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Innovation and zombie firms: Empirical evidence from Italy

Andrea Ascani[a,*], Lakshmi Balachandran Nair[b]

[a] Gran Sasso Science Institute (GSSI), Viale F. Crispi 7, 67100 L'Aquila, Italy
[b] LUISS Guido Carli University, Viale Romania 32, 00197 Rome, Italy

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ABSTRACT

Zombie firms are businesses that cannot repay debt from current profits over an extended period and yet continue to operate and avoid failure. This article specifically investigates whether and under what circumstances the presence of zombies in an industry constitutes a barrier to the innovativeness of non-zombies in the same sector. Conceptually, non-zombie firms may face tougher access to finance and fiercer market competition when zombies are in business, and this could reduce their innovative efforts. By analysing matched patent-firm data from Bureau van Dijk ORBIS Intellectual Property on 426,130 Italian firms from 2012 to 2018, we find evidence in favour of this negative intra-industry spillover. Nonetheless, this general relationship is subject to various contingencies. Specifically, zombies are detrimental to healthy firms that (i) depend on external sources of finance, (ii) operate in highly competitive markets, (iii) are more exposed to the erosion of their market shares, and (iv) do not possess a pre-existing strong knowledge base. Our findings have relevant policy and managerial implications.

1. Introduction

In the aftermath of the 2008 financial crisis and, more recently, in the post-pandemic years, a key implication of prolonged times of economic stagnation seems to materialise in the rise of so-called zombie firms (e.g. Adalet McGowan et al., 2018). The proliferation of these entities within industries and regions, in turn, may be a highly critical factor affecting the innovation capacity of healthy organisations.[1] Zombies are broadly defined as financially unhealthy businesses, namely, companies that are unable to repay debt costs from current profits over an extended time-period and yet continue to operate and avoid failure (e.g., Andrews and Petroulakis, 2019). Their presence may be connected to the increase of non-performing loans (NPLs) in the economy, that is bank loans the borrower has stopped serving, mostly conceded to weak firms that cannot sustain their business over time. In periods of crisis, in fact, banks and creditors may continue financing weak firms in the hope of recovering credits at a later stage or to postpone losses and the consequent deterioration of capital (Caballero et al., 2008). Under these circumstances, financially fragile firms are kept alive artificially through bank lending, thus starting a process that turns them into zombie firms. This matter clearly signals the increasing influence of the financial sector on firm activities and interactions (Feldman et al., 2021). Institutions such as the European Central Bank (ECB) and the Organization for Economic Cooperation and Development (OECD) have voiced strong concerns regarding the increase of NPLs, as these deteriorate the future capacity of banks to grant new loans and finance new projects (OECD, 2021). The stock of NPLs in the Euro area is at €356 billion in the second quarter of 2024, with particularly high shares of NPLs on total loans in countries such as Cyprus, Greece, Portugal, Spain and Italy, thus indicating a considerable pool of resources that can reinforce the zombification of some areas of the EU economy.

In this context, this paper analyses the intra-industry relationship between zombie firms and the innovation capacity of healthy firms, an area of inquiry that has received scant attention despite its relevance for understanding the potential hurdles to firms' innovative activities. Extant studies have focused, instead, on investigating the zombie-induced effects on aspects such as credit misallocation, employment and productivity dispersion (e.g., Caballero et al., 2008; Schivardi et al., 2017). This work also contributes to the literature on the obstacles to innovation (e.g., Iammarino et al., 2009; Coad et al., 2016; Arza and López, 2021; Iammarino et al., 2021) by emphasizing the survival of zombies as an additional and unexplored "revealed" barrier to the innovative activities of non-zombie firms. The working hypothesis of this article is that the zombification of local economies, in fact, can place

* Corresponding author.
E-mail addresses: andrea.ascani@gssi.it (A. Ascani), lbalachandrannair@luiss.it (L. Balachandran Nair).

[1] In this article, healthy firms are intended as synonymous of non-zombies.

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unknown and potentially very challenging obstacles to the innovation capacity of healthy organisations. Not only zombie firms may affect the innovativeness of an industry or local economy due to their individual financial weakness or by sustaining uncompetitive skills, technologies and practices, but the presence of organisations turning into zombies can also influence the within-industry innovation performances of non-zombie incumbents. This may occur by altering local competition and distracting resources from healthy firms, thus affecting their decisions to invest, innovate or upgrade existing routines and competences. Focusing on this spillover constitutes the object of analysis of this article.

Empirically, we focus on the case of Italy, a relevant example of a national economy within the EU with a relatively high share of zombie firms (Adalet McGowan et al., 2018). By analysing matched patent-firm data from Bureau van Dijk ORBIS Intellectual Property (IP) on 426,130 firms from 2012 to 2018 and estimating both Poisson pseudo-maximum likelihood models as well as instrumental variable regressions in a control function setting, we find that a 10 % increase in the employment share of zombie firms in a sector is related to a decrease of the innovation performance (i.e. patenting) of non-zombie organisations in the same industry ranging between 0.8 % and 2.8 %, depending on the method employed. Nonetheless, this general relationship is subject to various contingencies connected to both industry and firm characteristics that can also produce positive externalities under very specific circumstances.

The article is structured as follows: the next section reviews the literature on the effects of zombie firms; afterwards, we present the data and the methodological approach; subsequently, we discuss the results of the empirical analysis and, finally, we draw conclusions as well as policy and managerial implications.

2. Conceptual background

2.1. Literature on zombie firms

The recent literature on zombie firms emerges from the analysis of economic stagnation, recession and financial crises (e.g., Caballero et al., 2008; Acharya et al., 2019). The first academic detection of zombies refers to the case of the Japanese stagnation of the 1990s, during which a significant number of banks supported troubled Japanese firms to protect employment through debt forgiveness and financial concessions, thus contributing to their transformation into zombies (Hoshi, 2006). In recent years, some additional evidence is surfacing with several studies that consider the increase of zombie firms as a result of the 2008 financial crisis, by analysing zombies' characteristics and implications across OECD countries, their links with banks and their detrimental productivity effects (e.g., Schivardi et al., 2017; Adalet McGowan et al., 2018; Andrews and Petroulakis, 2019).

This line of work has evidenced that zombie firms have higher probabilities to be connected to weak banks, thus indicating that their presence may be partly explained from bank forbearance. In turn, surviving zombie firms can congest markets and this may slow down the productivity performance of healthy firms through reduced opportunities to access bank credit (Andrews and Petroulakis, 2019). According to some studies, this type of credit misallocation where a relevant share of bank loans is absorbed by zombie firms may have contributed to the slow pace of economic recovery in the EU after the 2008 crisis (Acharya et al., 2019). Furthermore, while these liquidity injections into zombie firms may have kept them alive in the short run, the evidence shows that many of these organisations would fail in the long term due to their low productivity performances. Nonetheless, while alive, zombie firms can easily depress industry aggregate productivity and crowd out investment levels and the employment growth of competing healthy companies (Banerjee and Hofmann, 2018; Acharya et al., 2019). While these represent the typical findings of the literature, other contributions highlight how preventing zombie firms from exiting the market may both mitigate the disruptions of supply chains and have positive demand externalities. According to Schivardi et al. (2017), in fact, allocating credit to the most fragile firms may hinder the propagation of the negative effects of economic recession, such as unemployment, even if this represents a misallocation of resources that distorts market competition. Furthermore, contrary to the main findings in the literature, not only do they find that the presence of zombie firms does not negatively affect the performance of healthy firms, but also that in some cases the spillover effect can turn positive if the survival of zombie firms contributes to aggregate demand and feeds industry input-output linkages.

2.2. Zombies and innovation: potential mechanisms for spillovers

The survival of firms that would typically exit the market in normal competitive conditions may unleash industry-wide effects on the innovative performance of healthy enterprises. As the literature suggests, credit misallocation from banks keeps zombie firms alive through the liquidity injections that could otherwise finance the activities of non-zombie organisations (Caballero et al., 2008). Therefore, competition on capital markets to access credit may increase within sectors characterised by a relatively high incidence of zombies. This implies that healthy and creditworthy firms face tougher market conditions to receive bank loans and finance their activities, including innovation. Consistently, financial constraints (internal and external to organisations) are identified as a relevant impediment to firm engagement in innovative activities by a large set of scholarly works investigating the barriers to innovation (e.g., Hottenrott and Peters, 2011). This barrier can be particularly relevant in the context of a country such as Italy, that is the focus of this article, as existing cross-country studies suggest that the lack of opportunities to access credit represents the primary obstacle to innovative activities for Italian firms (Bugamelli et al., 2012). Innovative activities of Italian firms, in fact, tend to be mostly associated with firms' internal resources (Hall, 2010) and, less than in other comparable European countries, with external finance received through linkages with banks as opposed to venture capital (Vacca, 2013). Hence, the presence of zombie firms within industries may hinder the innovation capacity of healthy firms through capital misallocation, that is a reduced access of non-zombies to the capital market. Extant empirical evidence corroborates the hypothesis that experiencing financial constraints strongly decreases the probability that firms will undertake innovative activities (Hyytinen and Toivanen, 2005; Savignac, 2008). While the above statements describe a general mechanism, at the micro level non-zombie firms are far from being a homogeneous group of entities, as it is plausible that some individual characteristics differ substantially from firm to firm. Considering this heterogeneity, then, paves the way to conceptualise the incidence and relevance of zombie-induced spillovers as partially depending from non-zombie characteristics. For example, the presence of more obstacles in accessing bank loans may encourage the healthiest firms among the non-zombies to exploit available finances (internal or external) more efficiently and this can potentially spur their innovative efforts. In other words, when facing the obstacles posed by zombies, the strongest non-zombies may be able to leverage their distinctive assets and transform the challenges into opportunities, while the rest of non-zombies may not be able to do so. In these circumstances, therefore, the survival of zombie firms can potentially generate intra-industry positive effects on the strongest non-zombies, by improving their use of available finances for innovation purposes for instance, whereas the rest of healthy firms may experience the general detrimental effects of facing surviving zombies.

Beside the more intense competition on the market for capital, the presence of zombies can also unleash more intense crowding on the market for goods and services. More congested markets imply that healthy companies would face more competitive pressures than in absence of zombie firms (Adalet McGowan et al., 2018; Andrews and Petroulakis, 2019). On the one hand, this may discourage the innovative efforts of healthy firms, as they can use available resources for less risk prone activities than innovation in markets that are more contested due to the survival of zombies. In this sense, the slow or absent reallocation of market shares towards the most productive firms, due to the retention of zombie organisations, may signal to healthy firms that their innovative efforts are not accompanied by a market advantage. On the other hand, it is plausible that when facing more competition in their market, some healthy businesses may attempt to increase their innovative efforts to reinforce and refine their competitive advantage (e.g., Thoenig and Verdier, 2003). This may specifically be the case of the strongest healthy firms, that is organisations already operating close to the technological frontier, since their internal knowledge base represents an advantage for further investment in innovative activities (Lee, 2009).

These considerations lead us to acknowledge that the intra-industry effects of zombies are not only heterogeneous along sector dimensions but can also be diverse for different sets of healthy firms, as the potential barriers to innovation can have distinctive implications depending on firms' attributes (Coad et al., 2016). As mentioned, healthy organisations with strong knowledge assets will be able to adopt different strategies than those with more fragile technological endowments (Freel, 2007; Montresor and Vezzani, 2015; Montresor and Vezzani, 2022). Similarly, healthy businesses enjoying larger market shares relative to those with more limited market power can be better positioned to face markets congested with zombie firms. In these circumstances, while the former group of healthy organisations may not suffer from the presence of zombies in terms of innovation activities, the latter group may face more constraints towards innovation due to a weaker market presence that can limit the scope for risky R&D investment. Along these lines, extant evidence on the non-financial barriers to innovation suggests that firms operating in markets with a presence of well-established competitors may reduce their innovative activities (Pellegrino and Savona, 2017).

Overall, while at the aggregate level the survival of zombie firms may contribute to generating hurdles to non-zombies' innovative activities, it is also possible that their presence produces a more complex and potentially ambiguous set of implications for different types of industries and non-zombie firms. In this sense, zombies can not only constitute themselves a barrier to the innovative capacity of non-zombies, but also amplify the relevance of other financial and non-financial barriers discussed in the literature (D'Este et al., 2012).

3. Data description

In this article we make use of Bureau van Dijk Orbis Intellectual Property (IP) data for Italy, which includes firm balance sheet linked to patent statistics. Specifically, Orbis data include the information needed to identify zombie firms and it thus represents a source already in use in the literature for this purpose (see Adalet McGowan et al., 2018; Andrews and Petroulakis, 2019). Patent data in Orbis IP, instead, come from Lighthouse IP, a private provider covering virtually all intellectual property authorities worldwide, from which we obtain the number of patents by firm as a measure of its innovation performance. Specifically, we focus on patents granted by the European Patent Office (EPO). Other recent works have employed Orbis IP to inspect innovation-related aspects of firm operations, including fourth industrial revolution trends (Benassi et al., 2020; Shi et al., 2020), technology supply dynamics (Bastianin et al., 2021) and automation (Santarelli et al., 2023), to mention a few. Regarding firm balance sheet information, we thoroughly follow the indications by Kalemli-Özcan et al. (2024) to clean and organise Orbis. In line with the previous literature on zombie firms, we only keep firms in manufacturing and services (NACE Rev.2 codes 10 to 83, excluding 64 to 66). Subsequently, we also exclude firms in sectors without patents over the sample period.[2]

In line with existing studies, we define zombie firms as firms older than ten years and with an interest coverage ratio (ICR) below 1 for three consecutive years.[3] Including in this definition only firms that are at least ten years of age is meant to exclude start-ups and very young firms that are typically not profitable. Regarding the ICR, instead, this captures the financial solidity of firms, and it is specifically defined as the ratio between a measure of firm profit and interest payments. A value below 1 entails that profits are not sufficient to repay debt service. Considering an ICR below 1 for three consecutive years, then, should signal that a firm is persistently weak from a financial standpoint.[4] As a measure of firm profit, we opt for Earnings before Interest, Taxes, Depreciation and Amortization (EBITDA), while most prior studies define zombie firms based on EBIT as a measure of profit, that is after depreciation and amortization costs are taken into account. Our choice is motivated by convincing arguments by Rodano and Sette (2019) that, in capital-intensive sectors where amortization is high, the gap between EBIT and EBITDA can be very wide, especially in times of economic crisis when earnings are lower. Furthermore, EBITDA more than EBIT is close to cash-flow, which represents a key element to cover interest fees. Given that EBITDA excludes more costs than EBIT, earnings are typically higher and therefore the share of zombie firms would be lower by using the former indicator.

Fig. 1 shows the yearly relevance of zombie firms during the sample period based on EBIT (light blue bars) and EBITDA (dark blue bars). It is evident that the EBITDA-based measure delivers a more conservative estimate of the zombie phenomenon, with shares ranging from 2 % and 4 % over the sample period, while the EBIT-based measure indicates shares of zombies between about 4 % and 7 %. Interestingly, the figure also shows that the employment and capital (in terms of tangible assets) possessed by zombie firms is much more limited when considering the EBITDA-based measure.

Fig. 2 shows the distribution of zombie firms by age in the most recent available year. The left panel suggests that there is an inverse relationship between age and zombie status, with the majority of zombies being relatively young firms with age between 10 and 19. In this case, we cannot observe substantial differences between EBITDA- and EBIT-based measures of zombie firms. The right panel, however, reveals that the share of zombies on total firms within each age category grows with age in our sample. This implies that while the many young zombie firms do not weigh much on the total for their age category, the relative incidence of older zombie firms tends to be larger. In this case, the EBITDA-based measure provides evidence of a more limited zombie phenomenon. A very similar pattern can also be noticed in terms of zombie incidence by firm size category in Fig. 3, left and right panel.

In terms of geographical distribution of zombie firms, Fig. 4 shows that the spatial configuration of this phenomenon may depend on how zombies are represented. The map on the left depicts the share of zombies by NUTS-3 and suggests the existence of spatial pattern whereby larger shares of zombie firms are in the Northern and Central

[2] Excluded sectors are NACE Rev. 2 two-digit codes 55 (Accommodation), 56 (Food and beverage service activities), 69 (Legal and accounting activities), 73 (Advertising and market research), 75 (Veterinary activities), 77 (Rental and leasing activities), 78 (Employment activities), 79 (Travel agency, tour operator services and related activities) and 81 (Services to buildings and landscape activities).

[3] In an empirical extension discussed in the results section, we also use a more stringent definition of zombies by additionally considering negative real sales growth, similar to Albuquerque and Iyer (2024).

[4] For example, if a firm has an ICR below 1 for year t_0, $t + 1$ and $t + 2$, then it is labelled as zombie in year $t + 2$, meaning that its financial weakness has been persistent for the last three years and has led the firm to become a zombie.

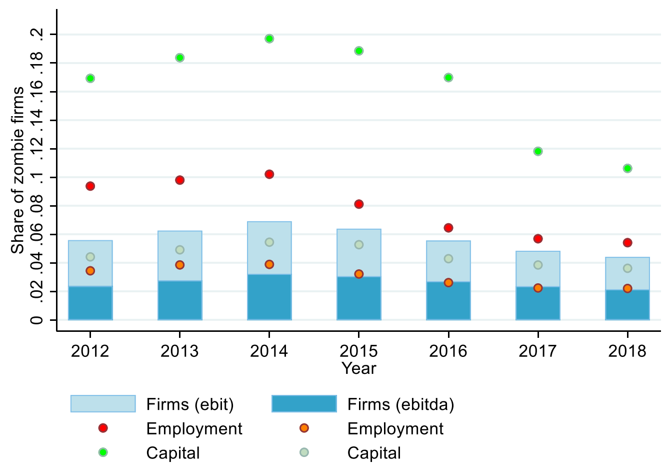

Fig. 1. Relevance of zombie firms in Italy, 2012–2018.
Notes: the figure shows the yearly relevance of zombie firms during the sample period based on EBIT (light blue bars) and EBITDA (dark blue bars). Also, the relevance of zombies is also reported in terms of their employment and capital endowment. Specifically, bright green dots denote employment in zombies defined using EBIT as profits, while opaque green dots regards zombie employment for the EBITDA-based definition. Similarly, bright red dots indicate the amount of capital sunk in zombies based on the EBIT definition, while opaque red dots report capital in zombies defined using EBITDA. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

provinces, while lower shares characterize the South. This may suggest that areas of the country that are typically associated with larger economic activity can be more prone to the zombification of local firms, plausibly because there are more firms and, thus, more intense competition. Nonetheless, the map on the right, instead, by considering the relevance of zombie firms in terms of employment shows a different geography of the zombie phenomenon, where higher shares are concentrated in hotspots associated with specific provinces. This is the case of representative provinces such as Turin and Milan in the Northwest, Trieste in the Northeast, Rome and Terni in the Centre, as well as Naples and Palermo in the South. These tend to be large metropolitan areas and/or locations with a strong industrial tradition. This may suggest that capturing zombies through their employment incidence may provide a more articulated indicator that reflects the importance of the phenomenon also in spatial terms, while the mere number of firms may overlook this aspect and may only reflect different levels of firm numerosity across the country.

In terms of sector incidence, Table 1 reports the top-10 NACE 3-digit industries by employment in zombie firms (based on EBITDA). Overall, the top-10 sectors by zombie employment represent almost 29 % of total employment in zombie firms. Nonetheless, this descriptive evidence suggests that in our sample zombies are scattered across many sectors and do not cluster disproportionately in specific industries.

Overall, this descriptive evidence and the considerations reviewed above provide very strong reasons to favour the EBITDA-based measure of zombie firms for empirical purposes.[5] At the end of this data cleaning process, we obtain observations for 426,130 firms from 2012 to 2018. Besides calculating an indicator for zombies, we also collect data on firm employment, tangible assets and age, to be used as covariates in the empirical analysis. Table A.1 in the Appendix provides summary statistics for the whole sample as well as the subsample of non-zombies and zombies, separately.

In line with the debate on the obstacles to innovation, an important distinction should be made between innovators in the reference period and non-innovators tout court (e.g. D'Este et al., 2012).[6] Table 2 presents this distinction in our sample, based on whether a firm is granted at least 1 patent (panel A) and 10 patents (panel B) over the sample period. In the case of zombies, we consider them as innovators only when they are

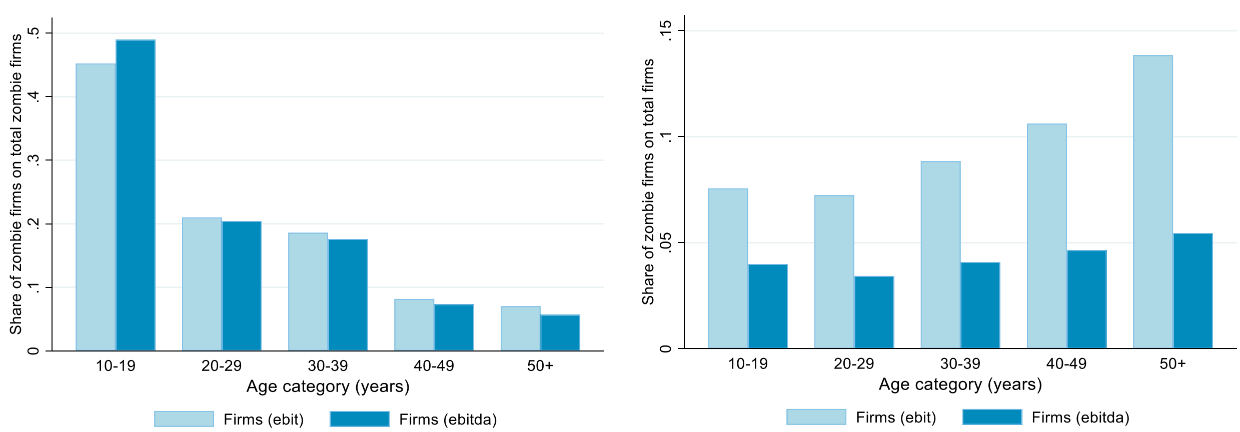

Fig. 2. Age and zombie firms, 2018.
Notes: the figure shows the distribution of zombie firms by age in 2018. Light blue bars denote zombies defined using EBIT as a measure of profits, while dark blue bars indicate zombies based on EBITDA as profits. The left panel measures the share of zombie firms by age group on total zombie firms. The right panel reports zombie firms as a share on total firms (zombies and non-zombies) by age group. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

[5] Our estimates yield statistically similar results when EBIT is used. These are available upon request.

[6] Previous studies on the elements hindering firm innovative activities exploit survey data, such as data from Community Innovation Surveys, and hence are able to capture many (self-reported) nuances of the distinction between innovators and non-innovators. By relying only on patent data in this study, instead, we are obliged to make a net distinction based on this sole indicator of innovation.

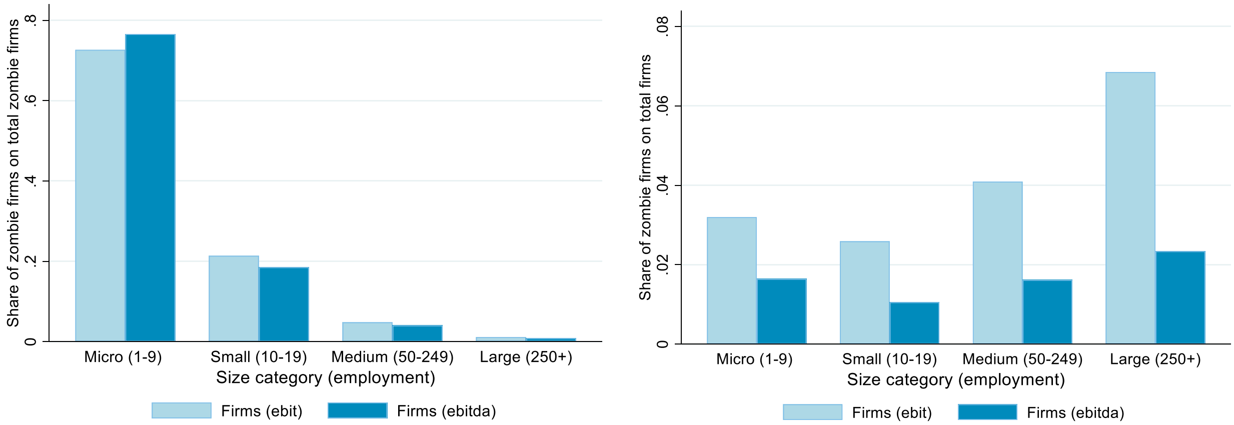

Fig. 3. Size and zombie firms, 2018.
Notes: the figure shows the distribution of zombie firms by size in 2018. Light blue bars denote zombies defined using EBIT as a measure of profits, while dark blue bars indicate zombies based on EBITDA as profits. The left panel measures the share of zombie firms by size class on the total of zombie firms. The right panel reports zombie firms as a share on total firms (zombies and non-zombies) by size class. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

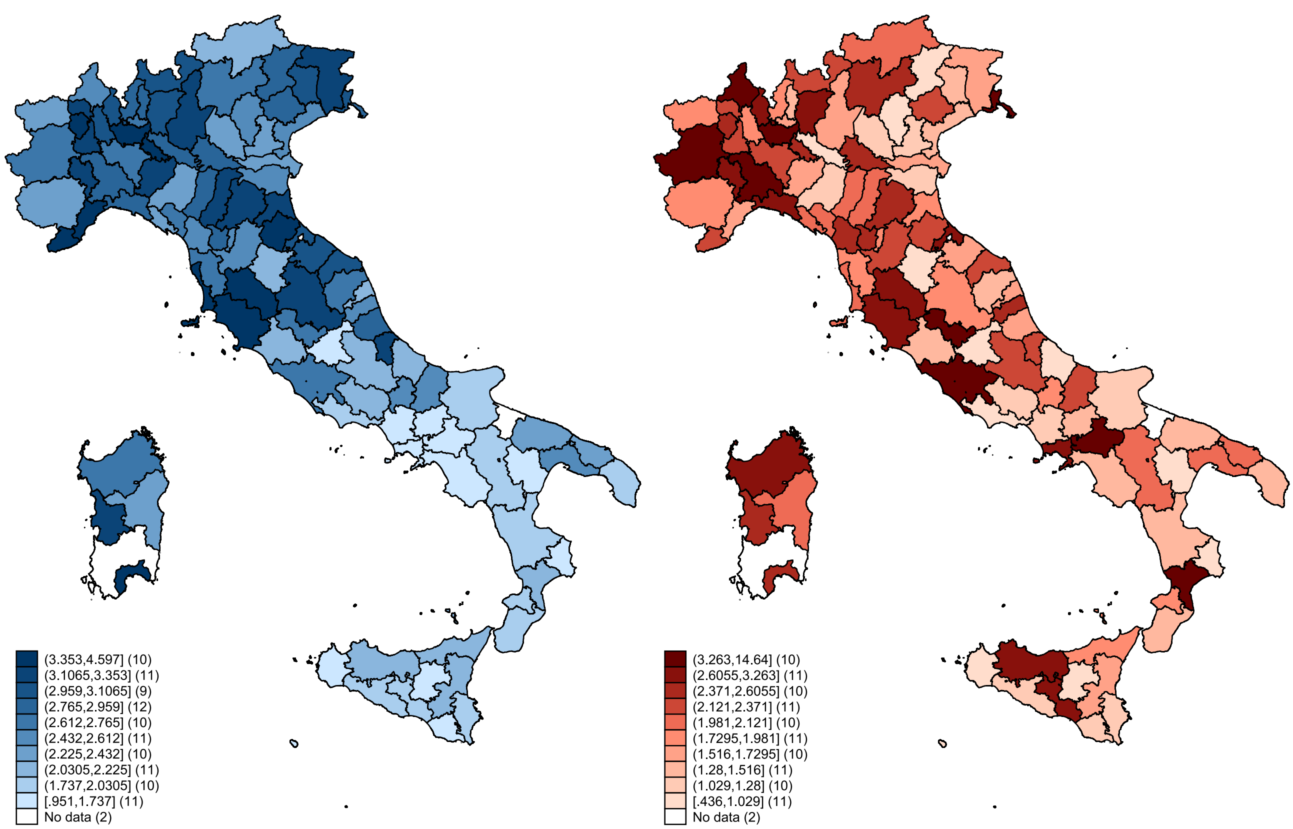

Fig. 4. The geography of zombie firms (EBITDA-based definition), 2012–2018.
Note: the map on the left shows deciles based on the number of firms; the map on the right depicts deciles based on employment in zombie firms. In both maps, the spatial unit is represented by NUTS-3 areas (i.e. provinces).

granted patents during the years in which they are effectively labelled as zombies. In panel A, innovators are 22,254 firms, that is about 5 % of the total number of firms. Interestingly, of these innovative entities, a minority stands out as zombie firms (5.7 %). Furthermore, as compared to non-zombie innovators, innovative zombie firms have a larger average number of patents. In panel B, when we consider all firms with at least 10 patents as innovators, the proportion of zombie innovators remain stable (6.0 %) and the mean number of patents is also higher for this subgroup of innovative companies. So far, the existence and incidence of zombie firms with granted patents is undocumented in the literature and may constitute a significant and puzzling pattern worthy of further investigation. Plausibly, these may be companies that heavily invested in specific projects that have not (or not yet) yielded a significant

Table 1
Top-10 sectors by employment in zombie firms, 2012–2018.

Rank	NACE (3 digits)	NACE description	%
1	302	Manufacture of railway locomotives and rolling stock	5.4
2	202	Manufacture of pesticides and other agrochemical products	3.6
3	241	Manufacture of basic iron and steel and of ferro-alloys	3.5
4	390	Remediation activities and other waste management services	3.1
5	303	Manufacture of air and spacecraft and related machinery	2.7
6	491	Passenger rail transport, interurban	2.5
7	244	Manufacture of basic precious and other non-ferrous metals	2.5
8	492	Freight rail transport	1.9
9	192	Manufacture of refined petroleum products	1.8
10	264	Manufacture of consumer electronics	1.6
Top-10 total			28.7

Table 2
Innovation, zombies and non-zombies, 2012–2018.

	Non-zombies	Zombies	Total
All firms	406,315 (95.1 %)	19,815 (4.9 %)	426,130
A. Innovators with at least 1 patent			
Firms	20,989 (94.3 %)	1265 (5.7 %)	22,254
Mean (patents)	18.1	30.2	
St. dev. (patents)	174.1	131.3	
B. Innovators with at least 10 patents			
Firms	14,510 (94.0 %)	919 (6.0 %)	15,429
Mean (patents)	24.8	40.1	
St. dev. (patents)	205.5	150.7	

Notes: mean and standard deviations are calculated on the subsamples of innovators only. In Panels A and B, means and standard deviations are averaged across the sample period.

economic or technological advantage.[7] This may be due to the lack of organisational links between technologies, products and their markets (Pavitt, 1998). Also, given that investing in innovation involves a certain degree of risk and uncertainty, this can cause financial distress to firms even when they possess a large pool of knowledge (Ma et al., 2022). Hence, it is possible that some firms enter a zombie status following this distress. While exploring the specific antecedents of innovative zombie firms remains beyond the aim and scope of this study, in Table A.2 in the Appendix we document that, as compared to non-zombie innovators, zombie innovators are older, possess larger amount of tangible and intangible assets, but are more indebted, experience lower sales and produce lower added value.

4. Methodology

4.1. Baseline framework

We start analysing the intra-industry relationship between healthy firm innovation and zombie firms by following the approach of previous studies, by estimating the following equation:

$$P_{ist+1} = \beta_1 D^{NZ}_{ist} + \beta_2 Zombie_{st} + \beta_3 Zombie\ spillover_{ist} + X_{ist}\gamma + \delta_t + \delta_s + \delta_p + \varepsilon_{istp} \quad (1)$$

where P denotes innovation captured by the number of patents of firm i, in year $t+1$ and NACE 2-digit industry s; D^{NZ}_{its} is a dummy variable equal to 1 for healthy firms; $Zombie_{ts}$ is an indicator of zombie presence in an industry s, that we measure through the log of the share of employment in zombie firms on total sector employment, similar to other works (e.g., Gouveia and Osterhold, 2018; Acharya et al., 2019). This implies identifying zombie firms through the interest coverage ratio defined in the data section (based on EBITDA as a measure of firm profits), aggregating the employment of zombies at the industry level and using it as a share on total industry employment. This variable captures the overall effect of zombie presence within industries. Nonetheless, our variable of interest is $Zombie\ spillover_{its}$, which is measured as $D^{NZ}_{its} \times Zombie_{ts}$. This interaction term provides an indication of the relative effect of the presence of zombies on the specific performance of healthy firms (Caballero et al., 2008). X is a vector of controls including firm age, capital and labour, captured respectively with tangible assets and employment. We also consider a set of dummies δ_t, δ_s and δ_p to control for time, industry and province unobserved time-invariant shocks potentially affecting firm innovative performance as well as the incidence of zombies. Finally, ε_{itsp} represents an error component which is clustered at the firm level in the estimations. While time, sector and province dummies can alleviate the omitted variable bias, the literature suggests that is also important to consider how industry and geographic unobserved shocks can be characterised by a specific time dimension (Acharya et al., 2019; Schivardi et al., 2020). Hence, we also extend the empirical model in Eq. (1) to include industry-year and province-year dummies. When including industry-year effects, however, the coefficient on the variable $Zombie_{ts}$, that is the absolute effect of zombie presence within a sector, cannot be estimated as it is absorbed by these dummies.

Considering the non-negative and count data nature of our dependent variable, i.e. patents, we estimate the above empirical model by implementing a Poisson Pseudo-Maximum Likelihood (PPML) estimator, developed by Silva and Tenreyro (2006) and extended to the case of multiple fixed effects by Correia et al. (2020). This estimator has desirable properties such as avoiding the problem of inconsistent estimates that characterize cases of least-square regression methods in presence of heteroskedasticity with a dependent variable taken in log form. Furthermore, the PPML does not make assumptions regarding over-dispersion in the outcome variable and, hence, it remains consistent also in cases of under- or over-dispersion. Silva and Tenreyro (2011) also show that the PPML estimator performs well in settings with many zeros.

4.2. Instrumental variable with a control function approach

While the empirical setting described above represents the standard framework in the literature to estimate the spillover effects of zombie firms on the activities of healthy organisations (see Caballero et al., 2008; Adalet McGowan et al., 2018; Acharya et al., 2019), it is possible that unobserved shocks can still affect the estimates by influencing zombies and non-zombies in a differentiated manner (Schivardi et al., 2020). To alleviate this issue, we propose an instrumental variable approach to estimate the effect of $Zombie\ spillover_{its}$. In the setting of a non-linear estimator such as the PPML and in presence of multiple fixed effects, we adopt the control function two-stage procedure of Lin and Wooldridge (2019), based on which we implement the following first-stage regression:

$$Zombie\ spillover_{ist+1} = \vartheta_1 D^{NZ}_{ist} + \vartheta_2 EZ_{ist} + X_{ist}\varphi + \delta_t + \delta_s + \delta_p + \delta_{ts} + u_{istp} \quad (2)$$

[7] One limitation of our approach is that we cannot observe patent quality. Thus, we cannot rule out the possibility that zombie innovators systematically obtain low-quality patents as compared to non-zombies.

where the endogenous regressor of Eq. (1) is now the dependent variable and EZ_{its} represents our instrument. This is estimated by OLS. Based on this, we estimate the following second-stage equation:

$$P_{ist+1} = \varphi_1 D_{ist}^{NZ} + \varphi_2 Zombie\, spillover_{ist} + \varphi_3 \widehat{CF}_{ist} + X_{ist}\omega + \delta_t + \delta_s + \delta_p + \delta_{ts} + v_{istp} \quad (3)$$

where the dependent variable is firm patent count as in Eq. (1) and the right-hand side of the equation includes both the endogenous variable $Zombie\ spillover_{its}$ and $\widehat{CF}_{its}$, that is the control function obtained in the first-stage as predicted OLS residual. The aim of including $\widehat{CF}_{its}$ is to control for variations in $Zombie\ spillover_{its}$ that are not captured by the instrument EZ_{its} in Eq. (2). Hence, in the second-stage regression, φ_2 should capture the effect of zombies on healthy firms net of the endogeneity connected to the presence of zombies within sectors across time. The second-stage equation is estimated via PPML. Standard errors in the second stage are obtained through bootstrapping, following the suggestions of Lin and Wooldridge (2019).

Regarding our instrument EZ_{its}, this is defined as $D_{its}^{NZ} \times EU15\ Zombie_{ts}$, where the first term is the indicator for non-zombie firms explained above and the second term consists of the contemporaneous average industry employment in zombie firms in other EU-15 countries, except Italy.[8] Overall, other EU-15 economies have a similar economic structure to Italy in terms of capital-labour ratio, income, comparative advantage, and technological progress and, hence, we posit that the share of zombie firms in the rest of the EU-15 has a similar industry composition as in Italy (later tested in the first-stage regression). To further support the relevance of the instrument, however, we also consider a version of EZ_{its} where the average industry employment in zombies in other EU-15 countries is weighted by the industry composition of the Italian provinces (NUTS-3) where each non-zombie firm is located. In this way, we can alleviate the presumption that the sector share of zombies is similar across EU-15 countries. All approaches yield substantially similar results.[9] The exogeneity of this instrument, instead, requires that credit misallocation shocks feeding or restraining zombie firms in other EU-15 countries do not cause changes in the incidence of zombie firms in Italy. Hence, if credit misallocation shocks are correlated across EU-15 countries, this estimation strategy would be threatened. Extant evidence shows that the phenomenon of zombie firms across European countries vary substantially, suggesting that most processes keeping zombie firms alive may have a national, rather international, dimension. Nonetheless, in a robustness exercise we exclude from the instrument countries such as Greece, Portugal and Spain that are characterised by a relatively high presence of zombie firms and that are found to share some common characteristics with Italy in prior studies on this theme (Acharya et al., 2019). Another potential threat to our instrumental variable strategy could come from international industry shocks that affect the share of zombie firms within sectors across EU-15 countries. This may be the case for instance of global demand shocks lowering the profitability of European industries. In another check, hence, we account for this potential issue by considering and comparing sectors with different exposure to global markets.

5. Results and discussion

5.1. Baseline estimates

We start by estimating Eq. (1) as explained in the previous section.

Table 3
PPML estimates of zombies' effect on firm innovation.

	(1)	(2)	(3)	(4)
Dep. Var.: Patents_{ist+1}				
D_{its}^{NZ}	0.4562**	0.4099**	0.4306**	0.3825**
	(0.2128)	(0.1812)	(0.2076)	(0.1852)
Zombie_{st}	0.2075	0.1912		0.1833
	(0.1363)	(0.1248)		(0.1237)
$\text{Zombie spillover}_{ist}$	−0.2827**	−0.2727**	−0.2775**	−0.2626**
	(0.1415)	(0.1312)	(0.1316)	(0.1303)
Age_{ist}	0.0121***	0.0079***	0.0079***	0.0080***
	(0.0024)	(0.0025)	(0.0024)	(0.0024)
Employment_{ist}	0.0002***	0.0002***	0.0002***	0.0002***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
$\text{Tangible assets}_{ist}$	0.5716***	0.5663***	0.5658***	0.5667***
	(0.0412)	(0.0375)	(0.0372)	(0.0374)
Observations	1,734,276	1,734,276	1,734,276	1,734,276
N of firms	426,130	426,130	426,130	426,130
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Province dummies	–	Yes	Yes	Yes
Year-Industry dummies	–	–	Yes	–
Year-Province dummies	–	–	–	Yes
Pseudo R-squared	0.424	0.456	0.458	0.459

Notes: Standard errors in parentheses are clustered by firm. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 3 reports the results. Besides the covariates, column 1 includes year and industry dummies to control for time and sector effects affecting firm innovation. Province dummies are included in column 2 to control for omitted time invariant spatial drivers of patenting activity. In column 3, we also add industry-time dummies to account for time varying sector shocks that can affect the performance of both zombies and non-zombies. As anticipated above, this specification does not allow to estimate the absolute role of zombies within industries, as this is absorbed by the fixed effects. Finally, in column 4, the inclusion of province-time effects aims at controlling for time-dependent geographical shocks influencing individual firm innovativeness. Results show a negative and statistically significant coefficient for the interaction term denoted by $Zombie\ spillover_{its}$, which suggests the existence of a negative intra-industry spillover effect from zombies on the innovation capacity of healthy organisations. The coefficient is also rather stable. Considering that the variable $Zombie_{ts}$ is taken in logs and that it also enters the interaction term, we can interpret the coefficient on $Zombie\ spillover_{its}$ as an elasticity. Hence, a 10 % increase in the interaction term is associated with a decrease in firm patents of 2.6 % to 2.8 %, depending on the specification. Put differently, a 10 % increase in the employment share of zombie firms in a certain sector is related to a decrease of patenting by non-zombie firms ranging from 2.6 % to 2.8 % within the same sector of activity. These baseline results echo the main findings of the literature that the presence of zombies can be harmful for the operations of healthy organisations (Caballero et al., 2008; Banerjee and Hofmann, 2018; Acharya et al., 2019). We then extend this notion to the case of innovative activities, thus suggesting that the survival of zombie firms may constitute a factor deterring the innovation of non-zombies. In this sense, this evidence also contributes to the debate on the barriers to innovation (e.g. D'Este et al., 2012; Coad et al., 2016) by highlighting that the obstacles to firm patenting can also be associated to the retention of a very specific category of firms that would exit the market in normal competitive conditions. Regarding the control variables, in line with our expectations we observe that non-zombie firms are more innovative than zombies, and that older firms as well as businesses with more labour and capital tend to be more innovative.

5.2. Baseline checks

We test the sensitivity of our baseline estimates to the heterogeneous presence of zombies across industries. It is possible, in fact, that the

[8] These countries include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Great Britain, Ireland, Netherlands, Portugal, Spain and Sweden. Luxembourg is excluded for insufficient observations.

[9] Overall, the structure of our IV broadly follows previous works such as Autor et al. (2013) who use (similar) third-country indicators as exogeneous shifters for home-country subnational variables.

negative spillover of zombies on healthy firms may be driven by the clustering of zombies in specific sectors. Hence, by considering the figures reported in Table 1 on the sector incidence of zombies, we re-estimate Eq. (1) by removing from our sample the top-3 industries by zombie employment. These industries amount to about 12.5 % of total zombie employment in the full sample, which is a noteworthy share of the phenomenon. The results, reported in Table A.3 in the Appendix, are in line with the baseline estimates of Table 3 in both quantitative and qualitative terms. Furthermore, similar to Albuquerque and Iyer (2024), we also test whether our results are sensitive to a more stringent definition of zombie firms by adding the condition that firms must experience at least two consecutive years of negative real sales growth to qualify as zombies. This is to ensure that zombies are persistently unprofitable and unproductive firms. Results are reported in Table A.4 in the Appendix. Interestingly, these estimates suggest that the spillover of zombies on healthy companies becomes larger in magnitude when we add sales growth to the zombie definition. Not only does this reassure us about the robustness of our approach, but it also suggests that our baseline estimates may represent a lower bound. We also check our baseline results by re-estimating Eq. (1) with a dependent variable being a dummy indicating whether or not a firm filed for a patent in a given year. This provides an indication of whether zombies affect the capacity of healthy firms to innovate at all. Results are reported in Table A.5 in the Appendix and remain in line with the evidence that zombies negatively affect the innovative capacity of non-zombies. Finally, we are concerned that our baseline estimates can be affected by the fact that some industries are less likely to patent as well as the fact that some industries may possess a higher innovation productivity than others. Hence, we re-estimate Eq. (1) by considering firm R&D expenditure as dependent variable. Unfortunately, Orbis IP is characterised by a paucity of information on R&D. As a result, we are able to collect this information only for a very limited subset of large companies. Results are reported in Table A.6 in the Appendix, suggesting that for this subsample of firms a negative link persists between the presence of zombies within industries and the performance of non-zombies.

5.3. Estimates for zombie innovators and non-innovators

We extend our baseline analysis to explore the specific effect of zombies on non-zombie innovators, rather than non-zombies tout court, and also to clarify whether both innovative and non-innovative zombie firms are detrimental to healthy organisations. Table 4 shows a set of results where the zombie spillover is specifically estimated for the subgroup of non-zombie innovators. Columns 1 to 3 regard innovators defined as firms with at least one patent during the sample period, while in columns 4 to 6 we re-run the same analysis for innovators with at least ten granted patents, as described in Table 2 above. Column 1 suggests that the effect of zombies on innovative healthy firms is almost three times larger than that estimated on all non-zombies in Table 3. Specifically, a 10 % increase in the employment share of zombies is related to a decrease of patenting by non-zombie innovators of about 9.1 %. In columns 2 and 3 we consider spillovers from zombie innovators and non-innovators, respectively. The negative spillover effects remain strongly significant and large in magnitude in the case of zombie innovators, indicating that this specific subgroup of zombie firms may produce the most relevant barriers to innovative healthy organisations. The effect of non-innovator zombies, instead, is more limited both statistically and in terms of economic incidence, suggesting that this subgroup can still affect non-zombies' innovative performance but to a more limited extent. Columns 4 to 6 yields similar results.

5.4. Instrumental variable estimates

Table 5 shows the estimates of the instrumental variable approach explained in section 4.2. We provide three different sets of estimations. Columns 1 and 2 report the first-stage and second-stage regressions, respectively, where the instrument EZ_{its} is the EU-15 average of 2-digit sector shares of zombie employment (excluding Italy). Column 3 and 4, instead, report estimates where the instrument is weighted by the Italian Census 2011 sector employment share of the province where each non-zombie firm is located; in columns 5 and 6, instead, weights are taken from a longer temporal lag, that is the Italian Census 1991. By weighting the instrument for the pre-existing industry composition of the national economy, we mean to reduce a potential issue connected with the possible large difference in the sector composition of zombie employment between Italy and other EU-15 countries. The first-stage regression results in columns 1, 3 and 5, indicate that the instrument is positively and strongly correlated with our instrumented variable. Also, the F-statistics is safely above the rule-of-thumb of 10. Furthermore, the coefficients on $\widehat{CF}_{its}$ can be interpreted as a test for the

Table 4
Zombie innovators and non-innovators.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: Patents_{ist+1}						
$D_{its}^{NZ\ INNO}$	1.5055*	1.644***	1.4437**	1.431**	1.983**	1.294**
	(0.8761)	(0.4899)	(0.7192)	(0.650)	(0.989)	(0.641)
Zombie spillover_{ist} ($= D_{its}^{NZ\ INNO} \times \text{Zombie}_{st}$)	−0.9072***			−0.612***		
	(0.2448)			(0.129)		
Zombie^{INNO} spillover_{ist} ($= D_{its}^{NZ\ INNO} \times \text{Zombie}_{st}^{INNO}$)		−0.8685***			−0.3063**	
		(0.1531)			(0.1408)	
$\text{Zombie}^{NON\text{-}INNO}$ spillover_{ist} ($= D_{its}^{NZ\ INNO} \times \text{Zombie}_{st}^{NON\text{-}INNO}$)			−0.1749*			−0.254*
			(0.0902)			(0.134)
Age_{ist}	0.0034	0.0031	0.0035	0.0054**	0.0058**	0.0058**
	(0.0024)	(0.0024)	(0.0024)	(0.025)	(0.024)	(0.024)
Employment_{ist}	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Tangible assets_{ist}	0.3494***	0.3577***	0.3489***	0.3317***	0.3286***	0.3283***
	(0.0379)	(0.0380)	(0.0382)	(0.0417)	(0.0415)	(0.0415)
Observations	1,734,276	1,734,276	1,734,276	1,734,276	1,734,276	1,734,276
N of firms	426,130	426,130	426,130	426,130	426,130	426,130
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year-Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R-squared	0.670	0.671	0.669	0.672	0.669	0.667

Notes: Standard errors in parentheses are clustered by firm. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Columns 1 to 3 are based on a definition of innovators as firms with at least one granted patent during the sample period; columns 4 to 6, instead, consider as innovators all firms with at least ten granted patents.

Table 5
Instrumental variable estimates with a control function approach.

	(1)	(2)	(3)	(4)	(5)	(6)
	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF
Dep. Var.:	Zombie spillover$_{ist}$	Patents$_{ist+1}$	Zombie spillover$_{ist}$	Patents$_{ist+1}$	Zombie spillover$_{ist}$	Patents$_{ist+1}$
D^{NZ}_{its}	−3.3380***	−0.1183	−3.4402***	−0.3179	−3.4730***	−0.2025
	(1.1448)	(0.2044)	(1.1521)	(0.7715)	(1.1645)	(0.5855)
$EZ_{its}(= D^{NZ}_{its} \times$ EU15 Zombie$_{st})$	0.0608***		0.0252***		0.0286***	
	(0.0011)		(0.0004)		(0.0005)	
Zombie spillover$_{ist}$ $(= D^{NZ}_{its} \times$ Zombie$_{st})$		−0.0847**		−0.1067**		−0.0913*
		(0.0424)		(0.0481)		(0.0471)
Age$_{ist}$	0.0001***	0.0121***	0.0001***	0.0121***	0.0001***	0.0122***
	(0.0000)	(0.0024)	(0.0000)	(0.0024)	(0.0000)	(0.0024)
Employment$_{ist}$	−0.0002**	0.0002***	−0.0002**	0.0002***	−0.0002**	0.0002***
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0001)
Tangible assets$_{ist}$	−0.0005***	0.5718***	−0.0010***	0.5718***	−0.0008***	0.5712***
	(0.0001)	(0.0411)	(0.0001)	(0.0414)	(0.0001)	(0.0411)
$\widehat{CF}_{ist}$ (1st stage OLS residual)		−0.3999		−0.7122		−0.6609
		(0.6866)		(0.6545)		(0.8718)
Observations	1,734,276	1,734,276	1,734,276	1,734,276	1,734,276	1,734,276
N of firms	426,130	426,130	426,130	426,130	426,130	426,130
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year-Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
F-stat	98.89		95.48		101.26	
R-squared	0.591		0.588		0.566	
Pseudo R-squared		0.424		0.424		0.424

Notes: Standard errors in parentheses are clustered by firm and are bootstrapped (100 replications). Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. In columns 1 and 2, the instrument is the EU-15 average of 2-digit sector shares of zombie employment (excluding Italy); in columns 3 and 4, this instrument is weighted by the Italian Census 2011 sector employment share of the province where each non-zombie firm is located; in columns 5 and 6, instead, weights are taken from the Italian Census 1991.

endogeneity of the instrumented variable, where the null hypothesis is exogeneity (Lin and Wooldridge, 2019). Hence, the non-statistical significance of $\widehat{CF}_{its}$ reassures us on the goodness of our IV approach. Regarding the second-stage regressions, we still detect a negative and statistically significant coefficient on *Zombie spillover*$_{its}$ across specifications, although the magnitude of the effect is more limited than in the baseline estimates of Table 2. This suggests that the baseline approach may suffer from an upward bias. In column 2, a 10 % increase in the employment share of zombie firms in a sector is related to a decrease of patenting by non-zombie firms of about 0.8 %. In columns 4 and 6, this elasticity slightly rises to 1.1 % and 0.9 %, respectively.

Table A.7 in the Appendix reports the estimates using the instrument constructed by excluding countries such as Spain, Portugal and Greece. Results are overall in line with Table 5, with slightly smaller effects. To account for industry specific shocks from global markets, which may affect the zombie presence within industries across EU-15 countries, we consider the global exposure of Italian sectors by using ISTAT data on imports and exports from 1997 to 2018. We then split the sample between industries above- and below-median values of exports and imports, to proxy their potential exposure to global shocks, such as demand shocks that may decrease firm profitability. Results are reported in Table A.8 in the Appendix and show that regardless of the global exposure of sectors, the negative spillover effect of zombies on non-zombies persists. This can be interpreted as indirect evidence that global shocks that can be transmitted through international channels such as export and import, and that can potentially affect industries in other EU-15 countries, seem not to influence our estimates, given the coefficient is similar also for industries that are weakly connected with global markets.

5.5. Some possible mechanisms

As discussed in the conceptual background section, one potential channel for spillover effects from zombies within sectors consists of increased competition on capital markets to access credit. This entails that healthy and creditworthy firms may face tougher conditions to receive bank loans and finance their activities, including innovation. We test this idea by constructing a measure of external finance dependence (EFD) of sectors, following Rajan and Zingales (1998), which provides us with a sector indicator of capital demand.[10] Subsequently, we split the sample in quartiles of sector EFD and estimate separate instrumental variable regressions for each quartile. Results are reported in Table 6, where columns 1 and 2 regard the first quartile of EFD, that is industries with the lowest dependence on external sources of finance; columns 3 and 4 consider the second quartile, columns 5 and 6 inspect the third quartile and, finally, columns 7 and 8 cover the fourth quartile of sector EFD, where firms face the highest levels of dependence on external financial resources. When considering the coefficients on *Zombie spillover*$_{its}$, the results suggest the existence of a fragmented effect from zombie firms on healthy firms' innovation. Specifically, the negative effect detected in the previous analysis tends to be concentrated in sectors with high and very high EFD (columns 6 and 8, respectively). The statistical significance is higher for firms in the fourth quartile (col. 8), while it remains at 10 % for the third quartile (col. 6). In terms of the economic significance of these estimated effects, instead, healthy firms operating in sectors subject to very high EFD experience a decrease in patenting equal to 2.2 % for a 10 % increase in zombie employment (col. 8), while for firms in the third quartile this negative effect is 1.3 %. At the other end of the spectrum, the coefficient turns positive and statistically significant at the 10 % level for firms in the first quartile of EFD (col. 2), thus signalling that firms with strong internal cash flow can experience beneficial effects from the presence of zombies. Specifically,

[10] EFD is calculated on US firm data from Compustat as the difference between capital expenditure and cash flow divided by the former. Hence it captures the investment that firms are unable to fund through internal cash flow, thus providing an indication of the external resources needed to run operations, that is, their demand for capital. Firm level calculations are then aggregated by NAICS sector medians. We subsequently convert NAICS industries into ISIC and then NACE by means of RAMON tables from Eurostat.

Table 6
Zombie spillovers and industry external finance dependence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF
Dep. Var.:	Zombie $spillover_{ist}$	$Patents_{ist+1}$	Zombie $spillover_{ist}$	$Patents_{ist+1}$	Zombie $spillover_{ist}$	$Patents_{ist+1}$	Zombie $spillover_{ist}$	$Patents_{ist+1}$
D^{NZ}_{its}	−3.6903***	0.1446	−3.6734***	0.2192	−3.5655***	0.0787	−3.7080***	−0.0231
	(0.0119)	(0.2184)	(0.0122)	(0.2418)	(0.0163)	(0.2430)	(0.0119)	(0.2017)
EZ_{its}	0.0172***		0.0176***		0.0206***		0.0163***	
	(0.0005)		(0.0005)		(0.0008)		(0.0005)	
Zombie $spillover_{ist}$		0.0562*		0.0294		−0.1301*		−0.2230**
		(0.0293)		(0.0265)		(0.0701)		(0.1059)
Age_{ist}	0.0001**	0.0092***	0.0001**	0.0082***	0.0001***	0.0047	0.0001**	0.0083**
	(0.0000)	(0.0031)	(0.0000)	(0.0027)	(0.0000)	(0.0033)	(0.0000)	(0.0033)
$Employment_{ist}$	−0.0002**	0.0003***	−0.0002**	0.0002***	−0.0002**	0.0002***	−0.0002***	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Tangible $assets_{ist}$	−0.0009***	0.6908***	−0.0008***	0.7477***	−0.0010***	0.6982***	−0.0007***	0.6774***
	(0.0001)	(0.0589)	(0.0002)	(0.0641)	(0.0002)	(0.0393)	(0.0001)	(0.0593)
$\widehat{CF}_{ist}$ (1st stage OLS residual)		−0.0702		−0.2724		−0.2459		−0.0071
		(0.2548)		(0.2373)		(0.2375)		(0.2727)
Observations	485,878	485,878	471,272	471,272	314,558	314,558	462,568	462,568
N of firms	117,537	117,537	113,322	113,322	82,847	82,847	112,424	112,424
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-stat	100.33		99.26		98.71		96.12	
R-squared	0.588		0.588		0.587		0.589	
Pseudo R-squared		0.486		0.430		0.420		0.489

Notes: Standard errors in parentheses are clustered by firm and are bootstrapped (100 replications). Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. In columns 1 and 2, the sample includes industries in the first quartile of EFD, that is sectors with the lowest dependence on external finance; columns 3 and 4 consider the second quartile of EFD; columns 4 and 6 regard the third quartile and, finally, columns 7 and 8 present the estimated for the subsample of sectors in the fourth percentile of EFD.

Table 7
Zombie spillovers and industry competition.

	(1)	(2)	(3)	(4)
	High competition industries		*Low competition industries*	
	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF
Dep. Var.:	Zombie $spillover_{ist}$	$Patents_{ist+1}$	Zombie $spillover_{ist}$	$Patents_{ist+1}$
D^{NZ}_{its}	−3.4429***	−0.1021	−3.6070***	−0.1107
	(1.1664)	(0.2003)	(1.5203)	(0.1896)
EZ_{its}	0.0109***		0.0102***	
	(0.0007)		(0.0010)	
Zombie $spillover_{ist}$		−0.0960**		−0.0512
		(0.0436)		(0.0496)
Age_{ist}	−0.0001	0.0051**	0.0001***	0.0043**
	(0.0001)	(0.0024)	(0.0000)	(0.0021)
$Employment_{ist}$	−0.0001**	0.0003***	−0.0001	0.0002**
	(0.0000)	(0.0001)	(0.0001)	(0.0001)
Tangible $assets_{ist}$	0.0005***	0.5469***	−0.0006***	0.5163***
	(0.0002)	(0.0666)	(0.0002)	(0.0882)
$\widehat{CF}_{ist}$ (1st stage OLS residual)		−0.2198		−0.1946
		(0.2266)		(0.2019)
Observations	935,238	935,238	799,038	799,038
N of firms	238,267	238,267	187,863	187,863
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes
Year-Industry dummies	Yes	Yes	Yes	Yes
F-stat	112.66		118.27	
R-squared	0.503		0.468	
Pseudo R-squared		0.462		0.257

Notes: Standard errors in parentheses are clustered by firm and are bootstrapped (100 replications). Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Columns 1 and 2 consider firms in sectors with highly competitive industries based on values of the HHI above the median, while columns 3 and 4 include firms in sectors with low competition.

Table 8
Zombie spillovers and firm market share.

	(1)	(2)	(3)	(4)
	High firm sales		*Low firm sales*	
	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF
Dep. Var.:	Zombie spillover$_{ist}$	Patents$_{ist+1}$	Zombie spillover$_{ist}$	Patents$_{ist+1}$
D^{NZ}_{its}	−2.0291**	−0.1679	−2.1275**	0.1025
	(0.7977)	(0.1903)	(0.8423)	(0.0884)
EZ$_{its}$	0.0094***		0.0101***	
	(0.0009)		(0.0011)	
Zombie spillover$_{ist}$		−0.1463**		−0.0750
		(0.0708)		(0.0491)
Age$_{ist}$	0.0001	0.0066**	0.0001	0.0068**
	(0.0001)	(0.0032)	(0.0001)	(0.0033)
Employment$_{ist}$	0.0002**	0.0003***	0.0001***	0.0003***
	(0.0001)	(0.0001)	(0.000)	(0.0001)
Tangible assets$_{ist}$	0.0007***	0.6951***	0.0009***	0.7244***
	(0.0002)	(0.1611)	(0.0003)	(0.1916)
$\widehat{CF}_{ist}$ (1st stage OLS residual)		−0.3022		−0.3406
		(0.2876)		(0.2902)
Observations	865,341	865,341	868,935	868,935
N of firms	213,044	213,044	213,086	213,086
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes
Year-Industry dummies	Yes	Yes	Yes	Yes
F-stat	108.72		103.33	
R-squared	0.472		0.487	
Pseudo R-squared		0.438		0.453

Notes: Standard errors in parentheses are clustered by firm and are bootstrapped (100 replications). Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1. Columns 1 and 2 consider firms with above-median values of sales relative to their industry mean, while columns 3 and 4 include firms with below-median values.

for an increase of 10 % of sector zombie employment, these healthy firms experience an increase in innovation of 0.6 %. While investigating the specific causes of this positive effect is beyond the scope of the present analysis, it is possible that these non-zombie firms are encouraged to use internal resources more efficiently for innovation purposes given the congestion that zombie firms can create on the market for goods and services. We cannot detect any significant effect for firms in the second quartile of EFD (col. 4). Overall, not only does this

Table 9
Zombie spillovers and firm knowledge base.

	(1)	(2)	(3)	(4)
	High firm intangibles		*Low firm intangibles*	
	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF
Dep. Var.:	Zombie spillover$_{ist}$	Patents$_{ist+1}$	Zombie spillover$_{ist}$	Patents$_{ist+1}$
D^{NZ}_{its}	−1.5402**	0.2130*	−1.6389**	0.1764*
	(0.6502)	(0.1187)	(0.6781)	(0.0933)
EZ$_{its}$	0.0181***		0.0153***	
	(0.0045)		(0.0040)	
Zombie spillover$_{ist}$		0.1901**		−0.2135**
		(0.0875)		(0.1052)
Age$_{ist}$	0.0002**	0.0072***	0.0002**	0.00564***
	(0.0001)	(0.0022)	(0.0001)	(0.0021)
Employment$_{ist}$	0.0002**	0.0004***	0.0002**	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Tangible assets$_{ist}$	0.0011***	0.9166***	0.0006**	0.5298**
	(0.0003)	(0.2054)	(0.0003)	(0.2596)
$\widehat{CF}_{ist}$ (1st stage OLS residual)		−0.3393		−0.3007
		(0.2876)		(0.2543)
Observations	866,641	866,641	867,635	867,635
N of firms	213,079	213,079	213,051	213,051
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes
Year-Industry dummies	Yes	Yes	Yes	Yes
F-stat	99.12		101.66	
R-squared	0.571		0.524	
Pseudo R-squared		0.502		0.483

Notes: Standard errors in parentheses are clustered by firm and are bootstrapped (100 replications). Significance levels: *** p < 0.01, ** p < 0.05, * p < 0.1. Columns 1 and 2 consider firms with above-median values of intangible assets relative to their industry mean, while columns 3 and 4 include firms with below-median values.

evidence suggest that the origin of financial resources used by healthy firms (internal or external) can be a relevant mechanism for zombies' spillovers on non-zombie organisations, but also that this source of heterogeneity conceals potentially contrasting effects for different groups of healthy firms. These results are in line with the existing evidence that financial constraints can represent a substantial barrier to the innovative activities of firms (Hyytinen and Toivanen, 2005; Savignac, 2008). However, an alternative explanation of these results could be that in industries with higher EFD a relatively higher presence of zombies may make financial intermediaries more alert in providing credit or demand collaterals to firms, including healthy organisations. Hence, non-zombies would suffer from lower access to finance not because this is absorbed by zombie firms, but because credit institutions become more alert across the board. While this may still be an (indirect) effect of the zombie-induced capital market congestion, it presumably follows a different mechanism that those described above.

As discussed in the conceptual background, the survival of zombies can also unleash more intense crowding on the market for goods and services. In fact, more congested markets imply that healthy companies would face more competitive pressures than in absence of zombie firms (Adalet McGowan et al., 2018; Andrews and Petroulakis, 2019). To explore the mechanism of market crowding as a potential channel for zombie spillovers, we consider the market concentration of industries based on their Herfindahl-Hirschman Index (HHI), calculated on firm sales data from Orbis. Table 7 presents the results for sectors divided based on the median of the HHI. Columns 1 and 2 show the first-stage and second-stage regressions for firms operating in highly competitive industries, while columns 3 and 4 regard firms in industries with low competition. We detect a negative coefficient for $\textit{Zombie spillover}_{its}$ in column 2, suggesting that zombie firms may displace healthy organisations through competitive dynamics in highly concentrated markets and this, in turn, discourages non-zombie firms' innovation. In particular, this coefficient implies that a 10 % increase in zombie employment generates a decrease of non-zombies' patenting of nearly 1 %. Consistently, extant evidence on innovation barriers suggests that concentrated market structures can determine firm innovation failures (e.g., Pellegrino and Savona, 2017). Hence, the presence of zombies contributes to further market congestions in sectors where competition is already strong, and this presumably crowds out healthy firms' incentives to innovate. In column 4, instead, the estimated coefficient on $\textit{Zombie spillover}_{its}$ remains statistically not significant, indicating that within sectors with low market competition, the survival of zombies does not affect non-zombie organisations' patenting activities. It is possible that in these circumstances the market power of incumbent firms is large enough to offset the congestion caused by the survival of zombies.

While industry characteristics can be important channels for zombie spillovers, investigating firm heterogeneity can reveal additional mechanisms through which zombie firms can affect the innovativeness of healthy businesses. For instance, firms with larger market shares can be better equipped to face the competitive distortions produced by zombies. In Table 8 we present the results of a set of estimations where we split the sample based on firms with above- or below-median sales relative to their industry mean. Surprisingly, the coefficient on $\textit{Zombie spillover}_{its}$ is negative and significant in the subsample of firms with above-median sales (column 2), while it remains not statistically significant for firms with relatively lower sales (column 4). This may imply that the survival of zombie firms primarily erodes the market shares of healthy organisations with larger market presence. In other words, these firms may be more subject to the detrimental effects of increased competition given their high exposure (Ascani and Gagliardi, 2020). This market-stealing effect may discourage these healthy firms from undertaking further risks connected to R&D investment, thus lowering their innovation efforts. Specifically, the coefficient in column 2 entails that healthy organisations experience a decrease in innovation of about 1.5 % for an intra-industry 10 % rise in zombie employment.

Finally, we consider firms' knowledge base as a source of heterogeneous spillover effects from zombies. In fact, healthy firms with strong knowledge assets can adopt different strategies than those with more fragile technological endowments (Montresor and Vezzani, 2022). Table 9 provides a set of results where we separately analyse firms with values of intangible assets relative to their industry mean above and below the median. Column 2 reports a coefficient on $\textit{Zombie spillover}_{its}$ that is positive and significant, suggesting that healthy firms endowed with a strong knowledge base may react to the survival of zombies by increasing their innovative efforts. This is in line with the notion of innovation as a strategy to reinforce firm's competitive advantage to face more intense competition (Thoenig and Verdier, 2003; Lee, 2009). Also, it is possible that when facing more competitive pressure, non-zombie organisations with a larger pool of knowledge resources are able to sort more successful innovative projects internally by cutting or slowing down projects with lower innovative potential (Caballero et al., 2008). In terms of magnitude, this effect implies that healthy firms increase their patenting by about 1.9 % for an increase of zombie employment of 10 %. In column 4, instead, we detect a negative spillover effect from zombies on non-zombies with more fragile knowledge endowments. These firms are probably unable to successfully re-organise their internal technological processes to face the changing market circumstances due to the survival of zombie firms. In these cases, the distortions brought by zombies generate a displacement effect that discourage their innovative efforts. The size of this effect is also non-trivial as patenting declines by about 2.1 % for a 10 % increase in zombie presence, according to our estimates.

Overall, this evidence suggests that the interplay between zombie and non-zombie organisations is characterised by a very articulated set of mechanisms that may give rise to effects in opposite directions, depending on the specific contingencies of industries and firms.

6. Concluding remarks

How zombie firms relate to the innovative capacity of healthy organisations remains an unexplored – yet critical – area of inquiry. Understanding this interplay becomes even more urgent in the context of the post-pandemic crisis, given that many governments and supranational institutions such as the EU have introduced extensive and ambitious schemes for economic recovery and resilience that include the massive injection of financial resources, more flexible bank regulations and temporary loan moratoria to ensure liquidity to business and ultimately support economic activities. If, on the one hand, these measures were important to sustain business operations during the most critical stages of the pandemic and to re-launch the economy, on the other hand, a marked increase in NPLs represents a potential risk connected to these massive interventions. Unsurprisingly, the proliferation of zombies is associated with the increase in NPLs, intended as bank loans conceded to weak firms that would exit the market in normal competitive conditions because they cannot sustain their business over time due to insolvency. In this sense, the emergence and retention of zombie firms signal the increasing and decisive influence of the financial sector on firm activities, behaviour and interactions, as recently discussed in the literature (Feldman et al., 2021). In this article, we have studied the intra-industry relationship between zombie firms and the innovation capacity of healthy firms, to understand the potential hurdles that surviving zombies generate for firm's innovative activities. Our empirical analysis has focused on the case of Italy, a relevant example of a national economy within the EU with a relatively high share of zombie firms (Adalet McGowan et al., 2018). By using Bureau van Dijk Orbis IP data on 426,130 firms from 2012 to 2018, we have found evidence of negative horizontal spillover effects in both our PPML baseline estimates and, albeit with a lower magnitude, in our instrumental variable strategy with a control function approach. An original insight of our analysis, furthermore, stands in the identification of zombie innovators as a specific subcategory of zombie firms. According to our estimates, these innovative zombie companies play the larger role in affecting the capacity of healthy innovators to pursue more innovative activities. Overall, these aggregate relationships can be explained by the increased competition faced by healthy businesses on two levels, that is: the capital market to access financial resources and the market for goods and services. Indeed, negative spillovers tend to be concentrated in sectors with a strong dependence on external financial resources for funding firm innovative activities as well as in sectors with high competition. Nonetheless, our results also suggest that the survival of zombies can trigger positive externalities on the specific group of healthy businesses with strong internal knowledge assets, which can be used more efficiently to face increased market competition. Similarly, we also detect positive effects on non-zombies operating within industries where they can accumulate enough cash flow to finance future innovative activities without depending on bank loans. Hence, while the overall effect of zombies on non-zombies may be detrimental, this general relationship is subject to various contingencies connected to both industry and firm characteristics that can also produce positive externalities under very specific circumstances.

Our results contribute to the debates on the impact of zombies on non-zombies (e.g. Caballero et al., 2008), that has provided scant evidence on the theme of innovative activities, and to the literature on the barriers to firm innovation (e.g. D'Este et al., 2012), by identifying zombie firms as a specific category of actors that can amplify both financial and non-financial difficulties to healthy organisations' innovative efforts.

This set of results has important policy and managerial implications. Limiting the survival of zombies can decongest both the capital market and the market for goods and services, thus removing the competitive distortions that generate detrimental effects on the innovation performance of healthy businesses. Nonetheless, as evidenced in prior studies, the survival of zombies can also keep input-output linkages alive, contribute to aggregate demand, and retain employment (Schivardi et al., 2017). Therefore, a more balanced policy approach would be to design conditional support schemes for zombies aimed at making them solvent and exit their zombie status, rather than exiting the market. However, considering that policy makers cannot directly influence firm profits, support measures should instead facilitate solvency. This can be achieved through, for instance, government incentives encouraging new investments into zombies by other private sector actors. This would not add to zombies' debt, but it may instead improve their financial assets. Zombie innovators can be particularly attractive if their knowledge resources can be used in a commercially viable manner. At the same time, policy instruments should also aim at limiting the zombification of new firms by adopting NPL reduction strategies through clear and adequate lending standards. In terms of managerial considerations, in order to avoid the displacement effects caused by zombies within a sector, our evidence suggests that healthy businesses should invest in reinforcing their knowledge assets, as these can constitute a fundamental ownership advantage that organisations can leverage when facing higher competitive pressures on both financial and non-financial markets.

While our analysis entirely focused on intra-industry effects, future research should also extend to vertical linkages between zombies and non-zombies in search of inter-industry dynamics that can affect the innovative performance of healthy organisations. Furthermore, while our analysis unveils the existence of innovative zombie firms as a specific subgroup of zombies, more research should pay attention to zombies' heterogeneity in search of their different roots, characteristics, organisational modes and evolution. Last but not least, future research on zombies should incorporate more extensive data on firm R&D and open the black box of innovation by considering indicators of patent quality.

CRediT authorship contribution statement

Andrea Ascani: Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lakshmi Balachandran Nair:** Writing – review & editing, Writing – original draft, Validation, Investigation, Conceptualization.

Declaration of competing interest

The authors declare no competing or non-financial interests.

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Appendix A

Table A.1
Summary statistics.

Variable name	Observations	Mean	Std. dev.	Min	Max
A. Full sample					
Patents	1,734,276	1.804	64.273	0	16,771
Dummy for non-zombie (D^{NZ})	1,734,276	0.977	0.14864	0	1
Zombie (sector employment share)	1,734,276	−3.724	0.7055	−8.142	−1.423
Zombie spillover (D^{NZ} × Zombie)	1,734,276	−3.646	0.891	−8.142	0
Age	1,734,276	15.462	13.521	0	153
Employment	1,734,276	15.623	138.263	1	35,876
Tangible assets	1,734,276	4.251	2.560	−6.908	17.401
B. Non-zombie sample					
Patents	1,653,633	1.732	49.574	0	16,771
Age	1,653,633	14.291	13.446	0	924
Employment	1,653,633	15.443	126.615	1	35,876
Tangible assets	1,653,633	4.245	2.543	−6.908	17.401

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Table A.1 (*continued*)

Variable name	Observations	Mean	Std. dev.	Min	Max
C. Zombie sample					
Patents	80,643	1.931	136.435	0	12,596
Age	80,643	24.450	14.146	10	150
Employment	80,643	23.392	390.497	1	33,636
Tangible assets	80,643	4.453	3.093	−6.032	15.285

Table A.2
Mean differences of zombie vs. non-zombie innovators, 2012–2018.

	(1)	(2)	(3)
Firm characteristics as dep. var.			
Employment_{ist}	−0.157***	−0.002	
	(0.057)	(0.052)	
$\text{Tangibles assets}_{ist}$	0.464***	0.323***	0.325***
	(0.092)	(0.086)	(0.072)
$\text{Intangible assets}_{ist}$	0.281***	0.300***	0.267***
	(0.096)	(0.096)	(0.082)
Sales_{ist}	−0.601***	−0.450***	−0.484***
	(0.076)	(0.072)	(0.040)
Age_{ist}	8.716***	8.806***	8.813***
	(0.620)	(0.601)	(0.597)
$\text{Interest expenses}_{ist}$	1.069***	0.946***	0.947***
	(0.088)	(0.086)	(0.073)
Value added_{ist}	−0.344***	−0.335***	−0.424***
	(0.067)	(0.065)	(0.042)
Additional covariates			
Employment	–	–	Yes
Year dummies	–	Yes	Yes
Industry dummies	–	Yes	Yes

Notes: results are for OLS regressions of firm characteristics (all taken in logs except age) on a dummy variable indicating a firm's status of zombie innovator, with baseline category being non-zombie innovator. Regressions in column (2) include year and fixed effects. Regressions in column (3) additionally include firm log employment as a control for size. The number of observations is 22,254 in all regressions. Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1. Standard errors are clustered by firm.

The results presented in Table A.2 are the estimated mean differences based on a series of OLS regressions of the following relationship:

$$Y_{ist} = \beta_1 D_{ist}^{Z\ inno} + X_{ist}\beta_2 + \varepsilon_{ist}$$

where Y represents different characteristics of firm i in sector s at time t, such as employment, tangible and intangible assets, sales, age, interest expenses and value added (all in logs except age); $D_{ist}^{Z\ inno}$ is a dummy taking value 1 if a firm is a zombie innovator and taking value 0 if a firm is a non-zombie innovator, where innovators are defined as firms with at least one patent over the sample period; X is a vector of additional covariates including firm size (log employment), year dummies and industry dummies (at the 2 digit level). Column 1 shows coefficients on $D_{ist}^{Z\ inno}$ for a set of regressions without additional covariates; regressions in column 2 include year and industry fixed effects; regressions in column 3 add a control for firm size. Overall, these results suggest that zombie innovators possess larger amounts of tangible and intangible assets, have older age, have higher debt service to repay, lower market shares and lower value added. The magnitude of these mean differences is non-trivial. Considering the within-sector coefficients in column 3, zombie innovators (as compared to non-zombie innovators) have 32.5 % more of tangible assets, 26.7 % more of intangible assets, almost 9 years more of age, 94.7 % higher interest expenses, 48.4 % lower sales and 42.4 % lower value added. Although purely descriptive in nature, these results document deep differences between zombie and non-zombie innovators, suggesting that the former are more mature firms that accumulated larger pools of knowledge and capital but struggle to be competitive on markets and are relatively much more indebted.

Table A.3
PPML estimates excluding the top-3 sectors by zombie employment.

	(1)	(2)	(3)	(4)
Dep. Var.: Patents_{ist+1}				
D_{its}^{NZ}	0.4326**	0.4307*	0.4409**	0.4316**
	(0.2190)	(0.2269)	(0.2185)	(0.2140)
Zombie_{st}	0.1994	0.1779		0.1702
	(0.1402)	(0.1304)		(0.1289)
$\text{Zombie spillover}_{ist}$ ($= D_{its}^{NZ} \times \text{Zombie}_{st}$)	−0.2727**	−0.2665**	−0.2684**	−0.2460*
	(0.1349)	(0.1344)	(0.1355)	(0.1349)
Age_{ist}	0.0125***	0.0081***	0.0081***	0.0082***
	(0.0024)	(0.0025)	(0.0025)	(0.0025)

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Table A.3 (*continued*)

Dep. Var.: $Patents_{ist+1}$	(1)	(2)	(3)	(4)
$Employment_{ist}$	0.0002***	0.0002***	0.0002***	0.0002***
	(0.0001)	(0.0001)	(0.0000)	(0.0000)
Tangible $assets_{ist}$	0.5687***	0.5643***	0.5639***	0.5647***
	(0.0417)	(0.0379)	(0.0377)	(0.0377)
Observations	1,733,121	1,733,121	1,733,121	1,733,121
N of firms	425,897	425,897	425,897	425,897
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Province dummies	–	Yes	Yes	Yes
Year-Industry dummies	–	–	Yes	–
Year-Region dummies	–	–	–	Yes
Pseudo R-squared	0.422	0.455	0.457	0.458

Notes: Standard errors in parentheses are clustered by firm. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Industries excluded in these regressions are NACE 302, 202 and 241.

Table A.4
PPML estimates based on more stringent definition of zombies.

Dep. Var.: $Patents_{ist+1}$	(1)	(2)	(3)	(4)
D^{NZ}_{its}	0.5449**	0.4737**	0.4722*	0.4584**
	(0.2325)	(0.2280)	(0.2562)	(0.2317)
$Zombie_{st}$	0.5157	0.4844		0.4720
	(0.3189)	(0.3235)		(0.3237)
Zombie $spillover_{ist}$ (= $D^{NZ}_{its} \times Zombie_{st}$)	−0.5353**	−0.5092**	−0.5082**	−0.5048**
	(0.2208)	(0.2243)	(0.2304)	(0.2253)
Age_{ist}	0.0122***	0.0080***	0.0080***	0.0080***
	(0.0024)	(0.0025)	(0.0024)	(0.0024)
$Employment_{ist}$	0.0002***	0.0002***	0.0002***	0.0002***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Tangible $assets_{ist}$	0.5730***	0.5678***	0.5672***	0.5682***
	(0.0411)	(0.0374)	(0.0371)	(0.0372)
Observations	1,734,276	1,734,276	1,734,276	1,734,276
N of firms	426,130	426,130	426,130	426,130
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Regional dummies	–	Yes	Yes	Yes
Year-Industry dummies	–	–	Yes	–
Year-Region dummies	–	–	–	Yes
Pseudo R-squared	0.428	0.431	0.454	0.458

Notes: Standard errors in parentheses are clustered by firm. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Zombies are here defined as firms of at least 10 years of age, with an interest coverage ration below 1 for three consecutive years, and with negative real sales growth for at least two consecutive years.

Table A.5
PPML estimates of zombie effects on whether non-zombies patent or not.

Dep. Var.: Patent $dummy_{ist+1}$	(1)	(2)	(3)	(4)
D^{NZ}_{its}	0.2934*	0.3371**	0.2991**	0.3115**
	(0.1587)	(0.1578)	(0.1513)	(0.1565)
$Zombie_{st}$	0.0188	−0.0032		
	(0.0421)	(0.0419)		
Zombie $spillover_{ist}$ (= $D^{NZ}_{its} \times Zombie_{st}$)	−0.1120**	−0.1071**	−0.1106**	−0.1089**
	(0.0427)	(0.0425)	(0.0432)	(0.0455)
Age_{ist}	0.0115***	0.0093***	0.0103***	0.0107***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
$Employment_{ist}$	0.0001***	0.0001***	0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Tangible $assets_{ist}$	0.2564***	0.2534***	0.2551***	0.2590***
	(0.0034)	(0.0034)	(0.0034)	(0.0035)
Observations	1,734,276	1,734,276	1,734,276	1,734,276
N of firms	426,130	426,130	426,130	426,130
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Province dummies	–	Yes	Yes	Yes
Year-Industry dummies	–	–	Yes	–
Year-Province dummies	–	–	–	Yes
Pseudo R-squared	0.155	0.164	0.179	0.185

Notes: Standard errors in parentheses are clustered by firm. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. In this set of regressions the dependent variable is a dummy indicating whether or not a firm filed for a patent in a given year.

Table A.6
OLS estimates of zombie effects on non-zombies R&D.

	(1)	(2)	(3)	(4)
Dep. Var.: ln $R\&D_{ist+1}$				
D^{NZ}_{its}	0.1361***	0.1420***	0.1287***	0.1266***
	(0.0305)	(0.0302)	(0.0311)	(0.0321)
$Zombie_{st}$	−0.0064	−0.0071		−0.0070
	(0.0071)	(0.0071)		(0.0067)
Zombie $spillover_{ist}$ (= $D^{NZ}_{its} \times Zombie_{st}$)	−0.0345***	−0.0333***	−0.0329***	−0.0310***
	(0.0094)	(0.0092)	(0.0098)	(0.0108)
Age_{ist}	0.0009***	0.0030***	0.0027***	0.0024***
	(0.0003)	(0.0004)	(0.0004)	(0.0004)
$Employment_{ist}$	0.0014***	0.0013***	0.0011***	0.0011***
	(0.0003)	(0.0003)	(0.0000)	(0.0000)
Tangible $assets_{ist}$	0.3584***	0.3627***	0.3511***	0.3590***
	(0.0035)	(0.0034)	(0.0034)	(0.0035)
Observations	43,472	43,472	43,472	43,472
N of firms	12,130	12,130	12,130	12,130
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Province dummies	–	Yes	Yes	Yes
Year-Industry dummies	–	–	Yes	–
Year-Province dummies	–	–	–	Yes
Pseudo R-squared	0.186	0.196	0.199	0.202

Notes: Standard errors in parentheses are clustered by firm. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. In this set of regressions the dependent variable is the log of R&D expenditure of firms.

Table A.7
Robustness check excluding Greece, Portugal and Spain from the instrumental variable.

	(1)	(2)	(3)	(4)	(5)	(6)
	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF
Dep. Var.:	Zombie $spillover_{ist}$	$Patents_{ist+1}$	Zombie $spillover_{ist}$	$Patents_{ist+1}$	Zombie $spillover_{ist}$	$Patents_{ist+1}$
D^{NZ}_{its}	−2.9318***	−0.1365	−2.8411**	−0.1918	−2.501**	−0.1566
	(1.1317)	(0.1812)	(1.1508)	(0.2143)	(1.1577)	(0.3031)
EZ_{its}(= $D^{NZ}_{its} \times$ EU $Zombie_{st}$)	0.0315***		0.0186***		0.0161***	
	(0.0096)		(0.0011)		(0.0032)	
Zombie $spillover_{ist}$ (= $D^{NZ}_{its} \times Zombie_{st}$)		−0.0691**		−0.0819*		−0.0574*
		(0.0336)		(0.0426)		(0.0311)
Age_{ist}	0.0001***	0.0107***	0.0001***	0.0110***	0.0001***	0.0106***
	(0.0000)	(0.0034)	(0.0000)	(0.0035)	(0.0000)	(0.0033)
$Employment_{ist}$	−0.0003***	0.0002***	−0.0003**	0.0002***	−0.0003**	0.0002***
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0001)
Tangible $assets_{ist}$	−0.0004***	0.3392***	−0.0007***	0.2923***	−0.0006***	0.3360***
	(0.0001)	(0.0628)	(0.0002)	(0.0697)	(0.0002)	(0.0698)
$\widehat{CF}_{ist}$ (1st stage OLS residual)		−0.6105		−0.8802		−0.7021
		(0.7002)		(0.7532)		(0.7270)
Observations	1,734,276	1,734,276	1,734,276	1,734,276	1,734,276	1,734,276
N of firms	426,130	426,130	426,130	426,130	426,130	426,130
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year-Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
F-stat	105.11		108.04		107.34	
R-squared	0.473		0.441		0.428	
Pseudo R-squared		0.391		0.385		0.384

Notes: Standard errors in parentheses are clustered by firm and are bootstrapped (100 replications). Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. In columns 1 and 2, the instrument is the EU-15 average of 2-digit sector shares of zombie employment (excluding Italy, Spain, Portugal and Greece); in columns 3 and 4, this instrument is weighted by the Italian Census 2011 sector employment share of the province where each non-zombie firm is located; in columns 5 and 6, instead, weights are taken from the Italian Census 1991.

Table A.8
Sector exposure to global shocks.

	(1)	(2)	(3)	(4)
	High global exposure		*Low global exposure*	
	1st stage OLS	PPML, CF	1st stage OLS	PPML, CF
Dep. Var.:	Zombie spillover$_{ist}$	Patents$_{ist+1}$	Zombie spillover$_{ist}$	Patents$_{ist+1}$
D^{NZ}_{its}	−3.8124***	−0.1276	−3.3953***	−0.3140
	(1.1664)	(0.2468)	(1.4619)	(0.2033)
$EZ_{its}(= D^{NZ}_{its} \times$ EU15 Zombie$_{st})$	0.0164***		0.0262***	
	(0.0007)		(0.0004)	
Zombie spillover$_{ist}$ $(= D^{NZ}_{its} \times$ Zombie$_{st})$		−0.0659**		−0.1035***
		(0.0301)		(0.0343)
Age$_{ist}$	−0.0001	0.0091***	0.0001***	0.0165***
	(0.0001)	(0.0034)	(0.0000)	(0.0037)
Employment$_{ist}$	−0.0001**	0.0003***	−0.0001	0.0002***
	(0.0000)	(0.0001)	(0.0001)	(0.0000)
Tangible assets$_{ist}$	−0.0008***	0.7082***	−0.0011***	0.4672***
	(0.0002)	(0.0666)	(0.0001)	(0.0604)
$\widehat{CF}_{ist}$ (1st stage OLS residual)		−0.1635		−0.2249
		(0.2454)		(0.2355)
Observations	270,418	270,418	1,463,858	1,463,858
N of firms	66,494	66,494	359,636	359,636
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes
Year-Industry dummies	Yes	Yes	Yes	Yes
F-stat	94.74		103.03	
R-squared	0.628		0.482	
Pseudo R-squared		0.495		0.257

Notes: Standard errors in parentheses are clustered by firm and are bootstrapped (100 replications). Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1. The instrument is the EU average of 2-digit sector shares of zombie employment (excluding Italy); Columns 1 and 2 consider firms in sectors with high global exposure, defined as above-median values of export and imports, while columns 3 and 4 include firms in sectors with low global exposure.

Data availability

The authors do not have permission to share data.

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