Zombie Credit and (Dis-)Inflation: Evidence from Europe*

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Abstract

We show that cheap credit to impaired firms has a disinflationary effect. By helping distressed firms to stay afloat, "zombie credit" can create excess production capacity, and in turn, put downward pressure on markups and prices. We test this mechanism exploiting granular inflation and firm-level data from eleven European countries. In the cross-section of industries and countries, we find that a rise of zombie credit is associated with a decrease in firm defaults and entries, average firm markups and product prices; lower productivity; and, an increase in aggregate sales as well as average material and labor cost. These results also hold at the firm level, where we document spillover effects to healthy firms in markets with high zombie credit. Our partial equilibrium estimates suggest that without a rise in zombie credit post 2012, annual inflation in Europe would have been 0.4 percentage points higher.

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1 Introduction

More than ten years after the global financial crisis, Europe's economic growth and inflation rate remain depressed, even though the European Central Bank (ECB) and other European central banks provided substantial monetary stimulus, including negative deposit rates, longer-term refinancing operations, and large-scale asset purchase programs. In former ECB President Mario Draghi's own words, *"although we have seen the successful transmission of monetary policy to financing conditions, and from financing conditions to GDP and employment, the final legs of the transmission process to wages and inflation have been slower than we expected. Wage growth is now strengthening as slack in the labor market diminishes. But the pass-through from wages to prices remains weak."*[1]

Europe's "missing inflation puzzle" bears a striking resemblance to Japan's "lost decades". Besides deflationary pressure, both economies have been characterized by ultra accommodative central bank policies, and zombie lending (i.e, cheap credit to impaired firms) by undercapitalized banks. Along with search-for-yield behavior of investors, these have collectively pushed borrowing costs to record lows, even for high-risk firms.[2][3] The glut of cheap debt has allowed many struggling firms to stay afloat, leading to a "zombification" of the economy (e.g., Borio and Hofmann, 2017 and Banerjee and Hofmann, 2018).

In this paper, we provide an explanation for the co-occurrence of a rise of zombie credit and low inflation levels shown in Figure 1. Building on Caballero et al. (2008), we illustrate in a simple model that by keeping alive distressed firms that would otherwise default, a rise of zombie credit prevents an adjustment in the industry-wide production capacity. The resulting excess capacity puts downward pressure on markups and product prices and thereby

[1] See Mario Draghi's speech "Twenty Years of the ECB's monetary policy" at the ECB Forum on Central Banking in Sintra on June 18, 2019. The speech is available at www.ecb.europa.eu.

[2] Caballero et al. (2008) and Giannetti and Simonov (2013) analyze this zombie lending phenomena in Japan and Acharya et al. (2019) find evidence for zombie lending in Europe.

[3] Since 2012, the average yield on European corporate junk bonds dropped by roughly two-thirds (with some junk bonds even starting to trade at sub-zero yields), while the ECB's cost-of-borrowing indicator for corporate loans more than halved. Sources: https://fred.stlouisfed.org/series/BAMLHE00EHYIEY, http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=124.MIR.M.U2.B.A2I.AM.R.A.2240.EUR.N, and "Sub-Zero Yields Start Taking Hold in Europe's Junk-Bond Market", Bloomberg, July 9, 2019.

lowers inflation.[4] We test this channel using granular inflation and firm-level data for a sample of 1.1 million firms from 11 European countries across 65 industries, which allows us to measure zombie credit and firm-level markups and to observe product-level prices. Our empirical analysis supports the zombie credit channel of downward pressure on inflation.

Specifically, our mechanism is consistent with a dynamic model where firms, potential entrants and incumbents, draw a productivity parameter every period and set prices to exploit their market power. If the productivity realization is high, incumbent firms survive and potential entrants enter. If the productivity realization is low, incumbent firms default and potential entrants do not enter. Following a negative demand shock that causes a price decline, zombie credit keeps alive some firms that would otherwise default, which prevents a downward adjustment in the number of active firms (compared to the case without zombie credit). The resulting excess production capacity puts downward pressure on firms' markups and prices. In equilibrium, zombie credit causes (i) a reduction in firm defaults and entries, firm markups, product prices, and productivity; and, (ii) an increase in sales, the number of active firms, and input costs.

The empirical analysis is based on a new data set, obtained by combining product level inflation data from Eurostat with firm-level accounting data from Bureau van Dijk's Amadeus database. Using input-output tables obtained from national statistical institutions, we calculate inflation at the industry-level from product-level data. Using Amadeus data, we measure zombie credit and firm markups. We define a firm as "zombie" if it meets two criteria: (i) the firm's interest coverage ratio is below the median and its leverage ratio is above the median – where medians are calculated at the industry-country level, and (ii) the firm obtains debt financing at a rate lower than the rate paid by the most creditworthy (AAA-rated) compara-

[4]For example, the Italian concrete and cement industry suffered from a global demand shock in 2008. Many firms subsequently struggled to pay interests and relied on their banks to remain alive and produce. The CEO of Cementir, one of the industry leaders in Italy, stated in 2017 that "*in Italy, in the cement industry, we have zombies kept alive by banks. [...] Banks do everything they can to keep these zombies alive to avoid realizing losses on their balance sheets.*" Industry representatives obtained in 2017 a Senate hearing (link) to discuss the ongoing crisis. In that hearing, they stated that "*the excessive productive capacity caused an unprecedented price competition that, in turn, caused firms to realize large losses.*"

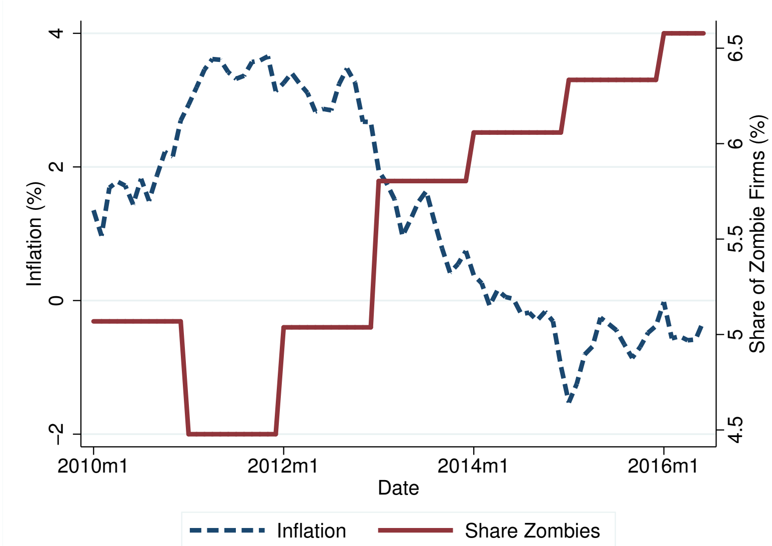

Figure 1: Zombie Credit and Inflation. This figure shows the year-over-year (yoy) growth of the CPI on the left axis and the asset-weighted share of zombie firms on the right axis in our sample. A firm is classified as zombie if it is low-quality (i.e., above median leverage and below median interest coverage ratio) and receives subsidized credit (interest expenses/debt smaller than that of the highest quality firms in a given year). Sources: Eurostat, Amadeus.

ble firms. We track the financial and real outcomes of zombie firms over time to mitigate the concern that their access to cheap credit is driven by a positive economic outlook. We find no improvement in economic activity for zombie firms: while low-quality non-zombie firms on average deleveraged and maintained their EBITDA return on total assets (ROTA), zombies increased their leverage and experienced a drop in their ROTA. Following De Loecker and Warzynski (2012), we estimate markups relying on optimal input demand conditions from standard cost minimization.

Our data supports the model predictions. In the cross-section of industries and countries, we find that industry-country pairs (henceforth called "markets") that experience an increase in the share of zombie firms subsequently have: fewer firm defaults and entries, a higher number of active firms, higher aggregate sales growth and average input costs (i.e., material and labor costs), as well as, lower average productivity, markups, and inflation growth. Our partial equilibrium estimates suggest that without a rise in zombie credit post 2012, annual inflation in Europe would have been 0.4 percentage points higher.

Our specifications include country-industry, country-year, and industry-year fixed effects to capture potential omitted variables such as country- and industry-specific shocks. The positive correlation between zombie credit and aggregate sales growth rules out that the negative correlation between zombie credit and inflation is driven by lower demand in markets with more zombie credit. The negative correlation with productivity suggests that zombie credit is extended to actual zombie firms and not to firms that are only temporarily weak. The positive correlation with input costs confirms the mechanism based on zombie credit induced excess capacity since more firms compete for the same factor inputs driving up their prices. To further mitigate endogeneity concerns, we instrument a market's zombie share with the average Tier-1 capital ratio of the banks connected to the firms in this market.[5] Our Instrumental Variable (IV) regression estimates confirm the negative effect of the share of zombie firms on inflation.

Finally, at the firm level, we document that the increased presence of zombie firms affected healthy firms active in the same market. In particular, we find that healthy firms that face a growing number of zombie firms have lower markups, investment, and sales growth, as well as higher input costs. These correlations are consistent with healthy firms trying to prevent a drop in market share and capacity utilization by pricing more aggressively.

The remainder of the paper is structured as follows. Section 2 reviews the related literature. Section 3 presents the intuition linking zombie credit to inflation. We present the formal model in Appendix A. Section 4 illustrates our data and empirical work. Section 5 and Section 6 show our empirical analysis at the industry-country level and at the firm level, respectively. Section 7 presents robustness checks. Section 8 concludes.

2 Related Literature

Our paper contributes to three strands of literature. First, our paper relates to the literature on zombie credit, started with the evidence from Japan in the 1990s. In that context, Peek and Rosengren (2005) document that banks close to the regulatory capital constraint

[5]The idea behind this instrument is that weakly-capitalized banks have strong zombie lending incentives (see, e.g., Schivardi et al., 2017, Acharya et al., 2019, and Blattner et al., 2019).

extended credit to their weak borrowers to avoid realizing losses on outstanding loans. Caballero et al. (2008) show that this zombie lending affected healthy firms, reducing their investment and employment growth. Giannetti and Simonov (2013) find that capital injections can stop zombie lending behavior if they are large enough. A few recent papers show that similar dynamics are at work in Europe during the sovereign debt crisis. Acharya et al. (2019) show that the ECB's Outright Monetary Transactions (OMT) program induced zombie lending by banks that remained weakly-capitalized. Schivardi et al. (2017) confirm that non-viable Italian firms obtained favorable bank credit from 2004 to 2013. Finally, using Portuguese data, Blattner et al. (2019) show that these distorted lending decisions caused a decline in productivity. For OECD countries, Adalet McGowan et al. (2018) show that the share of zombie firms increased over the period 2003-2013 and that the resulting market congestion is associated with lower investment and employment growth. Similarly, using firm-level data on listed firms in 14 advanced economies, Banerjee and Hofmann (2018) document a rise in the prevalence of zombies since the late 1980s, which they link to reduced financial pressure due to lower interest rates. We contribute to this literature by documenting the effect of zombie credit on firm markups and inflation.

Second, our paper relates to the literature that studies the effect of competition on firm price setting behavior and inflation. Campbell and Hopenhayn (2005), Lewis and Poilly (2012), and Lewis and Stevens (2015) provide evidence that markups are negatively related to the number of competitors in an industry. Aghion et al. (2018) find that the monetary easing induced by the OMT program announcement fostered growth especially for credit-constrained firms, and more so for higher product market competition. The authors argue that, if competition is high, weak firms can only avoid exit when funding is readily available. These findings support the notion that zombie credit and a resulting lower exit rate can lead to excess capacity, which puts downward pressure on markups and prices.

Third, our paper adds to literature that draws attention to the impact of financial frictions on inflation dynamics. Chevalier and Scharfstein (1996) highlight a "liquidity squeeze channel", arguing that liquidity-constrained firms have an incentive to raise prices to increase their current cash flows (assuming sticky customer relationships). Gilchrist et al. (2017) and de Almeida (2015) incorporate this mechanism into a general equilibrium model to explain the pricing behavior of U.S. and European firms in response to the 2007-08 financial crisis, respectively. Barth III and Ramey (2001) suggest the "cost channel" as a possible explanation for an increase (decrease) in inflation after a monetary tightening (loosening), which suggests that firms' pricing decisions are related to credit conditions as firms depend on credit to finance production. Christiano et al. (2015) introduce this cost channel into a New Keynesian model and argue that it helps to explain the only modest disinflation in the U.S. during the Great Recession.

3 Mechanism from Zombie Credit to (Dis-)Inflation

In this section, we describe the macroeconomic effects of zombie credit. In Appendix A, we develop a formal model which employs a framework similar to Caballero et al. (2008).

Consider an environment with imperfect competition among firms that produce a single good. The demand for this good is exogenous. The supply is the sum of the production by incumbent and entrant firms. Incumbent and potential entrants are subject to an idiosyncratic shock. Incumbent firms that receive a bad shock might be forced to exit and entrant firms that receive a good shock might enter. In equilibrium, holding demand constant, a higher number of firms leads to a more competitive market and therefore a lower price.

Suppose the economy is in a steady state, namely the number of firms that default each period is exactly offset by entrant firms. The equilibrium is illustrated by A in Figure 2, where the exogenous demand is equal to the production by the constant number of incumbent firms. To illustrate the effect of zombie credit, we analyze how the economy adjusts to a new equilibrium following a demand shock that reduces the demand to D'.

In the case with no zombie credit, the demand shock causes the price and quantity to decrease along the supply curve S to the new equilibrium N. The shock causes a direct drop in price; in turn, making the economy less attractive for both entrant and incumbent firms. More incumbent firms default and fewer potential entrant firms enter. The lower number of active firms has a positive effect on price, but not enough to offset the initial decline.

In the case with zombie credit, the demand shock again causes the equilibrium price and quantity to decrease, but this time along a flatter supply curve S^Z to the new equilibrium

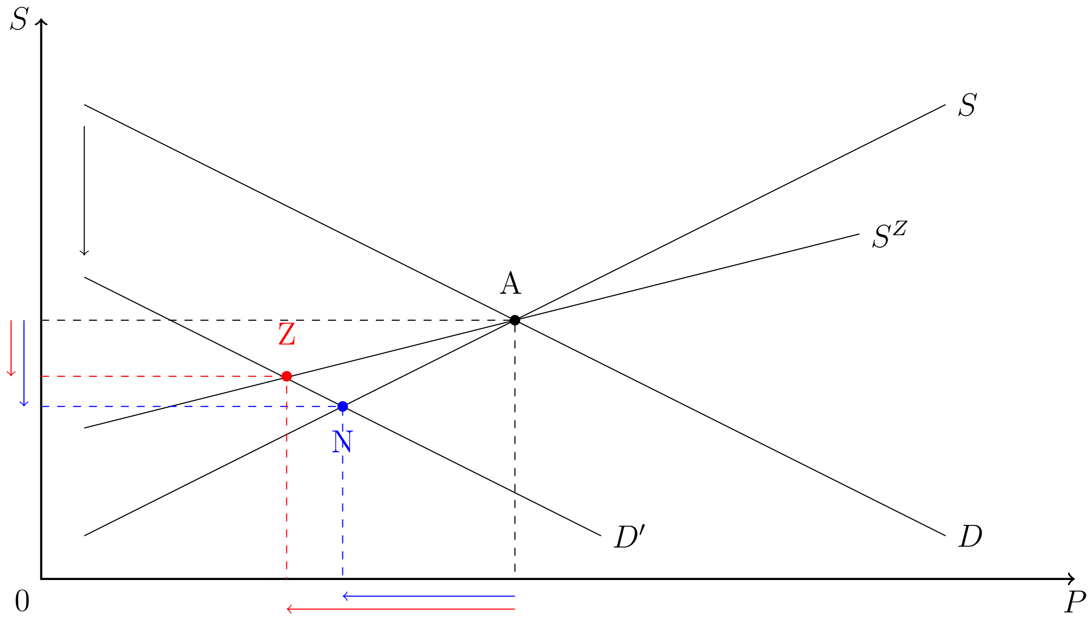

Figure 2: Zombie Credit Mechanism. This figure shows how zombie credit affects equilibrium prices.

Z. The shock causes a direct drop in price; in turn, making the economy less attractive for both entrant and incumbent firms. Similar to the adjustment with no zombie credit, fewer potential entrant firms enter. However, there is no (or weaker) adjustment through exit as some incumbent firms that would default because of the demand shock are kept alive. The result is a flatter supply curve: a reduction in price leads to a muted effect on quantities as some firms that would otherwise default are artificially kept alive.

To see this mechanism more formally, consider a linear demand $P = \alpha - Q$. Suppose the good is produced by surviving incumbent firms and entrant firms. A demand shock, denoted as α, affects the price of the good in three ways:

$$\frac{dP}{d\alpha} = \underbrace{\frac{\partial P}{\partial \alpha}}_{>0} + \underbrace{\frac{\partial P}{\partial Entry}\frac{\partial Entry}{\partial \alpha}}_{<0} + \underbrace{\frac{\partial P}{\partial Exit}\frac{\partial Exit}{\partial \alpha}}_{\substack{<0 \\ =0 \text{ with zombie credit}}}.$$

First, the direct effect: a lower demand (lower α) reduces the equilibrium price. Second, the offsetting indirect effect through entry: a lower price causes fewer firms to enter, increasing the equilibrium price. Third, the offsetting indirect effect through exit: a lower price causes more firms to default, increasing the equilibrium price. This last effect can be considered as being shut down in an economy with zombie firms as exit is obstructed by zombie credit.

This mechanism can also be adapted to a similar economy where firms are setting prices in the input markets. In this case, zombie credit causes "too many" firms to compete for the same inputs (e.g., labor and materials), increasing their prices.

In sum, zombie credit causes (i) a reduction in firm defaults and entry, firm markups, product prices, and productivity; and, (ii) an increase in sales, number of active firms, and input costs. In the remainder of the paper, we map these predictions to the data. In our empirical strategy we compare quantities and prices in markets with a high versus low prevalence of zombie firms. In other words, we compare equilibria that lie on the line between the steady state N and the steady state Z in Figure 2. To this end, we (i) define a "market" as an industry-country pair, and (ii) measure the market-level prevalence of zombie firms in the data. Consistent with the model, we show that markets with a high prevalence of zombie firms have lower firm default, entry, markups, productivity, and product prices; and, higher sales, number of active firms, and input costs (labor and material costs) compared with markets that have a low prevalence of zombie firms.

4 Data and Empirical Work

In this section, we describe our data set and our measures of zombie credit and firm markups.

4.1 Data

Our data set combines detailed firm level information and granular inflation data. The firm level data are financial information and firm characteristics from Bureau van Dijk's (BvD) Amadeus database. This database contains information about 21 million public and private companies from 34 countries, including all EU countries. BvD obtains the data, which is initially collected by local Chambers of Commerce, through roughly 40 information providers including business registers. Kalemli-Ozcan et al. (2015) show for selected European countries that Amadeus covers roughly 75-80% of the economic activity reported in Eurostat.

The inflation data is from Eurostat, which provides data for various consumer and producer price indices for all European countries. This data is very granular: consumer price data are at the product level (COICOP five-digit) and producer price data are at the industry level (NACE four-digit).

A key step is to merge the firm data (at the NACE level) and the inflation data (at the COICOP level). To perform this match, we obtained COICOP-NACE linking tables from several national statistical institutions of European countries. More precisely, we use the linking tables to calculate inflation at the industry-country level, by calculating a weighted average of all COICOP (consumer price categories) that are related to a NACE (two digits) industry.

Consider as an example the textiles industry (NACE 13). The CPI of this industry is a weighted average of the following COICOP categories: (i) clothing, (ii) furniture and furnishings, carpets and other floor coverings, (iii) household textiles, (iv) goods and services for routine household maintenance, and (v) other major durables for recreation and culture. Following the literature, we exclude utilities and financial and insurance industries from the sample. This provides us with a measure of the consumer price index (CPI) at the industry-country level for each month in our sample period.

Our final sample consists of 1,167,460 firms for 11 European countries and 65 different industries.

4.2 Identifying Zombie Firms

Following Caballero et al. (2008) and Acharya et al. (2019), we define zombie credit as credit that is extended to distressed firms at very low interest rates. Consistent with our model, the intuition is that these "zombie" firms would be more likely to default if they did not receive such credit.

In particular, we classify a firm as zombie firm if it meets the following two criteria. First, the firm is of low-quality, namely its interest coverage ratio is below the median and its leverage ratio is above the median.[6] Second, the firm obtains credit at advantageous low

[6] We calculate the firms' interest coverage ratio as EBIT/interest expense and measure their leverage ratio as (loans + short term credit + long term debt)/total assets. We calculate the median values at the industry-country-year level.

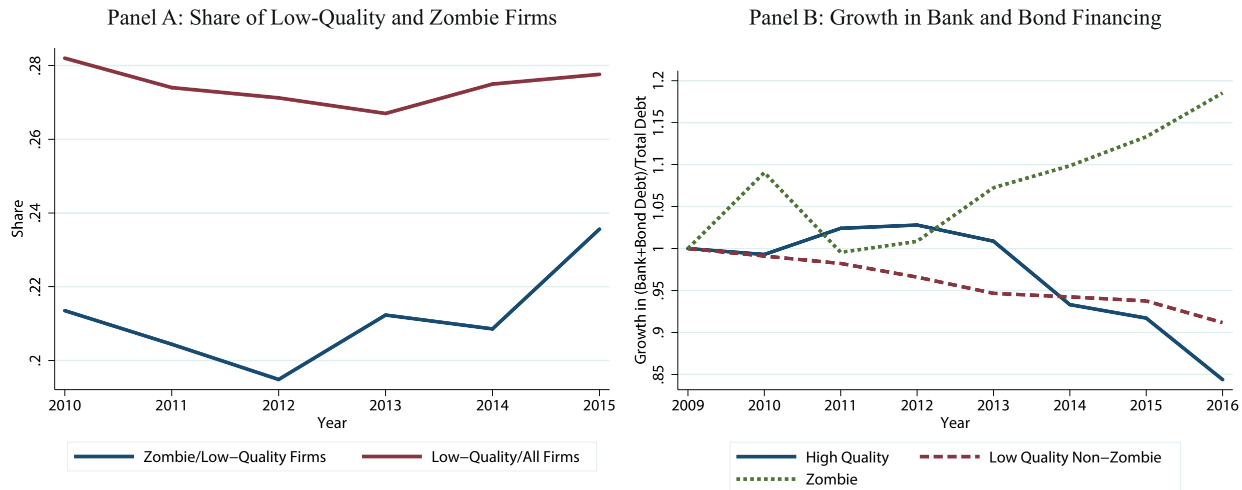

Figure 3: Firm Shares and Firm Financing. Panel A shows the share of zombie firms relative to all low-quality firms (blue line) and the share of low-quality firms relative to all firms (red line). Panel B shows the growth rate in bank and bond financing as a fraction of total debt relative to 2009 for zombie firms, low-quality non-zombie firms, and high-quality firms. A firm is classified as low-quality if it has a below median interest coverage ratio and an above median leverage. A firm is classified as zombie if it is low-quality and paid advantageous interest rates.

interest rates. That is, the share of its interest expenses relative to the sum of its outstanding loans, credit, and bonds in a given year is below the interest paid by the most creditworthy firms, namely AAA-rated European firms.[7]

Following De Loecker and Warzynski (2012) and De Loecker and Eeckhout (2019), we rely on optimal input demand conditions obtained from standard cost minimization to determine markups for each firm.[8] This approach has the advantage that it only requires firms' financial statements information and no assumptions on demand and how firms compete. Following De Loecker and Eeckhout (2019), we aggregate the firm markups in the respective market using the firms' turnover as weight.

As shown in Figure 1, the average share of zombie firms in our sample countries increased from roughly 4.5% to 6.7% during our sample period.[9] This rise of the zombies is mainly driven by more low-quality firms getting cheap credit at very low interest rates, and not

[7]We infer ratings of firms from their interest coverage ratio as in Acharya et al. (2019).

[8]See Appendix B for more details on the markup estimation.

[9]Figure 9 shows that alternative zombie definitions yield a similar time-series pattern in the share of zombie firms.

	High-Quality	Low-Quality No Zombie	Zombie
Markup	1.13	1.05	1.01
EBITDA Margin	0.090	0.046	0.014
Material Cost	0.424	0.476	0.552
Total Assets	1,617	1,726	1,607
Tangibility	0.327	0.312	0.190
Int. Cov.	4.90	1.01	-0.53
Net Worth	0.224	0.107	0.069
Leverage	0.161	0.351	0.437
Share Short Term Debt	0.337	0.510	0.525
Firm Age (years)	17.5	17.3	17.8
Interest Rate	0.028	0.039	0.009

Table 1: Firm Quality and Credit. This table presents descriptive statistics for our sample firms. We split firms into high-quality, low-quality non-zombie, and zombie. Median values calculated at industry-country-year level. A firm is classified as low-quality if it has a below median interest coverage ratio and an above median leverage. A firm is classified as zombie if it is low-quality and paid advantageous interest rates.

by firms that already enjoy access to cheap credit getting worse in quality. In particular, as shown by in Panel A of Figure 3, while the share of low-quality firms stayed constant at roughly 27% during our sample period, the share of zombie firms relative to low-quality firms increased from 19% to almost 24% between 2012 and 2015. Moreover, Panel B of Figure 3 shows that bank loans and bonds play an increasingly important role in the debt funding mix of zombie firms.

In Table 1, we present descriptive statistics for our sample firms separately for high-quality firms, low-quality firms that do not receive zombie credit, and low-quality firms classified as zombies. Zombie firms are weaker than low-quality non-zombie firms along several dimensions: zombie firms have on average a lower (even negative) interest coverage ratio, lower EBITDA margin (EBITDA/sales), lower net worth, less tangible assets to pledge for new loans, and a higher leverage. Nevertheless, these firms pay extremely low interest rates, even compared to high-quality firms. Given their low profitability, these firms likely would have had a much higher default probability if they would have had to pay a higher (more normalized) interest rate on their debt.

Importantly, the observed differences between low-quality non-zombies and zombies in terms of their profitability and interest coverage ratios seem not to be due to zombie firms

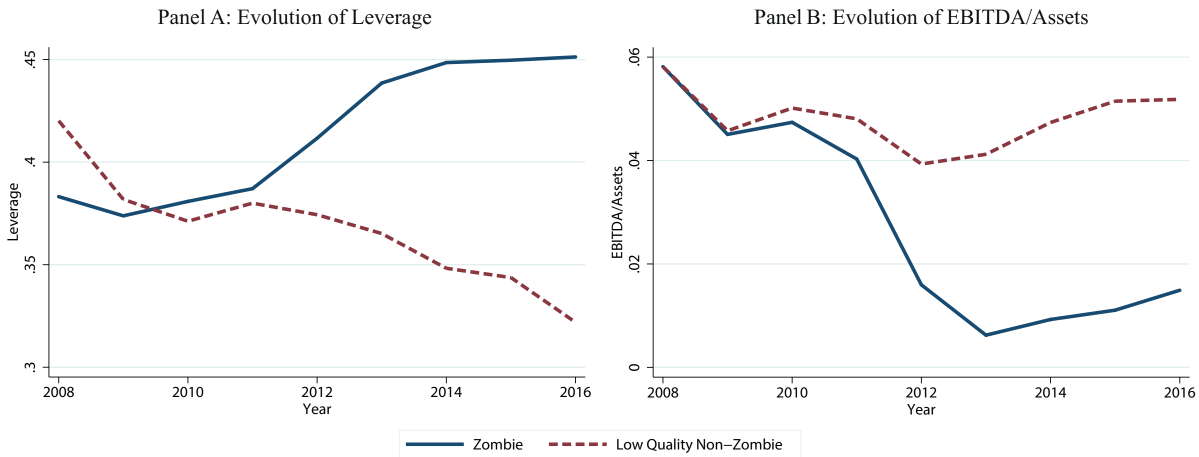

Figure 4: Long-Term Real Effects. Panel A shows the evolution of the asset-weighted leverage, while Panel B the evolution of the asset-weighted EBITDA/Assets ratios. The panels show firms that have been zombies continuously since at least 2012 and low-quality non-zombie firms that were never classified as zombies. A firm is classified as low-quality if it has a below median interest coverage ratio and an above median leverage. A firm is classified as zombie if it is low-quality and paid advantageous interest rates.

being on average younger and more reliant on short-term credit, that is, there are no significant differences in their average firm age or debt maturity structure (i.e., share of short term debt).

To rule out that the zombie firms' financial problems were caused by only temporary financial constraints and/or that they were able to access cheap funding due to their positive growth outlook we track the firms' financial and real outcomes over time. Panels A and B of Figure 4 plot the time series of the asset-weighted average leverage and the EBITDA/Assets ratios, respectively, for firms that have been zombies continuously since at least 2012 and low-quality firms that were never classified as zombies. Starting in 2011, zombie firms used their easy access to cheap credit to significantly increase their leverage, as shown in Panel A. In contrast, low-quality non-zombie firms were forced to deleverage. Panel B shows a significant drop for the average EBITDA/Assets ratios of zombie firms, while the ratio for low-quality non-zombies stayed roughly at its 2009 level.

As shown in Figure 5, the default frequency of zombies even increases towards the end of the sample period, which is further evidence that zombie firms were not able to recover despite their cheap credit financing. We further test this default pattern by estimating the

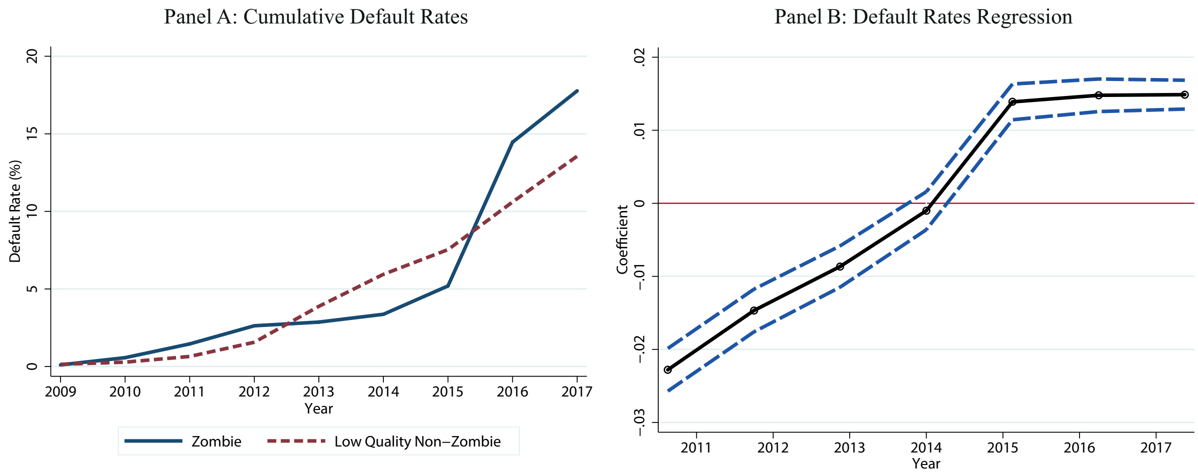

Figure 5: Firm Default Rates. Panel A shows the cumulative default rate of firms that have been zombies continuously since at least 2012 and low-quality non-zombie firms that were never classified as zombies. Panel B shows the coefficients from the regression in Eq. (1). A firm is classified as low-quality if it has a below median interest coverage ratio and an above median leverage. A firm is classified as zombie if it is low-quality and paid advantageous interest rates.

following specification separately for every year τ:

$$Default_{it} = \alpha + \beta_\tau \mathcal{I}_{t\tau} \times Zombie_{it} + \gamma X_{it} + \epsilon_{it}, \tag{1}$$

where $\mathcal{I}_{t\tau}$ is a yearly indicator variable equal to 1 if $t = \tau$ and 0 otherwise. The vector X_{it} includes the uninteracted *Zombie* variable as well as other firm characteristics. We also include industry-country-year fixed effects. Panel B of Figure 5 confirms that zombie firms default more toward the end of our sample period.

The general picture that emerges from Figure 4 and 5 is that there was no economic improvement for zombie firms after these firms gained access to cheap credit. This evidence suggests that their financial problems were of a fundamental nature.

5 Industry-Country Level Evidence

We start our empirical analysis of the zombie credit channel with testing our model predictions at the industry-country level.

In a first step, we provide non-parametric evidence on the correlation between the share of zombie firms in a specific market and the inflation level in this market, which is our main

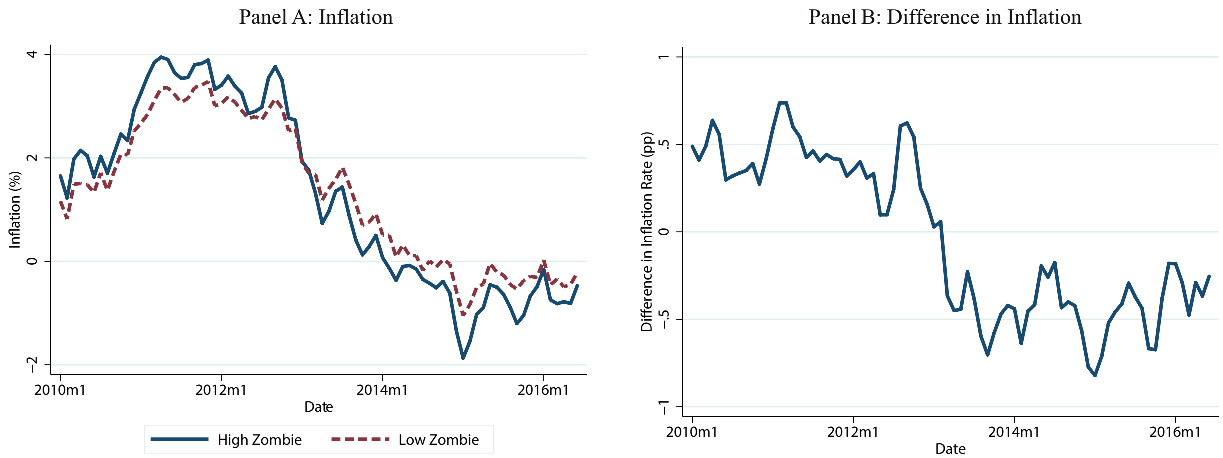

Figure 6: Inflation. Panel A shows inflation (yoy CPI growth) at monthly frequency for markets that experienced an above median increase in the asset-weighted share of zombie firms between 2009 and 2014 (High Zombie Growth) and firms with a below median growth in the share of zombie firms (Low Zombie Growth). Panel B shows the difference between the CPI growth of High vs Low Zombie Growth industries. A firm is classified as low-quality if it has a below median interest coverage ratio and an above median leverage. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details).

variable of interest. Figure 6 shows the CPI growth separately for markets that experienced a high (above median) and low (below median) growth in the share of zombie firms over our sample period. Markets with a high increase in zombie share had initially a higher CPI growth; however, starting in mid-2012, they experienced a decline in CPI growth compared to markets with a lower increase in zombie share. The timing of this reversal of the inflation dynamics thus coincides with the time when the ECB reduced the deposit facility rate to zero and launched massive unconventional monetary policy programs.

Next, we parametrically test our model predictions by running the following regression for industry h in country j in year t:

$$Y_{hjt} = \beta \times Share\ Zombies_{hjt,t-1} + \gamma_{ht} + \nu_{jt} + \mu_{jh} + \epsilon_{hjt}, \tag{2}$$

where Y_{hjt} is either inflation, change in average markups, aggregate sales growth, change in the number of active firms, firm default rate, or firm entry rate at the industry-country-year level. Our key explanatory variable is the asset-weighted share of zombie firms in a particular market: $Share\ Zombies_{hjt}$. In our preferred specification, we control for industry-country, country-year and industry-year fixed effects. Country-year fixed effects absorb all shocks at

	ΔCPI	ΔCPI	ΔCPI	ΔCPI
Share Zombies	-0.021**	-0.017**	-0.025***	-0.021***
	(0.008)	(0.007)	(0.009)	(0.007)
Observations	3,880	3,880	3,880	3,880
R-squared	0.491	0.723	0.522	0.754
Country-Industry FE	✓	✓	✓	✓
Year FE	✓			
Industry-Year FE		✓		✓
Country-Year FE			✓	✓

Table 2: Inflation: Industry-Country Evidence. This table presents industry-country-year level regressions. The dependent variable is the annual CPI growth rate (inflation) from t to $t+1$. *Share Zombies* measures the asset-weighted share of zombie firms in a particular market at t. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details). Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

the national level (e.g., changes in tax rates and national regulations) that could affect firms' policies and performance. Industry-year fixed effects absorb all shocks at the industry level (e.g., global demand shocks). Finally, country-industry fixed effects control for any time-invariant industry-country characteristics. In our most conservative specification, we also add lagged sales growth at the industry-country level to capture changes in the industry's performance in a particular country.

The estimation results in Table 2 confirm the non-parametric evidence from Figure 6: markets that experience an increase in the share of zombie firms subsequently have a lower CPI growth. This result is robust to controlling for different layers of fixed effects. Based on the estimates in Column (4), moving from the 10th to the 90th percentile of the zombie share distribution (an increase of 14.8pp) implies a 0.31pp lower inflation.

To provide a better sense for the economic importance of the growth in the share of zombie firms on inflation, we estimate a counterfactual inflation rate. More precisely, we assume that the share of zombie firms remained at its 2012 level for each market. Using our estimates from Table 2, we then calculate for each market what the CPI growth would have been under this alternative scenario for each market in the post 2012 period. In a final step, we aggregate these counterfactual inflation rates across all markets, using the respective weight an industry has in the overall CPI. The results are presented in Figure 7. The graph shows that for each year since 2012, inflation would have been on average 0.4 to 0.6pp higher

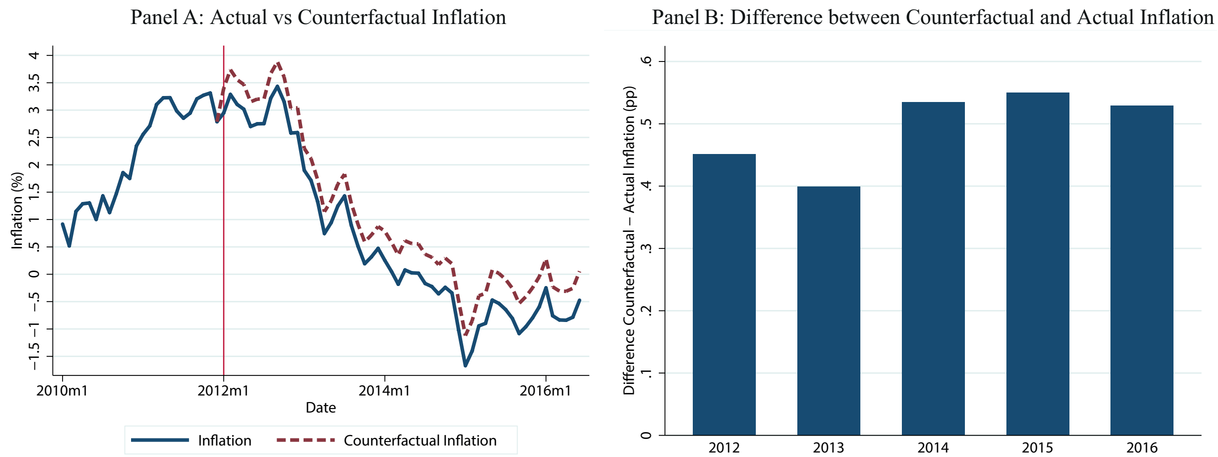

Figure 7: Inflation Counterfactual. Panel A shows the actual inflation rate in our sample and a counterfactual inflation rate. The counterfactual inflation rate (at market-level) is measured as the inflation rate that would have prevailed from 2012-2016, if the share of zombie firms had stayed at the 2012 level for a given market. These values are then averaged using actual weights for the aggregate CPI. Panel B shows the annual difference between the counterfactual and actual inflation rate.

if the share of zombies stayed at its 2012 level.

Finally, Table 3 provides some examples for markets that saw a large increase in the share of zombie firms in the post 2012 period. Consider, for example, the manufacturing industry in France, which saw a sharp increase in the share of zombie firms by 38.5%.[10] Considering our estimates from Table 2, this suggests that the CPI growth would have been 0.81pp higher in this market, compared to the observed CPI growth.

A remaining possible concern is that an increase in the share of zombie firms in a particular market could also be driven by a negative demand shock, which simultaneously leads to deflationary pressure in this market. To take into account the potential endogeneity of the share of zombie firms, we estimate IV regressions. As an instrument for a market's share of zombies, we propose the average capitalization, measured as Tier-1 to risk-weighted assets ratio, of the banks connected to the firms in this market, weighted by the number of firm relationships. We denote this instrument as *Average Tier-1 Ratio*. The idea behind this

[10]Note that French non-financial companies are particularly heavily indebted as their total debt to GDP ratio amounts to 136%. Only Chinese companies are even higher indebted with a debt to GDP ratio of 165%. Source: https://www.welt.de/finanzen/article203891540/Unternehmensanleihen-EZB-unterstuetzt-indirekt-Uebernahmen-von-US-Unternehmen.html.

Panel A: Industries with Increase

Country	Industry	CPI Growth (%)	ΔShare Zombie	Coefficient	Effect (pp)	Counterfactual CPI Growth (%)
France	Manufacturing	-4.19	38.5	-0.021	-0.81	-3.38
Italy	Transportation and Storage	-0.30	28.41	-0.021	-0.60	0.30
Portugal	Arts, Entertainment and Recreation	0.58	28.3	-0.021	-0.60	1.18
Slovenia	Manufacturing	-2.39	26.44	-0.021	-0.56	-1.83
Italy	Manufacturing	-2.60	22.44	-0.021	-0.47	-2.13
Panel B: Industries with Decrease						
France	Transportation and Storage	2.00	-54.7			
France	Other Service Activities	2.90	-34.9			
Spain	Information and Communication	2.80	-6.6			
Germany	Information and Communication	2.70	-1.0			
Germany	Manufacturing	2.60	-0.5			

Table 3: Examples: This table presents examples for some industries that saw a strong increase in the share of zombie firms after 2012. CPI growth depicts the actual CPI growth between 2012 and 2016 for the respective industry-country pair. Δ Share Zombie depicts the increase in the asset-weighted share of zombie firms post 2012. The coefficient is taken from the most restrictive specification in Table 2. The Effect is calculated as the produce of ΔShare Zombie and the Coefficient. The Counterfactual CPI growth shows what the inflation rate would have been without an increase in the share of zombie firms

instrument is that weakly-capitalized banks have zombie lending incentives. Schivardi et al. (2017), Acharya et al. (2019), and Blattner et al. (2019) provide evidence for zombie lending of weakly-capitalized European banks in the aftermath of the recent European sovereign debt crisis. These banks extended loans at very low interest rates to provide their impaired borrowers with the liquidity necessary to meet payments on other outstanding loans. Thereby, these banks avoided (or at least deferred) realizing immediate loan losses in the hope that the respective borrowers would eventually regain solvency.

A potential concern with this instrument could be that banks' capitalization is closely linked to the performance of the industries they are exposed to. Specifically, a larger exposure to firms in sectors that experienced a strong negative demand shock could result in larger loan losses and thus lower capital levels. However, our analysis of data from the European Banking Authority's EU-wide stress tests and capital exercises shows that banks' capitalization is to a large extent determined by the value loss of their holdings of government bonds from stressed European countries during the recent sovereign debt crisis and not loan losses. In particular, the rank correlation between the banks' pre-crisis (i.e., 2009) sovereign debt holdings from stressed countries and their equity change between between 2009 and 2012 is -0.49 (linear correlation is -0.53).

In our preferred IV specification (Table 4, Panels A and B), we determine the bank-firm

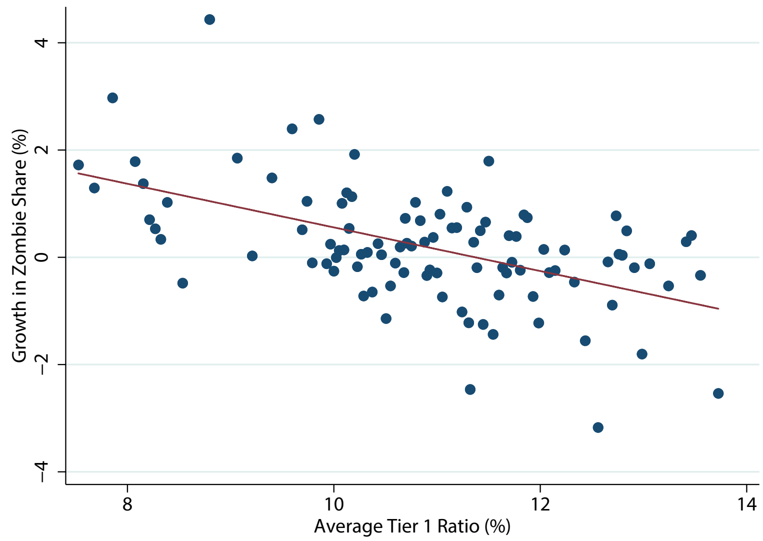

Figure 8: Bank Capitalization and Zombie Growth This figure presents a binscatter plot showing the relation between the lagged Tier-1 capital ratio (x-axis) and the growth in the share of zombie firms (y-axis). To calculate the the average Tier-1 capital ratio of an industry-country pair the number of firms a bank is connected to is used as weight. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details).

relationships using both Amadeus and DealScan. As a robustness check, we redo our analysis using bank-firm relationships solely from Amadeus (Panels C and D), as well as, using bank-firm relationships from DealScan for Italy and Amadeus for other countries (Panels E and F).[11]

Figure 8 shows that there is indeed a pronounced negative relationship between a market's *Average Tier-1 Ratio* and its zombie share growth. Building on this, Panels B, D, and F in Table 4 show the results of first stage OLS regressions explaining the share of zombie firms at time t in a particular market (denoted as $\widehat{Share\ Zombies}$) using the market's *Average Tier-1 Ratio* at $t-1$, and controlling for lagged market quality (i.e., its share of low-quality firms), as well as, different sets of fixed effects. In the first stage regressions, the instrument always has a negative and significant effect on $\widehat{Share\ Zombies}$. For example, in our preferred IV specification (Panels A and B), the F-statistic is between 12.1 and 13.9, while the p-value is always below 0.01, which confirms the strength of the instrument.

[11]Note that Amadeus does not contain bank-firm relationships for Italy.

Panels A, C, and E of Table 4 present the second-stage IV regression results, where we replace the *Share Zombies* with the predicted $\widehat{Share\ Zombies}$ based on the first stage regressions. The IV regression estimates confirm our results from Table 2, suggesting a causal negative effect of a market's share of zombies on inflation.

This disinflationary pressure resulting from a rise of zombie credit is also confirmed by our parametric test on the effect on average firm markups (see Panel A of Table 5). The estimated coefficients document that there is a stronger decrease in markups in markets that experienced a higher zombie share .

In Panel B of Table 5, the dependent variable is aggregate sales growth. Consistent with our model, we find that markets with a zombie share growth experienced higher aggregate sales growth rates. This positive correlation between the zombie share and sales growth suggests that the correlation between the zombie prevalence and inflation is not driven by lower demand at the industry-country level.

In Table 6, we isolate the correlation between changes in the zombie prevalence in a specific market and the number of active firms, firm default rate, and firm entry rate, respectively.[12] Again, we estimate Eq. (2), where now the dependent variable is the change in the number of active firms (Panel A), the share of firm defaults (Panel B), and the share of firm entries (Panel C). In line with our model predictions, the estimated coefficients confirm that the change in the zombie prevalence in a particular market is positively correlated with the growth in the number of active firms and negatively correlated with subsequent firm default and entry rates.[13]

Next, we check the evolution of the firms' productivity and cost structure. If the previous results are indeed due to zombie credit channel, that is, an increasing number of non-profitable firms that are kept alive by cheap credit, we expect to see in the respective markets: (i) a positive shock on the firms' factor input costs, and, (ii) a reduction in the

[12] We obtain this publicly available data from Eurostat, which reports it at the industry-country-level over time.

[13] In Table 10, we show that we obtain very similar results on firm defaults if we rely on the Amadeus database to classify firms as defaulted.

Panel A	ΔCPI	ΔCPI	ΔCPI	ΔCPI
$\widehat{Share\ Zombies}$	-0.399**	-0.302**	-0.457**	-0.273**
	(0.171)	(0.128)	(0.208)	(0.117)
Observations	2,090	2,090	2,090	2,090
Panel B	**Share Zombie**	**Share Zombie**	**Share Zombie**	**Share Zombie**
Average Tier-1 Ratio	-0.540***	-0.539***	-0.854***	-1.079***
	(0.155)	(0.144)	(0.235)	(0.288)
F-Test	12.2	14.0	13.3	14.1
Observations	2,090	2,090	2,090	2,090
R-squared	0.623	0.732	0.637	0.746
Panel C	**ΔCPI**	**ΔCPI**	**ΔCPI**	**ΔCPI**
$\widehat{Share\ Zombies}$	-0.402**	-0.306**	-0.494**	-0.238**
	(0.183)	(0.139)	(0.235)	(0.110)
Observations	1,945	1,945	1,945	1,945
Panel D	**Share Zombie**	**Share Zombie**	**Share Zombie**	**Share Zombie**
Average Tier-1 Ratio	-0.527***	-0.531***	-0.910***	-1.318***
	(0.162)	(0.152)	(0.283)	(0.353)
F-Test	10.6	12.2	10.3	13.9
Observations	1,945	1,945	1,945	1,945
R-squared	0.617	0.734	0.631	0.748
Panel E	**ΔCPI**	**ΔCPI**	**ΔCPI**	**ΔCPI**
$\widehat{Share\ Zombies}$	-0.400**	-0.302**	-0.461**	-0.272**
	(0.172)	(0.129)	(0.209)	(0.117)
Observations	2,090	2,090	2,106	2,090
Panel F	**Share Zombie**	**Share Zombie**	**Share Zombie**	**Share Zombie**
Average Tier-1 Ratio	-0.538***	-0.537***	-0.849***	-1.074***
	(0.154)	(0.143)	(0.233)	(0.285)
F-Test	12.2	14.0	13.2	14.2
Observations	2,106	2,106	2,106	2,106
R-squared	0.623	0.732	0.637	0.746
Country-Industry FE	✓	✓	✓	✓
Year FE	✓			
Industry-Year FE		✓		✓
Country-Year FE			✓	✓

Table 4: Instrumental Variable Estimation This table presents industry-country-year level IV regressions. Panels A, C, and E present the second stage results, while Panels B, D, and F present the first stage results. The dependent variable in Panels A, C, and E is the annual CPI growth rate (inflation) from t to $t+1$. *Share Zombies* measures the asset-weighted share of zombie firms in a particular market at t. Average Tier-1 Ratio measures the average Tier-1 Ratio of banks (weighted by the number of firm relationships) that are related to firms in an industry-country at $t-1$. Bank relationships are determined using Amadeus and DealScan in Panels A and B, solely Amadeus in Panels C and D, and Amadeus and DealScan solely for Italian firms in Panels E and F. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details). Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Panel A	ΔMarkup	ΔMarkup	ΔMarkup	ΔMarkup
Share Zombies	-0.052**	-0.054**	-0.057**	-0.063**
	(0.024)	(0.026)	(0.025)	(0.027)
Observations	3,261	3,261	3,261	3,261
R-squared	0.148	0.315	0.172	0.337

Panel B	Sales Growth	Sales Growth	Sales Growth	Sales Growth
Share Zombies	0.287**	0.400***	0.320***	0.420***
	(0.123)	(0.148)	(0.114)	(0.129)
Observations	3,894	3,894	3,894	3,894
R-squared	0.179	0.251	0.409	0.476
Country-Industry FE	✓	✓	✓	✓
Year FE	✓			
Industry-Year FE		✓		✓
Country-Year FE			✓	✓

Table 5: Markups, and Sales: Industry-Country Evidence. This table presents industry-country-year level regressions. The dependent variable is the turnover-weighted change in markups from t to $t+1$ in Panel A, and sales growth from t to $t+1$ in Panel B. *Share Zombies* measures the asset-weighted share of zombie firms in a particular market at $t-1$. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details). Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

average industry productivity.

Panels A and B of Table 7 investigate the evolution of firms' input costs, that is, material and labor cost, respectively. In line with our model predictions, an increase in the share of zombie firms in a specific market leads to higher average material costs in that market (see Panel A). The results on labor cost in Panel B also support the zombie credit channel. In particular, the interaction *Share Zombie*×*High Vacancy* is significantly positive, where the latter is a dummy equal to one for industries with an above median job vacancy rate.[14] However, this positive correlation between the zombie share and average labor costs only exists for markets with a high job vacancy rate and not for markets without a labor supply

[14]To measure the firms' labor costs, we use the annual change in the Eurostat's Labour Cost Index, which is designed to capture the labor cost pressure. For the job vacancy rate, we rely on Eurostat's job vacancy statistics, which calculates the rate as the number of job vacancies as a percentage of the sum of the number of occupied posts and job vacancies.

Panel A	Δ#Active Firms	Δ#Active Firms	Δ#Active Firms	Δ#Active Firms
Share Zombies	0.033**	0.038**	0.032**	0.037***
	(0.015)	(0.015)	(0.012)	(0.013)
Observations	4,098	4,098	4,098	4,098
R-squared	0.480	0.535	0.623	0.675
Panel B	**Default**	**Default**	**Default**	**Default**
Share Zombies	-0.013*	-0.016**	-0.013**	-0.016**
	(0.007)	(0.008)	(0.006)	(0.007)
Observations	3,903	3,903	3,903	3,903
R-squared	0.798	0.813	0.866	0.881
Panel C	**Entry**	**Entry**	**Entry**	**Entry**
Share Zombies	-0.016**	-0.018**	-0.013**	-0.014*
	(0.007)	(0.008)	(0.006)	(0.007)
Observations	4,116	4,116	4,116	4,116
R-squared	0.825	0.845	0.874	0.895
Country-Industry FE	✓	✓	✓	✓
Year FE	✓			
Industry-Year FE		✓		✓
Country-Year FE			✓	✓

Table 6: Number of Active Firms, Firm Defaults, and Firm Entries: Industry-Country Evidence. This table presents industry-country-year level regressions. The dependent variable is the change in the number of firms (Panel A), the share of firm exits (Panel B), and the share of firm entries (Panel C). *Share Zombies* measures the asset-weighted share of zombie firms in a particular market at $t-1$. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details). Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

shortage, as shown by the insignificant coefficient for *Share Zombie*. This evidence suggests that the higher average labor cost for (some) zombie markets is indeed induced by a higher number of active firms and the resulting fiercer competition.

Table 7, Panel C presents the results for the productivity test. Following Caballero et al. (2008), we measure productivity as *log(sales)–2/3*log(employment)–1/3*log(fixed assets)*. The regression shows that markets with an increase in the zombie prevalence experience a reduction in their firms' average productivity.

In sum, consistent with our model, we find that markets that experience an increase in the share of zombie firms subsequently have lower entry and exit rates, a larger growth in the number of active firms, higher aggregate sales growth rates, higher average input costs, lower

Panel A	Material Cost	Material Cost	Material Cost	Material Cost
Share Zombies	0.055**	0.055**	0.050**	0.050**
	(0.023)	(0.023)	(0.023)	(0.024)
Observations	3,701	3,701	3,701	3,701
R-squared	0.943	0.951	0.945	0.953
Panel B	**Labor Cost**	**Labor Cost**	**Labor Cost**	**Labor Cost**
Share Zombie	-0.005	0.001	-0.016	-0.013
	(0.021)	(0.022)	(0.023)	(0.025)
High Vacancy	-0.005	-0.001	-0.009	-0.005
	(0.006)	(0.006)	(0.006)	(0.006)
Share Zombie × High Vacancy	0.079**	0.064*	0.097***	0.083**
	(0.036)	(0.038)	(0.035)	(0.038)
Observations	1,022	1,022	1,022	1,022
R-squared	0.259	0.347	0.400	0.488
Panel C	**Productivity**	**Productivity**	**Productivity**	**Productivity**
Share Zombies	-0.283***	-0.281**	-0.259**	-0.248*
	(0.103)	(0.124)	(0.105)	(0.126)
Observations	3,811	3,811	3,811	3,811
R-squared	0.868	0.885	0.874	0.890
Country-Industry FE	✓	✓	✓	✓
Year FE	✓			
Industry-Year FE		✓		✓
Country-Year FE			✓	✓

Table 7: Input Costs and Productivity: Industry-Country Evidence. This table presents industry-country-year level regressions. The dependent variables are the industry material cost (material input cost/turnover, Panel A), the industry labor cost (Eurostat's labor cost index, Panel B), and asset-weighted productivity (*log(sales)–2/3*log(employment)–1/3*log(fixed assets)*, Panel C). *Share Zombies* measures the asset-weighted share of zombie firms in a particular market at $t-1$. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details). Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

average productivity, lower average markups, and lower CPI growth. Note that the observed negative correlation between the zombie share in a particular market and the inflation level in that market would also be consistent with cost channel (see, e.g., Barth III and Ramey, 2001) and the liquidity squeeze channel (e.g., Chevalier and Scharfstein, 1996). Specifically, the cost channel suggests that the glut of cheap debt decreased the financial expenses of zombie firms, which gave them more wiggle room to cut output prices. The liquidity squeeze channel suggests that low-quality zombie firms (i.e., liquidity constrained firms) have an incentive to raise prices to increase their current cash flows, while zombie firms do not have the necessity to react this way due to their access to cheap credit. However, the cost channel and the liquidity squeeze channel can neither explain the negative correlation between the zombie share and firm default and entry rates, as well as, productivity, nor the positive correlation with aggregate sales growth and input costs. Moreover, the cost channel cannot explain the negative correlation between between the zombie share and average markups. Hence, while these channels might have contributed to the disinflationary trend they were likely not the sole driver for the observed low inflation level in zombie markets.

Moreover, the evidence presented in Panels A-C of Table 7 suggests that the effect of the zombie credit channel on inflation presented in Table 2 and Table 4 constitutes a lower bound. In particular, since markets that experienced a zombie share increase have lower average productivity and higher average input costs, their production cost level is pushed upwards. Hence, without a change in markups, this costs push would increase prices. The observed inflation reduction for zombie industries thus implies that the excess production capacity induced the firms in these markets to lower markups to such an extent that it overcompensated the production costs increase.

6 Firm-Level Analysis

In this section, we take advantage of our detailed firm-level data to get a more granular picture of the effect of the zombie credit channel on firm behavior and pricing. In particular, we exploit the fact that the zombie credit channel predicts spillover effects on non-zombie firms active in markets with an increase in the zombie prevalence. Moreover, this analysis allows us to further separate the zombie credit channel from the cost and the liquidity squeeze channel, which do not predict such spillover effects between zombie and non-zombie firms.

According to the zombie credit channel, a rise of zombie credit leads to a higher number of competing firms and excess production capacity in the respective market. This market congestion leads to a sales decrease for individual non-zombie firms as more firms have to share a given demand level.[15] In turn, the affected non-zombie firms try to limit their drop in market share and capacity utilization by pricing more aggressively. At the same time, these firms face higher input prices due to an increased number of active firms that compete for a limited amount of resources.

In sum, the zombie credit channel thus predicts for individual non-zombie firms in zombie industries: lower sales growth, lower markups, and higher input costs (i.e., material and labor costs) compared to individual non-zombie firms in non-zombie industries. Following Caballero et al., 2008, we run the following regression at the firm-year level to test for these spillovers on non-zombie firms:

$$\begin{aligned} Y_{ihjt} &= \beta_1 \times Non-Zombie_{ihjt} + \beta_2 \times Non-Zombie_{ihjt} \times ShareZombies_{hjt-1} \\ &+ \gamma_{hjt} + \epsilon_{ihjt}, \end{aligned} \tag{3}$$

where our dependent variables are markup, sales growth, material cost, and labor cost. We include industry-country-year fixed effects to absorb any country-industry specific shocks. Our key coefficient of interest is β_2, that is, whether non-zombie firms that operate in markets with a high share of zombie firms perform differently than non-zombie firms in markets with a lower share of zombie firms.

The first column of Table 8 shows that non-zombie firms in markets with a low zombie prevalence have higher markups than zombie firms in the same market. However, consistent with our results at the industry-country level, markups of non-zombie firms tend to be lower the higher the share of zombie firms active in the same market. Moreover, we indeed see a drop in sales growth for individual non-zombie firms active in a market with a large zombie share increase (see Column 2 of Table 8). The results in Columns (3) of Table 8 confirm that non-zombie firms that have to compete against a higher number of zombie firms (relative to non-zombie firms in non-zombie industries) indeed pay higher input costs.

[15] Recall that, at the industry-country level, the zombie credit channel predicts a slight increase in aggregate sales for zombie industries due to the downward adjusted output prices and the resulting slightly higher aggregate demand. Table 5, Panel B confirms this prediction.

	Markup	Sales Growth	Material Cost	EBIT/Sales
Non-Zombie	0.060***	0.061***	-0.022***	0.086***
	(0.006)	(0.007)	(0.002)	(0.008)
Non-Zombie	-0.226***	-0.176***	0.064***	-0.198***
× Industry Share Zombies	(0.043)	(0.034)	(0.019)	(0.033)
Observations	4,211,633	5,922,959	4,653,410	5,910,165
R-squared	0.584	0.032	0.521	0.151
Industry-Country-Year FE	✓	✓	✓	✓
Firm-Level Controls	✓	✓	✓	✓

Table 8: Markup, Sales Growth, Input Costs, EBIT/Sales: Firm-Level Evidence. This table presents firm-year level regressions. The dependent variables are a firm's markup, sales growth, material cost (material input cost/turnover), or EBIT/Sales. *Non-Zombie* is an indicator variable equal to one if a firm is classified as non-zombie in year t. *Industry Share Zombies* measures the asset weighted share of zombie firms in an industry-country-year. Firm-level controls include net worth, leverage, the natural logarithm of total assets, and the interest coverage ratio. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details). Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Finally, the results in Column (4) of Table 8 suggests that there might be a zombie contagion from zombie to non-zombie firms in markets with a strong rise in zombie credit. That is, good firms in zombie markets not only suffer because they have lower individual sales growth due to the higher number of firms, but also because their profitability drops due to the excess-capacity-induced fiercer competition in these markets. As a result, initially good non-zombie firms can turn into zombies over time due to a high prevalence of other zombies in their markets.

7 Robustness

This section provides several robustness tests for our main results. First, we use alternative zombie firm classifications. Second, we redo our default rate tests employing a different data set. Finally, we conduct a placebo test for our firm-level analysis.

7.1 Alternative Zombie Classifications

To ensure the robustness of our results with respect to the zombie classification, we use various alternative zombie definitions and redo our analysis from Table 2. First, we calculate median values for leverage and the interest coverage ratio at the industry-year-level instead

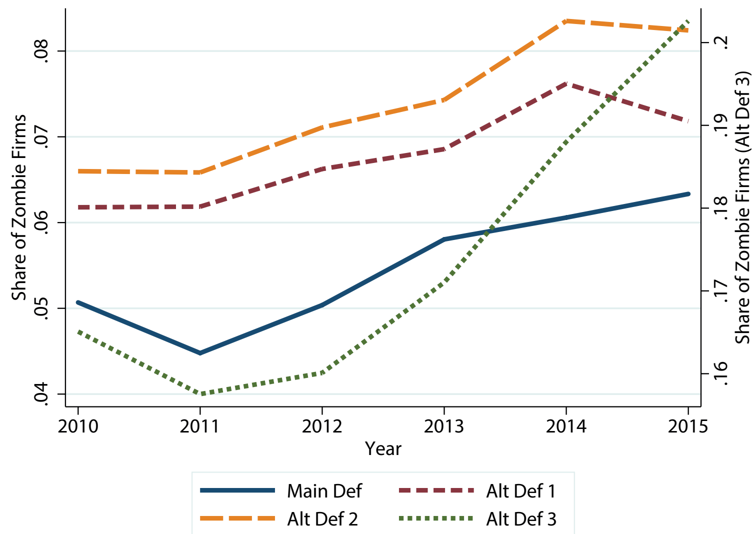

Figure 9: Alternative Zombie Definitions. This figure shows the evolution of the share of zombie firms for alternative zombie definitions. The blue solid line replicates our main measure of the share of zombie firms. Alt Def 1 (red dashed line) calculates median values for leverage and interest coverage ratio at the industry-year-level (instead of industry-country-year level). Alt Def 2 (orange dashed line) considers solely the interest coverage ratio criterion to define a firm as low-quality. Alt Def 3 (green dotted line) considers only the leverage criterion to define a firm as low-quality.

of the industry-country-year level (Panel A). Second, we consider solely the interest coverage ratio criterion instead of both the interest coverage ratio and leverage to define a firm as low-quality (Panel B). Third, we use solely the leverage criterion to define a firm as low-quality (Panel C). Figure 9 shows that these alternative classifications yield a similar time series pattern for the (increasing) share of zombie firms. Table 9 shows that our results on the effect of a rise in zombie credit on inflation are robust to using alternative zombie classifications.

7.2 Alternative Default Rate Measure

The Eurostat data used in Table 6 to analyse the effect on an increase in the share of zombie firms on exit rates does not distinguish between different types of exit (i.e., insolvency or dissolved for other reasons). Hence, as a robustness check, we redo this analysis using the legal status variable from Amadeus. In particular, to identify default events for our sample firms we flag firms that according to the legal status variable are in distress, insolvent, or

	ΔCPI	ΔCPI	ΔCPI	ΔCPI
Share Zombies (Alt. Def. #1)	-0.009*	-0.007*	-0.012**	-0.011***
	(0.005)	(0.004)	(0.005)	(0.004)
Observations	3,880	3,880	3,880	3,880
R-squared	0.491	0.723	0.521	0.754
Share Zombies (Alt. Def. #2)	-0.010**	-0.008**	-0.013***	-0.010***
	(0.005)	(0.004)	(0.005)	(0.004)
Observations	3,880	3,880	3,880	3,880
R-squared	0.491	0.723	0.521	0.754
Share Zombies (Alt. Def. #3)	-0.009**	-0.007**	-0.012**	-0.010***
	(0.005)	(0.004)	(0.005)	(0.004)
Observations	3,880	3,880	3,880	3,880
R-squared	0.491	0.723	0.521	0.754
Country-Industry FE	✓	✓	✓	✓
Year FE	✓			
Industry-Year FE		✓		✓
Country-Year FE			✓	✓

Table 9: Inflation: Industry-Country Evidence under Alternative Zombie Classifications. This table presents industry-country-year level regressions. The dependent variable is the annual CPI growth rate (inflation) from t to $t+1$. *Share Zombies* measures the asset-weighted share of zombie firms in a particular market at t. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details. Panel A calculates median values for leverage and interest coverage ratio at industry-year-level (instead of industry-country-year level). Panel B considers solely the interest coverage ratio criterion to define a firm as low-quality. Panel C considers only the leverage criterion to define a firm as low-quality. Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

bankrupt.[16] In Table 10, we show that we obtain similar results on the effect of a rise of zombie credit on firm defaults if we rely on the Amadeus default data.

7.3 Firm-Level Robustness

Finally, we conduct a placebo test for the firm-level results presented in Section 5. In particular, instead of employing the share of zombie firms as the main variable of interest, we use the share of low-quality firms; thus, muting the advantageous interest rate criterion.

[16] That is, we identify firms that have one of the following legal status in Amadeus: "Active (default of payments)", "Active (insolvency proceedings)", "Active (rescue plan)", "Bankruptcy", "Dissolved (bankruptcy)", "Dissolved (liquidation)", or "In liquidation".

	Default	Default	Default	Default
Share Zombies	-0.013**	-0.016***	-0.010*	-0.014**
	(0.006)	(0.006)	(0.006)	(0.006)
Observations	3,160	3,160	3,160	3,160
R-squared	0.826	0.845	0.894	0.913
Country-Industry FE	✓	✓	✓	✓
Year FE	✓			
Industry-Year FE		✓		✓
Country-Year FE			✓	✓

Table 10: Firm Defaults: Industry-Country Evidence based on Amadeus Data. This table presents industry-country-year level regressions. The dependent variable is the share of firm defaults at time t. *Share Zombies* measures the asset-weighted share of zombie firms in a particular market at $t-1$. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 4.2 for more details). Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The results presented in Table 11 show that the spillover effects on non-zombie firms do not occur *per se* when the share of low-quality firms increases in a market. This evidence suggests that the contagion to non-zombie firms is indeed caused by an increase in the share of actual zombie firms, that is, low-quality firms receiving subsidized credit.

Moreover, these results provide further evidence that the negative correlation between the rise of zombie credit and inflation is not linked *per se* to a deteriorating average firm performance in a specific market (e.g., due to a drop in demand). These impaired firms need to have been kept alive by readily available cheap credit, inducing a drop in default rates, to cause downward pressure on inflation.

	Markup	Sales Growth	Material Cost	EBIT/Sales
Non-Zombie	0.040***	0.037***	-0.017***	0.065***
	(0.010)	(0.006)	(0.004)	(0.006)
Non-Zombie	0.017	0.037	-0.002	0.022
× Industry Share Low-Quality	(0.038)	(0.024)	(0.009)	(0.033)
Observations	4,211,633	5,922,959	4,653,410	5,910,165
R-squared	0.565	0.033	0.5128	0.157
Industry-Country-Year FE	✓	✓	✓	✓
Firm-Level Controls	✓	✓	✓	✓

Table 11: Firm-Level Analysis Robustness. This table presents firm-year level regressions. The dependent variables are a firm's markup, sales growth, material cost (material input cost/turnover), or EBIT/Sales. *Non-Zombie* is an indicator variable equal to one if a firm is classified as non-zombie in year t. *Industry Share Low-Quality* measures the asset weighted share of low-quality firms in an industry-country-year. Firm-level controls include net worth, leverage, the natural logarithm of total assets, and the interest coverage ratio. A firm is classified as low-quality if it has a below median interest coverage ratio and an above median leverage. Standard errors are clustered at the industry-country level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

8 Conclusion

The low-growth, low-inflation environment that prevails in Europe after its sovereign debt crisis bears a striking resemblance to Japan's "lost decades" in the aftermath of its crisis in the early 1990s. Similar to the Bank of Japan's crisis response, the European central banks followed canonical demand-side theory and lowered interest rates, as well as, implemented massive quantitative easing programs to encourage more investment and consumption, hoping that this will lead to a surge in inflation. However, despite a significant drop in firm funding costs, inflation did not pick up as expected, which became known as Europe's "missing inflation puzzle" (see, e.g., Constâncio, 2015).

In this paper, we propose a novel supply-side channel that shows that policy measures that make cheap debt financing readily available to impaired firms have a disinflationary side effect, thereby providing an explanation for the persistent low inflation rates in Europe. Accommodative policy measures reduce financial pressure and thereby fuel the survival of weak firms with unsustainable business models. As these zombie firms proliferate, aggregate supply increases compared to the case where the business cycle runs its normal course. The resulting excess capacity puts downward pressure on producer prices, and, ultimately, depresses inflation levels.

We test this zombie credit channel using a new inflation and firm level data set that covers

1.1 million firms in 11 European countries across 65 industries. We show that industries that experienced a stronger rise of zombie firms subsequently experienced fewer firm defaults, lower average firm markups, product prices, investment, and productivity, an increase in aggregate sales, as well as, material and labor costs, and a lower inflation level.

These results draw attention to the often-neglected impact of supply-side financial frictions on inflation. Specifically, our findings highlight that while monetary and macroprudential policies are important to achieve macroeconomic and financial stability, closely monitoring their interaction with financial frictions at the micro-level and teasing out their precise transmission to the real economy are equally important. Otherwise, financial frictions can lead to unintended macroeconomic consequences of accommodative policies and work precisely against the policies' stated and assumed objectives of generating inflation and growth.

For accommodative monetary policy to be effective in times of a weakening financial sector, it should thus be accompanied by a targeted financial sector recapitalization program. A prime example for such a targeted recapitalisation was in the United States (US), where the Troubled Asset Relief Program (TARP) and the effective stress test of banks in the form of Supervisory Capital Assessment Program (SCAP) followed the failure of Lehman Brothers and coincided with the extra-ordinary easing of monetary policy by the Federal Reserve. The targeted recapitalization of the financial sector contributed to a faster recovery of the US economy. Indeed, after a brief deflationary period, the US inflation rate climbed back to around 2% in early 2010. Conversely, except for a few brief periods, the inflation rate in Japan has been close to zero since the mid-1990s. Similarly, the euro area inflation rate has been declining since the start of the loose monetary policy in 2012 and has remained below 1% in the period from 2014 to 2017.

Moreover, our results suggest that, at least for European countries that still have free sovereign debt capacity, a more expansive fiscal policy could potentially be an effective tool to raise inflation, since the resulting positive demand shock would absorb at least part of the zombie-induced excess capacity. Studying such interactions of fiscal and monetary policy tools is an important area for future research.

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Appendix A Model

In this appendix, we develop a simple dynamic model to analyze the relationship between zombie credit and inflation. We define an equilibrium with and without zombie credit and then compare equilibrium quantities and prices. The model adds imperfect competition among firms to a framework similar to Caballero et al. (2008). The reader is referred to the online appendix for formal derivations and proofs.

A.1 Setup

Time is discrete and the economy is populated by a large, but finite number of firms that produce a single good. Firms are identical in size and can be incumbent or potential entrants. At each date t, there are m_t incumbent firms and e potential entrant firms.

The problem of firms at each date t is as follows. First, firms (incumbents and potential entrants) pay a cost I to set up their capacity that allows them to draw their production y_{it} from a uniform distribution $y_{it} \sim U[0, 1]$. Second, incumbent firms simultaneously set prices. Third, firms learn the realization of their production y_{it} leading to profits $(p_t - c)y_{it} - I$, where c is the marginal cost. Depending on the realization of their production, potential entrant firms might enter the market and incumbent firms might default. A firm that makes negative profits is forced to default.

There is an exogenous demand $D_t(p_t) = \alpha_t - p_t$, where p_t is the average price set by incumbent firms. This aggregate demand is satiated starting with the production of the firm that sets the lowest price.[17]

Lemma 1. *Firms choose $p_{it} = p_t$, where*

$$p_t = \alpha_t - \frac{m_t}{2} \tag{A1}$$

[17] Given $p_t = \sum_i p_{it}/m_{it}$, this allocation rule resembles a limit order book used in stock exchanges. If multiple firms set the same lowest price, the demand is split evenly among them.

Proof. Suppose m_t identical firms set prices simultaneously at t before the realization of the production parameter in a single shot game. The marginal cost of production is c. There is only one good and the demand is $D(p_t) = \alpha_t - p_t$, where $\alpha_t \geq \frac{1}{2}(m_t + 1) + c$. The expected production is $\mathbb{E}(y_{it}) = \frac{1}{2}$. This problem is similar to a Bertrand price-setting model with an exogenous capacity constraint equal to the expected production. We claim that $p_{it} = p_t^* = \alpha_t - \frac{m_t}{2}$. Given the one shot nature of the game, we can ignore the time subscripts. Firm i optimally deviates from $p_i = p_{-i} < p^*$ because it can get a higher price on the residual demand given that other firms cannot produce more than $\frac{1}{2}$ in expectation. Firm i optimally deviates from $p_i = p_{-i} > p^*$ because it can undercut slightly the price and expect to sell its entire expected production. Firm i optimally deviates from $p_i < p_{-i}$ because it can get a higher price on the residual demand. □

Firms set prices knowing that their expected production is 1/2. In the unique equilibrium, the price p_t set by incumbents firms is such that the total expected production equals demand at the price p_t. It is not optimal for firm i to lower its price as it will end up selling at a lower price its entire expected production. It is also not optimal for firm i to increase its price as it can increase profit by increasing the expected quantity sold.[18] Because of the production constraint, firms charge a positive markup $(p_t - c)/c$.[19]

After the price is set, firms learn the realization of their production. An incumbent firm that generates negative profits is forced to default. Hence, the mass of defaulting firms D_t and the mass of surviving incumbent firms S_t are:

$$D_t = m_t \int_0^{\frac{I}{p_t - c}} di = \frac{m_t I}{p_t - c} \qquad S_t = m_t \int_{\frac{I}{p_t - c}}^1 di = m_t \left(1 - \frac{I}{p_t - c}\right).$$

A potential entrant firm that generates profits enters the market. The mass of entrants is:

$$E_t = e \int_{\frac{I}{p_t - c}}^1 di = e \left(1 - \frac{I}{p_t - c}\right).$$

[18]If α_t is large enough, the marginal revenue is greater than the marginal cost, that is, the firm can increase its profit by lowering the price and, in turn, increasing the quantity produced.

[19]The price p_t is determined in terms of cost as the numeraire. In our environment, we implicitly assume a form of rigidity on the cost side.

Total production N_t is the sum of the production of entrants and surviving incumbents:

$$N_t = (e + m_t)\left(1 - \frac{I}{p_t - c}\right). \tag{A2}$$

A.2 Equilibrium

In this section, we define an equilibrium with and an equilibrium without zombie credit.

Definition 1. *Given the demand parameter α, setup cost I, marginal cost c, an equilibrium without zombie credit (EqN) is price p_t, incumbents m_t, production N_t such that the product price is given by Eq. (A1), total production equals the sum of production by surviving incumbent and entrant firms according to Eq. (A2), and the number of incumbent follows $m_{t+1} = N_t$.*

The equilibrium without zombie credit (EqN) is governed by three conditions. First, the price of the good follows Lemma 1. Second, total production is the sum of the production of firms that enter the market and production of incumbent firms that survive. Third, the incumbent firms at $t + 1$ are the sum of entrants and surviving incumbent firms at t.

In the steady state equilibrium, the number of incumbent firms is constant ($m_{t+1} = N_t = m$) and defaults are exactly offset by entry:

$$\frac{mI}{p - c} = e\left(1 - \frac{I}{p - c}\right)$$

The equilibrium with zombie credit (EqZ) is characterized by an exogenous number of firms $\overline{S}$ that survive each period, leading to a total production of

$$N_t = e\left(1 - \frac{I}{p_t - c}\right) + \overline{S} \tag{A3}$$

Following Caballero et al. (2008), the idea is that favourable funding conditions might keep some firms alive that otherwise would default. Formally, the definition of EqZ is as follows:

Definition 2. *Given the demand parameter α, setup cost I, marginal cost c, and survivors $\overline{S}$, an equilibrium with zombie credit (EqZ) is price p_t, incumbents m_t, production N_t such* *that the product price is given by Eq.* (A1)*, total production equals the sum of production by surviving incumbent and entrant firms according to Eq.* (A3)*, defaults are such that surviving firms are* $\overline{S}$*, and the number of incumbent follow* $m_{t+1} = N_t$*.*

The equilibrium with zombie credit is characterized by four conditions. First, the price of the good follows Lemma 1. Second, total production is the sum of the production of firms that enter the market and production of the, now exogenously set, incumbent firms that survive. Third, defaults are such that surviving firms are constant at $\overline{S}$. Fourth, the incumbent firms at $t+1$ are the sum of entrants and surviving incumbent firms at t.

A.3 Macroeconomic Effects of Zombie Credit

We analyze the effects of zombie credit by comparing the equilibrium without zombie credit and the equilibrium with zombie credit following a negative demand shock, captured by a permanent decrease in α.[20] More specifically, we consider the case where EqN and EqZ are, before the shock, identical in a steady state equilibrium (the number of survivors $\overline{S}$ in EqZ is set equal to the number of survivors in EqN). Figure A.1 shows this comparison, where the solid lines correspond to EqN and the dashed lines correspond to EqZ. In both equilibrium concepts, the negative demand shock causes a contemporaneous collapse in prices. The adjustment to the new steady state depends on the type of equilibrium.

In EqN, the collapse in price leads to a contemporaneous decrease in entries and increase in defaults. One period after the shock, the lower number of active firms causes the price to rebound (higher productive capacity), which induces more firms to enter the market and fewer incumbent firms to default. Two periods after the shock, the now higher number of incumbent firms leads to a reduction in price and, in turn, an increase in defaults and a decrease in entries. This adjustment continues until the economy reaches the new EqN steady state where the price, defaults, and entry are lower and there are fewer incumbent

[20] In Figure A.2, we show that the intuition of the model holds when we compare the equilibrium without zombie credit and the equilibrium with zombie credit following a *temporary* demand shock.

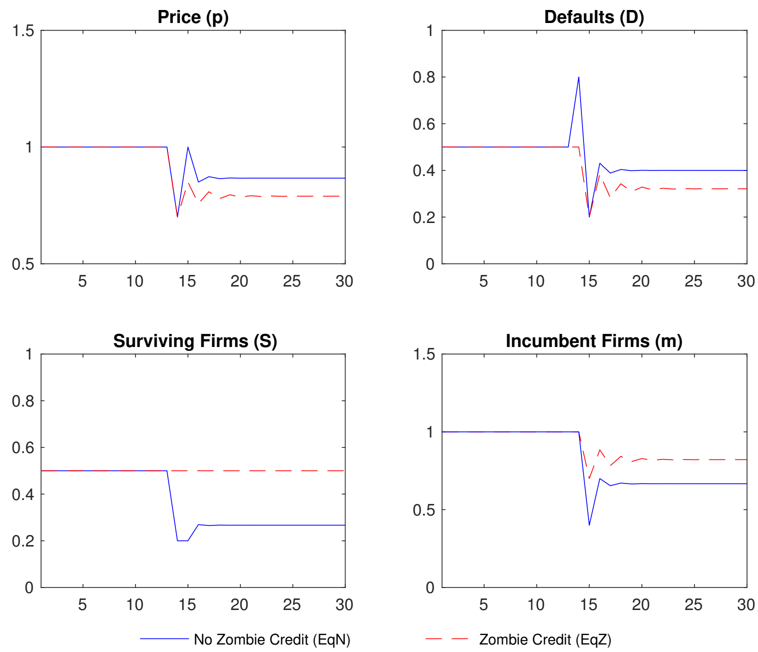

Figure A.1: Negative Demand Shock. This figure shows how equilibrium quantities and prices respond to a permanent decrease in α in EqN (solid lines) and in EqZ (dashed lines).

firms compared with the pre-shock steady state.

In EqZ, the collapse in price also induces a contemporaneous decrease in entries but defaults are held constant so as to keep the number of surviving firms also constant. This lack of adjustment through defaults causes the number of incumbent firms to go down less than in EqN one period after the shock. The price rebound also leads to an increase in entries, but this adjustment is muted compared to EqN. The lower number of incumbent firms causes a reduction in defaults in order to keep the number of survivors constant. Two periods after the shock, the number of incumbent firms is lower than in the previous period but higher than in EqN. This adjustment continues until the economy reaches the new steady state. Compared with the EqN steady state, the price, entry, and defaults are lower and there are more incumbent firms. More formally:

Proposition 1. *In the equilibrium with zombie credit, in steady state, fewer firms default, there are more incumbent firms, the price and markup are lower, and fewer firms enter compared with the steady state in an equilibrium with no zombie credit.*

Proof. The steady state conditions in EqN are $p = \alpha - \frac{m}{2}$ and $\frac{mI}{p-c} = e\left(1 - \frac{I}{p-c}\right)$. By combining them, we obtain:

$$m = \frac{e(\alpha - c - I)}{I + \frac{e}{2}} \qquad \text{and} \qquad p = \frac{2\alpha I + e(c+I)}{2I + e}$$

The steady state conditions in EqZ are $\widetilde{p} = \alpha - \frac{1}{2}\widetilde{m}$, $\widetilde{m} = e\left(1 - \frac{I}{p-c}\right) + \overline{S}$, and $\widetilde{D} = \widetilde{m} - \overline{S}$. Suppose that $\overline{S}$ is such that the EqN and EqZ equilibria are identical, namely

$$\overline{S} = \frac{2e(\alpha - c - I)^2}{(I + e/2)(2\alpha + e - 2c)}$$

Suppose $\alpha' < \alpha$. Combining the steady state conditions, we obtain a contradiction if $\widetilde{p}(\alpha') \geq p(\alpha')$. From $\widetilde{p}(\alpha') \geq p(\alpha')$, it follows that $S \leq m(\alpha')\left(1 - \frac{I}{p(\alpha')-c}\right)$. But it is easy to show that $S > m(\alpha')\left(1 - \frac{I}{p(\alpha')-c}\right)$. Hence, the contradiction. It follows that $m(\alpha') < \widetilde{m}(\alpha')$ and $p(\alpha') > \widetilde{p}(\alpha')$. It also trivially follows that entry, defaults, and markups are lower in EqZ compared with EqN. □

In the equilibrium with zombie credit, some firms that would default in the equilibrium without zombie credit are kept alive preventing a downward adjustment in the number of active firms and, in turn, causing a reduction in price. Let $p(\alpha, E(\alpha), S(\alpha))$ be the steady state price, expressed as a function of α. Note that the price functions are different in EqN and EqZ. Differentiating with respect to α yields:

$$\frac{dp}{d\alpha} = \frac{\partial p}{\partial \alpha} + \frac{\partial p}{\partial E}\frac{\partial E}{\partial \alpha} + \underbrace{\frac{\partial p}{\partial S}\frac{\partial S}{\partial \alpha}}_{= 0 \text{ in EqZ}}$$

Demand affects the price in three ways. First, the direct effect: a lower demand reduces the price in equilibrium. Second, a lower demand reduces entries, causing a reduction in price. Third, a lower demand induces more firms to default, which leads to a reduction in price. This third effect disappears in EqZ, where the number of surviving firms is not affected by the change in demand.

A.4 Effect on Input Costs

In a variation of the baseline model, we show in this section that input costs are higher in the equilibrium with zombie credit compared with the equilibrium without zombie credit.

The differences with the baseline model environment are as follows. First, the product price is now exogenous. Second, there is an exogenous supply of input $L_t = c_t - \mu_t$, where

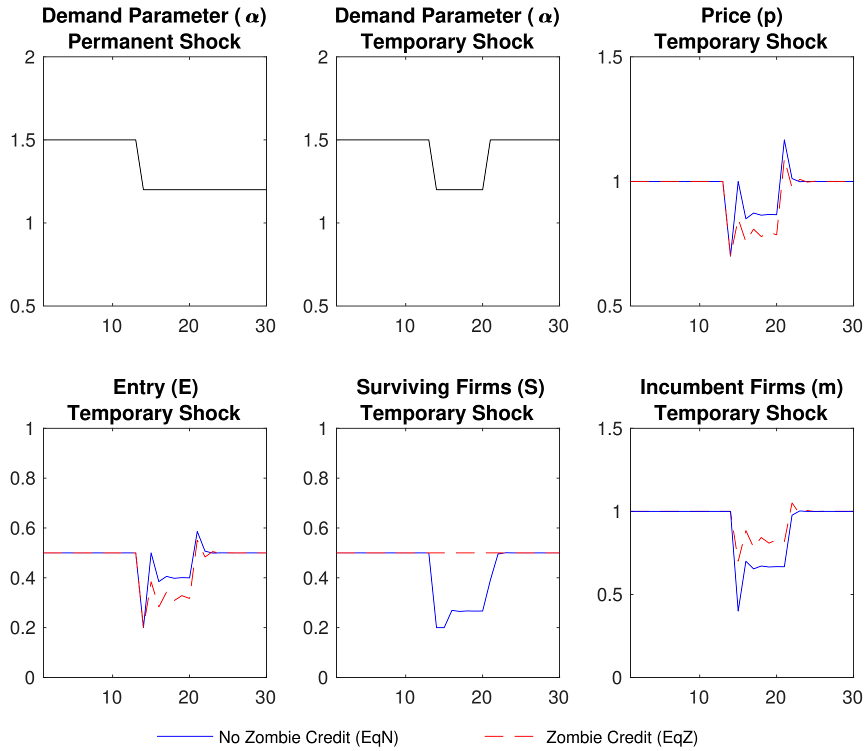

Figure A.2: Temporary Negative Demand Shock. This figure shows how equilibrium quantities and prices respond to a temporary decrease in α in EqN (solid lines) and in EqZ (dashed lines).

c_t is the price of input and marginal cost for each firm i. Third, after paying the setup cost I, firms set the price c_t of the input, knowing that their expected production is $1/2$. In this environment, the two equilibrium definitions take the product price as given and display the equilibrium condition for the input cost: $c_t = \frac{m_t}{2} + \mu_t$. The intuition for this expression follows the intuition from Lemma 1. Firms set the marginal cost of input c_t such that the total demand for the input equals its supply at the price c_t.

Similar to Section A.3, we can analyze the effect of a permanent decrease in the (now exogenous) product price on the (now endogenous) marginal cost. In the equilibrium without zombie credit, the negative demand shock reduces total production as the lower price reduces entry and increases exit. In the next period, the lower number of incumbent firms reduces the input price, causing an increase in entry and a decrease in exit. The resulting production increase causes a rebound in the number of incumbent firms in the next period. This adjustment continues until the economy reaches the new steady state with a lower number of active firms and lower input costs. Again, this adjustment is muted in the equilibrium with zombie credit.

Appendix B Markup Estimation

To obtain firm-level markups, we follow the procedure proposed by De Loecker and Warzynski (2012), which relies on the insight that the output elasticity of a variable production factor is only equal to its expenditure share in total revenue when price equals marginal cost of production. Under any form of imperfect competition, however, the relevant markup drives a wedge between the input's revenue share and its output elasticity.

In particular, this approach relies on standard cost minimization conditions for variable input factors free of adjustment costs. To obtain output elasticities, a production function has to be estimated. A major challenge is a potential simultaneity bias since the output may be determined by productivity shocks, which might be correlated with a firm's input choice.

To correct the markup estimates for unobserved productivity shocks, De Loecker and Warzynski (2012) follow the control function or proxy approach, developed by Ackerberg et al. (2006), based on Olley and Pakes (1996) and Levinsohn and Petrin (2003). This approach requires a production function with a scalar Hicks-neutral productivity term (i.e., changes in productivity do not affect the proportion of factor inputs) and that firms can be pooled together by time-invariant common production technology at the country-industry level.

Hence, we consider the case where in each period t, firm i minimizes the contemporaneous production costs given the following production function:

$$Q_{it} = Q_{it}(\Omega_{it}, V_{it}, K_{it}), \tag{A4}$$

where Q_{it} is the output quantity produced by technology $Qit(\cdot)$, V_{it} the variable input factor, K_{it} the capital stock (treated as a dynamic input in production), and Ω_{it} the firm-specific Hicks-neutral productivity term. Following De Loecker and Eeckhout (2019), we assume that within a year the variable input can be adjusted without frictions, while adjusting the capital stock involves frictions.

As we assume that producers are cost minimizing, we are thus are left with the following

Lagrangian function:

$$\mathcal{L}(V_{it}, K_{it}, \lambda_{it}) = P_{it}^{V} + V_{it} + r_{it}K_{it} + F_{it} - \lambda_{it}(Q(\cdot) - \overline{Q}_{it}), \tag{A5}$$

where P^V is the price of the variable input, r is the user cost of capital, F_{it} is the fixed cost, and λ_{it} is the Lagrange multiplier. The first order condition with respect to the variable input V is thus given by:

$$\frac{\partial \mathcal{L}_{it}}{\partial V_{it}} = P_{it}^{V} - \lambda_{it}\frac{\partial Q(\cdot)}{\partial V_{it}} = 0. \tag{A6}$$

Multiplying all terms by V_{it}/Q_{it}, and rearranging terms yields an expression for input V's output elasticity:

$$\theta_{it}^{v} \equiv \frac{\partial Q(\cdot)}{\partial V_{it}}\frac{V_{it}}{Q_{it}} = \frac{1}{\lambda_{it}}\frac{P_{it}^{V}V_{it}}{Q_{it}}. \tag{A7}$$

As the Lagrange multiplier λ is the value of the objective function as we relax the output constraints, it is a direct measure of the marginal costs. We thus define the markup as $\mu = P/\lambda$, where P is the price for the output good, which depends on the extent of market power.

Substituting marginal costs for the markup/price ratio, we obtain a simple expression for the markup:

$$\mu_{it} = \theta_{it}^{v}\frac{P_{it}Q_{it}}{P_{it}^{V}V_{it}}. \tag{A8}$$

Hence, there are two ingredients needed to estimate the markup of firm i: its expenditure share of the variable input, $P_{it}Q_{it}/P_{it}^{V}V_{it}$, which is readily observable in the date, and its output elasticity of the variable input, θ_{it}^{v}.

To obtain an estimate of the output elasticity of the variable input of production, we estimate a parametric production function for each industry (at the two digits NACE level).

For a given industry h in country j, we consider the translog production function (TLPF):[21]

$$q_{it} = \beta_{v1} v_{it} + \beta_{k1} k_{it} + \beta_{v2} v_{it}^2 + \beta_{k2} k_{it}^2 + \omega_{it} + \epsilon_{it}. \tag{A9}$$

where lower cases denote logs.[22] In particular, q_{it} is the log of the realized firm's output (i.e., deflated turnover), v_{it} the log of the variable input factor (i.e., cost of goods sold and other operational expenditures), k_{it} the log of the capital stock (i.e., tangible assets), $\omega_i = ln(\Omega_i)$, and ϵ_{it} is the unanticipated shock to output. Moreover, we follow best practice and deflate these variables with the relevant industry-country specific deflator.

We follow the literature and control for the simultaneity and selection bias, inherently present in the estimation of Eq. (A9), and rely on a control function approach, paired with a law of motion for productivity, to estimate the output elasticity of the variable input.

This method relies on a so-called two-stage approach. In the first stage, the estimates of the expected output ($\widehat{\phi}_{it}$) and the unanticipated shocks to output (ϵ_{it}) are purged using a non-parametric projection of output on the inputs and the control variable:

$$q_{it} = \phi_{it}(v_{it}, k_{it}) + \epsilon_{it}. \tag{A10}$$

The second stage provides estimates for all production function coefficients by relying on the law of motion for productivity:

$$\omega_{it} = g_t(\omega_{it-1}) + \varepsilon_{it}. \tag{A11}$$

We can compute productivity for any value of β, where $\beta = (\beta_{v1}, \beta_{k1}, \beta_{v2}, \beta_{k2})$, using $\omega_{it}(\beta) = \widehat{\phi}(\beta_{v1} v_{it} + \beta_{k1} k_{it} + \beta_{v2} v_{it}^2 + \beta_{k2} k_{it}^2)$.

[21]The TLPF is a common technology specification that includes higher order terms that is more flexible than, e.g., a Cobb-Douglas production function. The departure from the standard Cobb-Douglas production function is important for our purpose. If we were to restrict the output elasticities to be independent of input use intensity when analyzing how markup differs across firms, we would be attributing variation in technology to variation in markups, and potentially bias our results. (e.g., when comparing zombie vs non-zombie firms).

[22]We follow De Loecker and Eeckhout (2019) and do not consider the interaction term between v and k to minimize the potential impact of measurement error in capital to contaminate the parameter of most interest, i.e., the output elasticity.

By nonparametrically regressing $\omega_{it}(\beta)$ on its lag, $\omega_{it-1}(\beta)$, we recover the innovation to productivity given β, $\varepsilon_{it}(\beta)$.

This gives rise to the following moment conditions, which allow us to obtain estimates of the production function parameters:

$$E\left(\varepsilon_{it}(\beta)\begin{pmatrix} v_{it-1} \\ k_{it} \\ v_{it-1}^2 \\ k_{it}^2 \end{pmatrix}\right) = 0, \tag{A12}$$

where we use standard GMM techniques to obtain the estimates of the production function and rely on block bootstrapping for the standard errors. These moment conditions exploit the fact that the capital stock is assumed to be decided a period ahead and thus should not be correlated with the innovation in productivity. We rely on the lagged variable input to identify the coefficients on the current variable input since the current variable input is expected to react to shocks to productivity.

The estimated output elasticities are computed using the estimated coefficients of the production function:

$$\theta_{it}^v = \widehat{\beta}_{v1} + 2\widehat{\beta}_{v2} v_{it}, \tag{A13}$$

which allows us to calculate the markup of firm i.