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Demand drops and innovation investments: Evidence from the Great Recession in Spain

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ABSTRACT

The Great Recession, which began in 2008, brought about large contractions in aggregate consumption in many countries. In this research, we study the impact of heterogeneous decreases in demand on innovation investments by analyzing the evolution of innovation investments in a panel of Spanish manufacturing firms during the 2004–2013 period. We proxy heterogeneous variation in demand with net exit rates in the productive stratum of each firm, defined as the group of firms in the same industry and size class. These net exit rates are computed considering all firms in the stratum, including firms that are determined to be non-innovative firms. To support the identification strategy, we show that exit rates do not capture idiosyncratic unobservable characteristics among innovative firms. In addition, we control for the effect of time-varying credit constraints. We find that a one standard deviation increase in exit rates is associated with reductions of 1.5% in the share of firms investing in innovation. The drop is larger for smaller firms, which also experience greater decreases in sales. Since smaller firms are most sensitive to demand drops, they are the natural candidates to be the target of policies devoted to increasing R&D activities during crises. As additional analysis, we study firms' perceptions of the main obstacles to innovation to find that net exit rates capture the heterogeneous variation in demand, rather than credit constraints. Finally, when analyzing the exit patterns of firms in the sample, we confirm that the net exit rate in a firm's stratum does not drive the exit of firms in our sample.

1. Introduction

Whether expenditures on innovation activities are pro- or counter-cyclical has been the object of study in many contributions to the literature, both theoretical and empirical. Theoretical arguments are mixed (Barlevy, 2007; Arvanitis and Woerter, 2014; Ouyang, 2011). On one hand, pro-cyclicality is supported by a relaxation of liquidity and credit constraints during expansions. On the other hand, counter-cyclicality is justified by the lower opportunity cost of R&D during recessions. Absent a lack of consensus in the theoretical front, the effect of economic crises on firms' investments in innovation has remained an empirical question, indeed a very relevant one. Understanding how different factors affect incentives to invest in innovation is essential, given the key role that innovation plays in the process of total factor productivity growth, which is responsible for large cross-country differences in per capita incomes (Hall and Jones, 1999).

We contribute to the existing literature by analyzing a panel of Spanish manufacturing firms during the 2004–2013 period, which includes the Great Recession years. We exploit time, industry and firm size variation to supplement the panel with stratum-specific entry and exit rates. The net rate at which firms exit the market allows us to proxy heterogeneous variation in demand. Our results suggest that higher net exit rates relate negatively with innovation investments. Among smaller firms, this relationship is much stronger. This finding is consistent with the theoretical literature that regards differences in productivity as a determinant of both the distribution of firm sizes as well as of firms' incentives to invest in innovation (Melitz, 2003; Bustos, 2011; Dixit and Stiglitz, 1977; Hallak and Sivadasan, 2013; Guadalupe et al., 2012). In fact, smaller firms are also characterized by large drops in sales when exit rates are higher. This suggests a demand-driven effect on innovation. Our estimates are robust, not only for time-invariant (unobservable) firm characteristics, but also for the inclusion of sector-specific trends.

Facing market turbulence (Santos-Vijande and Alvarez-Gonzalez, 2007), firms optimally make their choices of strategies to react to economic crises (Fort et al., 2013), which involves the re-evaluation of ongoing or planned investment projects (Pindyck, 1991). Innovation-related projects are especially sensitive to market turbulence. For

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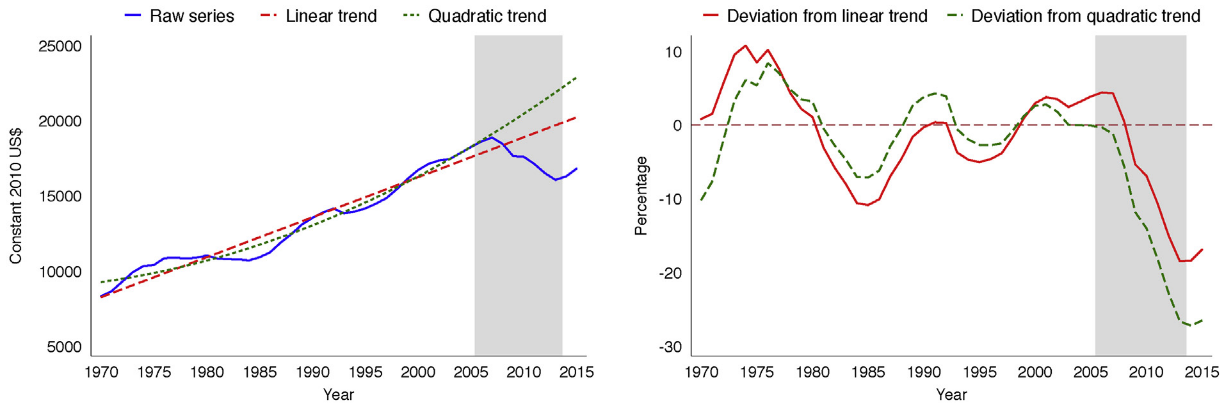

Fig. 1. Household final consumption expenditure per capita, Spain 1970–2015. *Note.* The left panel presents the series of household final consumption expenditure, which is reported in constant prices (2010 US$) and in per capita terms (source: World Bank). It also presents the linear and the quadratic trend (source: authors' calculations). The right panel presents deviations from the linear and the quadratic trends. The linear trend series is computed using predicted values from a linear regression of the raw series on the year variable (re-scaled to have 1970 = 1) for the pre-crisis sample (1970–2008). The quadratic trend is computed using predicted values from a linear regression of the raw series on the year variable and its square. The shaded area highlights the period 2004–2013, which is the object of our empirical analysis.

instance, Paunov (2012) uses firm-level data from several Latin American countries to provide evidence that many firms stopped their innovation efforts during the crisis, mainly due to financial constraints and negative demand shocks. The effect of the crisis on firm innovation may be heterogeneous depending on firm capabilities. In this line, Amore (2015) uses Compustat data to argue that those firms that have previous innovation experience during recessions have better performance in terms of patent outcomes during future downturns. In a similar way, Archibugi et al. (2013b) present evidence from a number of European countries on the impact of the crisis on innovation, suggesting that the crisis significantly reduced firms' willingness to invest in innovation, although the effect is heterogeneous. Such heterogeneity may be driven by product characteristics. For instance, Fabrizio and Tsolmon (2014) present empirical indicating that R&D spending is more pro-cyclical in industries characterized by faster product obsolescence.

The effect of recessions is not confined to business expenditures on R&D. Regarding public research, Cruz-Castro and Sanz-Menéndez (2016), document a sharp decrease in public R&D funds during the crisis, implemented via large budget cuts (see also Filippetti and Archibugi, 2011; Laperche et al., 2011). On the other hand, the crisis may have affected persistence of R&D activities (Geroski et al., 1997; Roper and Hewitt-Dundas, 2008; Cefis, 2003; Cefis and Orsenigo, 2001), as well as the composition of the set of innovating firms. Archibugi et al. (2013a) use panel data from the British version of the CIS, covering the period 2002–2008 to search for differences in the identity of innovating firms before and during the crisis to find that the crisis concentrated innovation activities mainly in previous innovators and some fast-growing new entrants.

Innovation has long-lasting effects on economic performance and hence, performance is ultimately affected by factors that impact firms' decisions to invest in innovation. In fact, using a sample of Chilean firms, Santi and Santoleri (2017) analyze the impact of innovation on subsequent sales growth to find that process, but not product, innovations increase sales among larger and mature firms. At a macro level, R &D efforts and imports of disembodied technology have been found to increase the total factor productivity of countries (Coe and Helpman, 1995; Mendi, 2007). Interestingly, a strand of the literature discusses the scope for a reverse direction of causality, namely lack of significant innovation as a cause in the recession. This thesis was proposed by Archibugi (2017a), prompting replies by Lundvall (2017), Steinmueller (2017), and Archibugi (2017b).

Oftentimes, the impact of a crisis on innovation prompts government intervention. Research on the impact of a crisis may shed light on policy design. Hud and Hussinger (2015) use data from the Mannheim Innovation Panel for 2006–2010 to study the impact of public R&D subsidies on small- and medium-sized firms in Germany. They find evidence consistent with a positive effect of subsidies, but also of the existence of a crowding-out effect. In this line, Brautzsch et al. (2015) using German data, find that R&D subsidies mitigated the decline of German GDP by half a percentage point in the year 2009. Bartz and Winkler (2016) show that young firms are more intensely affected by a crisis than larger firms, although in normal times they tend to grow faster.

As mentioned above, this paper makes use of Spanish firm-level data in a time span that includes the Great Recession. During this period, which began in 2008, the Spanish economy faced a sharp contraction in demand. Industrial production dropped by roughly 30%, and unemployment rose from 8% to 26% in 2013 (Bentolila et al., 2012). To illustrate the extent of the dramatic decrease, Fig. 1 presents the series of household final consumption expenditure (in per capita terms) over the period 1970–2015. The left panel presents the level of household final consumption expenditure in constant prices, as well as the linear and quadratic trends of the series. The sharp decrease in consumption during the Great Recession is apparent in this panel. This sudden drop is also illustrated in the right panel of Fig. 1, which shows the deviation of consumption from its pre-crisis trend.

An important consequence of this drop in demand was that during this period, a large number of firms ceased operations, resulting in a sharp increase in net exit rates across industries (García-Macia, 2017). This turbulent environment is likely to have affected firms' prospects for future returns on different types of investments. In particular, investment in innovation, riskier than many other investment categories, may be particularly affected. Indeed, according to the OECD, from 2008 to 2013, Business Enterprise R&D decreased in Spain by 14.5% in nominal terms. Yet, it is not clear how such a large reduction in demand was distributed across different industries and size groups.

The Great Recession had deep consequences in the composition of many industries in Spain (García-Macia, 2017). It is not clear that exit rate variation is fully caused by demand heterogeneity. Lack of financing could also have aggravated exit rates. In fact, lack of access to financing has been regarded as an important obstacle to innovation. Lee et al. (2015) studied a dataset of British firms to conclude that innovative firms are typically less likely to have access to financing, although the crisis impacted non-innovating firms relatively more (see also López-García et al. (2013) for an analysis using Spanish data). Pellegrino and Savona (2017) studied the relative importance of financing versus knowledge and market-related factors as obstacles to

Table 1
List of industries and macro-sectors.

Manufacturing sector	CNAE-93	CNAE-09	Macro sector
Food, beverages, and tobacco	2, 3	3	1
Textiles	4	4	2
Wearing apparel	5	5	2
Leather and footwear	6	6	2
Wood and cork	7	7	3
Paper and paper products	8	8	4
Printing and reproduction of recorded media	9	9	4
Chemical products	11	10	5
Pharmaceutical products	12	11	5
Rubber and plastics	13	12	3
Other non-metallic mineral products	14, 15	13	6
Manufacture of basic metals	16, 17	14	6
Fabricated metal products	18	15	6
Computer, electronic and optical products	20, 22, 23, 24	16	7
Electrical equipment	21	17	7
Other machinery and equipment	19	18	8
Motor vehicles, trailers and semi-trailers	25	19	9
Building of ships and boats	26	20	9
Aircraft, spacecraft and machinery thereof	27	21	9
Other transport equipment	28	22	9
Furniture	29	23	4
Other manufacturing	30, 31	24	4

Note: Fabricated metal products excludes machinery and equipment. We remove the sector "Repair and installation of machinery and equipment" since it was classified as a service activity under CNAE-93. The PITEC database identifies 56 industries up to 2008, and 44 industries from 2008 on, when the CNAE-09 classification system was introduced.

innovation. Using a panel of French firms, Aghion et al. (2012) find that liquidity constraints are an important determinant of R&D expenditures. Garicano and Steinwender (2016) argue that the Great Recession in Spain affected longer-duration investments. The mechanism behind this change is the reduced access to financing. Yet, they did not observe large effects on R&D investments. This suggests these results might apply more to less-productive (non-innovative) firms.[1]

In order to analyze these issues, we exploit time and stratum variation using financial ratios. We select ratios capturing the (median) liquidity and credit constraints in each stratum. The inclusion of these controls does not affect the relationship between net exit rates and investment. We cannot argue that credit constraints played a central role among innovative firms. Their superior ability to access credit could support this result. Furthermore, the negative relationship between rates and investment is stronger when deviations from trend in aggregate consumption are larger. We do not find evidence of changes in financing, nor important changes in perceptions. If anything, firms became more worried about the lack of demand.[2]

The remainder of the paper is organized as follows. Section 2 describes the data used in this paper. Section 3 discusses the empirical strategy, whose results are presented in Section 4. Finally, Section 5 presents concluding comments.

[1] In Section 4.2 we show that our estimates are robust to within-firm estimation, as in Garicano and Steinwender (2016). The methodology is presented in Section 3. While we focus only on innovation investments and on investments in tangible goods, we do not observe the same pattern in our sample. Their identification strategy relies on the existence of a homogeneous effect of demand shocks on different types of investment. Following a decrease in demand, this assumption may turn out to be problematic since the degree of competition in the industry may increase. This way, marketing expenses may decrease by less, or even increase, relative to innovation expenses.

[2] Net exit rates may capture alternative channels. They may signal the probability of exit of incumbent firms, affecting expected returns. But we do not observe large effects on perceived constraints. They also alter the degree of competition in the industry where the firm operates. Still, the direction of the effect of competition on innovation is still controversial (Schumpeter, 1942; Arrow, 1962; Vives, 2008).

Table 2
Firm characteristics, by firm size quartile.

	Size quartile			
	1st quartile	2nd quartile	3rd quartile	4th quartile
Any innovation investment	0.60	0.76	0.82	0.91
	(0.49)	(0.43)	(0.38)	(0.28)
R&D	0.54	0.69	0.78	0.87
	(0.50)	(0.46)	(0.42)	(0.34)
Buy	0.31	0.42	0.47	0.64
	(0.46)	(0.49)	(0.50)	(0.48)
Log innovation expenditure	6.69	8.90	10.18	12.54
	(5.56)	(5.19)	(4.86)	(4.21)
Log sales	14.11	15.51	16.55	18.10
	(1.04)	(0.76)	(0.76)	(1.15)
Subsidiary of foreign MNC	0.01	0.04	0.14	0.30
	(0.10)	(0.20)	(0.34)	(0.46)
Share of female employees	0.26	0.25	0.26	0.27
	(0.22)	(0.20)	(0.20)	(0.20)
Producing biotechnology	0.05	0.03	0.03	0.06
	(0.21)	(0.18)	(0.17)	(0.25)
Active in local market	0.96	0.97	0.96	0.92
	(0.21)	(0.17)	(0.19)	(0.27)
Active in Spanish market	0.93	0.97	0.97	0.98
	(0.25)	(0.16)	(0.17)	(0.15)
Active in other EU market	0.66	0.85	0.91	0.93
	(0.47)	(0.36)	(0.29)	(0.25)
Active in rest of the World	0.48	0.69	0.78	0.84
	(0.50)	(0.46)	(0.41)	(0.37)
Part of group of firms	0.11	0.22	0.45	0.80
	(0.31)	(0.41)	(0.50)	(0.40)

Note: Standard deviations in parenthesis. Size quartiles are determined over the sample distribution of the number of employees. "R&D" indicates the share of firms performing internal R&D, while "Buy" refers to purchase of external R&D, machinery or licensing. "Innovation inputs" instead refer to either R&D or Buy.

2. The data

In the empirical analysis in this paper, we make use of data from different sources. We combine the PITEC dataset, which provides detailed information about innovation inputs and outputs of a panel of Spanish firms, with data about market characteristics and sectoral financial ratios. We describe each source in this section.

2.1. The PITEC database

The PITEC (*Panel de Innovación Tecnológica*) database is a panel of Spanish firms surveyed yearly by the Spanish National Statistics Institute (INE). The questionnaire used is similar to the Community Innovation Survey implemented in many other European countries (see for instance Archibugi et al., 2013a; Ballot et al., 2015; Cassiman and Veugelers, 2006, 2002; Mohnen and Roller, 2005; van Beers et al., 2008). In particular, the dataset contains detailed information on firms' characteristics and on all inputs and outputs related to innovation. It includes activities in R&D, purchase of services, other activities linked to innovation, factors limiting investments in R&D, intellectual property rights, and innovations in production processes and products. The dataset also provides some information on firm characteristics, such as number of employees, sales and gross capital formation.

In our empirical analysis, we focus on manufacturing firms that were actively investing in internal R&D in 2004 and have been yearly surveyed until 2013. First, while the dataset includes firms in all sectors, we focus on the manufacturing sector in line with most empirical studies.[3] The reason to exclude services industries is that the role of

[3] We exclude from the sample firms in the "Repair and installation of machinery and equipment" sector and firms switching from manufacturing to services and vice-versa when CNAE-09 is introduced.

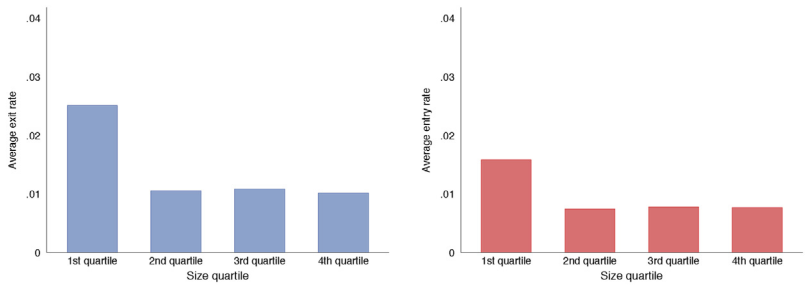

Fig. 2. Average exit and entry rates, by size quartile. *Note.* The left (right) panel shows the distribution of exit (entry) rates by firm quartile. Exit and entry rates are computed at size- and industry-stratum and are averaged over different quartiles. Exit and entry rates are defined in Section 2.2. Size quartile is determined on the basis of the distribution of number of employees in a specific year.

formal internal R&D is less relevant to this sector. In addition, the purchase of external services related to innovation might present deep differences compared to manufacturing. Second, the selection of firms that invest in R&D in 2004 is data-driven. This selection allows us to have a comparable panel for both small and large firms for the whole period.[4] Third, we select only firms that are active for the whole period under analysis. Therefore, we exclude firms exiting the market. This restriction is based on the decision to study the behavior of firms conditional on being active in the market. In this way, we can focus solely on investment decisions. In Section 4.5, we discuss in detail, the market exits for the firms we exclude. The cumulative hazard estimates tend to be rather small compared to the rest of the economy. This suggests that we are focusing on a relatively stable group of firms.

Firms are classified according to their main activity. The database provides an industrial classification based on the CNAE-93 for the period 2003–2008 and the CNAE-09 from 2008 on. These are used by the Spanish National Institute of Statistics. In the absence of a direct conversion of the two classifications, we homogenize them over time and use indicators for the macro sectors. Table 1 presents the list of selected sectors and their aggregation code into macro-sectors. The table also provides the correspondence between the CNAE-93 and CNAE-09 industry classifications.

A complete list of variable definitions is provided in Appendix B. Our main dependent variables of interest will be indicator variables for a firm doing internal R&D, as well as for buying technology in any period. In the buy category, we include the purchase of external R&D, machinery that embodies new technology, or licensed disembodied technology. Additionally, we make use of the logarithm of the total innovation expenditure. Table 2 presents summary statistics of selected firms by size quartile, where quartiles are defined according to the number of employees. We include the whole period 2004–2013. For firms with any innovation, the input ranges from 60% to 91% depending on their size. Since all firms are investing at the beginning of the period, this suggests that the propensity to stop investing is much larger among smaller firms. This pattern is similar when we distinguish between internal and external investments. Larger firms also tend to have a larger number of patent applications, to be part of a group, and to be active in the rest of the world. Among firms in the first quartile, only 11% form part of a group and 48% are active beyond the European market. Among larger firms, these shares are 80% and 84%. The share of female workers is uniform among firms, at around 25–27% of workers.

2.2. Industrial Survey: net exit rates

We supplement the PITEC database with industry-level information. We match each industry with aggregated data from the Industrial Survey (*Encuesta Industrial de Empresas*), which is managed by INE. We include information about profits and profit growth rates, inventory variation, total sales, personnel expenditures, total employment, hours worked, and gross capital formation.

Additionally, the Central Business Register (CBR), also managed by INE, provides information on registration of companies, on companies remaining in business, and on companies that exit the industry. This information is disaggregated by main economic activity and by number of employees. Entry and exit rates are available for the following groups: between one and five employees; between six and nine employees; between 10 and 19 employees; and 20 or more employees. Each firm is then matched using the number of employees and their main sector of activity, which allows us to construct sector- and size-specific entry and exit rates. More importantly, the rates incorporate all firms, including non-innovative firms. For our identification strategy, it is important to note that firms investing in internal R&D are the vast minority among small and medium firms. In fact, according to INE, in manufacturing sectors the share of firms investing in R&D is around 12% among small- and medium-sized enterprises (with 10–249 employees) and around 62% for firms with more than 250 employees.

This way, the matched data allows an analysis of the entry and exit rates in the stratum where innovative firms operate. Fig. 2 shows the average exit and entry rate by size quartile. In the first quartile, exit rates are much larger compared to the higher quartiles (3% versus 1%).[5] This pattern is similar for the entry rate with smaller firms characterized by a larger entry rate (around 2% versus 1% for larger firms). Entry and exit rates are positively correlated, with a correlation equal to 0.70 for firms in the first quartile and 0.36 for other firms (see Appendix A.1). This is in line with evidence showing that exit and entry rates depend on firm characteristics, with smaller and younger firms having higher exit rates, and tend to be positively correlated within strata of the economy (Malerba and Orsenigo, 1996; Abbring and Campbell, 2010; Dunne et al., 1988). However, there is evidence that suggests that this result may not always hold. In fact, using Portuguese data, Varum and Rocha (2012) challenge the conventional wisdom that exit rates affect more intensely smaller firms to show that during downturns, the hazard rate increases with size.

Since the Great Recession characterizes most of our period of interest, we focus on net exit rates. We define these as the change in the number of firms operating at year t in industry j and in size group s. The change is relative to the initial number of firms operating in the stratum. We hypothesize that this captures how reductions in aggregate demand affect firms in each stratum. If Δ_{jst} is the decrease in the number of firms at year t for a firm in industry j and of size group s, the net exit rate is defined by:

$$\text{netexit}_{\text{jst}} = \frac{\Delta_{\text{jst}}}{nsur_{\text{jst}-1} + nentry_{\text{jst}-1}} = \frac{nexit_{\text{jst}} - nentry_{\text{jst}}}{nsur_{\text{jst}-1} + nentry_{\text{jst}-1}} \quad (1)$$

where n_sur_{jst}, n_entry_{jst} and n_exit_{jst} are the number of firms surviving, entering and exiting industry j in size group s in year t,

[4] We select the period 2004–2013 since the database provides information for large firms (in excess of 200 employees) for the period 2003–2013 and for a panel of smaller firms for the period of 2004–2013. To analyze both, we restrict the sample to the periods where information for both is available. In the year 2005, the panel was expanded to include more firms, which we include in our sample. If we perform our analysis in the period 2005–2013, the results are unaffected.

[5] We distinguish between *small firms*, defined as firms in the first quartile of the size distribution, and *large firms*, defined as firms in the second, third and fourth quartiles.

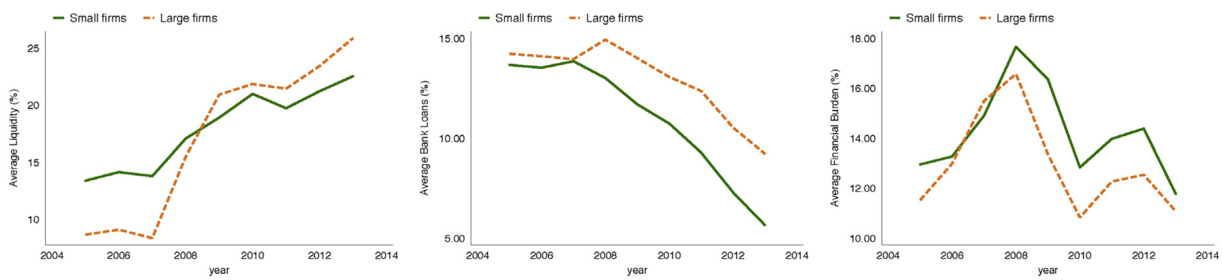

Fig. 3. Liquidity, bank loans and financial burden, 2004–2013. *Note.* Average liquidity is computed as the average ratio between cash plus short term financial assets and current liabilities. Average bank loans are computed as the average ratio between bank loans and total assets. Average financial burden is computed as the average ratio between financial expenses and net income. Ratios are matched at sector and sales group levels. Small (large) firms are defined as firms in the first (second-fourth) quartile of the size distribution.

respectively. The sum $n\_sur_{jst-1} + n\_entry_{jst-1}$ equals the total number of firms in the industry-size group at the beginning of year *t*. The net exit rate matched with sampled firms has an average of 0.30%, with a minimum of −3.45% and a maximum of 8.90% (see Appendix A.1).

In the empirical examination, we standardize the net exit rate using the whole period of analysis. One standard deviation corresponds to an increase in the net exit rate by around 0.79%. It is important to note that we are matching exit rates that include all firms. We do not discriminate between innovative and non-innovative firms. We do so to capture the situation of the whole stratum, rather than innovative firms only. In Section 4.5, we show that our sample is a relatively stable share of the market. In addition, the rates in the overall stratum do not explain firm exit in our sample (see Section 4.5), nor are related to idiosyncratic firm-level characteristics driving innovation investments (see Sections 3 and 4.2). This suggests that, conditional on all observable characteristics, we can identify the relationship between changes in the firm's environment and their innovation decision.

2.3. Financial ratios

We supplement our dataset with sectoral ratios of non-financial firms at the stratum level, defined by the combination of industry and size class. The information is provided by the Sectoral Rates of Non-Financial Corporations (RSE) database. It is managed by the Bank of Spain, the Central Business Register and the European Committee of Central Balance Sheet offices. We match each firm with the median value of different financial ratios within their sector and sales stratum.[6] The reason for doing this is that net exit rates may be capturing factors other than demand fluctuations. In particular, it is possible that liquidity and credit constraints, associated with periods of stronger recession, could be driving market exit (see Aghion et al., 2012; Garicano and Steinwender, 2016).

We select financial ratios that could proxy for liquidity and credit constraints. First, to proxy for liquidity constraints, we use the quick ratio. This is the ratio between current assets (measured by cash and short term financial assets) and current liabilities (measured by short-term debt). This ratio captures a firm's ability to meet its short-term obligations with its most liquid assets. A larger value of this ratio indicates availability of liquid assets and a lower likelihood of liquidity constraints. The sample average value of the quick ratio is equal to 17%. In Section 4, we standardize the ratio (with one standard deviation being equal to 9.4%) and we indicate it by *Liquidity*. Second, to proxy for credit constraints, we use the ratio between bank loans and total liabilities. We indicate it by *Bank Loans*. An increase in this ratio captures a reduction in credit constraints associated with banks. Our sample average equals 13%, with one standard deviation equal to 6.5%.

[6] Firms are classified in four sales groups: less than 2 million euros, between 2 million and 10 million euros, between 10 million and 50 million euros, and more than 50 million euros. These groups are used to match firms within each sector.

Third, we control for the burden of financial expenses, normalized by net revenue. We indicate this ratio by *Interest burden*. A higher value of this ratio shows a higher cost associated with financial activities, such as interest. In our sample, this ratio has an average of 13.2% with standard deviation of 4.85%. Fig. 3 presents the time series of the average of these indicators, as matched with the sampled firms.

Both liquidity and bank loans were relatively stable before the beginning of the recession in 2008. Liquidity is higher among smaller firms, while bank loans are comparable across firms. It is surprising that once the recession hits the economy, the strata where sampled firms operate become more liquid. Bank loans instead drop significantly. Larger decreases are seen among smaller firms. The drop in bank loans following 2007 was mainly driven by a sharp reduction in short term bank loans, compensated by an initial increase in the medium- to long-term bank loans and a drop after 2009 (see Appendix A.5).

3. Empirical strategy

Examining time and firm-level variations in innovation investment and market conditions allow us to exploit a fixed effect estimation method, controlling for time-invariant unobservable firm characteristics. This is particularly important in this setting, as it eliminates the possibility that firms in a given sector could be affected by different market conditions from peculiar, unobserved characteristics of the firm or the sector. In other words, we reduce identification issues to the possibility that net exit rates are correlated with idiosyncratic shocks. Given the large number of controls and the fact that our measure of exit rates is computed for all firms (without restricting it to the much smaller share of innovative firms), this possibility is remote.

Specifically, to measure the relationship between the contemporaneous variation in net exit rates, $netexit_{it}$, and the decision/outcome of firm *i* at time *t*, y_{it}, we estimate the following specification:

$$y_{\text{it}} = \alpha_0 + \alpha_N \,\text{netexit}_{\text{it}} + \mathbf{X}_{\text{it}}\beta + \sum_{t=2}^{T} \gamma_t d_t + \sum_{j=2}^{T} \sum_{t=2}^{J} \omega_{\text{tj}} d_t s_j + c_i + u_{\text{it}} \quad (2)$$

where $\mathbf{X}_{it}$ is a matrix of time-varying firm characteristics,[7] d_t are year fixed effects, s_i are macro-sector dummy variables (as specified in Table 1), c_i captures unobserved time-invariant firm characteristics and u_{it} are idiosyncratic error terms.

Our parameter of interest is α_N. It captures the change in the outcome variable due to the variation in the number of firms operating in

[7] Time-varying controls includes indicators for the firm being a subsidiary of a foreign multinational, being active in biotechnology activities, belonging to a group of firms, the share of female employees, and presence in the local, national, EU and other foreign markets. It also includes sector-level controls such as the logarithms of profits, hours worked, positive variation in inventory, and the growth in these three variables compared to the prior year. For profits and the variation in inventory, we censor negative values at zero and compute the logarithms as the variable plus one. We do not control directly for firm size since, in most specifications, we control for sector-by-size fixed effects.

the firm's stratum, once we control for the available observable characteristics and for firm-specific unobservable characteristics c_i. In our preferred specification, we also introduce a set of interaction terms between the year and macro-sector dummies and a set of interaction terms between size quartile and macro-sector. This allows us to control for unobservable macro-sector characteristics that are year-specific and for size-sector specific unobservable characteristics. We estimate Eq. (2) using fixed effects estimation.

When looking at discrete or censored outcomes, we compare our results using a fixed-effects linear probability model with those obtained outcomes using non-linear estimation methods. First, for discrete outcomes such as whether the firm invests in innovation, we make use of a Correlated Random Effects (CRE) Probit model to explain the probability that firm i invests in innovation at time t, i.e. $p(y_{it} = 1|netexit_{it}, \mathbf{Z}_{it}, c_i)$:

$$p(y_{\text{it}} = 1|\text{netexit}_{\text{it}}, \mathbf{Z}_{\text{it}}, c_i) = \Phi[\alpha_0 + \alpha_N \text{netexit}_{\text{it}} + \mathbf{Z}_{\text{it}}\beta + c_i] \tag{3}$$

where $\Phi()$ is the standard normal cumulative distribution function and $\mathbf{Z}_{it}$ is a matrix containing all observable characteristics (both constant and variable over time) of each firm. To control for characteristics that are constant over time, we average firm-level and sector-level observable characteristics over the whole period of analysis. The advantage of using this method is that, while in a pure random effects model the conditional distribution of c_i is independent from observable characteristics, the CRE framework allows (restricted) dependence between c_i and observable characteristics (Wooldridge, 2010).[8] Second, when looking at censored outcomes such as the intensive margin of innovation investment, we also estimate Eq. (2) using a CRE Tobit model censored at 0, which allows for correcting the estimates for corner solution outcomes. Similar to the case of discrete outcomes, we control for all observable characteristics (both constant and variable over time) of each firm.

In addition to our main specifications, we follow the identification procedure in Garicano and Steinwender (2016) to check whether net exit rates are capturing idiosyncratic shocks. For this purpose, we look at multiple investments within each firm and jointly estimate the following specification:

$$\begin{aligned} y_{\text{ict}} &= \alpha_0 + \alpha_N \text{netexit}_{\text{it}} + \alpha_C \text{netexit}_{\text{it}} \times \text{innov}_{\text{ict}} + \alpha_I \text{innov}_{\text{ict}} \\ &+ \mathbf{X}_{\text{it}}\beta + \sum_{t=2}^{T} \gamma_t d_t + \sum_{j=2}^{T} \sum_{t=2}^{J} \omega_{\text{tj}} d_t s_j + c_i + u_{\text{ict}} \end{aligned} \tag{4}$$

where y_{ict} is the investment of firm i on category c at time t, $innov_{ict}$ is an indicator variable that is equal to one if the observation refers to the category "investment on innovation" (which captures the category fixed effect); $\mathbf{X}_{it}$ is a matrix of time-varying firm characteristics; c_i captures unobserved time-invariant firm characteristics; and u_{it} are idiosyncratic error terms. We also introduce the set of controls used in the main specification. This procedure allows controlling for firm-by-year fixed effects. Since these controls capture firm-specific time-varying unobservable characteristics, the invariance of α_C to the addition of these controls is indicative of the validity of our identification strategy for Eq. (2).

Our analysis focuses only on firms that do not exit the market during the period 2004–2013. We do not focus on the direct relationship between net exit rates and the timing of a firm's exit from the market. If we estimate a survival model where our outcome of interest is market exit, we find that hazard ratios associated with net exit rates are not statistically different from one. This suggests that net exit rates computed among all firms, innovative and non-innovative, do not affect the probability of exiting the market among these firms. See Section 4.5 for a detailed discussion.

[8] c_i is assumed to be equal to $\psi_0 + \psi_1 \overline{\text{netexit}_i} + \overline{\mathbf{Z}}_i\lambda + a_i$, where $a_i|(netexit_{it}, \mathbf{Z}_{it})$ is distributed $Normal(0, \sigma^2)$.

4. Results

We focus on the firm's decision to invest in innovation and how this decision varies when net exit rates are higher in the firm's stratum of the economy. We analyze both the extensive margin (Section 4.1), i.e. whether a firm invests in these inputs, and the intensive margin (Section 4.2), i.e. how large the investments are in these inputs. We then discuss potential mechanisms at play.

4.1. Extensive margin

We start by looking at the decision to invest in any innovation activity. We consider internal R&D and buy strategies, which include external R&D, acquisition of machinery that embodies new technology, or disembodied technology in the form of licensing. Table 3 shows the estimated coefficients for Eq. (2) (columns 1–3 and 5–8) and Eq. (3) (column 4) where the dependent variable is equal to one if the firm invested in innovation at time t and zero otherwise. In columns 1–6, we look at any investment, while in columns 7 and 8, we look separately at R&D and buy strategies. This is an important distinction since internal R&D investments are typically characterized by a longer time horizon. They are also subject to a higher degree of uncertainty than external sources (Pindyck, 1991). In column 5, we restrict the sample to small firms, while in column 6, we consider only large firms. To test for the robustness of the estimates, we include different sets of controls. When estimating Eq. (2), we always include firm-level fixed effects. In column 1, we also include a set of year dummies, while in column 2, we control for industry-level characteristics and for macro-sector fixed effects. In columns 3 and 5–8, we add firm-level controls, proxies for liquidity and credit constraints, and control for sector-specific trends by introducing a set of interaction terms between year and macro-sector indicators. We also control for size-by-sector fixed effects, where size is reported in quartiles. When estimating Eq. (3), we control for year and macro-sector fixed effects and we include firm-level controls, proxies for liquidity and credit constraints, and average firm-level and sector-level characteristics over the period of analysis.

The propensity to invest decreases in strata where net exit rates are higher. A one standard deviation increase in the net exit rate induces a decrease in the probability of undertaking any type of innovation investment of around 1.5 percentage points. The result is consistent across different specifications and different estimation methods. Controlling only for firm and year fixed effects leads to a slightly higher coefficient, showing that controls only marginally pick up the effect of the net exit rate on other dimensions. Our estimates are also robust to extending Eq. (2) by controlling for contemporaneous firm-level sales (see Appendix A.2). The observed reduction in innovation investment is mainly driven by small firms and is for R&D investments only. We do not observe any significant effect for large firms, or for buy strategies.

While proxies of liquidity and credit constraints can be important predictors of innovation decisions, controlling for them does not affect our estimates on the role of net exit rates. Liquidity plays an important role in explaining the decision to invest, with a one standard deviation increase translating into a 3% increase in the share of firms investing. We do not find evidence of a large effect of bank loans on the decision to invest in innovation. The coefficient on bank loans is small and mainly driven by buy strategies. The positive coefficient suggests that investing firms are more able to access credit during recessions.

To rule out the existence of within-sector common shocks that are not accounted for by controls, we predicted the error component using our preferred specification (column 3). The computed intra-sector correlation of the idiosyncratic error term u_{it} is smaller than 0.001. This suggests that there are no additional sector- and time-specific common shocks, which are not captured by net exit rates. Intra-sector correlation for c_i is instead equal to 0.11. Unobservable time-invariant firm characteristics present patterns that are similar for firms operating in the same sector. It is also possible that our result could be measuring sector-

Table 3
Effect of net exit rate on innovation investment.

Dependent variable	Any investment in innovation (R&D and/or Buy)						R&D	Buy
Sub-sample	All firms	All firms	All firms	All firms	Small firms	Large firms	All firms	All firms
Estimation method	FE (1)	FE (2)	FE (3)	CRE (4)	FE (5)	FE (6)	FE (7)	FE (8)
Net exit rate	−0.022***	−0.022***	−0.015***	−0.010***	−0.014***	0.002	−0.015***	−0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.003)	(0.003)
Log profits (sector)		−0.000	−0.001	−0.001*	0.000	0.000	−0.001	0.001
		(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Log hours worked (sector)		0.041***	0.027**	−0.012	0.016	0.028**	0.015	0.017
		(0.011)	(0.012)	(0.010)	(0.029)	(0.013)	(0.013)	(0.016)
Liquidity (stratum)			0.032***	0.018***	0.038***	0.008**	0.023***	0.018***
			(0.004)	(0.005)	(0.011)	(0.004)	(0.004)	(0.005)
Bank loans (stratum)			0.002**	−0.000	−0.002	0.001	0.001	0.002**
			(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Financial burden (stratum)			−0.003***	−0.002***	0.001	−0.004***	−0.003***	−0.003**
			(0.001)	(0.001)	(0.004)	(0.001)	(0.001)	(0.001)
Observations	28,296	28,296	28,296	28,296	7243	21,053	28,296	28,296
rho	0.513	0.528	0.486		0.540	0.529	0.549	0.408
Firm FE	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro-sector FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector-level controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time-varying controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Time-by-Macro-sector FE	No	No	Yes	No	Yes	Yes	Yes	Yes
Size-by-Macro-sector FE	No	No	Yes	No	Yes	Yes	Yes	Yes

Note: Standard errors in parenthesis are clustered at firm level. The dependent variables are an indicator variable for any investment in innovation (columns 1–6), for investments in internal R&D (column 7) or purchase of external R&D, machinery or licensing (column 8). The net exit rate is defined at the sector- and size-stratum where the firm is operating (see Section 2.2) and is standardized over the whole period. The full list of controls is specified in Section 3. Rho is the share of the overall variance explained by the firm-level unobserved fixed effect.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 4
Net exit rates and aggregate trends.

Dependent variable	Any investment in innovation (R&D and/or Buy)				Invested in...	
					R&D	Buy
Estimation method	FE (1)	FE (2)	FE (3)	FE (4)	FE (5)	FE (6)
Net exit rate	0.007	0.007	0.004	0.005	0.003	0.008
	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)
Net exit rate × Post-2007	−0.035***	−0.031***				
	(0.006)	(0.006)				
Net exit rate × Reduction from trend			−0.002***	−0.002***	−0.001***	−0.001***
			(0.000)	(0.000)	(0.000)	(0.000)
Observations	28,296	28,296	28,296	28,296	28,296	28,296
rho	0.486	0.486	0.486	0.486	0.549	0.408
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Macro-sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Time-varying controls	Yes	Yes	Yes	Yes	Yes	Yes
Time-by-Macro-sector FE	No	Yes	No	Yes	Yes	Yes
Size-by-Macro-sector FE	No	Yes	No	Yes	Yes	Yes

Note. Standard errors in parenthesis are clustered at firm level. The dependent variable is an indicator variable for any investment in innovation, such as internal R&D, purchase of external R&D, machinery or licensing. The net exit rate is defined at the sector- and size-stratum where the firm is operating (see Section 2.2) and is standardized over the whole period. The full list of controls is specified in Section 3. % reduction from trend is defined as the percentage decrease of aggregate expenditure in per capita terms (in constant 2010 US$) from its quadratic pre-crisis trend. Rho is the share of the overall variance explained by the firm-level unobserved fixed effect.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 5
Effect of net exit rate on innovation expenditures.

Dependent variable	Overall expenditure on innovation (R&D + Buy expenditures)					
Sub-sample	Firms always investing				All firms	
Estimation method	FE (1)	FE (2)	FE (3)	FE (4)	FE (5)	CRE Tobit (6)
Net exit rate	0.003	0.002	0.005	0.038*	−0.166***	−0.365***
	(0.011)	(0.012)	(0.014)	(0.020)	(0.038)	(0.039)
Net exit rate × Reduction from trend				−0.004**		
				(0.002)		
Observations	12,861	12,861	12,861	12,861	28,296	28,296
rho	0.832	0.829	0.804	0.805	0.549	0.492
Firm FE	Yes	Yes	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Macro-sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Time-varying controls	Yes	Yes	Yes	Yes	Yes	Yes
Time-by-Macro-sector FE	Yes	No	Yes	No	Yes	No
Size-by-Macro-sector FE	Yes	No	Yes	No	Yes	No

Note. Standard errors in parenthesis are clustered at firm level. The dependent variables are overall expenditures on innovation (including R&D and Buy strategies), reported in logarithms. The net exit rate is defined at the sector- and size-stratum where the firm is operating (see Section 2.2) and is standardized over the whole period. The full list of controls is specified in Section 3. Rho is the share of the overall variance explained by the firm-level unobserved fixed effect.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 6
Within-firm comparison across investment types.

Dependent variable	Investment in category *c* at time *t* (in logarithm)				
Estimation method	FE (1)	FE (2)	FE (3)	FE (4)	FE (5)
Net exit rate	−0.259***	−0.245***	−0.195***	−0.198***	
	(0.038)	(0.038)	(0.038)	(0.040)	
Net exit rate × Any innovation investment	0.017	0.017	0.017	0.017	0.017
	(0.048)	(0.048)	(0.048)	(0.049)	(0.048)
Liquidity (strata)			0.284***	0.254***	
			(0.041)	(0.042)	
Bank loans (strata)			0.031***	0.036***	
			(0.007)	(0.008)	
Financial burden (strata)			-0.045***	-0.039***	
			(0.008)	(0.009)	
Observations	56,592	56,592	56,592	56,592	56,592
Firm and Year FE	Yes	Yes	Yes	Yes	No
Firm-by-Year FE	No	No	No	No	Yes
Category FE	Yes	Yes	Yes	Yes	Yes
Macro-sector FE	No	Yes	Yes	Yes	No
Sector-level controls	No	Yes	Yes	Yes	No
Time-varying controls	No	Yes	Yes	Yes	No
Time-by-Macro-sector FE	No	No	No	Yes	No

Note: Standard errors in parenthesis are clustered at firm level (columns 1–4) and at firm-by-investment level (column 5). The dependent variable is the value of investment in category *c* at time *t*. We make use of two categories: investment on innovation and investment on tangible goods. Innovation is a dummy variable equal to one if the category is "investment on innovation", zero otherwise. The net exit rate is defined at the sector- and size-stratum where the firm is operating (see Section 2.2) and is standardized over the whole period. The full list of controls is specified in Section 3.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

wide variation. The sector-level net exit rates are only partially correlated with sector-size-level net exit rates. The correlation is equal to 0.51.[9] Controlling for the sector-level net exit rate does not affect the coefficient on the stratum-level exit rate. See Appendix A.3.

Our next step is to study how the results in Table 3 vary with aggregate demand reductions. We can do this because our data includes some pre-recession years as well as the time of the Great Recession in Spain. First, we introduce in our estimating model a pre/post comparison. Specifically, we interact the net exit rate with a dummy variable equal to one if the period of observation is post-2007 and zero otherwise. We then study heterogeneity in terms of the deviation of aggregate expenditure from its trend. In

[9] We also test whether exit rates in the panel affect investments in innovation. The correlation between this measure and the overall net exit rate is even smaller and equal to 0.31. The coefficient on the overall net exit rate is robust to the inclusion of exit rates in the panel.

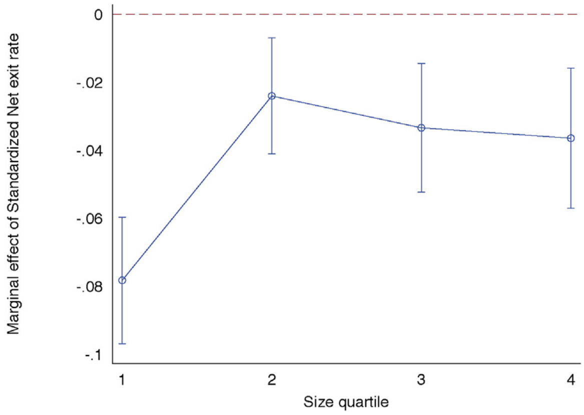

Fig. 4. Marginal effects of net exit rate on firm's sales, by size quartile. *Note.* Coefficients are estimated using fixed effects estimation for Eq. (2) and using interaction terms between net exit rates and indicator variables for firms' size quartile. The net exit rate is defined at the sector- and size-stratum where the firm is operating (see Section 2.2) and is standardized over the whole period. The coefficients are estimated including the full set of controls, including time fixed effects, firm and industry time-varying controls and time-by-sector fixed

particular, we define this deviation as the percentage decrease of aggregate expenditure in per capita terms for Spain (in constant 2010 US dollars) from its quadratic pre-crisis trend.[10]

Table 4 presents results for any innovation investment (columns 1–4), and for investments in R&D (column 5) and buy strategies (column 6). We may infer from the results that the reduction in investment happens in strata where exit rates are higher, but only in periods when negative deviations from the trend are larger. For each percentage decrease from the trend, one standard deviation increase in net exit rate reduces the propensity to invest by 0.2 percentage points. When consumption is at trend level, the coefficient is positive, but not significant. We also extend our analysis by keeping entry and exit rates separate. When aggregate consumption is not deviating from trend, higher entry rates have an opposite effect, compared to exit rates. Both effects are significant and tend to sum up to zero (see Appendix A.1).

4.2. Intensive margin

We next turn our attention to the yearly amount spent on any innovation activity. This includes internal R&D, external R&D, machinery and licensing. It is important to note that here we focus on the flow variable, rather than the stock of investment, since only the former is available in the dataset. Table 5 presents estimates for Eq. (2) (columns 1–5) and for a CRE Tobit model (column 6).[11] In columns 1–4, we restrict the sample to firms that have not stopped investing in innovation over the period of analysis, while in columns 5–6, we concentrate on all firms.

On average, innovation investments are not reduced in response to higher net exit rates among firms that do not stop investing in innovation. Innovative firms tend to allocate higher expenditures to innovation in periods in which aggregate consumption is at its trend level, while negative deviations from trend tend to reduce the investment in innovation. When aggregate consumption decreases by 1%, a one standard deviation increase in net exit rates is associated with a decrease of around 0.4 percentage points in innovation expenditure as a response to the increase in net exit rates. In comparison, when aggregate consumption at its trend level, innovation expenditure increases by roughly 4 percentage points when net exit rates increase by one standard deviation. During the overall period, these opposite effects tend to compensate. These results suggest that, in the period of analysis, net exit variation is mainly linked with the extensive margin of investment, rather than the intensive margin. This is also supported by estimates when looking at all firms, for which we highlight a large negative effect of increased net exit rates on overall expenditures on innovation, in line with the results shown in Table 3.

4.3. Robustness checks

4.3.1. Demand versus credit constraints

We have so far recorded that increases in net exit rates are associated with reductions in innovation investments. The reduction in innovation investments could have indeed been related to demand shocks. Yet, it could also be capturing additional financial constraints that are not captured by our controls. To test this hypothesis, we first study the role of idiosyncratic shocks that could be captured by net exit rates, and then analyze how variation in sales can be linked to our results.

To check whether net exit rates are capturing idiosyncratic shocks, for example credit shocks, we use within-firm estimation by using, for each firm, two investments at time t, as in the identification procedure used in Garicano and Steinwender (2016) (see Eq. (4) in Section 3). We focus on the investment in innovation and gross fixed capital formation, which are the two investment categories available in the dataset. Investments are reported in logarithms. Table 6 presents the estimates for Eq. (4) under different specifications. We focus on columns 4 and 5. Column 4 is our preferred specification in the paper, while in column 5 we introduce firm-by-year fixed effects. If firm-specific time-varying unobservable characteristics or shocks are correlated with net exit rate we would expect the coefficient on the interaction between net exit rate and the innovation investment dummy variable to change significantly across the two specifications. We observe instead that our estimate does not change. This suggests that, in our sample, net exit rates do not capture idiosyncratic variation that is not already captured by our controls.[12] Disaggregating further the innovation investment (for example, distinguishing between internal and external R&D) and running a similar estimation procedure lead to the same conclusion.

We then focus on the role of net exit rates in explaining variations in sales. This is important for two reasons. First, sales are closely associated with changes in aggregate demand. In our sample, sales among smaller firms follow aggregate consumption very closely (see Appendix A.2). The year-level correlation of the two series during the period 2004–2013 is equal to 0.91 (0.97 if we restrict the period to the 2008–2013 recession). This relationship is less clear for larger firms. In this case, the correlation between the two series drops to 0.60 (0.62 if we restrict the period to the recession). It is not surprising that aggregate expenditure shocks have a larger impact on smaller firms, as we also observe changes in investment behavior.

Second, during the recession, reductions in sales were also heterogeneous. Overall, higher exit rates are associated with a sharp decrease in sales. A one standard deviation increase in the net exit rate is linked with a reduction in sales by around 6 to 7 percentage points (see Appendix A.2). Since reductions in investments are mainly associated with small firms, we study how this coefficient changes when it interacts with size quartile dummies. Fig. 4 plots the marginal effects of net exit rates on firms' sales at the different quartiles of the size distribution. The marginal effect for smaller firms is large and negative. A one standard deviation increase

[10] We present the results with aggregate consumption for Spain. We predict the trend using a linear regression of the raw data on the time variable and its square and using the 1970–2007 period. Raw data were obtained from the World Bank DataBank. Our conclusions are robust to using European or world aggregate consumption. See Appendix A.4.

[11] Expenditures are reported in logarithms after adding one unit. Results are robust to outcomes in levels.

[12] We also notice that by focusing on these two investments, we do not observe any statistically significant difference in the way higher net exit rates translate into lower investments across investment categories. This suggests that, with respect to the investment categories and the type of firms we focus on, the results in Garicano and Steinwender (2016) do not fully apply in our setting.

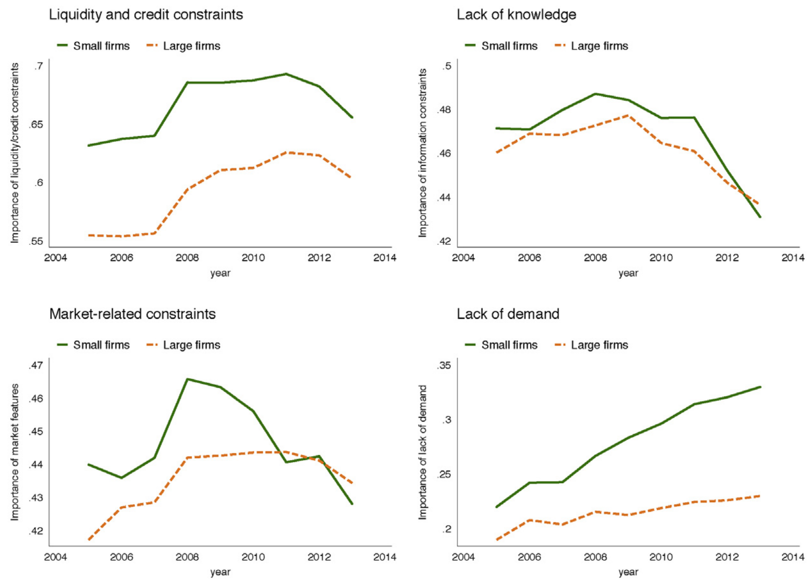

Fig. 5. Aggregate trends in importance of constraints for innovation. *Note.* For each topic, the dependent variable is built by averaging answers within the sub-group and rescaling them in a 0-1 scale, with 1 representing the highest relevance. Appendix A.7 presents a description of individual components.

translates into a reduction of around 8 percentage points. In the second, third and fourth quartile, the effect is much smaller and homogeneous across groups. This is also in line with the homogeneity in the average net exit rates among these firms.

At least among innovative firms, the link between net exit rates and heterogeneity in demand reduction is robust. To explore an alternative channel, we also focus on lack of financing. Among the firms investing in R &D, we do not observe changes in the way firms finance their investment, either with internal, external (from other firms and banks), public or foreign funding. See Table A8 in the Appendix.[13] We also do not observe evidence of investment diversification, both within innovation investments and across investments. Higher exit rates are linked to a reduction in all types of investments, including gross fixed capital formation. See the Appendix A.6.

4.4. Perceptions

Since we cannot control whether financing is an issue for the firms that have already stopped their investments, we complement our results with the firm's perceptions of the constraints to innovation investment. We use a set of 10 questions focusing on these constraints. For each question, the firm's representative ranked, on a scale 1 to 4, the importance of each element for the firm, from highly relevant to not relevant. The exact text of the question reads as follows: "*How important were the following factors hindering innovation activities or influencing the decision not to innovate?*" We re-scaled answers in a 0 to 1 scale, with the value 1 representing the highest importance. We grouped constraints into four categories: liquidity and credit constraints, lack of knowledge, market-related constraints, and lack of demand. Table A10 in the Appendix presents the questions and how they are divided into subgroups.

Fig. 5 shows the time series of these indexes by averaging the answers in each year and by distinguishing between small and large firms. In general, firms responded to the recession in the first part by reporting liquidity, credit and market-related constraints with increased importance. The importance of these factors reduces towards the end of the period, probably reflecting the change in interest rates. These constraints are more important for smaller firms, while lack of knowledge decreases over the period and is very similar across firm size. Lack of demand, however, is always increasing.

To understand whether perceptions are also heterogeneous across firms, we again look at net exit rates. Firms active in high-exit strata might update their perceptions differently. For example, if credit is perceived as a stronger constraint, it could suggest the presence of credit constraints. Table 7 presents the estimates for Eq. (2), where the dependent variables are the constraints indexes. Higher exit rates are significantly associated with an increase in the importance of lack of demand. On the other hand, we do not observe any significant coefficients for the other constraints. This again suggests that, among innovative firms, net exit rates, rather than credit constraints, capture heterogeneous variation in demand. Credit constraints are not particularly relevant for innovative firms.

4.5. Firm exit

To conclude this analysis, we focus on our decision to select only firms that do not exit the market during the period of analysis. One possible claim is that net exit rates and contemporaneous investments are drivers of exit rates in our target population. To analyze this potential channel, we selected all firms that are in the initial sample, but keep firms that exit the market during the period of interest to study directly how the probability of exit evolved over time among the firms initially sampled.

We define firm exit as a firm being in the dataset as temporary or indefinitely closed. Our outcome of interest is a dummy variable equal to zero if the firm is active in the market at time t, and one if the firm exits at time $t + 1$ and missing for every period following exit. Fig. 6 presents estimates of the Nelson-Aalan cumulative hazard estimates on the probability of exiting the market for the whole sample (left panel) and by firm size (right panel). First, we note that the cumulative hazard estimates tend to be rather small, showing that we are focusing on a relatively stable market in terms of exit rates. Second, as expected, hazard estimates are dependent on size, with smaller firms having higher hazard estimates. This difference becomes evident only during the period of crisis; whereas, before there was little difference between smaller and larger firms.

We check whether the variation in net exit rates explains the timing

[13] We also estimate Eq. (2) by interacting the net exit rates with the short-term interest rates for Spain. Given the European Central Bank's policy in response to the crisis, variation in interest rates seems to also capture variations in aggregate demand. When an interaction term with aggregate demand is also introduced, the coefficient becomes insignificant.

Table 7
Effect of net exit rate on perceived constraints to innovation investments.

Dependent variable	Degree of importance of...			
Estimation method	Liquidity/credit constraints FE (1)	Lack of demand FE (2)	Lack of knowledge FE (3)	Market-related constraints FE (4)
Net exit rate	−0.003	0.004*	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Log profits (sector)	−0.001	0.001	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Log hours worked (sector)	0.000	0.007	−0.001	−0.010
	(0.010)	(0.011)	(0.008)	(0.010)
Liquidity (stratum)	0.004	−0.009***	0.001	−0.000
	(0.003)	(0.003)	(0.003)	(0.003)
Bank loans (stratum)	−0.001	0.000	0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.001)
Financial burden (stratum)	0.002***	0.001**	0.001*	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
Observations	28,296	28,296	28,296	28,296
rho	0.527	0.447	0.532	0.509
Firm FE	Yes	Yes	Yes	Yes
Time-varying controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Sector-level controls	Yes	Yes	Yes	Yes
Time-by-Macro-sector FE	Yes	Yes	Yes	Yes
Size-by-Macro-sector FE	Yes	Yes	Yes	Yes

Note: Standard errors in parenthesis are clustered at firm level. For each topic, the dependent variable is an index built by averaging answers within the sub-group and rescaling them in a 0-1 scale, with 1 representing the highest relevance. The net exit rate is defined at the sector- and size-stratum where the firm is operating (see Section 2.2) and is standardized over the whole period. The full list of controls is specified in Section 3. Rho is the share of the overall variance explained by the firm-level unobserved fixed effect.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

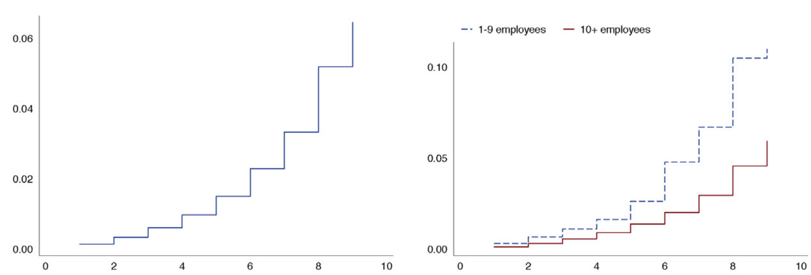

Fig. 6. Nelson-Aalan cumulative hazard estimates for market exit. *Note.* The left panel shows the Nelson-Aalan cumulative hazard estimates for the whole sample of firms investing in R&D in 2004, while the right panel presents the same estimates by firm size (number of employees). Time 0 is set to year 2004.

of exit among these firms. Table 8 presents hazard ratios estimates of different survival models and analyze the role of net exit rates on market exit. In columns 1–3, we estimate a Cox proportional hazards model, while in columns 4–6, we present estimates for a random-effect parametric model assuming an exponential survival distribution. In the estimation, we always control for firm-level and industry-level time-varying controls and for industry fixed-effects. Since we cannot control for firm fixed-effects, we add firm-level averaged controls (controls are averaged over the period of reference and includes average sales), lagged controls for firm size and the number of patents registered, and sector-level averaged controls. The latter are therefore specific to the firms originally investing in R&D, rather than the whole sector. In columns 2 and 4, we add a control for whether the firm invested in innovation at time *t*, while in columns 3 and 6, we also control for firm-level sales and average investment in innovation in the firm's stratum. The latter is computed as average log-expenditure among other firms in the same sector-size stratum of the firm. This variable aims to capture competitors' behavior.

Net exit rate presents a hazard ratio that is not statistically different than one. Adding controls specific to investment in innovation, sales and competitor's behavior at time *t* does not affect our estimates. This suggests that net exit rates in a firm's stratum do not drive the exit among firms in the specific market under analysis.

5. Conclusions

The Great Recession had a dramatic effect on the Spanish economy. Large reductions in aggregate consumption affected not only the overall economy, but also created deep differences across productive sectors. We hypothesized that a higher net exit rate proxies for higher reductions in demand. We analyzed whether higher stratum-specific rates are associated with innovation investment.

Bearing these considerations in mind, we analyzed a panel of Spanish manufacturing firms surveyed annually from 2004 to 2013. Variation in net exit rates indeed captures firms' choices of investment. The average effect is driven by smaller firms in the sample; however,

Table 8
Survival models for the probability of market exit.

Failure event	Temporary or Permanent market exit at time $t+1$					
Model	Cox	Cox	Cox	Parametric	Parametric	Parametric
Distributional assumption	–	–	–	Exponential	Exponential	Exponential
	(1)	(2)	(3)	(4)	(5)	(6)
Net exit rate	0.992	0.986	0.982	1.040	1.026	0.982
	(0.036)	(0.036)	(0.042)	(0.036)	(0.036)	(0.039)
Any innovation investment at time t		0.532***	0.559***		0.438***	0.475***
		(0.048)	(0.051)		(0.040)	(0.044)
Log sales at time t			0.412***			0.367***
			(0.029)			(0.033)
Average investment in innovation (stratum)			1.176***			1.079***
			(0.023)			(0.019)
Observations	31,803	31,803	31,799	31,803	31,803	31,799
Firm random effects	No	No	No	Yes	Yes	Yes
Firm FE	No	No	No	No	No	No
Year FE	No	No	No	No	No	No
Firm-level time-varying controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm-averaged controls	Yes	Yes	Yes	Yes	Yes	Yes
Sector-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Sector-level time-varying controls	Yes	Yes	Yes	Yes	Yes	Yes

Note: Estimates are hazard ratios. Robust standard errors are presented in parenthesis. The survival indicator is a dummy variable equal to zero if the firm is active in the market at time t, one if the firm exit at time $t+1$ and missing for every period following exit. The net exit rate is defined at the sector- and size-stratum where the firm is operating (see Section 2.2) and is standardized over the whole period. Share of competitors investing is the share of other firms (excluding the firm to which we assign the value) in the same sector and size stratum that are investing in any innovation activity. Firm-averaged controls are computed by averaging firm-level time-varying controls over the time. Sector-level time varying controls are computed by averaging firm-level time-varying controls at sector level. The full list of controls is specified in Section 3.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

the magnitude of these changes is not small. A one standard deviation increase in net exit rates – roughly 0.8% – leads to a reduction of around 1.5 percentage points in the share of firms investing in innovation. This is mainly driven by small firms and by the effect of investment in internal R&D. We suggest that this relationship between net exit rates and innovation expenditures is mainly linked to large deviations in aggregate demand, with access to finance playing a secondary role. The reduction in investment in higher in periods when the reduction from the trend is larger. At the same time, higher rates are associated with large reductions in sales. These are again concentrated among smaller firms.

The empirical results presented in the literature point at the central importance of private investments in innovation for the entire economy. This makes the study of private and public responses that could support R&D investments during recessions, including R&D subsidies, a relevant matter. Indeed, for the particular case of R&D subsidies, the potential risk of crowding out is smallest during recessions. Empirical evidence is complemented by our results that suggest that, since most of the decrease in innovation-related investments occurs among smaller firms, smaller firms should be particularly targeted in periods of low demand to maintain their incentives to invest in innovation. Furthermore, a countercyclical public expenditure in R&D is called for, which would partially offset the decline in business R&D expenditures, in order to maintain the national R&D capabilities. In so doing, the public authority should carefully select R&D projects that are clearly complementarity with businesses' R&D.

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Appendix Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.respol.2018.04.015.

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