are reported in brackets under the multinomial logistic regression coefficients.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

framework, we assumed a more clear-cut division according to which in regular times the model of creative accumulation prevails, while in times of crisis the model of creative destruction affirms itself. We are well aware that such a clear-cut division between the two models does not exist. We recognize that both patterns of innovation co-exist, and are likely to be also technology and industry specific (as tested empirically in [8]). However, our data suggest that during the recession firms' innovation behaviour is closer to creative destruction, while before the recession there is an overall landscape of creative accumulation.

More specifically, Innobarometer allowed us to test two hypotheses: a) that in periods of economic expansion firms that are already innovating are the most important drivers of increased innovation investment, supporting the technological accumulation hypothesis; and b) that economic crises generate turbulence, and that newcomers are eager to spend more to innovate, confirming the creative destruction hypothesis.

The empirical results support our arguments. The identikit of the innovators has in fact changed considerably. Before the economic downturn, firms expanding their innovations are: i) well-established; ii) engaged in formal research activities both internally and bought-in; iii) exploit strong appropriability conditions; and iv) involved in collaboration with suppliers and customers. During the economic downturn the few firms that are "swimming against the stream" by increasing their innovation investment are: i) smaller than before; ii) collaborating with other businesses; ii) exploring new market opportunities; iii) using methods of technological appropriation; and iv) less likely to compete on costs. Last but certainly not least, it also seems that younger firms are more likely to increase innovation investment after the crisis. While before the crisis technological opportunities have a positive impact on investment, during and after the crisis this is no longer true. On the contrary, in response to the crisis firms are more likely to explore innovative solutions by looking at opportunities in new markets.

This witnesses an important change in the drivers of innovation as a result of the economic downturn. Since innovation is less based on local searching and cumulative processes, and less based on R&D activities within large firms, we conclude that the relative importance of behaviours is changing from creative accumulation to creative destruction in the snap shot of the business cycle that the Innobarometer makes it possible to observe. The fact that firms exhibit a more "explorative" attitude, vis-à-vis an "exploitative" attitude, is consistent with a situation of greater uncertainty that they face.

During the crisis both formal R&D and technological opportunities stop to play a significant role in explaining companies' willingness to expand innovation. This might be interpreted as the result of a decline of technological opportunities in established sectors which is typical during recessions characterized by technological discontinuities [15]. Also, contrary to the previous period, innovation is driven by fresh opportunities in new markets. Our data cannot provide the 'identikit' of the new cluster of innovations that will generate the recovery (as indicated by Linstone and Devezas [36]), but at least provide some useful information to trace the identikit of the post-crisis innovating firm.

It could not be taken for granted that during a period of sustained growth firms' behaviour lean towards accumulative patterns of innovation. During economic upswings firms have access to greater financial resources and thus might be seen more likely to explore radical and risky solutions. Similarly, it can be conceivably maintained that during a depression large established firms are better equipped to manage a situation of fall in demand and lack of financial supply in the market. However, we show that this is not the case. The number of firms declaring to increase their innovation expenditure has dropped dramatically as results of the crisis. It seems that what matter are not large size and internal R&D, but flexibility, collaborative arrangements and exploration of new markets.

6.1. Prospects for future research

Future work should focus on accessing data which allows for estimates based on longer time periods, the inclusion of more countries and more precise indicators on innovation intensity and the direction of technological change. In particular, we suspect that the crisis is reinforcing the shift from the manufacturing to the service industries, as indicated by in-depth country case studies [37]. We can wonder if this is a general rule or is something associated to the current phase of capitalist development, where the manufacturing sector, the core generator of technological innovations, is progressively accounting for lower shares of income and employment while, on the contrary, the service sector is gaining shares and is more likely to compete through non-technological innovations and by finding new markets. We can speculate that, if the economic recession is reinforcing the shift from manufacturing to services, it would not be a surprise that the firms increasing their innovation investment are more likely to be driven by searching new business lines and business models than by technological opportunities. In order to corroborate this hypothesis a definition of innovation able to capture the process of change in both manufacturing and services is needed, since the relevance of past innovative experience is quite different across the two sectors [38,39]. For many years, the Schumpeterian economics has concentrated on the technological dimension of innovation, which is typical of the manufacturing industries, and has somehow denied the non-technological dimension, which is more common when innovating in services. Times are ready to use a wider understanding of innovation, similar to what was pioneered by Schumpeter himself a century ago in the first edition of the *Theory of Economic Development*. The definition provided by Innobarometer and used in this paper has the advantage to be more inclusive than others.

6.2. Limitations of the study

The analysis presented here is limited by the data and the statistical models. First, the results are confined to Europe, and exclude the US and Japan as well as emerging countries. Second, the data offer information on three time periods for the dependent variables (but not for the independent variables), which allows comparing innovation related investment patterns before, during and following on from the crisis. Time series data would be able to provide much better information on the effects of the crisis, and the next surveys will certainly shed light on this. Third, data do not allow singling out the dynamic at the industry level. Finally, some variables are not totally satisfactory. True, the Innobarometer survey offers a unique opportunity to shed light onto the impact of the recent economic downturn on innovation, but we are well aware of the limitations of having carried out such a clear-cut classification. We are however pleased to report that an analysis carried out for one country only, the United Kingdom, but on the wealth of data made available by the Community Innovation Survey (CIS), broadly confirm the results here presented [40]. CIS allowed us to use more robust data, namely the innovation expenditure carried out by companies. The analysis showed that fast growing before the crisis are those that were able to cope better and that continued to expand their innovative projects.

6.3. Policy implications

In terms of policy analysis, it should be seen what the restricted number of firms increasing the innovation investment will generate. Public incentives to promote innovation can either be directed towards supporting the already existing R&D infrastructures or towards fostering new entrants. Identifying the characteristics of the innovators during the turmoil, as we have tried to do here, can shed some light on how policy instruments interact with technological accumulation and creative destruction. In which group of firms will the Bill Gates and Steve Jobs, Larry Page and Sergey Brin of the next generation be found? And are we sure that European governments, more and more concerned with the knowledge based economy, are doing their best to foster creative innovators, even if this will imply the destruction of slow growing wood?

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Please cite this article as: D. Archibugi, et al., The impact of the economic crisis on innovation: Evidence from Europe, Technol. Forecast. Soc. Change (2013), http://dx.doi.org/10.1016/j.techfore.2013.05.005