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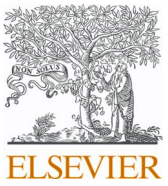

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Exploring SMEs' innovation investment strategy to increase innovation output in economic crises

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ABSTRACT

This study explores SMEs' innovation investment strategy by assessing their innovation investment level and the relative innovation investment effort during crises. The relative effort is measured by the positive values of the difference between the innovation investment made for the SME and that expected considering its external and internal characteristics. This study adopts a sequential multistage approach with a Spanish SME panel. The results show the relevance of the relative effort for generating product innovations during crises. Furthermore, the relative effort is significant above a level of innovation investment which reconciles the results of previous studies.

1. Introduction

Innovation (leading to technological progress) is identified as one of the main driving forces of economic resilience and growth. Firms play a key role in introducing these innovations in society and markets. However, the number of innovative firms and innovation investment sharply decreases recurrently during economic crises in many developed countries (Archibugi et al., 2013b, 2013a; Barlevy, 2007). Recent figures show that the COVID-19 crisis also curtailed the overall amount of innovation investment of firms (OECD, 2021a; Santos et al., 2021).

The literature identifies the lack of internal and external financial resources is responsible for the mostly pro-cyclical investment in innovation -invest less in crisis- (Cefis et al., 2020; Dias et al., 2021; Kabukcuoglu, 2019). The reduction in innovation investment during crises is even more prominent in micro, small, and medium enterprises (SMEs) (Kabukcuoglu, 2019; Roper and Turner, 2020). SMEs can face extra challenges such as the lack of proper technology or technical expertise, and less financial slack, which can deter them from investing in innovation activities (Eggers, 2020; Garrido-Prada et al., 2021; Miklian and Hoelscher, 2022; Thorgren and Williams, 2020).

However, the literature also suggests a strategic decision regarding investment in innovation (Archibugi et al., 2013b; Roper and Turner, 2020). Cincera et al. (2012) identify that firms' innovation investment strategy (IIS) can vary from a pro- to counter-cyclical strategy -invest more in crisis-; in case of the latter, firms may be encouraged by the potential benefits in the expected upswing. Similarly, Arvanitis and Woerter (2014) point out that firms can follow pro- or counter-cyclical R&D investment strategies depending on factor such as the opportunity cost, as well as firm and market characteristics not necessarily related to financial resources. Conti

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et al. (2020) posit that firms interpreted the economic crisis after the 2008 financial crisis as an opportunity by applying new knowledge to ensure improved firm performance.

In this article, we delve into the strategic component of investment in innovation aiming to gain a deeper comprehension of the consequences regarding IIS during a period of crisis for SMEs. Specifically, we argue that to understand the performance of the IIS, it should be inspected from two perspectives simultaneously: (1) the innovation investment level -this is the amount invested per employee in this article-, and (2) the relative innovation investment effort, hereafter relative effort, that the SMEs are achieving considering their individual contexts.

We define the relative effort as the firm's investment in innovation above what may be expected due to its internal and external characteristics, including the crisis context. A crisis period requires action in a turbulent short time frame, during which SMEs can be committed to innovation or be more cost-oriented (Beliaeva et al., 2020; Martin-Rios and Pasamar, 2018). Even companies, which reduce their investment (pro-cycle), may be rather making a relative effort to invest that shows their commitment to innovation. This relative effort can contribute to the increase in the innovation output via appropriation of innovation opportunities in the market, a lower opportunity cost of innovation, and more efficient use of resources (Dejardin et al., 2022; Khurana et al., 2022). The innovation strategy accounts for a significant share of SMEs' strategic actions (OECD, 2021b; Schmitt et al., 2016). As such, their failure to develop a proper IIS can drastically reduce economic resilience during periods of economic uncertainty.

Thus, this study examines the effect of SMEs' IIS on product innovation output during economic crisis analysing not only the level but also the relative effort made: What is the effect of relative effort and innovation investment level on product innovation output? Is the relative effort significant for product innovation output at any level of innovation investment?

To test our hypotheses, we used a panel of Spanish firms from 2005–2013. Spain entered a recession in late 2008 due to a lack of liquidity, rising defaults and debt that caused a bank bailout, a 25.5% unemployment rate at the end of 2013, and a GDP contraction from 2008 to 2013.[1] This period includes years of both growth and recession, which allows us to compare the effects of the IIS. We estimated a sequential model, generally called CDM model (Crepon et al., 1998) This kind of model lets us build the relative effort variable, capture the endogeneity of innovation, and control the feedback effect between innovation and its outcomes (Lööf et al., 2017).

The results show that the relationship between innovation investment and product innovation output remains positive and is stronger during crisis. Furthermore, once a minimum level of investment has been achieved, the relative effort can also increase product innovation output, with a slightly stronger positive effect during crisis The value of innovation investment level at which the relative effort becomes significant is around 660 and 400 euros per employee and year for the pre-crisis and crisis periods, respectively. This implies that the minimum investment required to make relative effort significant is approximately 94% of the average innovation investment value in the sample for the pre-crisis period and 109% for the crisis period.

Our study makes significant contributions and opens a promising avenue of research for understanding the performance of IIS over the business cycle. First, by proposing and measuring the SME's relative effort, we offer more accurate evidence of the IIS during crises. During a crisis, higher positive values of relative effort represent a higher commitment to innovation. As far as we know, no previous articles have accounted for the relative effort and have analysed its effect on innovation output. This new approach reconciles the literature in which, on the one hand, innovation investment can overcome the economic crisis (e.g. Exposito and Sanchis-Llopis, 2018; Peters et al., 2014; Spescha and Woerter, 2019), and on the other hand, the evidence shows a significant drop in innovation investment during the crises (Wen et al., 2023).

Second, our study extends the business cycle literature at the firm level, focusing on the outputs of IIS during a period of economic crisis. Studies have mainly focused on understanding the reasons for a largely pro-cyclical innovation investment (see Roper and Turner, 2020). However, less attention has been dedicated to the impact of IIS on SMEs' product innovation output during a crisis (Exposito and Sanchis-Llopis, 2018; Giotopoulos et al., 2022; Spescha and Woerter, 2019).

Finally, this article finds that a minimum level of investment in innovation is needed to make relative efforts effective. The insights arising from our study, therefore, contribute to the design and implementation of policy instruments that can enhance the efficiency of SMEs' innovation investment.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature and sets out the hypotheses. Section 3 describes the data and methodological procedure. The results are presented in Section 4. We finish with the discussion and conclusions of the research in Section 6.

2. Background framework

Our analysis combines two streams of literature. The first refers to the research on innovation investment at the firm level. There is consistent theoretical and empirical support that innovation investment is a necessary condition to generate innovation outputs (Hashi and Stojčić, 2013; Ramadani et al., 2019). Innovation output in this article means introducing new or significantly improved goods and services. The introduction of product innovations generally requires new processes, including new or improved methods of organisation and distribution, for the company or market (Mohnen and Hall, 2013; OECD/Eurostat, 2005, 2018). The underlying idea of this definition is that only the innovations implemented successfully can enhance the firm's performance and growth. Empirical evidence shows that innovation output is also a determining factor for the growth in firm sales, employment, and productivity (e.g. Audretsch

[1] Source for Spanish GDP: AMECO database

et al., 2014; Hall et al., 2016; Nathan & Rosso, 2022); however, the evidence is less conclusive when we only examine SMEs (Exposito and Sanchis-llopis, 2018).

Crucially, the impact of innovation investment in outputs innovation in SMEs may be moderated by contextual factors, both internal and external to the firm (Lichtenthaler, 2016). The relationship between innovation investment and its outcomes is usually tested in the background of macroeconomic expansion (Antonelli et al., 2013). During a period of crisis, the challenges to innovate and gather benefits from them are likely amplified given demand uncertainty, revenues decline, financial constraints, and less organisation slack (Amore, 2015; García-Carbonell et al., 2021).

Thus, the second stream of literature is how innovation investment performs in front of a crisis. The debate is generally discussed from a business cycle perspective, in which firms can follow a pro- or counter-cyclical IIS (Barlevy, 2007; Cincera et al., 2012). Many of these studies conclude that the pro-cyclical innovation investment rises as a mixture of the financial constraints suffered during a crisis period and a strategic decision based on the opportunities cost (Arvanitis and Woerter, 2014; Cefis et al., 2020; Cincera et al., 2012; Kabukcuoglu, 2019).

The debate on the potential returns from SMEs' IIS is unclear. Few studies have analysed the consequences of adopting different types of IIS in a context of crisis. Spescha and Woerter (2019) find that firms, including SMEs, with innovations based on R&D activities show higher sales growth rates than non-innovative firms in periods of crises. (Peters et al., 2014) suggest that product innovation was a critical factor for increasing employment by German SMEs during the 2008 crisis. However, Jung et al. (2018), focusing on the SME survival rate, conclude that only those SMEs capable of producing intellectual properties during the crisis increase their probability of survival. Exposito and Sanchis-llopis (2018) find that implementing product innovation, measured by a binary variable, impacts sales increases whereas other types of innovations increase the probability of organisational cost reduction. Finally, Giotopoulos et al. (2022) use a sample of Greek firms and find that innovation investment, measured by in-house R&D, positively affects innovation outputs only in medium and large firms during a period of crisis.

Our article delves into the strategic aspect of the IIS. Specifically, to get a complete picture of the SMEs' IIS and reconcile the previous literature, we should consider not only innovation investment but also the relative effort considering SMEs' internal and external characteristics. We further discuss the effect of relative effort at different level of innovation investment. This can bring significant new knowledge to develop a proper IIS for SMEs. We set out the hypotheses about the effects of investment on product innovation output and then focus on the effects of the relative effort. The next subsections describe the theoretical underpinnings supporting our hypotheses.

2.1. Impact of innovation investment on product innovation output

In most cases, the pursuit of innovation requires investments in a broad range of activities, such as R&D, training, software development, new internal organisation, market research, or relationships with external parties. Innovation investment allows SMEs' to define focused objectives, obtain access to sources of information, cooperation, partnerships, and public support, which can promote their capabilities (Laursen and Salter, 2006; Zouaghi et al., 2018).

Innovation investments can help firms develop a competitive advantage by increasing their knowledge base, keeping relevant human capital, and improving their learning capabilities (Zahra and George, 2002). The learning orientation and capabilities enhance SMEs' absorptive capacity, which means recognising the strategic value of new knowledge, and assimilating and exploiting it into new products, which can also be termed as entrepreneurial or sensing capacity (Cruz-Ros et al., 2021; Emre Yildiz et al., 2021; Murovec and Prodan, 2009). The entrepreneurial capacity brings opportunity recognition and rational intuition, which are key factors for innovation success during crises (Devece et al., 2016; García-Carbonell et al., 2021). Beliaeva et al. (2020) relate the firms' ability to identify opportunities during crises to an entrepreneurial orientation based on innovation which results in greater performance. Khurana et al. (2022) conclude that entrepreneurs intentionally shift their decision-making logic and provide opportunities for significant learning during crises. The authors find that SMEs which focus on incremental innovations reduce the probability of being constrained by their current knowledge and obtain more profitable economic opportunities. Similarly, Ferreras-Méndez et al. (2021) use a sample of Spanish SMEs and find that entrepreneurial orientation contributes to product innovation performance. Finally, Zouaghi et al. (2018) find that innovation outputs increase as higher R&D human capital increases by enhancing the internal capabilities of Spanish firms during the financial crisis.

From an evolutionary perspective theory, the absorptive capacity built by innovation investments reinforces the firm's dynamic capabilities, defined as '*the capacity of the company to integrate, build, and reconfigure internal and external expertise to face contexts that change rapidly*' (Klofsten et al., 2021; Teece et al., 2001). Dynamic capabilities allow firms to reform organisational and operational routines, implement new strategies, and facilitate adaptation that realigns resource configuration under uncertainty, such as during economic crises (Dejardin et al., 2022; Devece et al., 2016). Ferreira et al. (2020) note that the SME's dynamic capabilities generate competitive advantages and influence its overall performance indirectly via innovation. The SME's entrepreneurial orientation also produces superior efficiency of innovation investment. Clampit et al. (2021) conclude that SMEs took greater advantage of their dynamic capabilities than large firms during the COVID-19 crisis due to the former's flexible structures. Similarly, Dias et al. (2021) find that SMEs are more focused on using their resources and capabilities during a crisis, suggesting that they more effectively invest in innovation.

During a crisis, SMEs must increase the efficiency of resources. Innovation investment enhances tangible and intangible asset efficiency, promoting technological change and faster speed of innovations to market (Dejardin et al., 2022; Hervas-Oliver et al., 2014). Hence, higher innovation investment may generate greater innovation outputs during a crisis. Based on this discussion, we propose our first hypothesis as follows:

H1. : During a period of economic crisis, the higher the innovation investment, the greater the product innovation outputs. This effect is more pronounced than that in the pre-crisis period.

2.2. Impact of relative effort on product innovation output

The literature on strategic decision-making identifies that the innovation strategy forms a significant share of an SME's strategic actions (Schmitt et al., 2016). From an opportunity cost perspective, introducing a new product, service, or business process can cannibalise the returns from old ones (Harrison et al., 2014). Yet, the opportunity cost of a higher relative effort in innovations may be lower in crises since the expected profit from old products and processes declines. Barlevy (2007) and Cincera et al. (2012) argue that opportunity costs can cause firms' innovation investment to be counter-cyclical. Similarly, Arvanitis and Woerter (2014) describe some factors that may influence a firm's counter-cyclical investment behaviour, such as the share of R&D expenditure, firm characteristics, price competition, sector, and cooperation relationships.

From the perspective of supply, the crises may offer new business opportunities. SMEs that have higher relative effort seek to take advantage of the potential opportunities via innovation that competitors following a more aggressive cost-oriented IIS may leave in periods of crisis (Brockner and James, 2008). During a crisis, when consumers' disposable income is lower, their preferences can vary as well, such as focusing on covering basic needs at the lowest possible price. This can affect the sales of innovative products, which usually have a higher manufacturing cost during the introduction stage of the product cycle. However, using macroeconomic US consumer goods sector data and a sample of Swiss firms, Argente et al. (2018) and Spescha and Woerter (2018), respectively, conclude that the demand for innovative products during the last economic crisis exhibited no significant decline. These authors suggest that the decline in new products in the markets was due to a reduction in firms' innovation investment.

Further, when an SME does not have a clear commitment to innovation following a cut-oriented innovation strategy, new knowledge may not be enough to radically challenge the existing knowledge base and the technology driving sales (Choi & Williams, 2014). The new knowledge generated may not be sufficient to sustain the introduction period and success of innovations during a crisis. The efficiency of the innovation investment can be smaller than when the SME undertakes a higher relative effort on innovation. Thus, using the opportunity cost approach, we propose our second hypothesis as follows:

H2. *: During a period of economic crisis, the higher the relative effort, the greater the product innovation outputs. This effect is more pronounced than that in the pre-crisis period.*

Notably, the performance of relative effort may depend as well on the level of innovation investment. The relative effort requires the effective use of knowledge and technology. As highlighted in Section 2.1, greater innovation investment can bring greater innovation efficiency by: (1) fostering the development of dynamic capabilities (Hervas-Oliver et al., 2014) and (2) facilitating intrapreneurship (Klofsten et al., 2021). Intrapreneurship refers to an organisation's ability to react quickly and innovatively by making effective use of its stock of knowledge and resources for innovation. Greater dynamic capabilities boost the identification of market opportunities and assimilation of knowledge, which results in more favourable innovation trajectories.

Further, greater innovation levels are generally associated with superior persistence and experience in innovation (Antonioli and Montresor, 2021). Amore (2015) describes that companies with experience in innovation during previous economic crises obtain a greater innovation output in new crises. Bianchini and Pellegrino (2019) and Deschryvere (2014) uncover that the positive effects of persistence in product innovation outputs are particularly pronounced in SMEs. Thus, during a period of crisis, the relative effort performance can be higher as higher the innovation investment level, as experience, dynamic capabilities and intrapreneurship generate competitive advantages, expedited adaptation, and identification of innovative opportunities within the market.

Finally, from the intrinsic value perspective, innovation, especially R&D, implies incurring irreversible investments, or sunk costs (Falco and Renzi, 2015). During a period of crisis, the losses entailed by interrupting innovation investments can be higher than the potential losses of continuing them (Antonioli and Montresor, 2021). Thus, SMEs with high innovation investment may incur extra efficiencies of tangible or intangible assets, thereby increasing the efficiency of relative effort. Based on this discussion, we propose our third hypothesis as follows:

H3. *: During a period of economic crisis, the higher the innovation investment, the greater the performance of relative effort on product innovation outputs. This effect is more pronounced than that in the pre-crisis period.*

Fig. 1 summarises the conceptual framework of the IIS considering the innovation investment, relative effort, and product innovation output.

3. Methodology

3.1. Data

Data are extracted from the Spanish Technological Innovation Panel (PITEC), which is a survey to study the innovation activity of Spanish firms over time. PITEC includes a panel of innovative and non-innovative firms since 2003. This means that the same firms are

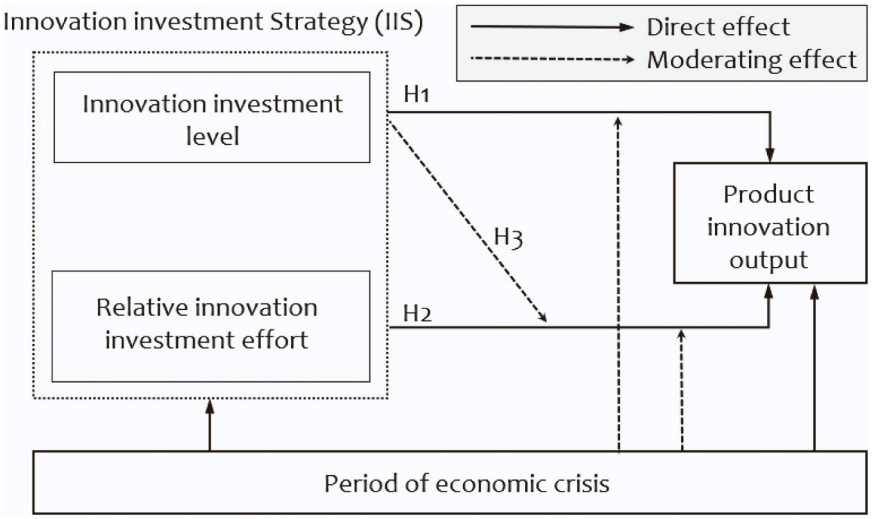

Fig. 1. Research model.

surveyed over the years. It follows the guidelines in the Oslo (OECD/Eurostat, 2005) and Frascati Manuals (OECD, 2015). PITEC is carried out by the Spanish National Statistics Institute (INE) in collaboration with FECYT and Cotec.[2] These panel data allow us to capture SMEs' IIS and solve some of the limitations of prior research based on cross-sectional data. From 2003–2005, PITEC was expanded with new firms and significant changes in the questionnaire. In 2014, to reduce the burden on the informant, a non-random rotation of companies was established in PITEC. These companies are left unexplored for two years. Therefore, we have not included post-crisis years in our analysis and only focused on firm information for the period 2005–2013 corresponding to the pre-economic crisis and crisis periods. The year 2013 was the last year of the Spanish economic recession until the COVID-19 pandemic struck in 2020. The same database and period has been used in recent articles (e.g. Bernal et al., 2022).

In the pre-crisis period, the annual Spanish GDP growth rate was 3.5%. The financial crisis began in 2008, reducing the GDP from a growth of 1.02% in the first quarter of the year to a decline of 1.73% in the first quarter of the following year. Although annual economic growth remained constant (0.2%) in 2010, it started declining again in 2011 until the end of 2013, with an annual GDP growth rate of −1.7%.

SMEs are defined as firms with less than 250 employees and less than 50 million euros on sales. This definition follows the European Union (EU) recommendation in the Official Journal 2003/361.[3] The initial sample contains 9995 SMEs (71,814 observations) with at least information for one year. We eliminated observations that report some kind of incident in the employment or sales variables and those with an obvious anomaly variable for a particular year (such as null or below to 10,000 € sales).[4] Since our models use lagged variables and variables constructed with information from previous years, some observations cannot be used in the regression model. However, we did not drop outliers' observations that had been winsorised to avoid estimation bias. The final sample consisted of an unbalanced panel of 9830 SMEs (68,080 observations) from all sectors.

3.2. *Methodological approach and estimation strategy*

To analyse the impact of the innovation strategy and investment level on innovation output during the crisis, we use a structural model called CDM (Crepon et al., 1998). The CDM model has been widely used in the literature on innovation and performance. It is considered one of the most influential contributions in recent literature on the economics of innovation (Lööf et al., 2017). The model consists of four causality stages: the decision of firms to innovate; their decision about the amount of innovation investment; the product innovation output; and the impact of product innovation output on firm growth. We utilise a refined version of the CDM suggested by Lööf and Heshmati (2002, 2006), correcting for simultaneity and selectivity biases (Hashi & Stojčić, 2013). Simultaneity bias arises because some factors influence the firm's decision to innovate, how much to invest, and its final performance. Selectivity bias arises from the fact that not all firms are engaged in innovation and some innovations are not successful. This sequential structural model approach includes the predicted value of one endogenous variable that enters the estimation of the next equation. The first two stages let us capture the IIS and control for its endogeneity. Stage three is used to validate our hypotheses, and stage four controls the

[2] FECYT: Spanish Foundation for Science and Technology. Cotec: Spanish Foundation for innovation.

[3] http://data.europa.eu/eli/reco/2003/361/oj

[4] Incidents reported: Problems of confidentiality and access, sales or employee variation due to takeovers, mergers, company split, temporary shutdown, bankruptcy, and company belonging to a sector of very high temporality.

feedback effect between innovation output and firm growth (Lööf and Heshmati, 2002, 2006).[5]

Let i = 1, …, N index firms, and t = 1, …, 9 index years from 2005 to 2013. The first equation accounts for the SME decision to innovate in period *t* to *t-2*; the second equation accounts for the average SME innovation investment in period *t* to *t-2*. $d^*_{i(t;t-2)}$ and $g^*_{i(t;t-2)}$ are two unobserved (latent) variables of the decision to innovate and the firm's investment in innovation, respectively:

$$d_{i(t;t-2)} = \beta_0 x_{0i(t;t-2)} + u_{0i(t;t-2)} \tag{1}$$

$d_{i(t;t-2)} = 1$ if $d^*_{i(t;t-2)} > 0$, otherwise $d_{i(t;t-2)} = 0$

Further,

$$g_{i(t;t-2)} \Big| \quad d_{i(t;t-2)} = \beta_1 x_{1i(t;t-2)} + u_{1i(t;t-2)} \tag{2}$$

$g_{i(t;t-2)} = g^*_{i(t;t-2)}$ if $g^*_{i(t;t-2)} > 0$, otherwise $g_{i(t;t-2)} = 0$

where $d_{i(t;t-2)}$ is an observable variable of SMEs' decision to innovate in *t* to *t-2* and $g_{i(t;t-2)}$ is the observable average firm investment in innovation in period *t* to *t-2*. Then, x_{0it} and x_{1it} are the vectors including the independent variables for Eqs. (1) and (2), respectively, and β_0 and β_1 are their corresponding parameters. u_{0it} and u_{1it} are random error terms with zero mean and constant variances, and are not correlated with the explanatory variables.

To disentangle whether the SME is making a relative innovation investment effort, we estimate the differences between the observed values $g_{i(t;t-2)}$ and predicted values (latent variable) of innovation investment $g^*_{i(t;t-2)} > 0$ defined in Eq. (2). Mathematically:

$$R_{i(t;t-2)} = g_{i(t;t-2)} - g^*_{i(t;t-2)} \tag{3}$$

Positive outcomes of $R_{i(t;t-2)}$ mean that the observed investment in innovation is higher than the predicted one considering the SME characteristics and the environment, whereas negative outcomes imply the opposite. Note that $g^*_{i(t;t-2)}$ and $R_{i(t;t-2)}$ capture different innovation investment dimensions. The former measures the innovation investment level after correcting the endogeneity of the innovation investment and represents the expected investment. The latter ($R_{i(t;t-2)}$) captures the over or under investment made compared with the expected investment. It lets us detect the SME's additional effort on innovation. This variable captures an additional strategic dimension. During a crisis, higher positive values represent a higher commitment to innovation whereas negative values indicate a cost-oriented IIS. Thus, $R_{i(t;t-2)}$ draws an additional dimension of the IIS.

To test our hypotheses, we isolate the positive values of $R_{i(t;t-2)}$ in the crisis and pre-crisis periods by creating two variables:

$$RE^{crisis}_{i(t;t-2)} = \begin{cases} R_{i(t;t-2)}, \& R_{i(t;t-2)} > 0 \text{in years of crisis} \\ 0, \& \text{ otherwise} \end{cases} \tag{4}$$

$$RE^{pre-crisis}_{i(t;t-2)} = \begin{cases} R_{i(t;t-2)}, \& R_{i(t;t-2)} > 0 \text{in years of pre} - \text{crisis} \\ 0, \& \text{ otherwise} \end{cases} \tag{5}$$

$RE^{crisis}_{i(t;t-2)}$ and $RE^{pre-crisis}_{i(t;t-2)}$ are the relative efforts in the crisis and pre-crisis periods, respectively. RE captures the additional investment to the expected investment. Higher values of RE exhibit the SME's higher commitment to innovation since the investment is higher than that expected by its circumstances. Thus, one of the advantages of RE is that it can capture the intensity of the relative effort.

The third stage is the production of product innovation function (innovation output), presented as follows:

$$k_{it} = a_g g^*_{i(t;t-2)} + a_{s1} RE^{crisis}_{i(t;t-2)} + a_{s2} RE^{pre-crisis}_{i(t;t-2)} + \beta_1 x_{2it} + u_{2it} \tag{6}$$

where k_{it} represents the observed level of product innovation output of SMEs in year t. $g^*_{i(t;t-2)}$ is the predicted values of innovation investment from Eq. (2). $RE^{crisis}_{i(t;t-2)}$ and $RE^{pre-crisis}_{i(t;t-2)}$ are as defined before. x_{2it} is the vector of other explanatory variables that includes, among others, the SME growth from the fourth stage to control for the feedback effect; the inverse Mill's ratios estimates from Eq. (1); and an auxiliary regression to control for selection bias correcting for the fact that SMEs can innovate with goals far from the introduction of new products for the market or company (see Table S2 in the Online Resource for more details) (Clauss et al., 2022; Hashi & Stojčić, 2013). Finally, a_g, a_{s1}, a_{s2}, and β_2 are the vectors of the coefficients of the explanatory variables, while u_{2it} is the random error term with mean zero and constant variance not correlated with explanatory variables (Griffith et al., 2006). To test hypothesis H3 we also include the interaction between our variables of interest; $g^*_{i(t;t-2)}$, $RE^{crisis}_{i(t;t-2)}$, and $RE^{pre-crisis}_{i(t;t-2)}$. The interaction provides information about the effect of the combination of the level of innovation investment and relative effort in pre-crisis and crisis periods.

Finally, the last equation of the model relates product innovation output to SMEs' growth. This equation is used to control the potential bidirectional relationship of product innovation output on a firm's growth and vice versa. We use a log-transformed Cobb–Douglas production function as follows:

$$q_{it} = \alpha \widehat{k}_{it} + \beta_3 x_{3it} + u_{3it} \tag{7}$$

[5] Extensive empirical evidence suggests that better firm performance creates new opportunities for innovations and that innovations stimulate firm performance. This effect of 'success brings success' is usually called the feedback effect (e.g., Galindo & Méndez, 2014).

with q_{it} as the dependent variable indicating the SME's growth rate in year t measured by an index variable; $\widehat{k}_{it}$ representing estimates of product innovation output from Eq. (4), where α is the elasticity of growth to changes in innovation output; x_{3it} is a vector of the independent variables; β_3 represents the corresponding unknown parameters; and u_{3it} is the error term, which is assumed to be uncorrelated with explanatory variables.

3.3. Econometric technique

The first two stages (Eqs. (1) and (2)) are estimated jointly through a double hurdle model (Cragg, 1971) in which observations on both innovative and non-innovative SMEs are included. The first and second hurdles correspond to factors affecting innovation participation and the innovation investment level decision, respectively. A different latent variable is used to model each decision process. Using a double hurdle model helps us overcome the limitation in Tobit and Heckman's model for calculating the probability of the positive (first stage) and actual values, given that it is positive (second stage) in different underlying processes; that is, different parameters (Burke, 2009). This model is closer to the firms' reality, where some firms do not want to innovate, while others do not have enough resources and capabilities to do so. The decision to innovate (participation) and how much to invest may also be related. Thus, we included the inverse Mills ratio from the first equation as explanatory term for the second equation (Burke, 2009).

The third and fourth stages are estimated as a system of equations using a generalised method of moments (GMM) three-stage least squares (3SLS) estimator as described in Wooldridge (2010). A GMM-3SLS estimator is asymptotically efficient and consistent under heteroscedasticity, being the optimal estimator. Using the system of equations with GMM, we can overcome the potential source of endogeneity of innovation input and the firm's growth in Eq. (6), and innovation output and firm's growth in Eq. (7), generally called the feedback effect. Furthermore, the innovation output variable is limited only to strictly positive values in the third stage, potentially yielding biased results for selectivity issues. To solve this problem, the two inverse Mills are inserted in the innovation output equation (Eq. (6)): one from Eq. (1) and another from an auxiliary regression correcting for the fact that SMEs can innovate with goals far from the introduction of new products for the market or company (Hashi & Stojčić, 2013).

3.4. Variables

3.4.1. Dependent variables

In our four-stage model, we have four different dependent variables. The first two stages capture the decision and investment in innovation. The third and fourth stages capture product innovation output and firm growth, respectively.

3.4.1.1. Decision to innovate. A firm's decision to innovate, the dependent variable in Eq. (1), is considered as long as it reported a positive value for innovation investment in period t to t-2. We use the full definition of innovation, including R&D investment, and investment in machinery, equipment, software, patents, know-how, and training of staff for innovation activities defined in the Oslo Manual (2005, 2018).

3.4.1.2. Innovation investment. As explained in Section 3.2, innovation investment level (input) is a dependent variable in the second stage, but also an explanatory variable of interest in the third stage. It is defined as the natural logarithm of the average amount invested per year in period t to t-2 on innovations divided by the average number of employees for the same period.[6] Since sales were quite volatile during the crisis due to exogenous shocks, which can distort the value of innovation investment level, we use the average number of SME employees. Imputing the value of three years reduces the distortions that occurred in the years of crisis and represents a huge advantage over previous research. One of the limitations of analysis based on CIS databases, or other cross-sectional data, is that it can only allocate the innovation investment of year *t*. However, just as the innovation roadmap takes place over several years, innovation investment is generally imputed over more than one period.

3.4.1.3. Product innovation output. In Eq. (6), innovation output is measured by the natural logarithm of the share of sales of new products and services (new to a firm and to the firm's market) of the SME. The Oslo Manual (2005, 2018), which is in line with our database year's period, indicates 'new' as an entirely new or substantially improved product or service. Thus, it is the logarithm of the percentage of total sales in year *t* due to products or services launched in period *t* to *t-2*. The sale of new products is considered the most robust measure since the introduction of new products or services includes the entire process of innovation and allows quantification of the commercial success of innovation (Mohnen and Hall, 2013).

3.4.1.4. Firm growth. Finally, we define the dependent variable of the fourth stage in Eq. (7) as firm growth measured through turnover variation. Since this variable is in logarithm, we built an index variable with a base number in 2005. The firm growth variable is frequently used in innovation-performance analysis mainly due to the anonymisation that innovation surveys have, excluding accounting variables and the company name, as in our database (Audretsch et al., 2014).

Table 1 presents descriptive statistics for the dependent variables. The percentage of SMEs with innovation investment in the

[6] Some authors define the innovation investment divided by any company size measure as innovation intensity or innovation investment intensity. However, we use the term innovation investment for simplicity.

Table 1
Descriptive statistics of the dependent variables during the period 2005–2013.

	Pre-crisis				Crisis				
	2005	2006	2007	2008	2009	2010	2011	2012	2013
Percentage of SMEs with innovation investment									
	88.01	86.22	82.33	77.28	73.32	69.77	66.45	62.74	59.35
Average and standard deviation innovation investment per employee (in logarithm) of the innovative SMEs									
Mean	8.05	8.14	8.15	7.99	7.41	7.15	7.45	7.25	7.16
Standard deviation	2.15	1.95	2.01	2.07	2.97	3.21	2.89	3.08	3.14
Percentage of SMEs with product innovation activities									
	55.16	54.30	52.15	53.63	55.58	56.31	44.12	39.38	37.71
Average percentage of SMEs' turnover in year t coming from goods or services that were new to the market or enterprise (from SMEs that report product innovation activities)									
	41.56	42.31	42.92	44.80	42.97	42.77	42.52	40.59	39.66
Index of sales growth (year 2005=100)									
Mean	100	121.80	138.28	142.30	125.27	128.03	134.10	127.45	126.90
Median	100	106.57	115.49	112.76	95.55	96.42	97.94	91.06	88.16

N = 9830 SMEs (68,080 observations)

sample decreased over the period from 88.01 to 59.35. A similar pattern is observed for the percentage of SMEs with product innovation activities implemented.[7] These statistics are similar to previous studies in which the number of innovative firms decreases during a period of crisis (e.g. Archibugi et al., 2013b). The average innovation investment per employee (in logarithm) decreased slightly during the period of crisis but the standard deviation increased, indicating possible strategic behaviours by firms. Similarly, the average percentage of SME turnover from product innovations is approximately 42%, with a significant decrease in the last year of the period of crisis. Finally, the mean (median) of the index of sales growth decreased from 142.30 (112.76) during the crisis to 126.90 (88.16) in the year 2013.

3.4.2. Explanatory variables

Apart from innovation investment level described in Section 3.4.1., the relative effort (RE) is captured by two variables. RE crisis ($RE^{crisis}_{i(t;t-2)}$) is the relative effort in the period of crisis measured as the positive values of the difference between the observed and predicted values of innovation investment (in logarithm). RE pre-crisis ($RE^{pre-crisis}_{i(t;t-2)}$) is the relative effort in the period of pre-crisis measured as the positive values of the difference between the observed and predicted values of innovation investment (in logarithms). As outlined in Section 3.2, we are examining the positive values of RE crisis and pre-crisis, while setting the negative values to zero to mitigate the risk of selection bias. However, one of the advantages of RE pre-crisis and RE crisis is that they can capture the intensity of the relative effort.

Table 2 compares the percentage of SME's turnover in year t coming from goods or services that were new to the market or firm (from SMEs that report product innovation activities). The T-Test confirms that there are differences between SMEs with and without RE. However, when we inspect the predicted innovation investment during the period, we find only a minimum difference from 8.33 in SME's with RE to 8.41 in SME's without RE.

3.4.3. Control variables

We further control for a set of variables that may influence the dependent variable of the fourth stage and have been identified in the literature (e.g. González-Bravo et al., 2021). A complete definition of the control variables is provided in the Online Resource (Table S1). The exogenous variables of Eq. (1) only included variables available for the whole sample (innovative and non-innovative SMEs) to avoid spurious correlations. In the explanatory variables of Eq. (2) we also included variables that may affect investment in innovation. Thus, we covered variables frequently identified in the literature as determinants of a firm's innovation and investment decisions.

The control variables can be divided into firm and market characteristics. Firm characteristics include the size of the SME, measured by the logarithm of the number of employees; two binary variables which equal one if the SME is the parent or subsidiary; and a binary variable if the SME is private with foreign participation. These variables capture external and internal support. We also include the SME age (in logarithm) to capture other internal entrepreneur capabilities. These include a proxy of the market pressure through a categorical variable of the SME's degree of internationalisation (abroad EU border) in the year t-2; a proxy of the SME's investment capacity measured by the logarithm of the firm's average gross investment on tangible assets in the period t to t-2 (GITA); a dummy if the SME is established in a technological park; and a dummy variable if the SME was able to introduce a successful innovation previously (t-3) to capture previous experience. Concerning the market characteristics, we include factors which can hamper innovation (cost, knowledge, and market), which may deter the firm from investing; Spanish representative sector dummies; and finally, a dummy variable of the economic crisis period starting in 2009 (in late 2008).

For the control variables of Eq. (2), we include variables that may affect investment in innovation as dummy variables identifying highly important sources of information about innovation (internal, market, and institutional sources); the proportion of investment in

[7] Note that product innovation activities mean product innovative activities implemented in the period t to t-2.

Table 2
Comparison of means of the percentage of SMEs' turnover in year t coming from goods or services that were new to the market or enterprise with and without relative effort.

Year	Relative effort	No relative effort	T-Test
2006	44.79	40.48	-3.53***
2007	44.75	39.72	-4.05***
2008	46.55	42.80	-3.00***
2009	45.60	40.27	-4.46***
2010	43.87	40.87	-2.45**
2011	44.93	39.64	-3.68***
2012	42.04	37.67	-2.84***
2013	43.12	35.09	-5.00***

Note: Results from SMEs that report product innovation activities. T-student reported in Mean T-Test. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 3
Results of the probability of investing in innovation [Stage 1, Eq. (1)] and the innovation investment determinants [Stage 2, Eq. (2)].

	Dependent variable:	Innovation decision		Innovation investment	
		Coefficient	Robust errors	Coefficient	Robust errors
Factors hampering innovation					
	Cost[a]	0.313***	(0.019)	-0.035*	(0.019)
	Knowledge[a]	0.042*	(0.024)	-0.025	(0.022)
	Market[a]	-0.237***	(0.018)	-0.072***	(0.018)
Firm characteristics					
	Firm size[b] (ln)	0.036***	(0.011)	-0.554***	(0.012)
	Firm age[b]	-0.116***	(0.020)	-0.133**	(0.020)
	GITA[b] (ln)	0.064***	(0.002)	0.028***	(0.002)
Type of company					
	PRIV[a]	-0.059	(0.039)	0.088**	(0.039)
	Parent[a]	0.177***	(0.046)	0.261***	(0.043)
	Subsidiary[a]	-0.037	(0.030)	0.237***	(0.030)
Firm environment					
	Tech. park[a]	0.553***	(0.066)	0.396***	(0.043)
	Export. t-2[a]	0.011***	(0.001)	0.087***	(0.012)
	Crisis[a]	-0.509***	(0.017)	0.047***	(0.016)
Previous experiences in innovation					
	Inno. in t-3[a]	1.064***	(0.022)		
Type of innovation					
	Intramural R&D[d]			0.007***	(0.000)
	Extramural R&D[a]			0.586***	(0.020)
Highly important sources of information about innovation					
	Internal[a]			0.339***	(0.018)
	Market[a]			0.191***	(0.018)
	Institutional[a]			0.085***	(0.025)
Cooperation with					
	Abroad Institutions[a]			0.325***	(0.031)
	Public Institutions[a]			0.149***	(0.023)
	Competitors[a]			0.209***	(0.030)
Access to subsidies					
	Public funds[a]			0.690***	(0.019)
	IMR.1			-0.957***	(0.141)
	Constant[b]	-0.101*	(0.061)	9.262***	(0.085)
Sector		Included		Included	
Observations		63,649		63,649	
Number of firms		8877		8877	
log pseudolikelihood		-102,106		-102,106	
Wald chi2 (21)		7201***		7201***	

Note:
[c]ordered categorical variable; d: continuous variable. GITA: Gross investment in tangible assets; PRIV: Private with foreign participation, IMR.1: Inverse Mills ratio. Cluster-robust standard errors in parentheses.
[a] binary variable;
[b] continuous variable in logarithmic form;
*** $p < 0.01$
** $p < 0.05$, and
* $p < 0.1$.

intramural R&D to total innovation investment from t to t-2; a dummy variable if SMEs invest in external R&D; and three dummy variables if SMEs cooperate on innovations with (1) other abroad enterprises or institutions, (2) public institutions and research centres, and (3) competitors and other firms in the same main market segment (coopetition) in periods t to t-2. Finally, we include a dummy if the SME received any public financial support from national or EU institutions, and a dummy variable of the economic crisis period starting in 2009 (in late 2008). We exclude the dummy variable if the firm was able to introduce a successful innovation previously since previous experience is already captured with the hampering innovation variables.

The control variables in Eq. (4) are: a binary variable if the SME was able to introduce a successful innovation previously (in t-3) to

Table 4
Determinants of the innovation output [Stage 3. Eq. (6)].

	Model 1	Model 2	Model 3
Inno. Investment	0.105***	0.088***	0.083***
	(0.016)	(0.018)	(0.019)
RE in crisis	0.162***	0.187***	-0.155
	(0.015)	(0.016)	(0.106)
RE in pre-crisis	0.095***	0.119***	-0.104
	(0.012)	(0.013)	(0.090)
Inno. Inv. x Crisis		0.037***	0.032**
		(0.013)	(0.014)
Inno. Inv. x RE in crisis			0.044***
			(0.013)
Inno. Inv. x RE in pre-crisis			0.029***
			(0.011)
Type of and experience in innovation			
External. R&D	0.001	-0.004	-0.006
	(0.011)	(0.013)	(0.013)
Proc. Inno.	0.077***	0.085***	0.088***
	(0.012)	(0.014)	(0.014)
Inno. in t-3	0.093***	0.119***	0.126***
	(0.030)	(0.034)	(0.034)
Cooperation and public support			
Coop. Abroad inst.	0.018	0.028	0.033
	(0.018)	(0.020)	(0.020)
Coop. Public inst.	-0.018	-0.030*	-0.029*
	(0.013)	(0.015)	(0.016)
Coop. Competitors	0.004	-0.004	-0.002
	(0.018)	(0.021)	(0.021)
Spa. Funds	0.004	0.002	-0.002
	(0.013)	(0.015)	(0.015)
UE funds	-0.022	-0.025	-0.032
	(0.022)	(0.025)	(0.025)
Firm characteristics			
Firm size	-0.059***	-0.074***	-0.069***
	(0.012)	(0.013)	(0.013)
High degree	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)
Tech. Park	0.163***	0.163***	0.169***
	(0.024)	(0.026)	(0.027)
Feedback effect			
Sales growth	0.502***	0.529***	0.517***
	(0.078)	(0.077)	(0.077)
Firm environment			
Crisis	-0.048**	-0.364***	-0.328***
	(0.019)	(0.116)	(0.126)
IMR.1	0.078	0.134**	0.144**
	(0.055)	(0.060)	(0.060)
IMR.2	0.016	-0.023	-0.014
	(0.048)	(0.058)	(0.058)
Constant	-0.139	-0.095	-0.031
	(0.332)	(0.362)	(0.362)
Sector	Included	Included	Included
Observations	28,608	28,608	28,608
F-test	1099.51***	1108.44***	1134.61***
Joint significance of sector dummies[a]	84.08***	82.68***	58.74***
Wald test[b]	19.37***	14.36***	
Wald test (Model 3)[c]			0.82

***p < 0.01, **p < 0.05, and *p < 0.1. See Supplementary Material for a further description of the variables.

[a] Wald test under the null of no joint significance.

[b] Test under the null that the linear expressions of RE crisis and RE pre-crisis are equal. Cluster-robust standard errors in parentheses.

[c] Test under the null that the linear expressions of [Inno. Inv. x RE in crisis] and [Inno. Inv. x RE in pre-crisis] are equal.

capture experience; a dummy if the SME was able to introduce process innovation in the same period (t to t-2); a binary variable if the SME invested in external R&D in the previous year (t-1); three dummies for cooperation with abroad firm or institutions, public institutions, or with competitors, respectively, in the period t to t-2; and two binary variables if the SME received any public financial support from national or EU institutions in the previous year. These variables help us capture the importance of external knowledge. We also include internal SME characteristics such as firm size; a proxy of the SME environment through a dummy if the firm is established in a technological park; the percentage of employees with high education; sector dummies including two if the SME operates in high-tech manufacture or services sector; a dummy for the period of economic crisis; the firm's growth level from the Eq. (5) to capture the feedback effect; and finally, to correct the selectivity bias, we include two inverse Mills ratios as described in the Methodology section.

Finally, Eq. (5) includes variables that may impact SME growth such as firm size (in logarithm); the SME age (in logarithm) to capture other internal capabilities; a proxy of the SME's investment capacity measured by the logarithm of the firm average gross investment on tangible assets in the period t to t-2 (GITA); market internationalisation thought the percentage of overseas sales outside the EU; a dummy variable for being part of a group of enterprises; a dummy variable if the SME is private and with foreign participation to capture external support; sectors dummies; and a dummy for the period of economic crisis starting in 2009.

4. Results

The descriptive statistics are presented in Appendix A. The correlation matrix is presented in Appendix B. The correlation between the relative effort in the pre-crisis and crisis (RE pre-crisis and RE crisis) periods is 0.54. However, the variance inflation factor for the independent variables in an ordinary least squares model is below 3 for all parameters. The estimates from the growth equation [Eq. (7)] are presented in the Online Resource (Tables S5 and S6) since no hypotheses are tested with those but are needed to calculate unbiased coefficients from Eq. (6).

4.1. Determinants of innovation investment

Table 3 presents the results of the double hurdle estimation. The left-hand side reports the probability of investing in innovations from 2005 to 2013. The right-hand side reports the estimation of the innovation investment equation. As explained above, these two stages are used as a necessary instrumentalisation to calculate the relative effort and control for the endogeneity of innovation investment.

Overall, we find that the probability of investing in innovation increases, with some factors hampering innovation, such as the costs of innovation. Hashi and Stojčić (2013) find a similar result. Firms find the factors hampering innovation as an opportunity to differentiate themselves to generate value-added that their competitors find difficult to replicate. The probability of investing increases as the company size and capacity to invest (GITA) increase, which is our proxy for available financial resources. It also increases if the SME is the parent company of a corporate group, is established in a technological park, and has overseas sales (outside the EU) in *t-2*. The link between exports and innovation is frequently found in the literature (Pla-Barber & Alegre, 2007). Similarly, there is consensus that technology parks increase firms' chances to invest in innovation (Albahari et al., 2017). Finally, previous experiences in innovation activities strongly increase the probability of undertaking innovation investment.

As expected, the period of macroeconomic crisis decreases the probability of investing in innovation. Factors that hamper innovation, such as market structure and company age, decrease the probability of undertaking innovation investment. Notably, it is the probability of investing in innovations rather than introducing innovations.

The innovation investment estimation results indicate that the period of economic crisis does increase innovation investment. Notably, SMEs that finally decide to invest in innovation tend to maintain the innovation intensity (innovation investment is divided by firm size). The sources of information about innovation, involvement in R&D, cooperation activities, and access to subsidies also increase innovation investment. One likely explanation is that firms try to keep cooperation agreements to split the risks and reduce uncertainty, especially in a crisis. Furthermore, firms with exposure to the international market (i.e. exports) and foreign participation also increase innovation investment. SMEs belonging to a group (parent or subsidiary) increase innovation investment. A higher capacity to invest (GITA) increases innovation investment. Finally, firms established in a technological park have higher levels of innovation investment.

Meanwhile, firm size and age decrease innovation investment, similar to the findings for non-SMEs (Coad et al., 2016). Finally, the competitive environment and framework of the company represented by the sector are contingent on determining investment in innovation. The inverse Mill ratio coefficient is significant, confirming the necessity of controlling for selectivity bias.

4.2. Innovation output

The third stage includes SMEs that have reported a positive product innovation output. Two inverse Mill's ratios are included to control for potential selectivity bias (Heckman, 1979). One comes from the first equation, and another comes from the auxiliary regression of Eq. (6) (see Online Resource Table S2). The results of the estimation by 3SLS-GMM are presented in Table 4. Three models test the hypotheses. Models 1 and 2 test hypothesis H1 through the interaction between innovation investment and the economic crisis period. These models also include the relative effort in the pre-crisis (RE pre-crisis) and crisis periods (RE crisis). A Wald test, under the null that the linear expressions of RE crisis and RE pre-crisis are equal, examines hypothesis H2. Finally, hypothesis H3 is tested by Model 3, which includes the interaction between innovation investment and the relative effort variables.

The coefficient of innovation investment has a positive and significant relationship with product innovation output in all models. Model 2 displays the effect of innovation investment during the period of crisis. The interaction shows a positive relationship (0.037). Further, the positive coefficient remains in Model 3. Thus, the significant coefficient of innovation investment in Model 1 and the interaction in Model 2 mean that hypothesis H1 is supported.

Models 1 and 2 also show positive coefficients for RE pre-crisis and RE crisis. Thus, one may say that the greater intensity of the relative effort increases the product innovation output. Notably, the Wald test, under the null that the linear expressions of RE crisis and RE pre-crisis are equal, is rejected, suggesting that the performance of the relative effort in the crisis is higher than in a pre-crisis period. Thus, hypothesis H2 is supported.

Model 3 shows a positive coefficient of the interaction between innovation investment, and RE pre-crisis and RE crisis. Thus, the relative effort performance depends on the level of innovation investment. Note that the non-significance of the RE pre-crisis and crisis coefficients in Model 3 indicates that in the absence of innovation investment, the relative effort does not have any impact on innovation output. Nevertheless, the Wald test, under the null hypothesis that the coefficient of [Inno. Inv. x RE in crisis] and [Inno. Inv. x RE in pre-crisis] are equal, is not rejected, suggesting that the slope is mostly the same for pre-crisis and crisis period. In essence, we cannot fully accept our H3 since the positive effect of innovation investment on RE performance remains consistent both pre-crisis and crisis period.

Fig. 2 graphically represents the average marginal effect of RE in pre-crisis and crisis on innovation output at different levels of innovation investment. The bars and dots surrounding the two lines indicate a 95% confidence interval. We find that RE pre-crisis and crisis increase innovation outputs. The marginal effect of RE pre-crisis is significant, at the 95% of confidence level, from a level of 6.5 for the logarithm of the innovation investment. The antilogarithm of 6.5 is equivalent to 665 euros per employee per year on innovation investment. For the crisis period, the value is 6 translates into a value of 403 euros per employee per year on innovation investment. Notably, the average innovation investment within the sample is 6.18 (equivalent to 483 euros per employee per year). When we split the sample in pre-crisis and crisis period the average innovation investment is 6.93 (1022 euros per employee and year) for pre-crisis period and 5.49 for the crisis period (242 euros per employee per year). This means that the minimum level of investment required to make relative effort significant is approximately 94% of the average value of innovation investment in the period of pre-crisis (6.5/6.93); and 109% in the period of crisis (6/5.49).

Amongst the control variables, extramural R&D has no significant effect on product innovation output. Process innovation increases product innovation output. Both types of innovation are related since the introduction of a new product and service usually requires new processes. Furthermore, having previous experience in innovation increases product innovation output.

We do not find any effect of cooperation with other foreign, public, and competitor institutions on innovation output. The last result does not imply that cooperation is not effective for other types of innovation activities (e.g. process or non-technological innovations); rather, it is not effective for the objective of introducing new products or services, which is our innovation output variable. Bernal et al. (2022) find similar results for Spanish firms' collaboration with competitors, suppliers, and customers. The authors conclude that knowledge spillovers can reduce the outputs of collaboration under some scenarios. Serrano-Bedia et al. (2018) also find complementarities between cooperation, and other internal and external sources of knowledge, which might explain our results. Next, Spanish and EU funds do not increase innovation output. One possible explanation is that institutional funds might focus more on remarkably long-term innovation output or other types of innovations.

Analysing SMEs' internal characteristics, the higher sales growth, the higher the innovation output. There is compelling evidence of a feedback effect in which SMEs with higher growth can also obtain higher innovation output, providing support for this kind of effect on SMEs (Galindo & Méndez, 2014). Next, SMEs' size decreases innovation output. This result is sensible since our variable of innovation output captures the share of new products and services on the market, which may be relatively smaller as the firm becomes larger. SMEs with higher percentage of high educated employees have higher product innovation outputs. Further, SMEs in technology parks achieve higher product innovation output. Next, the crisis is also contingent on innovation output, whereas most coefficients

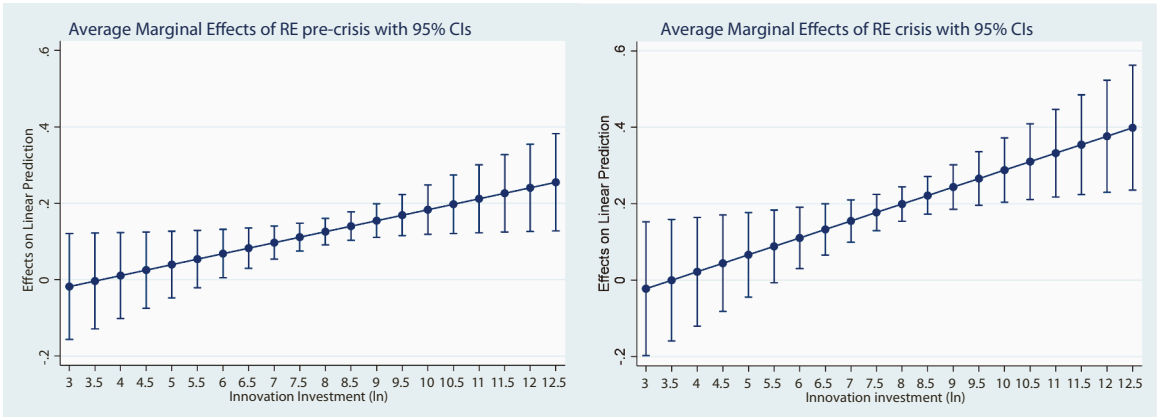

Fig. 2. Marginal effects of relative effort in the pre-crisis and crisis at different levels of innovation investment.

from the SME main sector are also significant; notably, the F-test rejects the null of no joint significance of sector dummies. Finally, the inverse Mill's ratio from the first equation (IMR.1) is not significant in Model 1, but it is significant in Models 2 and 3, suggesting the appropriateness of correcting for selection bias. The inverse Mill's ratio from the auxiliary regression (IMR.2) is not significant.

4.3. Additional analyses

We conduct two analyses reported in the Online Resource. We distinguish between new products to the SME and market as the innovation output variable. New products for SMEs are often used as an indicator of incremental or disruptive innovations, while new products for the market represent more targeted radical innovations. The results from Stages 3 [Eq. (6)] and 4 [Eq. (7)] are presented in Tables S3 and S5 respectively. Second, we inspect the effect of innovation investment and relative effort on innovation output by SME type size: micro, small, and medium (Tables S4 and S6). We do not find significant differences between new to the firm and market products/services. For new products for the SMEs, relative effort has the same positive effect in the crisis and pre-crisis periods. We do find some differences depending on the SME size on hypothesis H3. Specifically, in micro and medium firms the interaction of relative effort and innovation output has no significant effect on product innovation output for the crisis period. The latter finding does not invalidate the main implications discussed in this article, but it indicates that relative effort can increase product innovation output regardless of the level of innovation investment in micro and medium SMEs.

5. Discussion and conclusions

This study extends previous analyses by examining the performance of the SMEs´innovation investment strategy (IIS) including the innovation investment level and relative innovation investment effort -relative effort- in the same model for a period of economic crisis. Using panel data from Spanish SMEs, we shed light on the paradox where theoretical frameworks suggest that innovation should facilitate recovery from periods of crises. Nevertheless, the empirical evidence frequently demonstrates a decrease in innovation investment, especially among SMEs, during most economic crises, including the COVID-19 pandemic.

Concretely, we find that the relationship between innovation investment and product innovation output remains positive during crisis. Moreover, the positive effect is stronger during crisis. This result is in line with previous studies, which have not necessarily focused on SMEs (see Roper et al., 2020).

The measurement of SMEs' relative effort during crisis offers new evidence on the IIS. We find that relative effort is an essential variable to understand the total effect of the IIS on SMEs. Specifically, the relative effort increases product innovation outputs and the effect is stronger during crisis. From a strategic perspective, SMEs following an IIS in crisis pursue new knowledge and learning capabilities to detect market opportunities (Beliaeva et al., 2020; Khurana et al., 2022). Devece et al. (2016) use a sample of Spanish firms and find that innovation-driven entrepreneurship was more effective than necessity-driven entrepreneurship. Similarly, (Dias et al., 2021) and Clampit et al. (2021) find that SMEs were more effective in using their resources and capabilities during a crisis. Finally, Krishnan et al. (2022) conclude that entrepreneurial support via actions and operations minimises the risk of failure, and creates opportunities during a period of crisis. Thus, a relative effort may reinforce the development of new products via innovation-driven entrepreneurship, the assimilation of useful knowledge, and agile product adaptability (Dejardin et al., 2022; García-Carbonell et al., 2021).

However, the positive effect of the relative effort on product innovation is statistically significant when innovation investment reaches approximately 660 euros per employee per year in the pre-crisis and 400 euros per employee per year in the crisis period. These findings indicate the existence of a minimum value of innovation investment to make any relative effort significant. The minimum value represent 94% of the average investment in innovation in our sample for the pre-crisis period, and 109% of the average investment in innovation for the crisis period.

In other words, during crisis, the level of investment in innovation at which any relative effort becomes significant is lower (400 euros per employee per year compared to 660 euros in the pre-crisis period). Nevertheless, this also implies that during crisis, a higher level of innovation investment is required when compared to the average investment for the same period (109% of the average in crisis and 94% in the pre-crisis).

These results have huge implications for SMEs in a period of turbulence. From an evolutionary perspective, SMEs that carry out innovation activities accumulate knowledge, and extract technology and technological trajectories that help them improve innovation performance (Antonioli and Montresor, 2021). However, new knowledge may not be enough to radically challenge the existing knowledge base and the technology driving sales under a low level of investment, resulting in its ineffectiveness (Choi and Williams, 2014). Morgan et al. (2020) conclude that not all SMEs equally benefit when they change their strategies, including the innovation strategy, in crisis. This is because it is harder to exhibit adequate efficiency due to the lack of capabilities and uncertainty. In other words, under low levels of innovation investment, specifically below approximately 400 euros per employee per year or below the average innovation investment in our sample, any relative effort is worthless. In such cases, SMEs should focus on opportunities in their current markets, reconsider innovative projects performance, establish which are the known markets of the SME (Khurana et al., 2022), and avoid making a relative effort.

The difference in the effect of a relative effort at values of innovation investment helps justify the reduction in the number of innovative SMEs (and large firms) as well as the decline in the average investment found during periods of crisis from a strategic perspective (e.g. Kabukcuoglu, 2019; Roper and Turner, 2020). At low levels, innovation investment may be insufficient, and therefore, inefficient for the development of successful product innovations in this kind of turbulent period.

Importantly, innovation investment and outputs depend on other firms and environmental characteristics. The bidirectional

positive relationship between innovation output and firm growth, generally called the *feedback effect*, is particularly relevant. Firm growth may generate extra resources, such as cash or access to better investment conditions, that can provide a competitive edge in crisis by enhancing operating adaptation and sustaining innovations (La Rocca et al., 2019). Previous experience in innovation is another key element for increasing the relative effort and generating innovation outputs. Experience in related projects can reinforce organisational capabilities, learning economies, and the sharing of valuable information, which can reduce the negative impact of the economic crisis on innovation performance (Teece, 2014). Amore (2015) concludes that companies with experience in innovation during previous economic crises obtain a greater yield on their innovation in new crises. Khurana et al. (2022) find that crisis affects the SMEs' decision-making logic and provides opportunities for significant learning. Therefore, SMEs that do not have enough experience with innovations or are involved in innovation on an occasional basis must re-evaluate the performance of their innovations in times of crisis to avoid inefficiencies.

Although it is not the main objective of the article, we find that the greater the product innovation output, the greater the SME growth. Moreover, the positive effect is larger in a period of economic crisis. The results confirm the Schumpeterian growth theories for the particular case of SMEs, suggesting that there is no decline in demand for innovative products in a period of crisis (Argente et al., 2018). From a strategic perspective, this implies that innovation investment led to an entrepreneurial orientation of SMEs. This capacity realigns and regains the balance of the SME, and helps it position itself for longer-term growth (Beliaeva et al., 2020; Lim et al., 2020; Miklian & Hoelscher, 2022)

The results from our analyses provide useful insights to managers and policymakers. First, managers are advised to determine their relative effort in innovation before compromising further investments. To strategically decide on the relative effort to undertake investment, they should know the minimum level of investment that makes this effort profitable analysing the average innovation investment in their markets. For instance, this effort may be too difficult to manage in economic crises, since it may require organisational restructuring and strong attention to identifying business opportunities. This can create investment inefficiencies to the point of being counterproductive to the introduction of innovations. Under insufficient levels of innovation investment – in our sample, below the average innovation investment for the period of crisis-, SMEs should instead focus on opportunities in their current markets and only keep more productive innovative projects. However, managers should understand that innovation investment is a fundamental tool for innovation performance and SME' growth in a period of crisis. SMEs with a structure for innovation based on experience and continued investment may be the ones who can take advantage of relative effort and investment in innovation in times of crisis. Managers should build a proper environment to encourage intrapreneurial and entrepreneurial capabilities within the firm, which may help boost the efficiency of innovation investments and any additional investment effort.

Policymakers should develop policies to avoid the double innovation speed phenomenon, whereby some SMEs should over-invest while others do not. Policies for disseminating technical and informal knowledge, training for innovation of entrepreneurs and workers, or collaboration with institutions may reduce the minimum value of investment in innovation for which the relative effort is significant by SMEs (Audretsch and Belitski, 2020; Mulligan et al., 2022). Patrucco et al. (2022) identify increased use of four types of innovation policy instruments in OECD countries: formal consultations with stakeholders and experts; fellowships, and postgraduate loans and scholarships; networking and collaborative platforms; and dedicated support for research infrastructures. These instruments may be in the right direction to increase the product innovation outputs of SMEs.

This study has some limitations. First, the indicators used to measure some firm characteristics are not neutral for empirical results (Audretsch et al., 2014). We selected the most frequently used dependent and independent variables in this field for comparability and data limitations; the results may differ if other variables are used. Second, the study focused on Spanish SMEs in the period 2005–2013. While our research underscores the imperative of incorporating measures of relative effort to ascertain the performance of the innovation investment strategy, it is important to acknowledge, however, that the outcomes, particularly the point at which relative effort becomes statistically significant, may not be representative of a specific sector, economy, or period. Hervás-Oliver et al. (2021), using a sample in the economic expansion period, find different innovation drivers for SMEs in the EU regions. Future studies can be more specific and updated regarding the points from which the investment in innovation is effective, particularly regarding sectors, sizes in a more recent period. Further, future studies should clarify specific strategic decisions that may increase the efficiency of the IIS investment strategy for SMEs. For instance, SMEs may focus on science and technology-based innovations, or on more technical learning-by-doing, which potentially changes innovation output in a period of crisis (Parrilli & Radicic, 2021). Finally, firm growth and innovation deserve further investigation in future studies, especially on how the outputs of innovation impact a firm's growth during a period of crisis for SMEs which adopt an IIS.

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Declaration of Competing Interest

The authors have no relevant financial or non-financial interests to disclose.

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Appendix A

Table A1
Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Inno decision	0.75	0.43	0	1
Inno. Investment (ln)	6.18	3.85	0	14.72
Inno. Invest. Prediction (ln)	7.86	1.23	3.8	12.80
Inno. Output (ln)*	3.18	1.29	0.1	4.60
SMEs growth (ln)	4.58	0.72	1.18	7.45
RE crisis	0.29	0.58	0	6.49
RE pre-crisis	0.38	0.65	0	5.8
Size (ln)	3.36	1.19	0	5.52
Private	0.08	0.27	0	1
Age (ln)	2.97	0.64	0	5.73
GITA (ln)	7.55	5.7	0	20.69
Parent	0.05	0.23	0	1
Subsidiary	0.18	0.38	0	1
High degree	29.05	29.65	0	100
Tech. park	0.05	0.22	0	1
Export level	0.55	0.79	0	3
Export (t-2)	5.84	13.61	0	100
Innovator (t-3)**	0.75	0.44	0	1
Intramural R&D	41.14	42.05	0	100
Extramural R&D	0.22	0.42	0	1
Process Inno.	0.48	0.50	0	1
Internal sources	0.43	0.50	0	1
Market sources	0.31	0.46	0	1
Institutional sources	0.13	0.33	0	1
Cost factors	0.53	0.50	0	1
Knowledge factors	0.18	0.38	0	1
Market factors	0.40	0.49	0	1
Coop. Abroad inst.	0.06	0.24	0	1
Coop. Public inst.	0.17	0.38	0	1
Coop. Competitors	0.06	0.24	0	1
Public support	0.31	0.46	0	1
Spanish funds	0.18	0.39	0	1
UE funds	0.05	0.21	0	1
Crisis dummy	0.52	0.50	0	1

Observations: 68080; * Obs.: 33715; ** 62,895.

Appendix B

Table B2
Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Inno. Input	1.00											
(2) RE crisis	0.07	1.00										
(3) RE pre-crisis	0.05	-0.11	1.00									
(4) External. R&D	0.40	0.08	0.08	1.00								
(5) Process. inno.	0.24	0.10	0.10	0.21	1.00							
(6) Inno. in t-3	0.32	0.09	0.06	0.18	0.28	1.00						
(7) Coop. Abroad	0.30	0.00	0.02	0.19	0.14	0.08	1.00					
(8) Coop. Public	0.46	0.05	0.00	0.34	0.18	0.13	0.38	1.00				
(9) Coop. Competitors	0.30	0.03	-0.01	0.17	0.11	0.08	0.36	0.37	1.00			
(10) Spa. Funds	0.47	0.07	0.05	0.29	0.15	0.13	0.23	0.36	0.24	1.00		
(11) UE funds	0.29	0.06	0.02	0.15	0.07	0.05	0.29	0.29	0.26	0.28	1.00	

(*continued on next page*)

Table B2 (*continued*)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(12) Sales growth	0.14	0.05	0.07	0.12	0.15	0.11	0.08	0.12	0.09	0.13	0.07	1.00
(13) Firm size	-0.40	0.05	0.03	0.09	0.17	0.07	0.08	0.04	0.04	0.09	0.04	0.18
(14) Tech. Park	0.30	0.02	-0.01	0.11	0.04	0.05	0.11	0.17	0.15	0.18	0.19	0.10
(15) High degree	0.48	0.09	0.07	0.12	0.00	0.10	0.12	0.21	0.17	0.24	0.20	0.11
(16) Crisis	-0.08	0.33	-0.34	-0.10	-0.10	-0.02	-0.06	-0.02	0.00	-0.04	-0.01	-0.15
(17) Construction	-0.17	-0.02	-0.02	-0.04	-0.06	-0.10	-0.03	-0.03	-0.02	-0.04	-0.02	-0.05
(18) Health	-0.05	-0.03	0.03	-0.03	-0.02	-0.05	-0.02	0.00	0.00	0.00	0.00	0.03
(19) Energy	0.00	0.01	0.00	0.00	0.01	-0.01	0.00	0.01	-0.01	0.00	0.00	0.01
(20) Hospitality	-0.23	-0.02	-0.02	-0.05	-0.07	-0.10	-0.02	-0.04	-0.02	-0.04	-0.02	-0.01
(21) Food	-0.09	0.00	0.01	0.00	0.05	0.02	-0.02	0.00	-0.02	-0.02	-0.02	0.04
(22) Textile	-0.03	-0.01	0.00	0.01	0.02	0.02	0.01	-0.01	-0.01	0.02	-0.02	-0.02
(23) Trade	-0.09	-0.04	-0.03	-0.04	-0.06	-0.06	-0.03	-0.05	-0.04	-0.06	-0.04	-0.03
(24) HT manu.	0.19	0.00	0.01	0.08	0.03	0.06	0.04	0.04	0.02	0.07	0.00	0.03
(25) HT serv.	0.36	0.03	0.00	0.08	0.02	0.02	0.15	0.17	0.15	0.18	0.24	0.05
(26) IMR1	-0.51	-0.02	-0.18	-0.27	-0.36	-0.73	-0.16	-0.22	-0.13	-0.25	-0.13	-0.25
(27) IMR2	-0.72	-0.13	-0.16	-0.42	-0.51	-0.68	-0.31	-0.41	-0.25	-0.41	-0.17	-0.23
(28) Inno. Output	0.14	0.05	0.05	0.04	0.04	0.03	0.04	0.04	0.03	0.06	0.04	0.05
(29) GITA	0.26	0.02	0.09	0.21	0.29	0.18	0.14	0.17	0.10	0.21	0.10	0.22
(30) Export	0.16	0.05	0.00	0.13	0.12	0.17	0.10	0.08	0.03	0.11	0.03	0.08
(31) Company age	-0.32	0.08	-0.08	-0.04	0.02	0.02	-0.05	-0.08	-0.07	-0.08	-0.06	-0.14
(32) Part. Group	0.01	0.05	0.00	0.08	0.05	0.04	0.09	0.05	0.02	0.06	-0.01	-0.01
(33) PRIV	-0.01	0.03	-0.02	0.02	0.02	0.03	0.08	0.00	0.00	-0.01	-0.02	0.00

Variables	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
(12) Sales growth	1.00											
(13) Firm size	0.18	1.00										
(14) Tech. Park	0.10	-0.03	1.00									
(15) High degree	0.11	-0.29	0.24	1.00								
(16) Crisis	-0.15	-0.04	0.02	0.01	1.00							
(17) Construction	-0.05	0.04	-0.02	-0.07	0.01	1.00						
(18) Health	0.03	0.00	-0.01	0.05	-0.06	-0.03	1.00					
(19) Energy	0.01	0.00	0.00	-0.02	0.02	-0.02	-0.02	1.00				
(20) Hospitality	-0.01	0.08	-0.02	-0.07	0.01	-0.02	-0.01	-0.01	1.00			
(21) Food	0.04	0.03	-0.05	-0.11	0.00	-0.05	-0.04	-0.03	-0.02	1.00		
(22) Textile	-0.02	0.03	-0.04	-0.09	-0.01	-0.03	-0.02	-0.02	-0.02	-0.04	1.00	
(23) Trade	-0.03	-0.02	-0.03	-0.05	0.02	-0.05	-0.04	-0.03	-0.02	-0.07	-0.04	1.00
(24) HT manu.	0.03	-0.01	0.06	0.05	-0.04	-0.04	-0.04	-0.02	-0.02	-0.06	-0.04	-0.06
(25) HT serv.	0.05	-0.04	0.20	0.27	0.04	-0.04	-0.03	-0.02	-0.02	-0.06	-0.04	-0.06
(26) IMR1	-0.25	-0.18	-0.18	-0.16	0.34	0.21	0.05	0.03	0.30	0.00	-0.02	0.08
(27) IMR2	-0.23	-0.11	-0.14	-0.24	0.20	0.16	0.06	0.02	0.20	0.03	-0.01	0.11
(28) Inno. Output	0.05	-0.09	0.06	0.11	-0.03	-0.02	-0.02	0.00	-0.01	-0.04	0.01	-0.02
(29) GITA	0.22	0.33	0.06	0.01	-0.15	-0.05	-0.02	0.03	-0.01	0.06	-0.01	-0.05
(30) Export	0.08	0.19	-0.01	-0.03	0.03	-0.10	-0.10	-0.04	-0.06	0.02	0.06	-0.04
(31) Company age	-0.14	0.31	-0.15	-0.30	0.22	0.00	-0.04	-0.01	0.00	0.06	0.08	0.02
(32) Part. Group	-0.01	0.29	0.01	0.03	0.05	-0.01	-0.03	0.03	0.00	-0.01	-0.02	0.01
(33) PRIV	0.00	0.16	-0.02	0.00	0.07	-0.04	-0.03	-0.01	0.01	-0.03	0.00	0.03

Variables	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
(25) HT serv.	1.00							
(26) IMR1	-0.14	1.00						
(27) IMR2	-0.09	0.78	1.00					
(28) Inno. Output	0.06	-0.06	-0.10	1.00				
(29) GITA	0.05	-0.58	-0.42	-0.01	1.00			
(30) Export	-0.06	-0.28	-0.29	-0.01	0.19	1.00		
(31) Company age	-0.14	0.10	0.09	-0.14	0.04	0.18	1.00	
(32) Part. Group	0.01	-0.09	-0.13	-0.03	0.15	0.10	0.04	1.00
(33) PRIV	0.00	-0.03	-0.06	-0.02	0.08	0.12	0.05	0.34

Appendix C. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jengtecman.2024.101816.

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