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Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

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JEL Classification: E44, G21

Keywords: zombie lending, capital misallocation

Fabiano Schivardi - fabiano.schivardi@gmail.com
LUISS University, EIEF and CEPR

Enrico Sette - enrico.sette@bancaditalia.it
Bank of Italy

Guido Tabellini - guido.tabellini@unibocconi.it
Università Bocconi and CEPR

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Identifying the Real Effects of Zombie Lending*

Fabiano Schivardi† Enrico Sette‡ Guido Tabellini§

May 12, 2020

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Several papers study the real effects of zombie lending based on regressions showing that the performance of healthy firms relative to zombie firms deteriorates as the fraction of zombie firms increases. This finding is interpreted as evidence of a negative spillover from zombies to healthy firms. We argue that this commonly used approach faces a serious identification problem. Under general conditions on the distribution of firm performance, the deterioration of the relative performance of healthy firms is a mechanical consequence of an increase in the fraction of zombies and cannot be interpreted as evidence of negative spillovers.

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†LUISS University, EIEF and CEPR, fschivardi@luiss.it

‡Bank of Italy, enrico.sette@bancaditalia.it.

§Department of Economics and IGIER, Bocconi University; CEPR, CES-Ifo, CIFAR, guido.tabellini@unibocconi.it.

1 Introduction

There is clear evidence that recessions accompanied by a banking crisis tend to be both more severe and longer lasting (Dell'Ariccia, Detragiache & Rajan 2008, Reinhart & Rogoff 2013). However, there is less consensus on the specific channels thorough which weak banks deepen the through and delay the recovery. On one side, there could be a reduction in the *quantity* of credit supplied, which impairs the capacity of firms to finance working capital and investments. On the other, the *quality* of credit supply could deteriorate if undercapitalized banks engage in lending to weak firms (the zombies) to avoid the emergence of losses and provisioning. Distinguishing between the two channels is important to formulate appropriate policies. If the problem is quantity, expansionary monetary policy can contribute to fix it. But if the problem is quality, channeling resources through banks without first restoring their financial health might actually be counterproductive, as it would increase the extent of zombie lending.

Following an influential paper on the prolonged Japanese stagnation of the 1990s (Caballero, Hoshi & Kashyap 2008), a growing empirical literature finds support for the second channel. The argument is that zombie lending reduces restructuring and delays the recovery because it impedes reallocation of assets from low productivity uses (the zombies) to high productivity uses (the non zombies), increasing misallocation (Hsieh & Klenow 2009). Zombie lending can hurt healthy firms in two ways: first, it reduces the flow of bank credit that is available to healthy firms, if credit supply is limited; second, lending to non-viable firms is equivalent to a subsidy that hurts their healthy competitors in product and input markets.

The perverse incentives that push banks to engage in zombie lending are particularly strong when banks have a weak capital structure, because in that case provisioning and raising capital becomes particularly difficult. As a consequence, zombie lending is the subject of a growing number of papers studying the European financial and sovereign debt crisis (see, for example, Acharya, Eisert, Eufinger & Hirsch 2019, McGowan, Andrews & Millot 2018, Schivardi, Sette & Tabellini 2019, Storz, Koetter, Setzer & Westphal 2017, Blattner, Farinha & Rebelo 2018, Anderson, Riley & Young 2019). Most of these papers confirm the original finding of Caballero et al. (2008). These results play an important role in the debate on bank restructuring, supporting the view, largely embraced by the regulatory bodies, that banks need to increase their capital and clean up their balance sheets from bad loans to improve the quality of their credit supply. The implication for firms is that zombies should "stop walking", letting them fail to allow the beneficial cleansing effects of their failure to materialize.[1]

In this paper, we argue that the empirical framework commonly applied in the literature to estimate the effects of zombie lending on healthy firms suffers from a serious identification problem that can bias the results towards finding a negative spillover even when this is not actually the case. In a nutshell, the framework correlates the performance of non zombies relative to that of zombies with the sectoral share of zombies, interpreting a negative coefficient as measuring the negative spillovers: when more zombies are active, healthy firms perform relative worse. To account for common shocks, the regression is saturated with sector-year dummies. We show that this correlation can arise naturally from standard shocks which, by shifting the distribution of firms performance to the left, mechanically increase the share of zombies and reduce the *relative* performance of healthy firms, absent any spillover. We provide analytical conditions on the performance distribution under which this is actually the case and show that such conditions are likely to be satisfied in the settings typically considered in the literature. This effect is not accounted for by sector-year dummies, which only control for shocks that hit firms equally.

Next, we argue that the fix to this problem is the usual one: finding exogenous variation in the share of zombies with respect to aggregate shocks. The literature has not followed this approach, given its reliance on sector-year dummies. In the final section we discuss the main contributions to the literature, and argue that none of them is completely immune from the possibility that the share of zombies is correlated with aggregate shocks. As a consequence, we conclude that the correlation on which the literature basis the claim that zombies hurt healthy firms is likely be spurious and cannot offer a solid scientific basis for policy prescriptions.

This result contributes to an important academic and policy debate. In fact, while keeping zombies alive increases misallocation in the long run, there might be beneficial effects in downturns. First, avoiding bankruptcies prevents layoffs. This in turn can

[1] Acharya, Crosignani, Eisert & Eufinger (2020) go one step further, claiming that also the low inflation rate in Europe is partially attributable to zombie lending. In their view, keeping zombies alive increases output supply and puts downward pressures on markups through increased competition, thus reducing price growth.

mitigate the adverse aggregate demand externalities that are important during a recession (Mian, Sufi & Trebbi 2015). Firms closures can also disrupt input-output relationships that, at least in the short run, can be difficult to substitute for (Barrot & Sauvagnat 2016).[2] Given that the effects are ex ante ambiguous, policy prescriptions should be based on uncontroversial empirical evidence.

The rest of the paper is organized as follows. Section 2 illustrates the approach of the literature and the identification problem it faces. Section 3 assesses to what extent the various definitions of zombies used in the literature are vulnerable to the it. Section 4 concludes.

2 The Identification Problem

In this section we illustrate the approach of the literature and the identification problem it faces.

2.1 The Approach in the Literature

The regression framework typically use to analyze the effects of zombies on heathy firms is the following:

$$X_{ijt} = \beta_0 + \beta_1 D^{NZ}_{ijt} + \beta_2 Z_{jt} + \beta_3 D^{NZ}_{ijt} * Z_{jt} + D_t + S_j + \varepsilon_{ijt} \tag{1}$$

where X is a measure of activity (say employment growth) of firm i in sector j and year t, D^{NZ}_{ijt} is a dummy equal to 1 for non zombie firms, Z_{jt} measures the presence of zombies in a sector (in Caballero et al. (2008) it is the share of assets of zombie firms in total sectoral assets, in Acharya et al. (2019), McGowan et al. (2018), Gouveia & Osterhold (2018), Blattner et al. (2018) it is the share of zombie firms in a sector), D_t and D_j are year and sector dummies and ϵ_{ijt} an error term. The coefficient β_1 measures the correlation between the share of zombies in the sector and the zombie performance, and β_2 captures the differential effect for non zombies. A negative estimate of β_2 is interpreted as evidence of negative spillovers from zombies to non zombies: the higher is the share of zombies, the worse is the relative performance of healthy firms.

[2] Historically, one of the causes of the long lasting effects of the Great Depression is often connected to Andrew Mellon, who famously defended the cleansing effect of the Depression by urging President Hoover to " Liquidate labor, liquidate stocks, liquidate the farmers, liquidate real estate... purge the rottenness out of the system."

The key identification problem in estimating this regression is that the share of zombies is correlated with shocks affecting the performance of both zombies and non-zombies, such as demand shocks. An adverse demand shock in sector j is bound to increase the share of zombies and also negatively affect the performance of healthy firms operating in the same sector. This problem is well understood by the literature, which addresses it by specifying the vector of dummy variables as a full set of (country-)sector-year[3] dummy variables D_{jt} and estimate the equation:

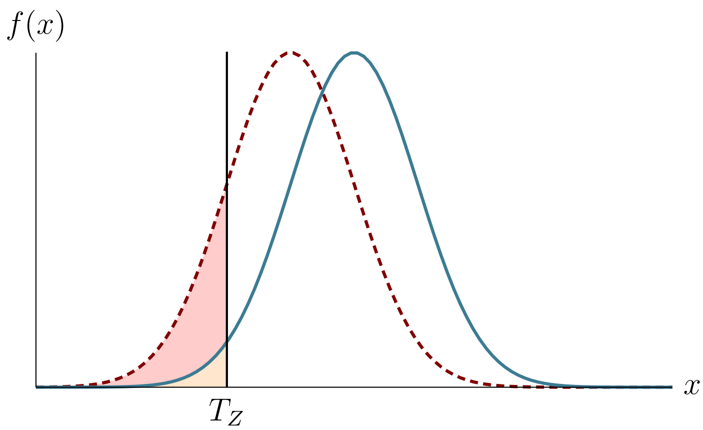
$$X_{ijt} = \beta_0 + \beta_1 D_{ijt}^{NZ} + \beta_3 D_{ijt}^{NZ} * Z_{jt} + D_{jt} + w_{ijt}. \tag{2}$$

In this equation, the absolute effect of the presence of zombies in a sector cannot be estimated anymore, as absorbed by the sector-year dummy; one can only estimate the relative effect on non zombies, relative to zombies, β_3. Still, provided that the coefficient β_3 correctly identifies the negative spillovers, this is sufficient to state that, if $\beta_3 < 0$, zombies hurt healthy firms, at least in a relative sense. And given that the sector-year dummies take care of all unobserved heterogeneity at the sector-year level, this might seem a robust empirical framework.

Unfortunately, this is not the case in a standard setting of firms heterogeneity. This problem is illustrated in Figure 1, where the continuous curve depicts a hypothetical distribution of firms performance in a sector, where we use a normal with mean five and unit standard deviation. The horizontal axis is a measure of firm "quality", such as growth prospects, which translates in firm performance, that is, actual growth. Zombie firms are those below a given threshold, T_Z in the Figure. Healthy firms are those to the right of T_Z. We are interested in the difference between the average performance of healthy vs. zombie firms, namely $\mu^{NZ} - \mu^{Z}$, where $\mu^{NZ} \equiv E(X|X > T_Z)$ and $\mu^{Z} \equiv E(X|X \leq T_Z)$ denote the mean performance of healthy and zombie firms respectively, with X denoting firm performance. In particular, we want to know how exogenous changes in Z_{jt}, the share of zombies in sector j at t, affect $\mu^{NZ} - \mu^{Z}$ through possible spillover effects, such as distortions of competition or lower credit supply to healthy firms. According to the empirical framework of the literature, this can be assessed by the estimate of β_3 in equation (2): in fact, by OLS estimation, β_3 captures the conditional correlation between the share of zombies Z_{jt} and the relative performance of healthy firms $\mu^{NZ} - \mu^{Z}$.

[3] Caballero et al. (2008) use data only for Japan, Blattner et al. (2018) for Portugal, while Acharya et al. (2019), McGowan et al. (2018) and Acharya et al. (2020) use data for multiple countries.

Figure 1: The effect of a common shock on zombies and non zombies



The figure plots two normal distributions with unit variance and mean $\mu_L = 4$ and $\mu_H = 5$, respectively. T_Z is the threshold to be classified zombie.

The implicit identifying assumption behind this approach is that, *in the absence of spillover effects*, shocks that change the share of zombies have the same effect on the average performance of zombies and healthy firms, that is, they do not affect $\mu^{NZ} - \mu^{Z}$. Under this assumption, observed variations in $\mu^{NZ} - \mu^{Z}$ associated with variations in the share of zombies can be entirely attributed to spillover effects. Unfortunately, this assumption is unlikely to hold in the data and, therefore, β_3 cannot identify the effects of zombies on non-zombies even if one includes sector-year dummy variables in equation (2). To see this, suppose that the sector is hit by a negative shock that shifts the whole distribution of firms to the left, to the dashed curve depicted in Figure 1. Three things happen. First, the share of zombie firms, Z_j, increases (the area to the left of T_Z rises, as illustrated by the shaded area in Figure 1). Second, both conditional means μ^{NZ} and μ^{Z} change, and presumably drop.[4] This is the standard identification problem discussed above, addressed in the literature by the inclusion of area-sector-year dummy variables. Third, the difference between the conditional means $\mu^{NZ} - \mu^{Z}$ could also be affected, in a manner that depends on the shape of the distribution of firms' performance. This third identification problem is neglected in the literature, but it can lead to totally spurious conclusions on the effects of zombies on healthy firms.

[4]Note that, for some distributions, a leftward shift might actually increase μ^{NZ}, the conditional mean above the threshold. However the mean surely decreases for log-concave distributions (Barlow & Proschan 1975), a family that includes many commonly used distributions, such as the normal, the Laplace and the logistic.

2.2 An Analytical Result

Consider first a symmetric distribution of firm performance, i.e., $X \sim F(.)$ and $F(.)$ is symmetric. A shift to the left of the distribution is equivalent to a shift to the right of the the threshold T_Z defining zombie firms. But for a large class of symmetric distributions, a shift to the right of the threshold T_Z automatically causes a reduction in the difference between the conditional means $\mu^{NZ} - \mu^{Z}$, provided that the threshold T_Z is below the unconditional mean of X, i.e., $T_Z < E(X)$. That is, a drop in the (average) performance of healthy firms relative to zombies cannot be interpreted as evidence of negative spillovers from zombies to healthy firms. It can be a mechanical consequence of a deterioration of the average performance of all firms, or equivalently of an increase in the fraction of zombie firms. Specifically, the appendix proves the following result:

Proposition 1. *Consider a random variable X with density $f(.)$ and cumulative distribution $F(.)$, and let $\mu^{NZ} \equiv E(X|X > T_Z)$ and $\mu^{Z} \equiv E(X|X \leq T_Z)$. Suppose that the following conditions hold:*

1. *X is integrable, i.e. $E[|X|] < +\infty$*

2. *f is symmetric around $E[X]$, that is $f(x + E[X]) = f(E[X] - x)$*

3. *f is differentiable almost everywhere and*

$$f'(x) \begin{cases} > 0 & \textit{if } x < E[X] \\ = 0 & \textit{if } x = E[X] \\ < 0 & \textit{if } x > E[X] \end{cases}$$

4. *$E[|X - E[X]|] > \frac{1}{4f(E[X])}$*

If $T_Z < E[X]$, then

$$\frac{\partial \left(\mu^{NZ} - \mu^{Z}\right)}{\partial T_Z} < 0.$$

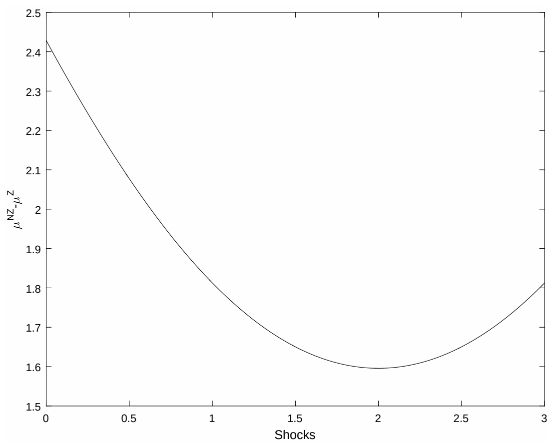
All four conditions in the Proposition are satisfied for any Normal distribution. The first three conditions are also satisfied for a large class of symmetric distributions, such as the Cauchy, the Logistic and the Student's t.[5]

[5] Condition 4 is a sufficient, but not necessary, condition. It says that the highest density must be sufficiently high, relative to the absolute deviation from the mean.

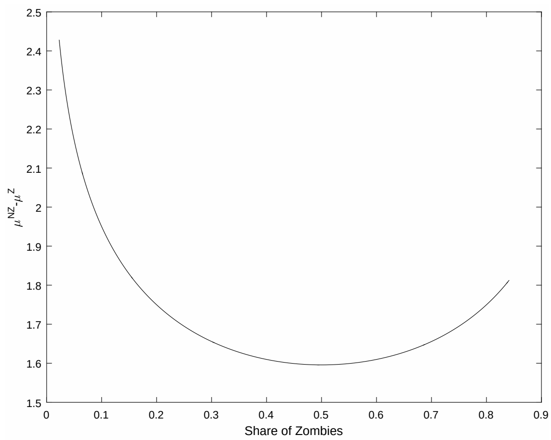
We illustrate this result for a normal distribution with unit variance and mean equal to 5 (the choice of the mean and variance is inconsequential for the results since the conditions in Proposition 1 are satisfied for any normal distribution). Assume that firms below 3 are classified as zombies, i.e. $T_Z = 3$. We perform the following experiment. We generate negative shocks $s = 0.01, 0.02, ..., 3$ that progressively shift the distribution to the left, $\mu(s) = 5 - s$, and compute $\mu^{NZ}(s) - \mu^{Z}(s)$, that is, the difference in the average quality of non-zombies and zombies, for each value of s. Panel A of figure 2 plots $\mu^{NZ}(s) - \mu^{Z}(s)$ against the shock s and shows that it is decreasing for $s < 2$, that is, as long as the zombie threshold T_Z is to the left of the mean of the distribution (for $s = 2, \mu(s) = 3 = T_Z$). Panel B plots $\mu^{NZ}(s) - \mu^{Z}(s)$ against the share of zombies, that is, the share of firms below 3, which obviously increases with s. Here too we find a negative relationship, as long as the share of zombies is below 50%.

The condition that $T_Z < E(X)$ is generally met in the papers on zombie lending. For example, in Acharya et al. (2019) the share of zombies varies between 3% in Germany and 20% in Italy, while in Caballero et al. (2008) it varies between sector and over time, but it exceeds 20% only in a few years in Services and Real Estate (see their Figure 3).

Figure 2: Difference in non-zombies vs. zombies average performance



(a) Relative performance and aggregate shocks



(b) Relative performance and share of zombies

The graphs report the difference in the conditional mean of zombies and non-zombies, $\mu^{NZ} - \mu^{Z}$. In Panel (a) it is plotted against the aggregate shock $s = 0, 0.01..., 3$, which determines the leftward shift in the performance distribution, as illustrated in Figure 1. In Panel (b) it is plotted against the share of zombies implied by the leftward shift in the distribution shown in Panel (a).

Thus, in a very standard setting and without any negative spillovers occurring from zombies to non zombies, the estimation of Equation 2 would deliver a negative coefficient β_3, corresponding to a negative relative performance of healthy firms as the share of zombies increases. But this simply reflects a property of the distribution of firms, and has nothing to do with the hypothesis that a larger share of zombies hurts healthy firms through spillovers in credit, product or input markets.

We have experimented numerically with some non-symmetric distributions typically used in the literature to model the distribution of firm performance. Specifically, we have computed the conditional expectations above and below a threshold T_Z as the distribution shifts leftward (and the share of zombies increases). In unreported results, we find that the correlation between the share of zombies and $\mu^{NZ} - \mu^{Z}$ can be both positive and negative, depending on the distribution and the parameters that characterize it. For example, the relationship is continuously decreasing (that is, $\mu^{NZ} - \mu^{Z}$ decreases when the fraction of zombies increases) for the exponential distribution, while the opposite occurs for the Pareto distribution. For the Lognormal, it depends on the parametrization, and it can go from decreasing to increasing as for the normal case to continuous increasing as in the Pareto. Not surprisingly, the first case occurs for parameterizations that make the Lognormal similar to the normal (i.e., for a Lognormal with parameters μ, σ, with low σ) and the second to the Pareto (large σ). Only for the uniform distribution $\mu^{NZ} - \mu^{Z}$ does not vary with the share of zombies.

2.3 Direction of the Bias

We have shown that regressions of the relative performance of healthy firms on the share of zombies can give rise to estimates of β_3 different from zero even in the absence of any spillovers. The estimated coefficient can be positive or negative, depending on the shape of the performance distribution, While this is enough to show that such regressions are not able to identify spillovers, it is interesting to discuss the most likely direction of the bias, since the literature has generally estimated a negative coefficient using this methodology. If the distribution is such that the difference in performance of non zombies and zombies decreases with the share of zombies, then the regression results would imply negative spillovers even when there are none. When the difference in performance increases with the share of zombies, on the other hand, the regression coefficient is biased towards zero and it provide a lower bound for the true effect.

While it is not possible to give a general answer to the direction of the bias, we believe that in practice the spurious negative estimate is the most likely result for two reasons. First, note that while distributions with a fat left tail such as the Pareto and the Lognormal with high σ are typically used to model the firm size distribution, in the zombie literature the relevant measure of performance is a measure of firm *growth*, such as of labor or sales. Figure 3 plots the distribution of the first difference in log employment (defined in terms of wage bill) for a large sample of the Italian incorporated businesses[6] for 2007, the last year before the financial crisis, and 2012, the through of the European sovereign debt crisis. To make the graph readable, we exclude firms with values below -1 and above 1. We use the Epanechnikov kernel function with bandwith 0.0121 (the standard command in Stata). Two aspects are worth noticing: first, the densities are closer to the normal shape and do not resemble the Pareto at all. Second, during the crisis there is a leftward shift in the distribution, similar to the one we constructed in Figure 1.

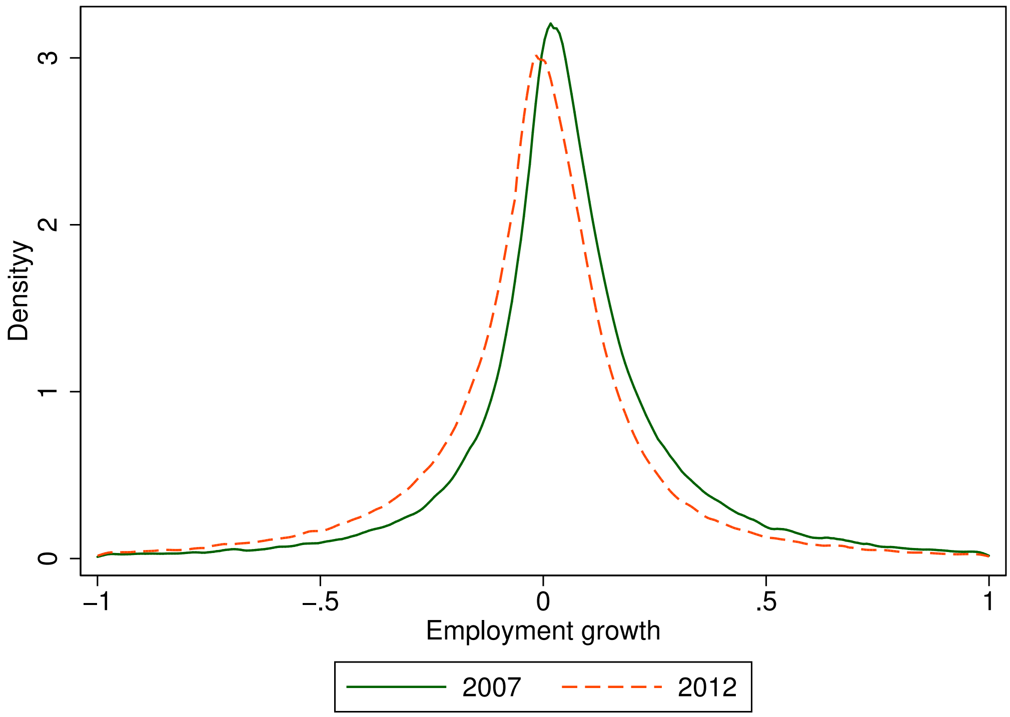
The second reason for which a spurious correlation is likely to emerge is that there is another factor that might induce a decrease in $\mu^{NZ} - \mu^{Z}$ as the distribution shifts to the left. The reason is that very low quality firms could exit the market. This would limit the drop in performance of (surviving) zombies (and hence the drop in $\mu^{Z}(s)$) when shocks hit. This can be seen again in Figure 4, where we also added an exit threshold T_D. When we shift the distribution to the left, the drop in the average quality of zombies is reduced by the fact that extremely low quality zombies drop out of the market. At the same time, as long as the density is higher at the zombie threshold T_Z than at the exit threshold T_D, we still obtain that a leftward shift in the distribution increases the mass of zombies.

3 Sources of variability in the share of zombies

The identification issue illustrated above can be restated in standard econometric language by saying the error term w_{ijt} in Equation 2 can be correlated with $D_{ijt}^{NZ} * Z_{jt}$, despite sector-year dummies. This formulation clarifies that, as usual, the causal interpretation of the β_3 coefficient requires some exogenous variation in the share of zombies with respect to aggregate performance shocks. The literature implicitly assumes that such variability

[6]The sample is that used by Schivardi et al. (2019) and comprises all the incorporated Italian firms with at least one banking relationship.

Figure 3: Distribution of employment growth in Italian firms, 2007 and 2012



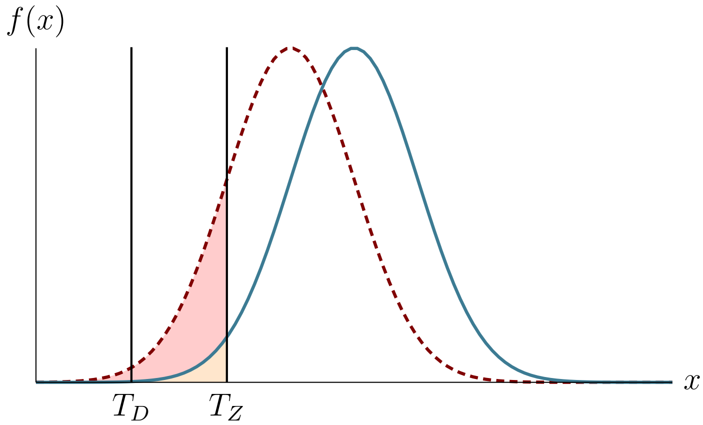
The graph reports the distribution of the growth rate of employment, defined as the first difference of the log of the wage bill, for 2007 and 2012 for the sample of incorporated businesses in Italy used in Schivardi et al. (2019).

comes from banks behaviour, as banks increase the share of zombies by engaging in zombie lending. However, possibly because this subtle identification problem is not fully understood, given that aggregate shocks are controlled for by time-sector effects, almost no paper takes the standard approach of finding an instrument.[7] Rather, bank behaviour is incorporated in the definitions of zombies. It is therefore useful to discuss these definitions in some detail, to assess if they are likely to satisfy the exogeneity requirement.

In the seminal work of Caballero et al. (2008), zombie firms are defined as firms that receive subsidized credit, that is, for which the interest payments over outstanding debt (a measure of average interest rate) is below the prime rate, measured by the average rate charged to high quality borrowers. If one believes that the number of zombies allowed to survive varies as a result of a change in lending policies by banks, and that such a change in uncorrelated with shocks to the economy-wide distribution of firm performance, then

[7]The only exception we are aware of is Blattner et al. (2018), which uses the industry exposure to a regulatory shock imposed by the European Banking Authority.

Figure 4: The effect of a common shock on zombies and non zombies



The figure plots two normal distributions with unit variance and mean $\mu_L = 4$ and $\mu_H = 5$, respectively. T_Z is the threshold to be classified zombie and T_D is the threshold for exit.

our critique would not apply. Yet such an assumption is fragile, since banks' incentives to subsidize firms are stronger when they are more at risk of defaulting. A negative aggregate shock to firm performance would increase the number of firms at risk and therefore the incentives for banks to extend subsidized credit, in which case exogeneity fails.

Things get more problematic in the subsequent literature, which moved towards definitions of zombie based on performance measures, in some cases integrated with indicators of banks lending policies. Storz et al. (2017) use the combination of negative ROA, negative net investment and low EBITDA over debt. Acharya et al. (2019) classify as zombies firms that, in addition to subsidized credit, also have a rating of BB or lower while Acharya et al. (2020) use interest coverage below the median and leverage above it. McGowan et al. (2018) and Gouveia & Osterhold (2018) only use interest coverage ratio. Schivardi et al. (2019) define as zombies firms with a low ROA and a high leverage which, in their sample of mostly private, small firms, can be attributed to high bank debt. All these definitions contain a component of performance, possibly coupled with some indication of evergreening by banks (subsidized credit, high debt).[8] It seems unlikely that these definitions pass the exogeneity requirement, that is, that the share of zombies is orthogonal to shocks that shift the performance distribution.

[8]The definition of subsidized credit may also be affected by firm's performance when it is based on firm's ratings. As these are proxies of firm's default probability they also depend on firm's performance.

To assess if the results of the literature are likely to be biased, in Schivardi et al. (2019) we have replicated the regressions run by the previous literature on a large sample of Italian firms for the period 2008-2013. The dependent variables are various measures of firm performance (the growth rates of the wage bill, capital spending and sales), and the specifications correspond to equations (1) and (2) above, with j denoting the province-sector and t the year. We define as zombie a firm that is highly indebted and for which the returns on assets have been systematically below the cost of capital of the safest firms. We also find that, as the share of zombies increases, all performance measures deteriorate more for healthy firms than for zombies, under both specifications. Despite the substantial differences in the sample of firms and institutional setting, we obtain magnitudes similar to those in the literature: the estimates of β_3 for the the capital growth equation 2 are -0.08 in Caballero et al. (2008), -0.018 in Acharya et al. (2019) and -0.043 in our case, and similarly for employment growth. Unfortunately, however, this finding is likely to be a mechanical consequence of the leftward shift in the distribution and cannot in itself be interpreted as evidence of negative spillovers from zombies to non-zombies. In fact, when we replace the share of zombie firms on the right-hand-side of (1), Z_{jt}, with an arguably exogenous supply side indicator of bank lending to zombie firms, we find no evidence that zombie lending hurts healthy firms.[9]

4 Conclusions

We show that the framework used in the literature to identify the effects of zombie lending on the real economy suffers from a serious identification problem, due to the fact that the share of zombies can be mechanically correlated with the relative performance of healthy firms. As a consequence, this correlation cannot be interpreted in a causal sense. We believe this is an important result, as it casts doubts on the policy prescription emerging from this literature, that zombie lending slows down the recovery. These prescriptions

[9]The only other paper that we are aware of that tries to address this issue is Acharya et al. (2020), which show that the negative estimate of β_3 disappears when defining zombies only on the basis of performance, that is, relaxing the subsidized credit condition. While this is a useful step toward addressing the identification issue we raise, we do not believe that this is sufficient to fully solve it for the reasons explained above. Within our framework, this result could be explained by the fact that the less stringent definition pushes the zombie threshold to the right in Figure 1, where the correlation between the share of zombies and the relative performance of non zombies becomes weaker. In particular, in Acharya et al. (2020) zombies are firms with interest coverage below the median and leverage above it. These two conditions are likely to be correlated, so that the resulting share of zombies could be close to 50%, where the effect becomes zero (see Figure 2, Panel B).

have played an important role in the policy debate following the financial and sovereign debt crisis, and they may also become relevant in addressing the COVID-19 crisis. It is therefore important that they are backed by flawless empirical evidence. Future research will need to put more emphasis on exogenous variation in the number of zomby firms to determine if these prescriptions are correct.

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A Proof of Proposition 1

Proof. For ease of notation, we replace T_Z with c. Fix $c < E[X]$. Without loss of generality, assume $E[X] = 0$, otherwise we consider $Y = X - E[X]$ and $f_Y(y) = f\left(E[X] + y\right)$. By ease of notation call:

$$M(c) := E[X|X > c] \quad m(c) := E[X|X < c]$$

It is easy to show that:

$$M'(c) = \frac{f(c)}{1 - F(c)}(M(c) - c)$$

and:

$$m'(c) = \frac{f(c)}{F(c)}(c - m(c))$$

Where F is the cumulative distribution function of X.
Now notice that:

$$E[X] = F(c)m(c) + (1 - F(c))M(c)$$

By recognizing that $E[X] = 0$, we have:

$$m(c) = -\frac{1 - F(c)}{F(c)}M(c)$$

Then our proof becomes to prove that:

$$g(c) = M(c) - m(c) = M(c)\left[1 + \frac{1 - F(c)}{F(c)}\right] = \frac{M(c)}{F(c)}$$

is strictly decreasing as $c < 0$.

Our proof will rely on three different lemmas.

Lemma 1. $g'(0) = 0$.

Proof. Differentiating $g(c)$ we obtain:

M(c)

$$\begin{aligned}
g'(c) &= \frac{M'(c)F(c) - f(c)M(c)}{(F(c))^2} \\
&= \frac{f(c)}{(1-F(c))(F(c))}\left[M(c)-c\right] - \frac{f(c)M(c)}{(F(c))^2} \\
&= \frac{f(c)F(c)(M(c)-c) - (1-F(c))f(c)M(c)}{(1-F(c))(F(c))^2} \\
&= \frac{f(c)F(c)M(c) - f(c)F(c)c - (1-F(c))f(c)M(c)}{(1-F(c))(F(c))^2} \\
&= \frac{f(c)M(c)(F(c)-1+F(c)) - f(c)F(c)c}{(1-F(c))(F(c))^2} \\
&= \frac{f(c)M(c)(2F(c)-1) - f(c)F(c)c}{(1-F(c))(F(c))^2} \\
&= \frac{f(c)}{F(c)\,(1-F(c))}\left[\frac{2F(c)-1}{F(c)}M(c) - c\right]
\end{aligned}$$

By symmetry, $F(0) = \frac{1}{2}$. Hence $g'(0) = 0$. QED.

Lemma 2. $\lim_{c \to 0^-} g'(c) < 0 < \lim_{c \to 0^+} g'(c)$

Proof. We have that:

$$\begin{aligned}
g'(c) &= \frac{f(c)}{F(c)\,(1-F(c))}\left[\frac{2F(c)-1}{F(c)}M(c) - c\right] \\
&= \frac{f(c)}{(F(c))^2\,(1-F(c))}\left[(2F(c)-1)M(c) - cF(c)\right] \qquad (3) \\
&= \frac{f(c)}{(F(c))^2\,(1-F(c))}h(c)
\end{aligned}$$

where $h(c) = (2F(c)-1)\,M(c) - cF(c)$. Thus, $g'(c) < 0$ if and only if $h(c) < 0$. Note that $h(0) = 0$ by symmetry.

Next, differentiate $h(c)$:

$$\begin{aligned}
h'(c) &= 2f(c)M(c) + M'(c)(2F(c)-1) - F(c) - f(c)c \\
&= 2f(c)M(c) + \frac{f(c)}{1-F(c)}(M(c)-c)(2F(c)-1) - F(c) - f(c)c
\end{aligned}$$

We have that:

$$\begin{aligned}
h'(c) > 0 \Leftrightarrow\ & 2f(c)M(c) + \frac{f(c)}{1-F(c)}(M(c)-c)(2F(c)-1) - F(c) - f(c)c > 0 \\
\Leftrightarrow\ & 2f(c)M(c) + \frac{f(c)}{1-F(c)}(2F(c)-1)M(c) - \frac{f(c)}{1-F(c)}(2F(c)-1)c - cf(c) > F(c) \\
\Leftrightarrow\ & f(c)M(c)\left[2 + \frac{2F(c)-1}{1-F(c)}\right] - f(c)\left[\frac{2F(c)-1}{1-F(c)} + 1\right] c > F(c) \\
\Leftrightarrow\ & f(c)M(c)\left[\frac{2-2F(c)+2F(c)-1}{1-F(c)}\right] - f(c)\left[\frac{2F(c)-1+1-F(c)}{1-F(c)}\right] c > F(c) \\
\Leftrightarrow\ & f(c)M(c)\left[\frac{1}{1-F(c)}\right] - f(c)\left[\frac{F(c)}{1-F(c)}\right] c > F(c) \\
\Leftrightarrow\ & M(c)\left[\frac{1}{1-F(c)}\right] - \left[\frac{F(c)}{1-F(c)}\right] c > \frac{F(c)}{f(c)}
\end{aligned}$$

So:

$$h'(c) > 0 \Leftrightarrow\ M(c)\left[\frac{1}{1-F(c)}\right] - c\left[\frac{F(c)}{1-F(c)}\right] > \frac{F(c)}{f(c)} \tag{4}$$

Now consider the point $c = 0$. By simmetry the above inequality reads:

$$M(0) > \frac{1}{4f(0)} \tag{5}$$

Moreover, also by symmetry, one can show that

$$M(0) = \frac{1}{F(0)} \int_c^{+\infty} xf(x)\,dx = 2\int_c^{+\infty} xf(x)\,dx$$

and:

$$\begin{aligned}
E[|X|] &= \int_{-\infty}^{0} -xf(x)\,dx + \int_0^{+\infty} xf(x)\,dx \\
&= \int_0^{+\infty} yf(-y)\,dy + \int_0^{+\infty} xf(x)\,dx \\
&= 2\int_0^{+\infty} xf(x)\,dx \\
&= M(0)
\end{aligned}$$

where the second equality follows from substituting $y = -x$ and the third is true thanks to the symmetry of $f(x)$. Hence, (5) and (4) can be written as:

$$h'(0) > 0 \Leftrightarrow E[|X|] > \frac{1}{4f(0)}$$

that holds by assumption 4.

We have shown that $h(0) = 0$ and $h'(0) > 0$. Since $h(c)$ is continuously differentiable, this means that $h(c) < 0$ in a left-neighbourhood of 0 and $h(c) > 0$ in a right-neighborhood of 0. As as a consequence, $g'(c) < 0$ and $g'(c) > 0$ in a left-neighbourhood and right-neighborhood of 0 respectively. QED

Lemma 3. *Suppose that there exists $c^* < 0$ such that $g'(c^*) = 0$. Then $g''(c^*) < 0$.*

Proof. Suppose that there exists $c^* < 0$ such that $g'(c^*) = 0$. By (3):

$$c^* = \frac{2F(c^*) - 1}{F(c^*)} M(c^*) \tag{6}$$

which can be rewritten as:

$$M(c^*) = \frac{c^* F(c^*)}{2F(c^*) - 1} \tag{7}$$

Then replacing $M(c^*)$ with the RHS of (7) into (4), we obtain:

$$\begin{aligned}
h'(c^*) > 0 \Leftrightarrow\ & M(c^*)[\frac{1}{1 - F(c^*)}] - [\frac{F(c^*)}{1 - F(c^*)}]c^* > \frac{F(c^*)}{f(c^*)} \\
\Leftrightarrow\ & \frac{c^* F(c^*)}{2F(c^*) - 1}\left[\frac{1}{1 - F(c^*)}\right] - \left[\frac{F(c^*)}{1 - F(c^*)}\right] c^* > \frac{F(c^*)}{f(c^*)} \\
\Leftrightarrow\ & \frac{c^*}{1 - F(c^*)}\left[\frac{1}{2F(c^*) - 1} - 1\right] > \frac{1}{f(c^*)} \\
\Leftrightarrow\ & \frac{c^*}{1 - F(c^*)}\left[\frac{2 - 2F(c^*)}{2F(c^*) - 1}\right] > \frac{1}{f(c^*)} \\
\Leftrightarrow\ & \frac{2c^*}{2F(c^*) - 1} > \frac{1}{f(c^*)} \\
\Leftrightarrow\ & 2c^* f(c^*) - 2F(c^*) + 1 < 0
\end{aligned}$$

where the sign of the inequality has been changed since:

$$2F(c^*) - 1 < 0$$

This follows from symmetry, given that:

$$c^* < 0 \Rightarrow F(c^*) < \frac{1}{2}$$

So, we have shown that $h'(c^*) > 0$ if and only if:

$$p(c^*) = 2c^* f(c^*) - 2F(c^*) + 1 < 0$$

Consider the function $p(c)$ with $c \leq 0$. Then: (i) $p(0) = 0$; (ii) $p'(c) = 2cf'(c) < 0$ if $c < 0$ by assumption 3. Since $c^* < 0$ and $p(c)$ is continuously differentiable, (i) and (ii) imply $p(c^*) > 0$.

Now we want to evaluate $g''(c)$. Note first of all that, by (3), $g'(c)$ can be written as:

$$g'(c) = \frac{f(c)h(c)}{(F(c))^2(1 - F(c))} = \frac{N(c)}{D(c)}.$$

Differentiating w.r. to c :

$$g''(c) = \frac{N'(c)D(c) - D'(c)N(c)}{(D(c))^2}$$

where:

$$N'(c)D(c) = [f'(c)h(c) + h'(c)f(c)][F(c)]^2(1 - F(c)) \tag{8}$$

Now we can recognize that $h(c^*) = 0$, given that $g'(c^*) = 0$ by assumption. As a consequence $N(c^*) = 0$ and hence $D'(c^*)N(c^*) = 0$

Thus we have:

$$g''(c^*) = \frac{N'(c)}{D(c)} = \frac{f(c^*)}{(F(c^*))^2\,(1 - F(c^*))} h'(c^*)$$

where both equalities follow from from $h(c^*) = 0$. Since $h'(c^*) < 0$, we thus have $g''(c^*) < 0$. QED

Now we complete the proof of the Proposition by contraddiction. By Lemmas 1 and 2, $c = 0$ is a point of local minimum of $g(c)$. By Lemma 3, any point $c^* < 0$ such that $g'(c^*) = 0$ must be a local maximum of $g(c)$. Thus, Lemma 3 also implies that $c^* < 0$, if it exists, must be unique, since $g(c)$ is continuously differentiable and we cannot have two consecutive local maxima. Thus, existence of $c^* < 0$ implies that $g'(c) > 0$ for any $c < c^*$. But this is impossible, because:

$$\lim_{c \to -\infty} g(c) = \lim_{c \to -\infty} \frac{M(c)}{F(c)} = \lim_{c \to -\infty} \frac{m(c)}{F(c) - 1} = +\infty$$

where the second equality follows from $m(c) = -\frac{1-F(c)}{F(c)} M(c)$. Thus, a point $c^* < 0$ such that $g'(c^*) = 0$ cannot exist. By Lemmas 1 and 2, therefore, 0 is the only critical point and $g'(c) < 0$ for any $c < 0$.QED

As an application, we show that $X \sim N(\mu, \sigma^2)$ satisfies the assumptions. The first three ones are obvious, so we focus on the fourth. By the properties of the Gaussian distribution:

$$\begin{cases} E[|X - E[X]|] = \sigma\sqrt{\frac{2}{\pi}} \\ f(E[X]) = \frac{1}{\sqrt{2\pi\sigma^2}} \end{cases}$$

With easy computations:

$$E[|X - E[X]|] > \frac{1}{4f\,(E[X])} \Leftrightarrow \sqrt{\frac{2}{\pi}} > \frac{\sqrt{2\pi}}{4} \Leftrightarrow 4 > \pi$$

that is true.