Has the global financial crisis had different effects on innovation performance in the agri-food sector by comparison to the rest of the economy?

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1. Introduction

The agri-food industry is one of the most important sectors in the European Union and it is highly significant in terms of economic output and employment (Hirsch & Gschwandtner, 2013). In addition, it is a leading industrial sector in the Spanish economy and the fifth largest in Europe (Alarcón, Polonio, & Sánchez, 2013); it plays an important role in Spain's economy contributing 7.2% of its GDP and more than 20% of total employment (Spanish Food & Drink Industry Federation, 2014). Traditionally, the agri-food sector is considered a Low-Tech intensive industry and the evidence supports the view that a firm's returns and growth depend on its capacity to innovate (Capitanio, Coppola, & Pascucci, 2009). This is because European food markets are characterized by high market saturation and strong competition (Hirsch & Gschwandtner, 2013) and it allows firms to grow more quickly and be more profitable than non-innovators (Atalay, Anafarta, & Sarvan, 2013).

Nowadays, the globalization and expansion of financial markets and the current economic crisis are changing the rules of the economy. Innovating in times of crisis is seen by many authors as an opportunity to grow, survive and succeed and as the attempt to maintain or develop competitiveness in today's global markets (Kühne, Vanhonacker, Gellynck, & Verbeke, 2010; Mohezar & Nor, 2014; Peters, Shane, & Torgerson, 2009). Despite the importance of innovation during crisis, most of the empirical literature dealing with the impact of an economic crisis on innovation has focused only on firms' innovation investment (Paunov, 2012) or on customer behaviour (Ásgeirsdóttir, Corman, & Noonan, 2012; Mansoor & Jalal, 2011).

However, this study focuses on analyzing the overall effects of an economic crisis, both in terms of innovation inputs and innovation performance. On this background, the overall objective of this work is to examine the impact of the economic crisis on the probability of Spanish firms to introduce innovations and on innovative sales opened up by a new product. In this sense, we studied firms' decisions to engage in innovation taking into account all the types of innovation described by the Oslo Manual (OCDE, 2005) i.e. technological and non-technological innovations. Additionally, we measured performance in terms of the market success of firms' innovations according to the share of turnover generated by new products.

We chose the Spanish case because it is one of the countries which have suffered most seriously from the financial crisis in the EU (Sinitsky, 2013).

Finally, this paper developed a conceptual model highlighting different innovation indicators which impact on the innovative performance of firms related to the past literature like business factors (in-house R&D; external R&D; domestic and foreign cooperation in innovation) and the international strategy of the firm measured by export operations.

2. Literature review

2.1. Source of innovation in the agri-food sector

Agri-food industries are traditionally regarded as a sector with low levels of R&D intensity (Capitanio et al., 2009; Grunert et al., 2008), which has been confirmed to be true in the case of Spain (Garcia Martinez & Briz, 2000). Despite relatively low R&D investments, innovation for this sector has become an important instrument in the turbulent environment that increasing globalization creates, which includes changing quality demands and price discount fights among retailers (Batterink, Wubben, & Omta, 2006). Food firms are mainly process-innovation oriented (Batterink et al., 2006) and both product and process innovation are to a large extent characterized by incremental rather than radical changes (Bayona et al., 2013; Fortuin & Omta, 2009; Hervas-Oliver et al., 2014). The importance of incremental innovation is associated with constraints on the demand side (including retailer behaviour) and conservative consumer behaviour (Capitanio et al., 2009; Filippaios, Papanastassiou, Pearce, & Rama, 2009).

Regarding the origin of agri-food innovations, a large part of them seem to start from customer and retailer demands, marketing strategies, consumer perception of quality and safety and environmental pressure[1]. Vanhonacker et al. (2013) indicate that few innovations are widely accepted by consumers in this sector, where 50% of new products launched on the market fail (Ronteltap, van Trijp, Renes, & Frewer, 2007). Consumer acceptance is crucial to the adoption and dissemination of new technologies in food production and to the success of any new product launched on the market (Garcia Martinez & Briz, 2000). Additional detailed

[1] The implementation of food safety management systems has grown significantly in the food production chain in order to improve food security. European food safety regulation covers a broad range of regulatory techniques and standards including the GlobalGAP, IFS, Marks & Spencer's Field-to-Fork, Tesco Nurture, (Kirezieva et al., 2015).

knowledge of consumer preferences in terms of food technology innovations can help minimize innovation failure rates (Chen, Anders, & An, 2013). In this context, marketing innovation plays an important role in the food sector apart from product and process innovation when it comes to creating information exchange between producers and consumers and to the success of new food products in the market.

Particularly in times of crisis, when consumers' confidence and overall consumer expenditures are greatly affected, both the demand and the supply side pay great attention to the price trends of food products (Koutsimanis, Getter, Behe, Harte, & Almenar, 2012). The foregoing considerations are based on the literature and indicate the importance of all types of innovation in the agri-food industry. Firms in this sector tend to innovate so as to stand out from their competitors at all times and fulfil the needs and expectations of their customers, particularly in times of crisis, and also to sustain prosperity, attain long term goals and develop competitiveness in today's global markets (Kühne et al., 2010; Mansoor & Jalal, 2011).

2.2. Determinants of firm innovative performance

This section describes the conceptual framework built on the basis of the Resource-Based View (RBV) (Berney, 1991) and the Dynamic Capabilities Theory (Teece et al., 1997) to analyze how firms may adapt, assimilate and deploy their behavior, resources and capabilities within a changing environment. Using the Resource-Based View (RBV) of the firm as a theoretical backdrop; we aim to find out the relative impact of different activities beyond formal R&D (internal and external), sources of innovation outside firms' boundaries (domestic and foreign cooperation in innovation) and firms' internal characteristics (firm size, business sector and productivity) on their short- and long-term competitive position. Extending the RBV theory, we build on the Dynamic Capabilities Theory to examine why and how some firms have handled the current crisis better than others and how factors (inputs) allow firms to effectively face the crisis by improving their innovative performance during such periods. We argue that managers of firms that want to achieve competitive advantage need to adapt, integrate and reconfigure resources and competences to match the changing market (Makkonen, Pohjola, Olkkonen, & Koponen, 2014; Teece et al., 1997). We summarize our arguments in a set of hypotheses listed below.

2.3. Firm factors

The first determinant on firm innovative performance is Research and Development activities (R&D). R&D is considered to be one of the key drivers for innovation (Bascavusoglu-Moreau & Tether, 2012). R&D has a particularly successful impact on innovation efforts when firms carry it out in a continuing way (Köhler, Sofka, & Grimpe, 2012). Moreover, a strong set of internal competencies in R&D not only increases firms' innovative outputs but also allows them to use and exploit knowledge acquired outside the firm (Artz, Norman, Hatfield, & Cardinal, 2010). In this regard, some authors find that the different options for using innovation inputs (internal or external) affect innovation performance more than the R&D effort in general terms (López Rodríguez & García Rodríguez, 2005).

However, the rapid advance of technological knowledge, the growing costs of R&D and shorter product life cycles make it impossible for any firm to sustain all the abilities and knowledge required for production in-house (Berchicci, 2013). In this line, Koschatzky (2001) suggests that firms which do not exchange knowledge in innovation reduce their knowledge base on a long-term basis and lose the capability to enter into exchange relations with other firms and organizations (Avermaete, Viaene, Morgan, & Crawford, 2003). According to this agreement, firms should open their R&D activities to external sources as the externalization of R&D activities allows firms to search for new external knowledge sources outside their environment to benefit from complementary sets of knowledge from external agents and improve their performance and innovate successfully. There is agreement in the literature that the agri-food industries are slightly more open than other Spanish firms in this regard (Bayona et al., 2013). Furthermore, it is crucial for firms to be able to identify and exploit the significant value of external knowledge from other sources of innovation. This capability enhances the firm's absorptive capacity introduced by Cohen and Levinthal (1989), who argue that internal R&D investments are necessary for firms not only to increase innovative outputs but to enhance their capability to assimilate and exploit better sources of knowledge generated outside its boundaries effectively. Firms that depend totally on external partners sometimes lack internal R&D processes themselves and the ability to fully capture and assimilate external knowledge (Chesbrough & Teece, 1996), which suggests that external knowledge should be used to complement rather than substitute for internal R&D (Vega-Jurado, Gutiérrez-Gracia, & Fernández-De-Lucio, 2009). However, previous studies have found empirical evidence that firms with international R&D are more likely to generate

innovative products and achieve higher sales growth due to these new products as compared to firms that innovate domestically only (Peters & Schmiele, 2010). This suggests that the internationalization of R&D increases the chances of firms participating in international knowledge sharing. Foreign knowledge will increase firms' innovativeness and market success with innovations when they possess the necessary abilities to make use of their knowledge base. A key reason for firms to go abroad with R&D activities is getting access to new knowledge not available in their home country (Dachs, Borowiecki, Kinkel, & Schmall, 2012). In line with this, we put forward the following hypotheses:

H1.a. Firms that carry out internal R&D will see a positive impact on firm performance in relation to firms that do not.

H1.b National or international external technology acquisition positively correlates with firms' innovative performance.

H1.c. The effect of international R&D can be expected to be stronger than national R&D.

As a consequence of the recent financial crisis, many companies have been forced to reduce their investment in innovation. Milić (2013) suggests that investments in innovations and future growth are at risk during an economic crisis, when most organizations cut their R&D budgets. Paunov (2012) shows that in Latin American countries the current crisis has led many firms to put a halt to ongoing innovation projects. Moreover, Filippetti and Archibugi (2011) note that in certain countries in Europe the percentage of firms reducing investments in innovation is higher than those increasing their innovation expenditure. Similarly, Cincera, Cozza, Tübke, and Voigt (2012) highlight the fact that a large percentage of companies in Europe have reduced R&D activities as a result of the crisis. Given the decrease of R&D efforts during a crisis, we hypothesize that:

H1.d. It is to be expected that the positive effect of internal R&D on firms' innovative performance will be lower during economic crisis.

H1.e. It is to be expected that the positive effect of external R&D on firms' innovative performance will be lower during economic crisis.

The second determinant of innovation performance is cooperation agreements, they is one of the dimensions of open innovation and an additional knowledge sourcing strategy. Cooperation with external partners has proved to be essential in the case of SMEs, where the cost of innovation is more significant as compared to other sectors due to their limited labor, financial and material resources (Laforet, 2013). Bayona et al., (2013) found that cooperation

in Spanish agri-food firms has a positive effect on innovation performance. However, firms have opportunities to cooperate with different kinds of partners, namely national, international, industrial and institutional partners. Cooperation with a specific type of partner is generally more likely to be chosen if that type of partner is seen as an essential source of knowledge for innovation success. Belderbos, Carree, and Lokshin (2004) used Dutch data on innovating firms and found that competitor and supplier cooperation is associated with incremental innovations, whereas customers and universities are important sources of knowledge for firms pursuing radical innovations. Similarly, Harhoff, Mueller, and Van Reenen (2014) highlights the fact that collaborations with customers are intended to adapt existing products to new markets and can boost sales of products abroad. Due to international economy integration, R&D cooperation is not limited by national borders. Some studies have found a positive impact of international R&D cooperation on innovation performance. Arvanitis and Bolli (2013) analyzed the differences between national and international innovation cooperation in five European countries: Belgium, Germany, Norway, Portugal and Switzerland, and found that innovation performance of firms improves with international cooperation but remains unaffected by national cooperation. Miotti and Sachwald (2003) studied French manufacturing firms and showed that innovation performance is not affected by innovation cooperation agreements with national partners but is positively influenced by cooperation with foreign partners. However, Jaklic, Damijan, and Rojec (2008) find positive effects of national but not of international innovation cooperation in Slovenian firms. During the latest years of crisis, cooperation has become a more attractive strategy to cope with it for Spanish business; this is particularly the case with SME firms, which have considerably increased cooperation. Given the double aim of the collaborative strategy; pooling knowledge and sharing development costs, this strategy should increase in periods of economic downturns (Laperche, Lefebvre, & Langlet, 2011) so as to preserve the innovation capacity of firms. In line with the empirical studies above, we expect that an economic crisis will lead to the development of collaborative strategies (Laperche et al., 2011). Hence, the following hypotheses are proposed:

H2.a. Cooperation agreements with different national partners will have a positive effect on the innovative performance of the firms.

H2.b. Cooperation agreements with international partners will have a positive effect on the innovative performance of the firms.

H2.c. It is to be expected that this positive effect of cooperation agreements on firms' innovative performance will be easier to be perceived during economic crisis.

Numerous studies have shown that the export variable is important in a firm's ability to innovate. Firms competing in international markets are under intense innovation pressure in general, which reveals itself in a constant need to provide innovative products to remain competitive (Kirner, Kinkel, & Jaeger, 2009). Almeida and Fernandes (2008) found that firms that export are more likely to innovate than firms selling only to the domestic market. Nieto and Santamaría (2007) also showed that export intensity has a positive and significant effect on the likelihood of achieving incremental innovations. However, in the current crisis exporting has become an attractive and sustainable route to survive and get out of recession not only for large companies but also for many SMEs. Peters et al., (2009) argue that a weaker dollar would be beneficial for the American agricultural sector since it would result in higher export earnings, higher commodity prices, and an increase in production. Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín (2012) suggest that the economic crisis has driven firms to sell their goods and services abroad. Because of the decrease in domestic demand, firms have found that their products are more difficult to sell in their local markets. In most cases, the motivation of firms to expand their markets seems to respond to the need to survive a global market and to achieve a more stable competitive position (Filipescu, Rialp, & Rialp, 2009). Hence, we propose the following hypothesis:

H3.a. The export variable is positively related to innovative firm performance.

H3.b. It is to be expected that his positive effect will be higher during economic crisis.

2.4. Firm internal characteristics

Although business factors are key drivers of innovation performance, the role of firm internal characteristics cannot be neglect. Firm size, business sector and productivity, have a considerable impact on innovation performance. Productivity is considered to be the most reliable indicator for evaluating the economic performance of a firm. Crucini, Kose, and Otrok, (2011) suggested that total factor productivity shocks have been a primordial source of fluctuations in global economic activity. Empirical findings suggest that the relationship between firm productivity and innovation activities is positive. Doraszelski and Jaumandreu (2007) found that R&D spending is highly positively associated with the probability of introducing a new product and process innovations, investments which in turn increase firms' productivity. The same authors highlight that innovative firms have higher labor productivity

and are bigger than firms that do not innovate. In terms of type of innovation, Parisi, Schiantarelli, and Sembenelli (2006) analyzed Italian firms and found that the introduction of process innovation has a sizeable effect on productivity. Cassiman and Martinez-Ros (2007) suggest that product innovation rather than process innovation affects firm productivity. Moreover, Antonioli, Mazzanti, and Pini (2011) find a positive impact of organizational and technological innovations on labour productivity. Hence, the following hypothesis is proposed:

H4. There is a positive relationship between firm productivity and innovative performance.

Recent empirical evidence generally shows a positive relation between firm size and the likelihood of innovation (Alarcón et al., 2013), but some studies show a non-significant (Lööf, Heshmati, Asplund, & Nåås, 2001) or even a negative relationship between firm size and probability of innovation (Pavitt, Robson, & Townsend, 1987). Bayona et al., (2013) detected a positive relation between larger firms and innovation because of improved access to human and financial resources and profit persistence. Damanpour (2010), on his part, suggests that size has a more positive association with process than with product innovations. The recent downturn will negatively impact not only investment and production but it has also revealed employment problems related to higher unemployment rates (Ashford, Hall, & Ashford, 2012). Spain is one of the countries that witnessed the most marked expansion with a sharp fall in employment (Ortega & Peñalosa, 2012). Therefore we hypothesize that:

H5.a. Size has a positive impact on the innovative performance of firms.

H5.b. This positive effect is expected to be lower during economic crisis.

2.5. Impact of an economic crisis on innovation performance

Many studies show the various changes which occurred when the global crisis hit. Some of the effects of the current economic crisis on consumers are employment uncertainty and a growing unemployment rate and an income fall, all of which in turn affect customer purchase behaviour, mostly negatively (Dave & Kelly, 2012; Mansoor & Jalal, 2011). Consumers tend to be more careful, planning their expenditure and focusing on spending efficiency, reducing consumption level in different ways according to each product category (Mansoor & Jalal, 2011). Dave and Kelly (2012) note a link between low-income households and unhealthy food consumption; they found a countercyclical effect for unhealthy foods and significant procyclical effects for healthy food. That is, lower incomes caused by an increasing unemployment rate and/or reduction in working hours during a period of recession tend to

raise the substitution of healthy food (e.g. fruits and vegetables) for unhealthy food consumption (e.g. snacks, cheap fast food or limited service restaurants) in both old and young adults. Chang, Gunnell, Sterne, Lu, and Cheng (2009) also note that young and middle-aged adults are more affected by a change in economic circumstances (such as an increase in unemployment and lower income) than older people.

Another study by Ásgeirsdóttir et al., (2012) analyzed the effects of a macroeconomic downturn in Ireland on a range of health behaviors. Based on a longitudinal health and lifestyle survey from 2007 to 2009, they concluded that the crisis in Iceland resulted in the adoption of less healthy lifestyles such as a reduction in the consumption of fruits, vegetables, vitamins and supplements and an increased use of fish oil, food with little nutritional value and smoking as a response to stress. Furthermore, the same authors confirmed that the effect of a crisis was greater on the working-age population in relation to the adult population. Blanchard (1993) found that the 1990-1991 recessions in the USA was largely the result of a "consumption shock" This fact suggests that changes in consumption can predict changes in output. Consumer confidence was much weaker than that which could be accounted for by its usual correlation with an exogenous shock to the economy, including future income, unemployment rate, and inflation.

Under these conditions, innovative businesses suffered the lower demand for their products and hence foresaw substantial uncertainties over future trends in consumption (OECD, 2012). Filippetti and Archibugi (2011) suggest that the drop in demand played a substantial role in firms' decisions regarding innovation investments. Moreover, not all sectors and categories of products have been affected in the same way by these environment changes. For example, due to the importance of the food sector as a necessary element to human survival, the impact of the recent crisis has been lower than in any other sector of the economy in Spain (Baamonde, 2009). Food will continue to represent a significant percentage of consumer expenditure in Spain (AAFC, 2012). Katchova and Enlow (2013) analyze the financial performance of publicly traded agribusinesses when compared to all firms over the 1961-2011 period. They show that agribusinesses had a strong financial performance and outperform the sample of all firms based on a series of financial ratios. These findings are important for investors considering adding agribusinesses to their investment portfolios particularly during the recent economic recession. Schiefer, Hirsch, Hartmann, & Gschwandtner (2013) focused on the EU food sector and also found evidence of weak economic fluctuations which explained the

difference in firm performance when compared to firm-specification characteristics. In line with this, we put forward following hypotheses:

H6.a. The economic crisis had a negative impact on firms' innovative performance

H6.b. It is to be expected that the effect of the economic crisis will be lower in the agri-food sector than in any other sector of the economy.

Following the extant literature, a theoretical model of the case study was developed. In this framework we have studied the factors selected for our model of analysis and the hypothesized relationships between them in depth (Figure 2.1).

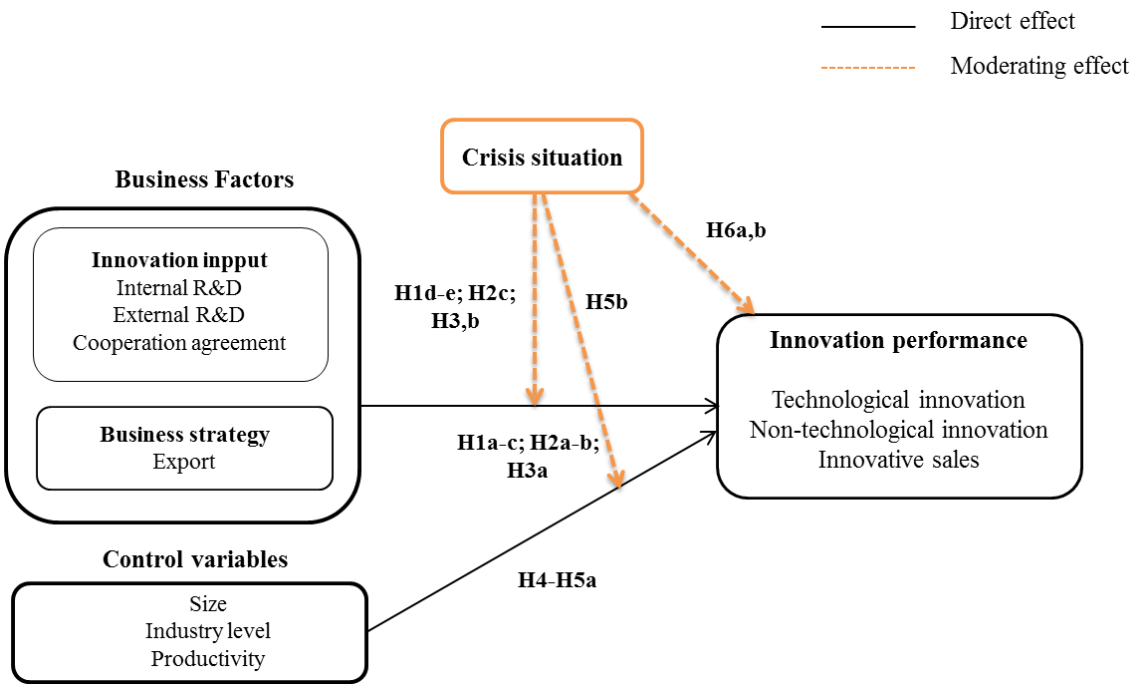

Figure 1. Theoretical model and hypotheses

2.6. Models used

The econometric models used are random effects logit model and random-effects Tobit models[2]. Those frameworks take into account the existence of multiple observations of each

[2] We are considering a sample of the whole population of Spanish firms; the random effects model would be more appropriate for a large population (Henderson & Ullah, 2005).

firm in different periods of time and compute a different intercept for each of the observations in each period of time (Un, Cuervo-Cazurra, & Asakawa, 2010).

The logit with panel-level random effects for firm *i* in period *t* can equivalently be written as:

$$Y_{it}^{*} = \alpha + \beta\, X_{it-1} + \mu_i + \varepsilon_{it} \qquad (i = 1; \ldots; n;\ t = 1; \ldots; T)$$

Where $\begin{cases} Y_{it} = 1 \text{ if } Y^{*}_{it} > 0 \\ 0 \text{ 0therwise} \end{cases}$

Y^{*}_{it} denote the unobservable propensity to innovate, α is the constant term, β is a vector of parameters and X_{it-1} is the vector of explanatory variables[3]. The random effect model decomposed the error term into two components ($u_i + \varepsilon_{it}$) in order to take account of unobserved heterogeneity; one of which is specific to each firm's i (u_i), and a component ε_{it} stands for other unobserved variables (random error). The random-effects Tobit model is obtained such that:

$$Y_{it}^{*} = X_{it-1}\beta + \alpha_i + \varepsilon_{it} \qquad (i = 1; \ldots; n;\ t = 1; \ldots; T)$$

While $\begin{cases} y_{it} = y^{*}_{it} & \text{if } y^{*}_{it} > 0 \\ y_{it} = 0 & \text{if } y^{*}_{it} \leq 0 \end{cases}$

We make the usual random effects assumption that α_i and ε_{it} are independent and identically distributed of $x_{i1},\ldots,x_{iT}$, with zero means and variances σ^2_{α} and σ^2_{ε}, respectively.

In order to test our hypothesis (H2-6) cited above about the effect of a crisis on firm performance, a set of interaction terms between each explanatory variable and the time dummy (D_2010-2012) is included in both the Logit and Tobit models.

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[3] We lagged all independent and control variables (except sector dummies which do not vary across panel waves) by one period with respect to innovation output variables. This approach allows us to minimize endogeneity and to justify the inclusion of this variable as an ex-ante explaining variable (Bradley, Wiklund, & Shepherd, 2011).

2.7. Data set description

This section illustrates the dataset analysis and variables description. The database used for our empirical analysis has been taken from the Spanish Technological Innovation Panel (PITEC)[4], which is carried out on a yearly basis by the Spanish National Statistics Institute (INE) in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). The data are collected annually, gathering data since 2003, the latest available year at the present time being 2012.

For the purposes of this present paper, we used information from PITEC for the 2008–2012 period[5] and we studied all the Spanish sectors available in PITEC. Then, we organized them separately under three principal sectors: agriculture, cattle, forestry, fishing–(NACE-2009 code 0000-), food, beverages, and tobacco (-NACE-2009 code 0003-) and the rest of Spanish firms. According to OECD (2005), the concept of innovation performance encloses multidimensional measures in terms of technological innovation, non-technological innovation and the percentages of sales generated by new products. In this study we use categorical and numerical indicators of innovative performance. The first categorical indicator output is measured by dichotomous variables, which indicate whether or not the firm introduced an innovation during the last 2 years (from t-2 to t). We distinguish between four types of innovation described in the Oslo Manual (OCDE, 2005): product, process, organizational and marketing innovations. The second output is the quantitative indicators of innovation performance based on the share of turnover derived from new or improved products during the last 2 years (from t-2 to t). These variables can be used to provide important information on the impact of product innovation on turnover and on the degree of innovativeness of the firm.

As explanatory variables, we introduce binary variables indicating whether the firm undertakes R&D development activities and cooperation agreements, and if firm operates in international markets for developing innovation. Furthermore, we include a set of control

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[4] The Database is located free on the FECYT site: http://icono.fecyt.es/PITEC .

[5] Due to the particularities of this survey, some of the output variables of interest such as organizational and marketing innovations are available only for years 2004 and 2005 and then disappear again until 2008.

variables related to firms' characteristics: Firm size and firm productivity. In addition, as the innovation behavior of firms depends on the sector in which it operates, we also controlled a firm's sector on the two digit NACE codes by using dummy variables coded '1' if the firm belongs to the respective two-digit sector, and '0' otherwise. We created dummies for the agricultural and food sectors. The rest of the sector was used as the control group.

Finally, a time dummy D_2010-2012 which corresponds to years 2010 and 2011 was added to the econometric model in order to control for the long-term effect of the crisis on the innovation performance of firms. The baseline will be years 2008 and 2009[6]. According to Ghemawat (1993), during general business downturns, this investment has tended to decline two to four times faster than output. Based on this work, we assume that the effect of a crisis on firm performance is seen not at the beginning of the crisis but later on, and thus we consider two periods: (a) 2008-2009: the "beginning of the crisis", (2) 2010-2012: "during the crisis". Table 2.1 lists the description of all the variables used in detail.

Table 1. Description of the variables

Variables	Definitions	Mean	Std.Dev.
Dependent Variables			
INN_Product	1 if the firm introduced product innovation, 0 otherwise	0.561	0.496
INN_Process	1 if the firm introduced process innovation, 0 otherwise	0.590	0.492
INN_Organizational	1 if the firm introduced organizational innovation, 0 otherwise	0.457	0.498
INN_Marketing	1 if the firm introduced marketing innovation, 0 otherwise	0.300	0.458
INN_Radical	The percentage of the firm's sales from products new to the market	9.892	22.828
INN_Incremental	The percentage of the firm's sales from products new to the firm	46.187	45.992

[6] The 2008-2012 period was characterized by a significant decrease in both demand for innovative products and in the share of firms achieving innovations in all Spanish sectors. We noted that the effect of the crisis began to show a negative impact on almost all innovation inputs and outputs from the year 2010 onwards. The number of companies carrying out exporting operations has increased significantly (approximately 5.4% for the food industry and 4.9 % for the total sector).

Independent Variables			
Innovation sources			
InternalR&D_continuous*	1 if the firm engaged in-house R&D activities continuously	0.422	0.494
Internal R&D_occasional*	1 if the firm engaged in-house R&D activities occasionally	0.104	0.306
External R&D_Nat	1 if the firm engaged in national external R&D activities	0.209	0.406
External R&D_Inter	1 if the firm engaged in international external R&D activities	0.012	0.111
Cooperation partners			
COOP_Ind_NAT	1 if the firm cooperated in innovation with national industrial agents (customers, suppliers, competitors and firms belonging to the same business group), 0 otherwise	0.212	0.409
COOP_Ind_INTER	1 if the firm cooperated in innovation with international industrial agents (universities, public research organizations, technologic centers and commercial laboratories/R&D enterprises), 0 otherwise	0.227	0.419
COOP_Instit_NAT	1 if the firm cooperated in innovation with national institutional agents, 0 otherwise	0.100	0.300
COOP_Instit_INTER	1 if the firm cooperated in innovation with international institutional agents, 0 otherwise	0.051	0.220
EXPORT	1 if firms that operate outside Spain, 0 otherwise		
Firm variables			
SIZE	Ln (total number of employees)	4.047	1.696
Productivity per employee	Ln (ratio of firm sales to the total firm employees)	11.772	1.054
Sectoral dummies			
Food_SEC**	1 if the firm belongs to food, beverages sector, 0 otherwise	0.073	0.258
Agri_SEC**	1 if the firm belongs to agricultural sector, 0 otherwise	0.013	0.113
Dummy time			
D_2010-2012	Time dummy, 1 if the observation corresponds to the period 2010-2012, 0 if the period is 2008-2009.	0.579	0.494

*The firm not engaged in in-house R&D activities was used as reference category; ** The rest of the sector was used as the baseline category

Figure 2.2 shows changes in macroeconomic indicators (GDP rate growth per capita, unemployment rate) in Spain as a response to the crisis. As Figure 2.2 shows, the greatest impact of the economic crisis in Spain was suffered from 2009 on. Like many developed countries affected by a crisis (Peters et al., 2009 on the USA), the global crisis had a prompt and significant impact on Spain; the unemployment rate went from 8.5 percent in 2006 to

26.1 percent in 2013. Spain's gross domestic product also saw a negative growth rate from 2009 onwards. GDP fell 6.8 percent in 2009 vs. 2.9 percent in the previous year.

The crisis also had a negative impact on household consumption patterns in Spain–food, restaurant and hotels and housing, each accounting for around 17%, 16% and 22% of consumption expenditure respectively–had the largest weightings (Eurostat, 2015). Trends in consumption in Spain during the crisis decreased by 2 percent in non-food items, the sectors more affected being clothing, household equipment, transport and recreation/culture. Food, alcohol and tobacco consumption remained stable from 2006 to 2011, growing by nearly 0.5% percent in 2013. This provides some initial evidence to the fact that crises have a lesser effect on this sector as compared to the whole sector.

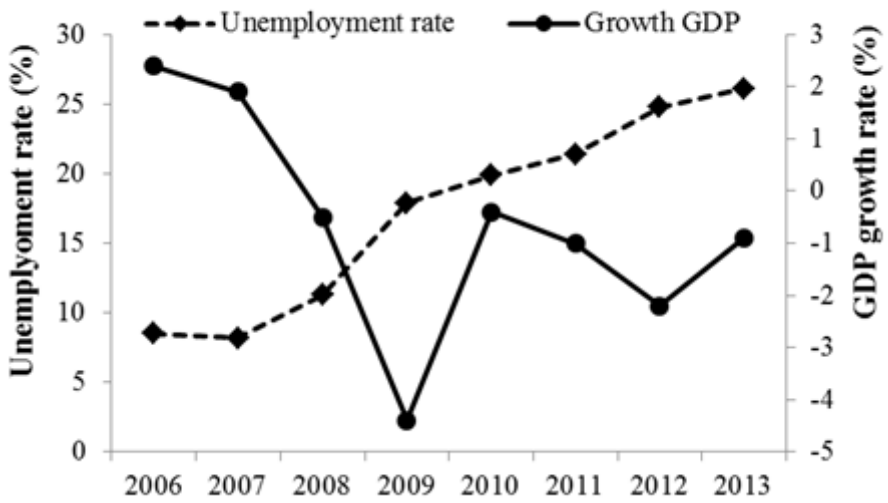

Figure 2. Trends in gross domestic product (GDP) growth rate per capita and unemployment rate as the percent of total labor force in Spain during 2008-2012 (Source: Eurostat and the Word bank)

2.8. Main outcomes of the dataset

Figure 2.3 shows the growth rate of sales and employment in different types of firms (innovative versus non-innovative firms). We define firms which implemented an innovation during the period under review (OCDE, 2005) as innovating firms. We can see that the effects of the financial crisis differed considerably across sectors. The agriculture and food sectors are less affected in terms of sales and employment. The unemployment rate increased and

reached 7.7%, 4.5% and 3.9% in 2012, while sales dropped by -7.6%, -0.6% and -3% for all firms, agriculture and food industry, respectively.

The difference across innovative and non-innovative firms shows that innovating firms maintained employment and sales rates better than their non-innovating counterparts. It is interesting to note that both the food and agriculture industries were able to derive better shares of sales from innovation than the total Spanish sector; innovating firms show a significantly positive sales growth in agriculture sector while non-innovative ones have a negative sales growth, which confirms the importance of innovation in this sector.

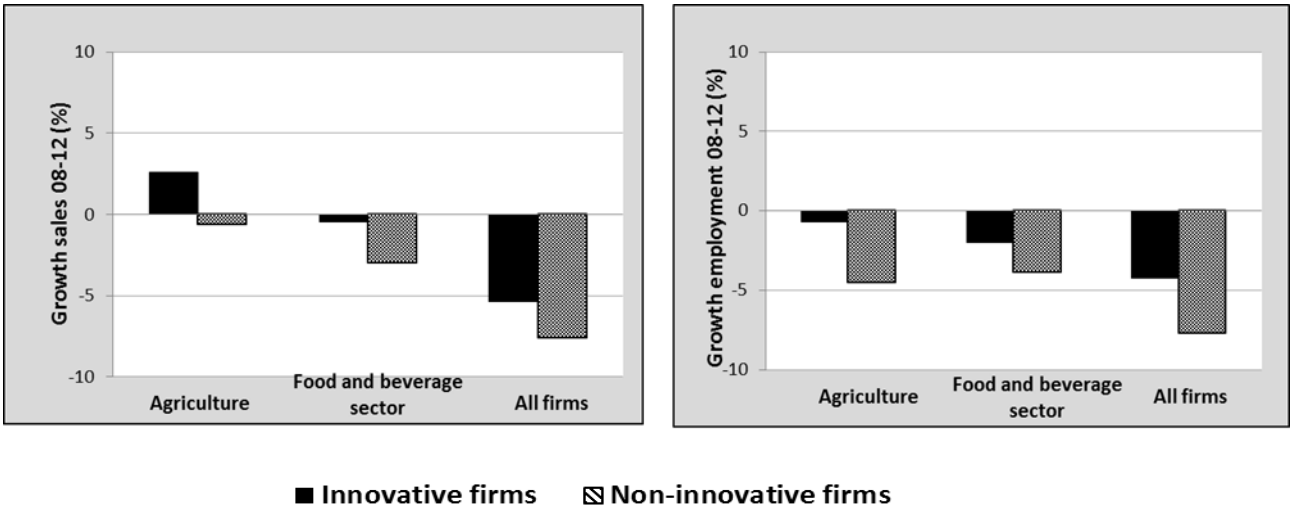

Figure 3. Sales and employment growth rates for innovative and non-innovative firms over the 2008-2012 period.

2.9. Measurement model test and discussions

The results of random-effects Logit model and Random-Tobit estimations[7] are reported in Table 2.2 and Table 2.3, respectively. In order to test our proposed hypotheses, we estimated various models. In the Table 2.2, models (1), (3), (5) and (7) are the base models present the estimation's results for each innovation output (product, process, marketing and organizational innovation) and models (2), (4), (6) and (8) introduce the interactions between

[7] The models were tested for multicollinearity and the correlation values among all variables are quite low; a maximum of 0.483 was obtained. This value is below 0.56, the maximum value recommended for the multicollinearity test. Therefore, we calculated variance inflation factors (VIFs) for each correlation and obtained a maximum of 1.69. This level is well below the rule of thumb cut-off of 10 (Neter, Kutner, Nachtsheim, & Wasserman, 1996), which indicates that multicollinearity does not pose a problem to our estimation models.

each explanatory variable and the time dummy (D_2010-2012). In Table 2.3, models (1) and (3) show the relationship between explanatory variables and innovative product sales. Interactions between the each explanatory variable with the time dummy (D_2010-2012) are included in models (2) and (4).

Table 2. Factors influencing the decision to innovate: Random-effects logit model estimation

	Technological innovations				Non-technological innovations			
	Product innovation		Process innovation		Organizational innovation		Marketing innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Continuous_Internal R&D$_{t-1}$	2.598***	2.578***	1.290***	1.266***	1.241***	1.229***	1.377***	1.363***
	(0.057)	(0.057)	(0.052)	(0.052)	(0.053)	(0.053)	(0.059)	(0.059)
Occasional_Internal R&D$_{t-1}$	1.739***	1.733***	1.194***	1.174***	0.831***	0.810***	0.874***	0.856***
	(0.065)	(0.065)	(0.063)	(0.064)	(0.063)	(0.064)	(0.070)	(0.070)
External R&D_Nat$_{t-1}$	0.252***	0.250***	0.361***	0.352***	0.264***	0.259***	0.198***	0.198***
	(0.054)	(0.054)	(0.051)	(0.051)	(0.050)	(0.050)	(0.052)	(0.053)
External R&D_Inter$_{t-1}$	0.819***	0.829***	0.857***	0.864***	0.675***	0.674***	0.282	0.288
	(0.202)	(0.203)	(0.193)	(0.193)	(0.184)	(0.184)	(0.189)	(0.190)
COOP_Ind_NAT$_{t-1}$	0.541***	0.549***	0.568***	0.577***	0.438***	0.443***	0.262***	0.259***
	(0.062)	(0.062)	(0.059)	(0.059)	(0.058)	(0.058)	(0.062)	(0.062)
COOP_Instit_NAT$_{t-1}$	0.511***	0.495***	0.342***	0.328***	0.230***	0.223***	0.135**	0.138**
	(0.064)	(0.064)	(0.060)	(0.061)	(0.060)	(0.060)	(0.064)	(0.064)
COOP_Ind_INTER$_{t-1}$	0.426***	0.424***	0.288***	0.294***	0.297***	0.294***	0.186**	0.183**
	(0.092)	(0.093)	(0.086)	(0.087)	(0.082)	(0.082)	(0.083)	(0.083)
COOP_Instit_INTER$_{t-1}$	0.124	0.120	0.113	0.149	0.315**	0.317**	0.209*	0.199*
	(0.126)	(0.126)	(0.118)	(0.120)	(0.113)	(0.113)	(0.112)	(0.112)
SIZE$_{t-1}$	0.074***	0.067***	0.461***	0.458***	0.441***	0.445***	0.132***	0.132***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.019)	(0.021)	(0.021)
Export$_{t-1}$	0.463***	0.477***	-0.063	-0.047	0.057	0.067	0.273***	0.277***
	(0.049)	(0.050)	(0.046)	(0.046)	(0.048)	(0.048)	(0.052)	(0.052)
Productivity$_{t-1}$	0.139***	0.140***	0.156***	0.158***	0.065**	0.067**	0.077**	0.079**
	(0.026)	(0.026)	(0.025)	(0.025)	(0.026)	(0.026)	(0.030)	(0.030)
FOOD_SEC	-0.235*	-0.239*	0.664***	0.676***	0.019	0.013	1.010***	1.007***
	(0.123)	(0.124)	(0.116)	(0.117)	(0.124)	(0.124)	(0.137)	(0.137)
AGRI_SEC	-1.067***	-1.0715***	0.484*	0.508**	-0.821**	-0.829**	-0.733**	-0.769**
	(0.265)	(0.267)	(0.254)	(0.257)	(0.283)	(0.285)	(0.325)	(0.328)
D_2010-2012	-0.753***	-0.789***	-0.721***	-0.737***	-0.355***	-0.369***	-0.038	-0.061
	(0.032)	(0.036)	(0.030)	(0.033)	(0.030)	(0.033)	(0.032)	(0.037)
Interactions terms								

D_2010-2012*Food_SEC		0.052		-0.344***		-0.218*		-0.147
		(0.127)		(0.121)		(0.115)		(0.119)
D_2010-2012*Agri_SEC		-0.374		-0.282		-0.115		-0.548
		(0.273)		(0.265)		(0.282)		(0.313)
D_2010-2012*Continuous_Internal R&D$_{t-1}$		0.297***		0.231***		-0.029		-0.042
		(0.079)		(0.074)		(0.075)		(0.088)
D_2010-2012*Occasional_Internal R&D$_{t-1}$		0.471***		0.217**		-0.182*		-0.082
		(0.108)		(0.106)		(0.107)		(0.117)
D_2010-2012*External R&D_NAT$_{t-1}$		-0.027		-0.004		0.004		-0.042
		(0.093)		(0.087)		(0.084)		(0.088)
D_2010-2012*External R&D_INTER$_{t-1}$		0.682**		0.234		0.274		0.152
		(0.328)		(0.319)		(0.295)		(0.302)
D_2010-2012*COOP_Ind_NAT$_{t-1}$		-0.223**		-0.065		-0.087		-0.253**
		(0.108)		(0.102)		(0.098)		(0.102)
D_2010-2012*COOP_Instit_NAT$_{t-1}$		0.108		-0.075		-0.149		0.209**
		(0.105)		(0.099)		(0.097)		(0.102)
D_2010-2012*COOP_Ind_INTER$_{t-1}$		-0.071		-0.034		0.068		0.209
		(0.159)		(0.148)		(0.136)		(0.135)
D_2010-2012*COOP_Instit_INTER$_{t-1}$		0.203		-0.394*		0.079		0.063
		(0.214)		(0.206)		(0.188)		(0.180)
D_2010-2012*SIZE$_{t-1}$		0.196***		0.206***		0.077***		-0.071***
		(0.020)		(0.019)		(0.019)		(0.021)
D_2010-2012*Export$_{t-1}$		-0.202**		-0.173**		0.081		-0.052
		(0.072)		(0.066)		(0.067)		(0.072)
D_2010-2012*Productivity$_{t-1}$		-0.074**		-0.043		0.036		-0.003
		(0.033)		(0.030)		(0.031)		(0.034)
Constant	-2.822***	0.558***	-3.652***	0.800***	-3.659***	-0.378***	-4.408***	-1.948***
	(0.317)	(0.035)	(0.301)	(0.033)	(0.323)	(0.036)	(0.364)	(0.044)
Wald $\chi 2$	3911.88***	3970.92***	2722.93***	2793.69***	1917.01***	1936.00***	1062.25***	1085.08***
AIC	39404.67	39299.65	43837.63	43720.42	42809.55	42797.39	37802.63	37799.28
BIC	39543.31	39550.95	43976.27	43971.71	42978.2	43048.69	37941.27	38050.58

Standard errors are reported in parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 3. Estimation results for innovation output: Sales of new products

	Sales due to Incremental Innovations		Sales due to Radical Innovations	
	(1)	(2)	(3)	(4)
Continuous_Internal R&D$_{t-1}$	3.626***	3.568***	2.227***	2.193***
	(0.088)	(0.088)	(0.061)	(0.061)
Occasional_Internal R&D$_{t-1}$	2.933***	2.876***	1.600***	1.575***
	(0.103)	(0.103)	(0.071)	(0.072)
External R&D_NAT$_{t-1}$	0.159**	0.164**	0.232***	0.231***
	(0.075)	(0.075)	(0.049)	(0.049)
External R&D_INTER$_{t-1}$	0.716***	0.706***	0.449***	0.452***
	(0.261)	(0.260)	(0.170)	(0.169)
COOP_Ind_NAT$_{t-1}$	0.620***	0.607***	0.256***	0.251***
	(0.089)	(0.088)	(0.058)	(0.058)
COOP_Instit_NAT$_{t-1}$	0.378***	0.359***	0.564***	0.556***
	(0.091)	(0.096)	(0.060)	(0.060)
COOP_Ind_INTER$_{t-1}$	0.232*	0.218*	0.246***	0.236***
	(0.119)	(0.118)	(0.076)	(0.076)
COOP_Instit_INTER$_{t-1}$	0.062	0.046	0.351***	0.338***
	(0.157)	(0.157)	(0.099)	(0.099)
SIZE $_{t-1}$	0.187***	0.173***	-0.057**	-0.060**
	(0.032)	(0.036)	(0.022)	(0.022)
Export $_{t-1}$	0.546***	0.549***	0.340***	0.347***
	(0.076)	(0.076)	(0.051)	(0.051)
Productivity $_{t-1}$	0.296***	0.296***	-0.003	-0.002
	(0.044)	(0.044)	(0.030)	(0.030)
FOOD_SEC	-0.307	-0.320	-0.392***	-0.384**
	(0.212)	(0.213)	(0.149)	(0.149)
AGRI_SEC	-1.438***	-1.437***	-0.642**	-0.700**
	(0.466)	(0.468)	(0.325)	(0.327)
D_2010-2012	-0.848***	-0.975***	-0.544***	-0.670***
	(0.046)	(0.052)	(0.031)	(0.037)
Interactions terms				
D_2010-2012*Food_SEC		-0.241		0.256**
		(0.180)		(0.123)
D_2010-2012*Agri_SEC		-0.478		-0.671**
		(0.429)		(0.294)
D_2010-2012*Continuous_Internal R&D$_{t-1}$		1.111***		0.528***
		(0.118)		(0.083)
D_2010-2012*Occasional_Internal R&D$_{t-1}$		1.093***		0.531***
		(0.169)		(0.118)
D_2010-2012*External R&D_NAT$_{t-1}$		0.043		-0.009
		(0.123)		(0.079)
D_2010-2012*External R&D_INTER$_{t-1}$		1.093***		-0.122
		(0.414)		(0.269)
D_2010-2012*COOP_Ind_NAT$_{t-1}$		-0.221		0.058
		(0.143)		(0.093)
D_2010-2012*COOP_Instit_NAT$_{t-1}$		0.336**		0.042
		(0.142)		(0.092)
D_2010-2012*COOP_Ind_INTER$_{t-1}$		-0.055		-0.020
		(0.185)		(0.117)
D_2010-2012*COOP_Instit_INTER$_{t-1}$		0.045		-0.025
		(0.240)		(0.150)
D_2010-2012*SIZE$_{t-1}$		0.228***		0.152***

		(0.029)		(0.020)
D_2010-2012*Export$_{t-1}$		-0.051		-0.127*
		(0.102)		(0.068)
D_2010-2012*Productivity$_{t-1}$		-0.115**		-0.031
		(0.050)		(0.034)
Constant	-5.376***	0.796***	-2.874***	-1.853***
	(0.534)	(0.062)	(0.369)	(0.050)
Wald $\chi 2$	3102.08***	3240.00***	2507.55***	2585.90***
AIC	114257.5	114073.9	88320.56	88217.13
BIC	114404.8	114333.9	88467.87	88477.09

Standard errors are reported in parentheses. * p < 0.1;** p < 0.05;*** p < 0.01

As predicted in H1.a, in-house R&D on both continuous and occasional basis were found positive and significant in all models showed in table 2.2 (models 1, 3, 5 and 7) and in table 2.3 (models 1 and 3). The results indicate that firms that carry out internal R&D have a better innovative performance in relation to firms that do not.

Our results also support H1.b and H1.c, the estimations display that the acquisition of both national and international extramural R&D has a positive impact on a firm's decision to engage in innovation (models 1, 3, 5 and 7, table 2.2) and on innovative product sales (models 1 and 3, table 2.3). The effects of international extramural R&D exceed the impact of national extramural R&D on all innovation output measures (Tables 2.2 and 2.3). This implies that the internalization of R&D activities can be beneficial for companies to achieve more innovation. This is in line with most other studies (Peters & Schmiele, 2010), which tend to find that firms that have international R&D activities are more likely to launch new products than firms with home-based R&D only. However, the coefficients of interaction term between dummy time (D_2010-2012) and internal R&D (D_2010-2012*continuous_Internal R&D and D_2010-2012*occasional_Internal R&D) are positive and statistically significant in model 2-4 (Tables 2.2 and 2.3), suggesting that internal R&D not only has a positive impact on firm's innovation performance as revealed by H.1.a, but it also keeps playing an important role during crisis as determinants of product (β=0.297 and β=0.471; $p<0.01$) and process (β=0.231 and β=0.217; $p<0.01$) innovations and innovative sales performance (β=1.111 and β=1.093; $p<0.01$ in radical innovation; β=0.528 and β=0.531; $p<0.01$ in incremental innovation). However, in model 6-8 (Table 2.2), continuous in-house R&D drop its significance as a determinants of non-technological innovations which the interaction term between dummy time (D_2010-2012) and internal R&D is negative and non-significant. Whereas, the interaction between occasional in-house R&D and crisis variable (D_2010-2012) is negatively signed and significant in model 6 (Table 2.2), the results can be explained by a decrease in the

number of firms carrying out R&D investment in innovation in times of crisis.-Therefore, H.1.d is partly confirmed.

Likewise, the positive and significant interaction terms (D_2010-2012*External R&D_INTER) observed in Table 2.2 (β=0.682, p<0.01; model 2) and in Table 2.3 (β=1.093, p<0.01; model 2) showed the importance of internalization of R&D activities on firm's decision to engage in product innovation and to increase the percentage of innovative sales due to the variety of knowledge shared abroad, particularly in times of crisis. However, domestic R&D activities lose significance as a determining factor on the commercial success of product innovation. Our H1.e is partially supported.

Regarding cooperation agreements, the effect of the different types of partner in cooperation on a firm's innovation performance varies and mainly depends on the type of innovation, as well as on the degree of novelty of the innovations. Cooperation agreements with national partners show positive and significant effects on firm's decisions to innovate and on firm innovativeness, both incremental and radical, thus supporting H2.a. For international partners, cooperation with industrial agents had a positive impact on achieving all innovations types and innovative product sales, collaboration with international institutional partners shows a positive and significant effect only for non-technological innovations and radical innovation. We can see that the effect of national cooperation is stronger than international cooperation on the achievement of all kind of innovations, which contradicts H2.b. During crisis, the significant and negative coefficients of the interactive terms of (D_2010-2012*COOP_Ind_NAT) shown in models 2 and 8 (Table 2.2), implying a decrease in the effect exercised by cooperation on achieving both product and marketing innovations during a crisis. However, contrary results showed when innovative sales is concerned, models (2) indicate that the interactive terms (D_2010-2012*COOP_Instit_NAT) have a positive and significant sign, illustrating that cooperation can help firms to improves their innovative sales during crisis, although, the other types of cooperation loses its significance, this effect may be related to the decrease of internal R&D efforts made by firms during a crisis seem to reduce the exploitation of external knowledge sources derived from innovation cooperation agreements to increase innovative sales. These results contradict H2.c. The export variable has positive impact for product and marketing innovations (models 1 and 7; Table 2.2), and it has the expected positive sign in Table 2.3 (models 1 and 3). Thus, H3.a is supported. Turning to the interaction terms, the results do not support H3.b, the coefficient of interaction term between the dummy time (D_2010-2012) and export variable is negative

and significant in both product and process innovation (β=-0.202 and β=-0.173; p<0.05, Table 2.2), similar results revealed in Table 2.3 with radical innovation (β=-0.127; p<0.1). The negative export-innovation link displayed in crisis period maybe associated to decline of internal R&D efforts made by firms in such period. Prior studies argues that greater R&D investment in time of crisis enlarge a firm' flexibility and enhance its export intensity (Lee, Beamish, Lee, & Park, 2009).

As far as the control variables are concerned, our results indicate a positive relationship between firm's productivity and all innovation outputs (models 1, 3, 5 and 7; Table 2.2). In Table 2.3, a positive relationship between a firm's productivity and sales due to incremental innovation (β=0.296; p<0.001) is well showed, giving support to H4. In Models 2 (Table 2.2) as well as in model 2 (Table 2.3), the significant and negative interaction (D_2010-2012*Productivity) showed a negative relation between firm productivity and firm innovative performance. Two possible justifications for this latter result are that a decrease in R&D spending and innovation investment by firms during a crisis adversely affects firms' productivity; the literature argues that investing in innovation and more specifically in internal R&D activities increases firms' productivity (Cassiman & Martinez-Ros, 2007; Doraszelski & Jaumandreu, 2007; Parisi et al., 2006). Another possible justification would be that in a recession period many firms opt for cutting costs through manpower adjustments and freezing pay rates, increasing job insecurity and consequently decreasing productivity (Pappas, 2014) .

Regarding firm size, size has a positive impact on the decision of firms to innovate (Table 2.2) and on sales of products new to firms (Model 1, table 2.3) whereas its effect is significantly negative on sales of products new to the market (Model 3, table 2.3). Our H5.a is partially supported. Testing the H5.b, the positive and significant coefficients of (D_2010-2012*SIZE) in Table 2.2 (models 2, 4 and 6) and in Table 2.3 (models 2 and 4) contributes to a better understanding the important role of the human capital during a crisis in the process of innovation as well as in the successful of innovative sales. Thus, H5.b is not supported.

As regards to crisis variable, H6.a proposed that the economic crisis had a negative impact on firms' innovative performance. Our results showed that the effect of crisis is more pronounced for technological innovation than non-technological innovation, firms become less likely to generate product (β=-0.753; p<0.01) and process innovation (β=-0.721; p<0.01) to a great extent and in organizational innovation to a less extent (β=-0.355; p<0.01). These results are expected given the drop in R&D investments in innovation during a crisis as already stated above. Paunov (2012) highlights three principal aspects that drive a business to

put a halt to innovation or innovation investments during a crisis: the first one is uncertainty regarding the outcomes of such investments. Second, initial costs of innovation are high and require firms to have important financial resources and these costs may or may not be recovered. Third, a handsome share of the investment is directed at skilled workers and if the innovation project is abandoned or left unfinished workers will be dismissed and knowledge capital will be lost. However, we find a non-significant effect of crisis on marketing innovation. This relates that all industries still innovate in marketing innovation during crisis in order to creating information exchange between producers and consumers and to fulfil the needs and the expectations of customers for the success of new products in the market. Juříková, Jurášková, and Kocourek (2012) found that companies that increased their marketing budgets during a recession gained market share three times as quickly as those that had cut them. Similarly, in Table 2.3; we showed that the economic crisis negatively affects the turnover of innovative sales; this decrease is not surprising and is probably the result of consumers' frugality in times of crisis and the drop of innovative product demand, supporting H6.a.

Concerning the variables related to the sector, as can be noted from Table 2.2, the food industry is significantly more likely to introduce process (β=0.664; p<0.01) than other Spanish sectors, but have a lower probability of achieving product (β=-0.235; p<0.05) when compared to the other Spanish firms. Even though the food industry is oriented to process innovation as revealed by different studies (Batterink et al., 2006), our study has shown that marketing innovation was also considered important in the food industry. The model (7) in Table 2.2 shows that food firms are significantly more likely to introduce marketing innovation (β=1.101; p<0.001) than other Spanish sectors. This has to do with the particularity of this sector, which is focused on market possibilities and the needs of end users. Regarding the agriculture sector, we found that this sector is more focused on process innovation than other types of innovations. The model (3) in Table 2.2 shows that agricultural firms are significantly more likely to introduce process innovation (β=0.603; p<0.01) than other Spanish firms, but have a lower probability of achieving product (β=-1.067; p<0.001), marketing (β=-0.821; p<0.05) and organizational (β=-0.733; p<0.05) innovations when compared to the other Spanish firms (Models 1, 5 and 7; Table 2.2). This result is interesting because it shows that agricultural firms keep engaging specifically in process innovation rather than on diverse types of innovation to reduce exposure to risk and thus to attain higher survival odds. Regarding sales of new products, our findings suggest that agricultural firms

are less innovative in terms of both incremental and radical innovations than the rest of Spanish firms, while the food industry shows the same behaviour as the rest of Spanish firms in terms of incremental innovation. These results are in line with those in Garcia Martinez and Briz (2000), who found that the food industry is characterized by incremental rather than radical changes due to demand-side constraints and consumers' conservative behavior.

Finally, the results partially supported the H 6.b, which provide that the economic crisis will be lower in the agri-food sector than in any other sector of the economy in Spain. The interactive term between crisis variable and food sector in table 2.2 (D_2010-2012*Food_SEC) is significant and has negative coefficients (β=-0.344; p<0.05) in models (4) and (β=-0.218; p<0.05) in model (6), implying that this sector decrease their efforts to make process and organizational innovations during crisis period respect to the other sector, but still innovate in product and marketing innovation at the same level (non-significant coefficients). This result is interesting because it shows that food firms keep engaging specifically in product and marketing innovation rather than on others types of innovation to still competitive by differentiated its products and even explore new markets. Besides, the agriculture sector shows the same behaviour as at the beginning of the crisis in all types of innovation in order to get competitive. In Table 2.3, the interaction term between food sector and dummy time (D_2010-2012*Food_SEC) is statistically significant and positive (β= 0.256; p<0.01, model 4), which indicates that the food sector is more likely to increase sales due to radical innovations during the crisis than at the beginning of the 2008-2009 crisis. These results show that the impact of the recent crisis has been lower in this sector. Hence, our H 6.b partially supported. Table 2.4 includes a summary of the final confirmed or rejected status of the different hypotheses proposed in the study.

Table 4. Overview of hypotheses and findings

Hypothesis	Results
Effect of R&D activities	
H1.a. Firms that carry out internal R&D will see a positive impact on firm performance in relation to firms that do not	✓
H1.b. National or international external technology acquisition positively correlates with firms' innovative performance	✓
H1.c. The effect of international R&D can be expected to be stronger than national R&D	✓
H1.d. It is to be expected that the positive effect of internal R&D on firms' innovative performance will be lower during an economic crisis	partially supported
H1.e. It is to be expected that the positive effect of external R&D on firms' innovative performance will be lower in an economic crisis	partially supported
Effect of cooperation	
H2.a. Cooperation agreements with different national partners will have a positive effect on the innovative performance of the firms	✓
H2.b. Cooperation agreements with international partners will have a positive effect on the innovative performance of the firms	×
H2.c. The positive effect of cooperation agreements on firms' innovative performance will be easier to be perceived in times of crisis	×
Effect of export	
H3.a. The export variable is positively related to innovative firm performance	✓
H3.b. It is to be expected that his positive effect will be higher in an economic crisis	×
Effect of productivity	
H4. There is a positive relationship between firm productivity and innovative performance	✓
Effect of firm size	
H5.a. Size has a positive impact on the innovative performance of firms	partially supported
H5.b. This positive effect is expected to be lower in an economic crisis	×
Effect of crisis	
H6.a. The economic crisis had a negative impact on firms' innovative performance	✓
H6.b. The effect of the economic crisis will be lower in the agri-food sector than in any other sector of the economy in Spain	partially supported

3. Conclusions and implications

Companies are affected in many different ways by economic crises. Some have been forced to reduce their investment in R&D and others put a halt to innovation as a result of uncertainty regarding the market success of innovations and the fear of not recovering production costs. In the Spanish case study employed, the findings provide several important implications for theory and practice. First, while innovation as a driver of firm performance has been well established in the literature (Kühne et al., 2010), our paper provides the importance of innovation during recession periods as key mechanism for organizational growth and even survive in tough economic times, especially in the food and agriculture sectors. The results reveal that agri-food firms' profits and growth depend on their ability to innovate.

The food industry tends to engage in product and marketing innovations at the same level rather more frequently than in other types of innovations during a time of crisis and is more likely to increase its sales due to radical innovations than other Spanish sectors. On the other hand, the agricultural sector continues to invest in all type of innovation at the same level in order to stay competitive and to attain long-term viability and even survive in tough economic crisis. Second, increasing innovative performance should be a goal for many firms, especially in difficult time to cope better and hence survive in tough economic times. The current paper has confirmed that engagement in internal R&D activities not only influences the firms' innovative performance, which is quite shown in literature (Bayona et al., 2013; Vega-Jurado et al., 2009) but also has an important role during crisis as determinants of product and process innovations and on the success of the innovations.

Additionally, opening up R&D activities to external knowledge by means of the acquisition of external R&D as well as by cooperation agreements allows firms to have access to more knowledge, which helps their innovation process and improves innovative sales. In order to take advantage of this expansion of knowledge access base through acquisition of external R&D and cooperation, companies have to make more efforts in continuous in-house R&D investment. Senior managers should be encouraged to persist in their investment in in-house R&D activities which do not depend solely on the acquisition of knowledge outside their environment and the exploitation of relevant external knowledge should also be set as a priority (Tsai & Hsieh, 2009).

Third, the results provide evidence that business managers should be aware of the importance of innovation in times of crisis and of the need to invest more in R&D in a continuing rather than occasional fashion, which would lead to better productivity levels and to the international competitiveness of their firms. The relationship between a firm's innovative performance and productivity and export intensity becomes more negative during the crisis period than at the beginning of the crisis as a consequence of the fall in R&D efforts seen in firms over the course of the crisis. As Dabla-Norris, Kersting, & Verdier (2010) pointed out that innovation is crucial to firm performance as it increases productivity in a direct and measurable way.

Fourth, our findings highlight the importance of the human capital in the process of innovation; firm size keeps playing a significant role in explaining innovation outputs during a crisis. This should be taken into account by company managers, who should keep a staff of skilled workers and persist in investment in innovation, which promotes higher levels of employment and job creation.

3.1. Perspectives for future works

This study faced some limitations and these could suggest lines of future studies. Our paper is limited in terms of years due the particularity of the PITEC database cited above, which provides information until 2012 with some output variables of interest available only as from 2008. Therefore, the effect of the crisis is not yet clear enough so as to confirm some of our hypotheses; we need more post-2012 years to prove the whole set of hypotheses. Furthermore, it would be interesting for future study to compare the innovative behaviour of firms pre- and post-crisis[8]. Another limitation of the PITEC database is the lack of both information about agri-food sub-sectors and financial indicators, which can help to capture the effect of crisis in several productive agri-food sectors and also to boost other financial ratios (i.e. total assets of firm, return on assets, return on sales). A promising future study path would be to carry out a comparative study of the innovative behaviour of Spanish firms during an economic crisis in relation to other countries using a similar database, when they

[8] In this regard, Bowden and Zhu (2008) point out the advantages of carrying out the analysis of this sector with long time series. Further to that, the special nature of the agricultural sector cycles should be taken into account in the analysis (Jianfei & Xiaorong, 2012)

are available, for pre- and post-crisis years combined with the use of models which take into account both individual innovation capabilities of firms and their environmental and contextual role (industry, GDP, market power, among others).

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