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

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Abstract

We show that cheap credit to impaired firms has a negative effect on inflation. By preventing firms from defaulting, this "zombie" credit increases competition that, in turn, has a negative effect on product prices. We test our mechanism exploiting granular data on prices and firm level data from eleven European countries. After confirming that cheap credit to distressed firms has dramatically increased since 2012, we find that, in the cross-section of industries and countries, an increase in the share of zombie firms is associated with a decrease in firm markups, product prices, firm default, and an increase in sales. Our results are stronger for non-tradable products, more affected by local credit markets, and hold at the firm level, where we document spillover effects to healthy firms in industries with high zombie credit.

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1 Introduction

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 non-eurozone central banks implemented important measures of monetary stimulus, including negative deposit rates, longer-term refinancing operations, and large-scale asset purchases. In 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 labour market diminishes. But the pass-through from wages to prices remains weak."[1] This low-inflation environment, along with the extraordinary monetary easing, bears a striking resemblance to Japan's "lost decade." Similar to Japan in the early 1990s, Figure 1 shows that the European economy after the crisis has been characterized by decreasing inflation and increasing cheap credit extended to impaired "zombie" firms.[2]

We show that zombie credit impairs the transmission of firms' improved financing conditions to inflation. Building on Caballero et al. (2008), we show in a simple model that, by keeping alive firms that would otherwise default, zombie credit causes an increase in competition that, in turn, leads to lower firm markups and lower inflation. We test this channel using granular inflation and firm level data for a sample of 1.1 million firms in 11 European countries across 65 industries, allowing us to measure zombie credit and firm level markups and observe product level prices. Our empirical analysis supports this zombie credit channel and rules out competing mechanisms.

We illustrate our mechanism in a dynamic model where firms, potential entrants and incumbents, draw a productivity parameter every period and set prices to exploit their

[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 credit misallocation in Japan and Acharya et al. (2019) analyze credit misallocation in Europe.

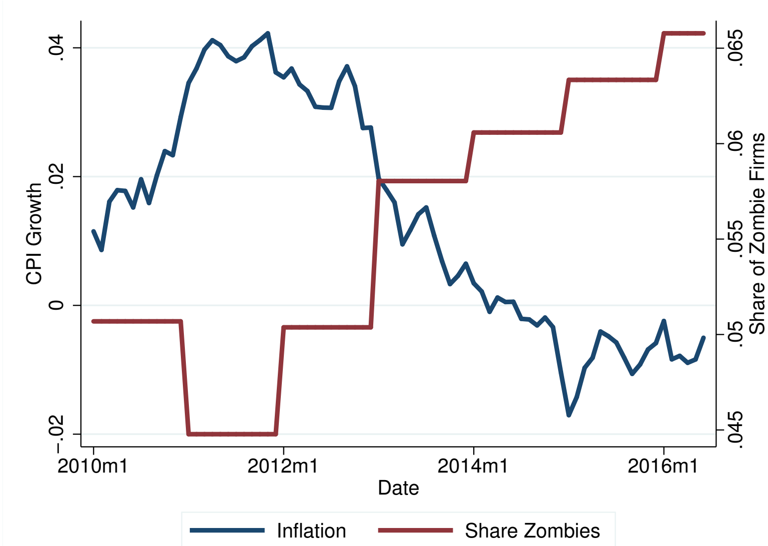

Figure 1: Zombie Credit and Inflation. This figure shows the year-over-year (yoy) growth of the Consumer Price Index (CPI) on the left axis and the asset-weighted share of zombie firms on the right axis in our sample. A firm is classified as zombie if it is low-quality (i.e., above median leverage and 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.

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. The resulting high number of active firms, compared with the case with no zombie credit, increases competition lowering, in turn, firms' markups and prices. In equilibrium, zombie credit has four effects: a reduction in product prices, firm markups, firm defaults, and an increase in the number of active firms.

The empirical analysis is based on a new data set, obtained by combining official 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 firms' markups. We define a firm as zombie if it meets two criteria: (i) the firm 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 credit at a rate lower than the rate paid by the most creditworthy (AAA-rated) comparable firms. Following De Loecker and Warzynski (2012), we measure markups relying on optimal input demand conditions from standard cost minimization.

Our data supports the four model predictions. In the cross-section of industries and countries, industry-country pairs that experience a larger increase in the share of zombie firms subsequently experience a lower growth in inflation, smaller markups, higher sales growth and more active firms, and fewer defaults than industry-country pairs with a smaller increase in zombie firms. Our specifications include country-industry, country-year, and industry-year fixed effects to capture potential omitted variables such as country-specific and industry-specific shocks. Finally, the *positive* correlation between change in zombie credit and sales rules out that the negative correlation between zombie credit and inflation is driven by lower demand in industry-country pairs with more zombie credit.

We run two additional tests to rule out competing channels. First, we show that industry-country pairs that experience a larger increase in the share of zombie firms subsequently have lower investment, higher material costs, and lower productivity than industry-country pairs with less zombie credit. The negative correlation with investment and productivity confirms that zombie credit is extended to zombie firms and not to firms that are temporarily weak. The positive correlation with material costs confirms the competition mechanism as firms compete for the same material inputs driving up their price. Second, we show that the negative correlations between zombie credit and inflation and between zombie credit and markups primarily occur in non-tradable industries, where local credit conditions are likely particularly important.

Finally, we document, at the firm level, that the increased presence of zombie firms affects healthy firms within an industry-country. In particular, we find that healthy firms competing with a growing number of zombie firms have lower markups, investment, and sales growth and higher material costs compared with healthy firms competing with fewer zombie firms. These correlations are consistent with healthy firms trying to limit the drop in market share by pricing more aggressively.

Our paper contributes to three strands of literature. First, it relates to the macro literature on resource misallocation. Restuccia and Rogerson (2008) and Hsieh and Klenow (2009) show that the misallocation of resources has a negative effect on productivity.[3] Whited and Zhao (2018) extend the analyses to the allocation of debt and equity on firms' balance sheets and Midrigan and Xu (2014) show that finance frictions distort entry and technology adoption decisions and this misallocation causes loss in productivity. Finally, Gopinath et al. (2017) analyze the southern European countries in the early 1990s and document a significant increase in the dispersion of the return to capital across firms and in the associated productivity losses.

Second, our paper relates to the literature on bank zombie lending, 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 extended credit to weak firms to avoid realizing losses and Caballero et al. (2008) show that this zombie lending affected healthy firms, reducing their investment and employment growth. Giannetti and Simonov (2013) show that capital injections can stop this perverse portfolio choice 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 OMT program induced zombie lending by weakly capitalized banks and Schivardi et al. (2017) confirm that non-viable Italian firms obtained favorable bank credit from 2004 to 2013. Finally, Blattner et al. (2019) show that these distorted lending decisions caused a decline in productivity. After confirming that weak European firms increasingly obtained cheap credit since 2012, we contribute to this literature by documenting the effect of zombie lending on inflation and firm markups.

Third, our paper relates to the literature on competition and firm price setting behavior (Campbell and Hopenhayn, 2005; Lewis and Stevens, 2015; Przybyla and Roma, 2005; Auer and Fischer, 2008; Lewis and Poilly, 2012; Binici et al., 2012).

The remainder of the paper is structured as follows. Section 2 presents an intuitive model linking credit misallocation to inflation. Section 3 illustrates our data and empirical work. Section 4 and Section 5 shows our empirical analysis at the industry-country level and at

[3] Moll (2014) develops a general equilibrium model to study the effect of financial frictions on capital misallocation and aggregate productivity. Buera et al. (2011) analyze the the relationship between total factor productivity and financial development across countries.

the firm level, respectively. Section 6 concludes.

2 Model

In this section, 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 the associated quantities and prices. The model adds imperfect competition among firms to a framework similar to Caballero et al. (2008).

2.1 Setup

Time is discrete and the economy is populated by a continuum of firms that produce a single good. There is an exogenous demand $D_t(p_t) = \alpha_t - p_t$ for this good. Firms are identical in size and can be incumbent or potential entrants. The mass of incumbent firms is m_t and the mass of potential entrant firms is e.

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. Depending on this realization, potential entrant firms might enter the market and incumbent firms might default.

Lemma 1. *If $\alpha_t \geq \frac{1}{2}(m_t + 1)$, firms choose $p_{it} = p_t$, where*

$$p_t = \alpha_t - \frac{m_t}{2} \tag{1}$$

Firms set prices knowing that their expected production is 1/2. In the unique Nash 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.[4]

After the price is set, firms learn the realization of their production. The profit of firm i is is $p_t(y_{it} - c) - I$. An incumbent firm that generates negative profits is forced to default. Hence, the mass of defaulting firms D_t in every period is:

$$D_t = m_t \int_0^{\frac{I}{p_t - c}} di = \frac{m_t I}{p_t - c}$$

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

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

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

$$N_t = (e + m_t) \left(1 - \frac{I}{p_t - c}\right) \tag{2}$$

2.2 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, mass of incumbents m_t, total production N_t such that total production equals the sum of production by surviving incumbent and entrant firms according to (2), the product price is given by (1), and the number of incumbent firms follow $m_{t+1} = N_t$.*

The equilibrium without zombie credit (EqN) is governed by three conditions. First, total production is the sum of the production of firms that enter the market and production of

[4] If $\alpha_t \geq \frac{1}{2}(m_t + 1)$, the expected production is small relative to market demand and the marginal revenue is greater than the marginal cost.

incumbent firms that survive. Second, the price of the good follows markup pricing. Third, the incumbent firms at $t+1$ are the sum of entrants and surviving incumbent firms at t. In steady state, 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 that survive each period. Based on the literature on zombie lending, the idea is that lenders might keep some firms that should default alive in order not to realize losses on their balance sheets. In the online appendix, we incorporate lenders in the model and show that lenders might prefer, in some circumstances, the EqZ over the EqN. Formally, the definition of EqZ is as follows:

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

The equilibrium with zombie credit is characterized by four conditions. First, 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. Second, defaults are such that surviving firms are constant at S. Third, the price of the good follows markup pricing. Fourth, the incumbent firms at $t+1$ are the sum of entrants and surviving incumbent firms at t.

2.3 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. More specifically, we consider the case where the EqN and EqZ are, before the shock, identical (the number of survivors S in EqZ is set equal to the number of survivors in EqN). Figure 2 shows this comparison, where the solid lines correspond to EqN and the dashed lines correspond to EqZ. In both equilibrium concepts, the negative shock causes a contemporaneous collapse in prices as firms lose market power.

The adjustment to the new steady state depends on the type of equilibrium. In EqN, the collapse in price causes a contemporaneous decrease in entry and increase in defaults. One period after the shock, the lower number of active firms cause the price to rebound (higher market power) inducing more firms to enter the market and fewer incumbent firms to default.[5] Two periods after the shock, the now higher number of incumbent firms causes a reduction in price and, in turn, an increase in defaults and a decrease in entry. This adjustment continues until the economy reaches the new EqC steady state here the price, defaults, and entry are lower and there are fewer incumbent firms compared with the original steady state.

In EqZ, the collapse in price causes a contemporaneous decrease in entry but defaults are held constant so as to keep the number of surviving firms also constant. This lack of adjustment through defaults causes, one period after the shock, the number of incumbent firms to go down less than in EqN. As competition goes down, the price rebounds causing entry to also increase but these adjustments are muted compared with EqN. The fewer incumbent firms causes defaults to go down 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 EqZ 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,*

[5] The number of surviving incumbent firms is constant because two opposing effects exactly offset each other: (i) the higher price causes defaults to go down and (ii) there are fewer incumbent firms at the beginning of the period.

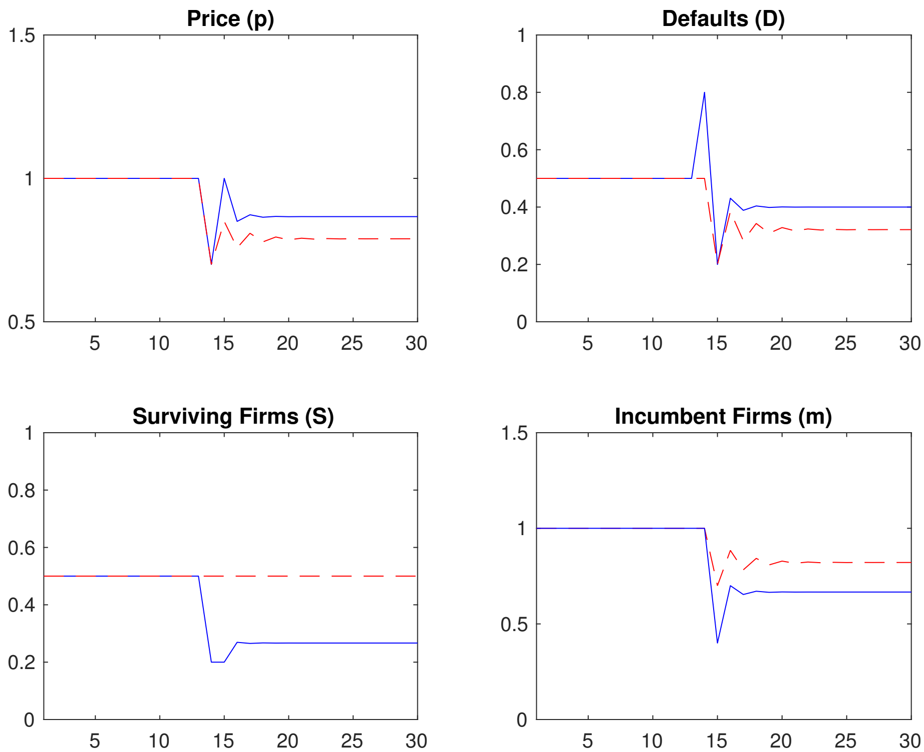

Figure 2: Negative Demand Shock. This figure shows how equilibrium quantities and prices respond to an increase in η in EqN (solid lines) and in EqZ (dashed lines).

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.

In the equilibrium with zombie credit, some firms that would default in the equilibrium without zombie credit are kept alive increasing competition and, in turn, reducing the price. Let $p(\alpha, m(\alpha))$ be the steady state price in EqZ, expressed as a function of α. Differentiating with respect to α yields:

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

Demand affects the markup in three ways. First, the direct effect: higher elasticity of demand reduces firms' market power. Second, the equilibrium effect through entry: a lower price causes fewer firms to enter. Third, the equilibrium effect through defaults: a lower price causes more firms to default. This third effect disappears in EqZ, where the number of surviving firms is not affected by the demand for the good.

3 Data and Empirical Work

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

3.1 Data and Empirical Measures

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 (consumer price index) at the industry 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. We exclude utilities and financial and insurance industries from the sample. This provides us with a measure of the consumer price index at the industry-country level for each month in our sample period.

	High-Quality	Low-Quality No Zombie	Low-Quality 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
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 low-quality zombie. A firm is classified as low-quality if it has a below median interest coverage ratio (EBIT/interest expense) and an above median leverage (interest bearing debt/total assets). Median values calculated at industry-country-year level. A firm is classified as zombie if it is low-quality and has interest expenses/debt smaller than that of AAA-rated European firms in a given year.

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

3.2 Empirical Measures: Zombie Credit and Markups

Following Caballero et al. (2008) and Acharya et al. (2019), we define zombie credit as credit that is extended to distressed firms at advantageous (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 (EBIT/interest expense) is below the median and its leverage ratio (interest bearing debt/total assets) is above the median.[6] Second, the firm obtains credit at advantageous low interest rates. That is, its annual interest rate (interest expense/total interest bearing debt) in a given year is below the interest paid by the most creditworthy firms, namely AAA-rated European firms.[7]

[6] We calculate the median values at the industry-country level.

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

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 that receive zombie credit. Low-quality zombie firms are weaker than low-quality non-zombie firms along several dimensions: zombie firms have a lower (and 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.

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 industry-country pair using the firms' turnover as weight.

4 Empirical Evidence: Industry-Country Level

We start our empirical analysis of the zombie lending channel with testing our four model predictions at the the industry-country level. In a second step, we consider and discuss alternative supply-side channels that could also have affected the European inflation dynamics.

4.1 Model Predictions

In a first step, we provide non-parametric evidence on the correlation between the share of zombie firms in an industry and the inflation level in this industry, which is our main variable of interest. Figure 3 shows the CPI growth separately for industries that experienced a high (above median) and low (below median) growth in the share of zombie firms over our sample

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

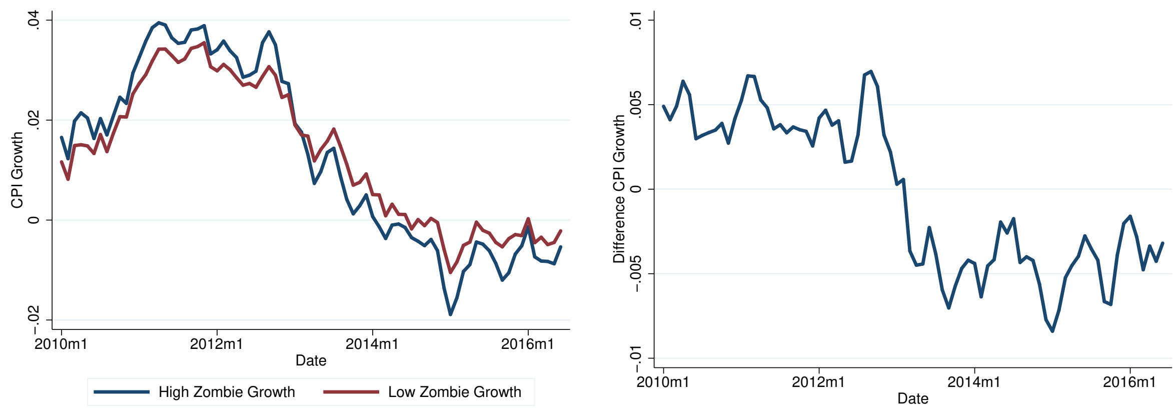

Figure 3: Inflation. The left figure shows inflation (yoy CPI growth) at monthly frequency for industry-country pairs that saw an above median increase in the asset-weighted share of zombie firms between 2009 and 2014 (High Zombie Growth) and firms with a below median growth in the share of zombie firms (Low Zombie Growth). The right figure shows the difference between the CPI growth of High vs Low Zombie Growth industries. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details).

period. Industries with a high zombie increase had initially a higher CPI growth, but, starting in mid-2012, these industries experienced a decline in CPI growth compared to industries with a lower zombie increase. 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 test parametrically the five model predictions by running the following regression for industry h in country j in year t:

$$Y_{hjt} = \beta \times \Delta ShareZombies_{hjt,t-1} + \gamma_{ht} + \nu_{jt} + \mu_{jh} + \epsilon_{hjt}, \tag{3}$$

where Y_{hjt} is either inflation, firm markups, sales growth, the change in the number of active firms, or firm default rate at the industry-country-year level.

Our key explanatory variable is the lagged change in the asset-weighted share of zombie firms in an industry-country pair: $\Delta ShareZombies_{hjt}$. In our preferred specification, we control for country-industry, country-year and industry-year fixed effects. Country-year fixed effects absorb all shocks at 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 Panel A of Table 2 confirm the non-parametric evidence from Figure 3: industry-country pairs that experience a larger increase in the share of zombie firms subsequently have a lower growth in CPI. This result is robust to controlling for different layers of fixed effects. Based on the estimates in column (4), a 10 percentage points (pp) increase in the share of zombie firms in a given country-industry is associated with a 0.3pp lower inflation rate. This effect corresponds to 13% of the standard deviation of CPI growth.

In Panel B, the dependent variable is the turnover-weighted average markup in an industry-country-year. In line with our model prediction, the estimated coefficients document lower markups in industries that experienced a larger zombie increase. Based on the estimates in column (4), a 10pp increase in the share of zombie firms in a given industry is associated with a 1.7pp reduction in markups, corresponding to 27% of the markup standard deviation.[9]

In Panel C, the dependent variable is sales growth. Again, consistent with our model, we find that industries with a high zombie share growth experienced higher sales growth rates. Note that this positive correlation between the zombie share growth 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 3, we isolate the correlation between changes in the zombie prevalence and the number of active firms and firm defaults in an industry, respectively. To measure the number of active firms and defaults we rely on publicly available data from Eurostat. Eurorstat reports data on active firms and firm defaults at industry-country-level over time. This ensures that we can accurately measure these two variables and that we do not miss active or defaulted firms in Amadeus due to a potential lack of reported data. Again, we estimate

[9] In the Appendix, we show that these results are robust to replacing the markup with the EBITDA margin (EBITDA/Sales), where a 10pp increase in the zombie share in a given industry is associated with a 1pp reduction in the EBITDA margin.

Panel A	ΔCPI	ΔCPI	ΔCPI	ΔCPI	ΔCPI
Δ Share Zombie	-0.030***	-0.028***	-0.031***	-0.030***	-0.030***
	(0.010)	(0.008)	(0.011)	(0.008)	(0.008)
Industry Sales Growth					0.001
					(0.002)
Country-Industry FE	✓	✓	✓	✓	✓
Year FE	✓				
Industry-Year FE		✓		✓	✓
Country-Year FE			✓	✓	✓
Observations	3,212	3,212	3,212	3,212	3,212
R-squared	0.492	0.730	0.511	0.748	0.748

Panel B	Markup	Markup	Markup	Markup	Markup
Δ Share Zombie	-0.146***	-0.159***	-0.153***	-0.167***	-0.166***
	(0.033)	(0.034)	(0.032)	(0.033)	(0.032)
Industry Sales Growth					0.006
					(0.010)
Country-Industry FE	✓	✓	✓	✓	✓
Year FE	✓				
Industry-Year FE		✓		✓	✓
Country-Year FE			✓	✓	✓
Observations	2,847	2,846	2,847	2,846	2,846
R-squared	0.966	0.973	0.967	0.974	0.974

Panel C	ΔSales	ΔSales	ΔSales	ΔSales
Δ Share Zombie	0.253**	0.317***	0.294***	0.373***
	(0.098)	(0.108)	(0.086)	(0.098)
Country-Industry FE	✓	✓	✓	✓
Year FE	✓			
Industry-Year FE		✓		✓
Country-Year FE			✓	✓
Observations	3,219	3,219	3,219	3,219
R-squared	0.141	0.215	0.339	0.407

Table 2: Inflation, Markups, and Sales: Industry-Country Evidence. This table presents industry-country-year level regressions. The dependent variable is the annual CPI growth rate (inflation) from t to $t+1$ in Panel A, the turnover-weighted average markup at time t in Panel B, and sales growth from t to $t+1$ in Panel C. Δ*Share Zombie* measures the increase in the asset-weighted share of zombie firms in an industry-country pair from $t-1$ to t. *Industry Sales Growth* is the growth in aggregate sales at the industry-country level from $t-1$ to t. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details). Standard errors clustered at the industry-country level. *** p<0.01, ** p<0.05, * p<0.1.

Panel A	Δ#Active Firms	Δ#Active Firms	Δ#Active Firms	Δ#Active Firms	Δ#Active Firms
Delta Share Zombie	0.022**	0.023*	0.024**	0.026**	0.029***
	(0.011)	(0.012)	(0.010)	(0.010)	(0.011)
Industry Sales Growth					-0.007*
					(0.004)
Observations	3,362	3,362	3,362	3,362	3,181
R-squared	0.479	0.534	0.630	0.681	0.688

Panel B	Default	Default	Default	Default	Default
Delta Share Zombie	-0.013**	-0.013**	-0.014***	-0.014***	-0.015***
	(0.005)	(0.006)	(0.004)	(0.004)	(0.005)
Industry Sales Growth					0.001
					(0.002)
Observations	3,283	3,283	3,283	3,283	3,071
R-squared	0.813	0.829	0.881	0.895	0.894
Country-Industry FE	✓	✓	✓	✓	✓
Year FE	✓				
Industry-Year FE		✓		✓	✓
Country-Year FE			✓	✓	✓

Table 3: Number of Active Firms and Firm Defaults: Industry-Country Evidence. This table presents industry-country-year level regressions. The dependent variable is the change in the number of firms (Panel A) and the share of firm defaults (Panel B). Δ*Share Zombie* measures the increase in the asset-weighted share of zombie firms in an industry-country pair from $t-1$ to t. *Industry Sales Growth* is the growth in aggregate sales at the industry-country level from $t-1$ to t. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details). Standard errors clustered at the industry-country level. *** p<0.01, ** p<0.05, * p<0.1

Eq. (3), where now the dependent variable is the change in the number of active firms (Panel A) and the share of firm defaults (Panel B). The estimated coefficients confirm that the change in the zombie prevalence in an industry-country is positively correlated with the growth in the number of active firms and negatively correlated with subsequent firm default rates. In Table C.2, we show that we obtain similar results on firm defaults if we rely on the Amadeus database to classify firms as defaulted.

In sum, in line with our model predictions, we find that industry-country pairs that experience a larger increase in the share of zombie firms subsequently have higher sales growth rates, a larger growth in the number of active firms, lower exit rates, lower markups, and lower CPI growth.

4.2 Alternative Supply-Side Channels

While the collective evidence presented in Section 4.1 is consistent with the zombie lending channel, the literature has suggested further (financial frictions-induced) supply-side effects that could also have affected the European inflation dynamics.

First, the "cost channel" states that firms' pricing decisions are directly related to credit conditions since firms depend on credit to finance production. Hence, their marginal production costs are affected by monetary policy rates (see, e.g., Barth III and Ramey, 2001).[10] This channel thus provides a possible explanation for a decrease in inflation after a loosening of monetary policy. In particular, the channel predicts that firms that get access to cheap credit (i.e., zombie firms) have lower financial expenditures and, in turn, can reduce output prices accordingly. It, however, makes no predictions about firms' markups or other firm variables.

Second, Chevalier and Scharfstein (1996) draw attention to a liquidity squeeze effect on output prices by arguing that liquidity constrained firms have an incentive to raise prices to increase their current cash flows (assuming sticky customer relationships), even though this reduces their future market share.[11] Therefore, this liquidity squeeze channel predicts an increase in markups and a decrease of investments in future market shares for firms that struggle to remain liquid (i.e., zombie firms).

Third, Caballero et al. (2008) argue that the presence of zombie firms distorts the normal creation and destruction patterns that usually follow negative shocks. The resulting distortion depresses productivity by preserving inefficient units at the expense of more productive potential entrants.[12] This productivity channel thus predicts lower efficiency and, as

[10] Christiano et al. (2015) introduces the cost channel into a New Keynesian model and shows that it helps to explain the only modest disinflation in the U.S. after the 2007-08 financial crisis.

[11] 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 after the 2007-08 financial crisis, respectively.

[12] In line with these theoretical predictions, Caballero et al. (2008) find that during the Japanese crisis the average productivity was lower in industries with more zombies. Adalet McGowan et al. (2018) and Acharya

a result, higher average production costs in industries with a high zombie share. Extending this argument by Caballero et al. (2008), we would except to see upwards price pressure and higher inflation in zombie industries if the productivity channel is indeed active.

Comparing the predictions of the zombie lending channel and the three alternative supply-side channels and checking their consistency with the results documented in Section 4.1 yields the following observations.

First, the observed negative correlation between the zombie share in an industry-country pair and the inflation level in that market could in general, in addition to the zombie lending channel, be also explained by the cost channel. The productivity channel and the liquidity squeeze channel, on the other hand, push inflation in industries with a high zombie share in the opposite direction than observed in the data. Hence, if the productivity and/or the liquidity squeeze channel are indeed active, the magnitudes of the zombie lending channel effect of an increase in the zombie share on inflation presented in Panel A of Table 2 would constitute a lower bound.

Second, the negative correlation between the zombie share in an industry-country pair and the average markups and sales growth cannot be explained by one of the alternative channels.

Third, if the liquidity squeeze channel was active, we would expect that, on average, firms decrease investments more in industries in which we observe no increase or only a slight increase in the availability of cheap zombie credit.

Fourth, while the cost and the liquidity squeeze channels make no prediction regarding the firms' production costs, the zombie lending and productivity channels predict an increase in these costs for zombie firms.

Finally, a unique feature of the zombie lending channel is that it is competition related, that is, it predicts that fiercer competition created by the higher number of firms (due to low exit rate) and the resulting positive supply shock depressed inflation. Hence, if the zombie

et al. (2019) find similar evidence for the period 2003-2013 in OECD countries and the post-2014 period in Europe, respectively.

lending channel is indeed an important driver for depressed inflation levels, we expect that the effects are stronger in non-tradable than tradable industries. For tradable industries, markets are across country lines (or even global) and are thus not so much affected by local conditions in a specific industry-country pair. In contrast, local conditions should matter significantly more for non-tradable industries where sold goods need to be produced locally.

4.3 Investment, Material Costs, and Tradeability

Using these distinct predictions about the firms' investment and cost levels, as well as, the influence of product tradeability, we conduct three additional tests at the industry-country level to more clearly separate the zombie lending channel from the other possible supply-side channels.

We start with investigating the evolution of investment. The results in Panel A of Table 4 show that industries with a higher zombie prevalence increase experienced a lower investment level in the following year. In particular, a 10pp increase in the share of zombie firms in a given industry is associated with a 1.25pp investment reduction. This evidence indicates that the observed sales growth increase in industries with a strong zombie share increase is indeed most likely driven by an increase in the number of active firms (as suggested by the zombie lending channel), and not by a positive industry outlook. One possible explanation for this investment drop in zombie industries is the liquidity squeeze channel, which suggests that (liquidity-constrained) zombie firms lower investments to boost internal cashflows. If this channel was indeed active, it prevented an even larger decrease in markups and thus inflation in zombie industries.

Next, we check the evolution of the firms' productivity and cost structure. If the results presented in Section 4.1 are indeed due to an increasing number of non-profitable firms that are kept artificially alive by cheap credit, we expect to see in the respective industries (i) a competition-induced positive shock also on the firms' input costs, and, (ii) a reduction in the average industry productivity. In particular, regarding hypothesis (i), the higher number of firms in these industries (relative to non-zombie industries) should not only lead to higher competition on the firms' customer side, but also shift more negotiation power towards their supplier as more firms have to compete for a limited amount of resources.

Panel B of Table 4 investigates the evolution of material cost, a key input factor of production. In line with the prediction of the zombie lending channel, an increase in the share of zombie firms in an industry-country pair leads to higher average material costs in that industry. While consistent with the zombie lending channel, this evidence could also be explained by the productivity channel, which argues that zombie firms are inefficient in their resource usage and, if the number of zombies in an industry raises, the industry's average material costs should increase.

Table 4, Panel C presents the results for the productivity test, where we measure productivity as *log(sales)–2/3*log(employment)–1/3*log(fixed assets)*. Consistent with the zombie lending and the productivity channel, the regression shows that industries with an increase in the zombie prevalence experience a reduction in their average productivity. This evidence suggests that the effect of the zombie lending channel on inflation presented in Panel A of Table 2 constitutes a lower bound. In particular, since industries that experienced a zombie firm increase have lower average productivity and higher average material 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 higher competition induced the firms in these industries to lower markups to such an extent that it overcompensated the production costs increase.

Finally, we split industries into tradable and non-tradable sectors and redo our analysis. To classify industries, we rely on the UN Comtrade database, which reports imports and exports for each country at the four digit NACE level. Any industry included in the UN Comtrade database is classified as tradable.

Table 5 presents the results of this sample split. Panel A shows that the negative effect of the rise in the zombie share on inflation primarily occurs in non-tradable industries. A 10pp increase in the zombie share implies a 0.37pp lower inflation level in these industries, corresponding to 15% of the standard deviation of CPI growth. Panel B confirms that the markup reduction is also primarily occurring in non-tradable industries, where a 10pp increase in the zombie share leads to a markup reduction of 2.1pp.

The collective evidence in Section 4.3 reinforces the notion that the zombie lending channel was responsible for the markup and, in turn, inflation reduction in industries that experi-

Panel A	CAPX	CAPX	CAPX	CAPX	CAPX
Δ Share Zombie	-0.134***	-0.137***	-0.122**	-0.125**	-0.127***
	(0.047)	(0.048)	(0.048)	(0.049)	(0.049)
Industry Sales Growth					-0.011
					(0.017)
Observations	2,659	2,659	2,659	2,659	2,659
R-squared	0.377	0.467	0.398	0.488	0.489

Panel B	Material Cost	Material Cost	Material Cost	Material Cost	Material Cost
Δ Share Zombie	0.065***	0.070***	0.066***	0.072***	0.075***
	(0.023)	(0.024)	(0.023)	(0.024)	(0.024)
Industry Sales Growth					0.013*
					(0.008)
Observations	3,084	3,084	3,084	3,084	3,084
R-squared	0.948	0.954	0.949	0.956	0.956

Panel C	Productivity	Productivity	Productivity	Productivity	Productivity
Δ Share Zombie	-0.187**	-0.195*	-0.201**	-0.211*	-0.205*
	(0.088)	(0.108)	(0.092)	(0.113)	(0.122)
Industry Sales Growth					0.101**
					(0.044)
Observations	3,163	3,163	3,163	3,163	3,163
R-squared	0.870	0.888	0.874	0.892	0.893
Country-Industry FE	✓	✓	✓	✓	✓
Year FE	✓				
Industry-Year FE		✓		✓	✓
Country-Year FE			✓	✓	✓

Table 4: Investment, Material Cost, and Productivity: Industry-Country Evidence. This table presents industry-country-year level regressions. The dependent variables are asset-weighted investment (CAPX/fixed assets measured in $t+1$, Panel A), the industry material cost (material input cost/turnover, Panel B), and asset-weighted productivity (*log(sales)–2/3*log(employment)–1/3*log(fixed assets)*, Panel C). Δ*Share Zombie* measures the increase in the asset-weighted share of zombie firms in an industry-country pair from $t-1$ to t. *Industry Sales Growth* measures the growth in aggregate sales at the industry-country level from $t-1$ to t. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details). Standard errors clustered at the industry-country level. *** p<0.01, ** p<0.05, * p<0.1

enced a strong increase in the prevalence of zombie firms. Moreover, the results suggests that the productivity and liquidity channel were likely active, leading to an increase in the average production cost level and a counteractive markup pressure in zombie industries. Thereby, these channels prevented an even stronger inflation decrease in these industries. Overall, this industry-level evidence thus suggests that the estimated magnitude of the effect of the zombie lending channel on inflation in Panel A of Table 2 represents a lower bound.

	Tradable	Non-Tradable
Panel A	ΔCPI	ΔCPI
Δ Share Zombie	-0.007	-0.037***
	(0.007)	(0.010)
Observations	1,434	1,778
R-squared	0.860	0.706
Panel B	Markup	Markup
Δ Share Zombie	-0.055***	-0.225***
	(0.020)	(0.042)
Observations	1,290	1,556
R-squared	0.990	0.963
Industry-Year FE	✓	✓
Country-Year FE	✓	✓
Country-Industry FE	✓	✓

Table 5: Tradable vs Non-Tradable Industries: Industry-Country Evidence. This table presents industry-country-year level regressions, separately for tradable and non-tradable industries. The dependent variable is the annual CPI growth rate (inflation) from period t to $t+1$ (Panel A) and the turnover-weighted average markup (Panel B). Δ*Share Zombie* measures the increase in the asset-weighted share of zombie firms in an industry-country pair from $t-1$ to t. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details). Standard errors clustered at the industry-country level. *** p<0.01, ** p<0.05, * p<0.1

5 Firm-Level Analysis

To more clearly separate the zombie lending channel from the other supply-side channels outlined in Section 4.2 and to more precisely estimate its impact on price levels, we next exploit our detailed data at the firm-level.

The zombie lending channel predicts that an increase in the zombie prevalence leads to distorted market competition in the respective market. In particular, the market congestion in zombie industries should lead to a sales decrease for individual non-zombie firms as more firms have to share a given demand level. In turn, the affected firms try to limit the drop in market share by pricing more aggressively. At the same time, these firms face higher input prices due to a decreased bargaining power vis-a-vis their suppliers as more firms compete for a limited amount of resources. Finally, we expect to see a slight increase in aggregate sales at the industry-country level due to the downward adjusted output prices and the resulting slightly higher overall demand.

In sum, the zombie lending channel thus predicts for zombie compared to non-zombie industries: (i) higher aggregate sales growth, as well as, (ii) lower sales growth, lower markups, and higher material costs for individual non-zombie firms.

Importantly, the zombie lending channel is the only supply-side channel that predicts these spillover effects of an increase in the zombie prevalence in a certain industry-country pair on non-zombie firms that are active in the same market. Observing such spillover effects thus provides strong evidence that the zombie lending channel is active.

Following Caballero et al., 2008, we run the following regression at the firm-year level to test for spillovers on non-zombie firms:

$$\begin{aligned} Y_{ihjt} &= \beta_1 \times Non-Zombie_{ihjt} + \beta_2 \times Non-Zombie_{ihjt} \times ShareZombies_{hjt-1} \\ &+ \gamma_{hjt} + \nu_i + \epsilon_{ihjt}, \end{aligned} \tag{4}$$

where our dependent variables are markup, sales growth, material cost, and investment. 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 industries with a high share of zombie firms perform differently than non-zombie firms in industries with a lower share of zombie firms.

Consistent with our results at the industry-country level, the first column of Table 6 shows that, while non-zombie firms in general have higher markups than zombie firms, the markup is significantly lower for non-zombie firms that operate in an industry with a higher zombie prevalence. Moreover, while we see an increase in aggregate sales growth for zombie industries at the industry-country level (see Panel C of Table 2), we indeed observe a drop in sales growth for individual non-zombie firms active in industries with a large zombie share increase (see Column (2) of Table 6).

The results in Column (3) of Table 6 confirm that non-zombie firms that have to compete against a high number of zombie firms indeed pay higher material costs. Finally, the results in Column (4) of Table 6 show that non-zombie firms that are active in industry-country pairs with a high zombie prevalence invested less, which reinforces the notion that these industries suffer from oversupply and thus a lack of profitable investment opportunities.

	Markup	Sales Growth	Material Cost	CAPX
Non-Zombie	0.060***	0.061***	-0.022***	0.014***
	(0.006)	(0.007)	(0.002)	(0.002)
Non-Zombie	-0.225***	-0.176***	0.063***	-0.049**
× Industry Share Zombies	(0.043)	(0.034)	(0.019)	(0.020)
Observations	3,780,340	5,290,486	4,252,590	3,306,336
R-squared	0.585	0.032	0.525	0.065
Industry-Country-Year FE	✓	✓	✓	✓
Firm-Level Controls	✓	✓	✓	✓

Table 6: Markup, Sales Growth, Material Cost, Investment: Firm-Level Evidence. This table presents firm-year level regressions. The dependent variables are a firm's markup, sales growth, investment (CAPX/fixed assets), or material cost (material input cost/turnover). *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 3.2 for more details). Standard errors clustered at the industry-country level. *** p<0.01, ** p<0.05, * p<0.1.

6 Conclusion

Starting in 2012, during a period of extraordinary monetary easing by the ECB, inflation started to decline and banks extended more and more cheap credit to non-viable firms in Europe. In this paper, we link bank zombie credit and inflation dynamics. The economic mechanism is intuitive. By keeping alive firms that would otherwise default, zombie credit congests product markets causing, in turn, lower firm markups and product prices.

We test this channel using a new inflation and firm level data set that covers 1.1 million firms in 11 European countries across 65 industries. First, we calculate inflation at the industry level, measure zombie credit, and firms' markups. Second, we show that industry-country pairs that experience a larger increase in the share of zombie firms subsequently experience a lower growth in inflation, smaller markups, higher sales growth, and fewer defaults than industry-country pairs with a smaller increase in the share of zombie firms. Finally, we run a series of additional tests that further support our mechanism.

Our results suggest that the European low-growth, low-inflation environment, along with a negative deposit rate and ample central bank liquidity, bears a striking resemblance to Japan's "lost decades" in the aftermath of its crisis in the early 1990s, from which Japan's economy is still recovering. Similar to the Bank of Japan's crisis response, the ECB implemented a very accommodative monetary policy to induce more investment and consumption and, in turn, inflation. However, inflation did not rise as predicted by canonical macroeconomic models and remained well below the ECB's 2% target. In this paper, we provide an explanation for this "missing inflation puzzle" (see Constâncio, 2015).

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Appendix A. Model Appendix

A.1 Derivations and Proofs

Lemma 1. 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. $\square$

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

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

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 EqCM compared with EqC. $\square$

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:

$$Q_{it} = Q_{it}(\Omega_{it}, V_{it}, K_{it}), \tag{A1}$$

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:

$$\mathcal{L}(V_{it}, K_{it}, \lambda_{it}) = P_{it}^{V} + V_{it} + r_{it}K_{it} + F_{it} - \lambda_{it}(Q(\cdot) - \overline{Q}_{it}), \tag{A2}$$

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:

$$\frac{\partial \mathcal{L}_{it}}{\partial V_{it}} = P_{it}^{V} - \lambda_{it}\frac{\partial Q(\cdot)}{\partial V_{it}} = 0. \tag{A3}$$

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

$$\theta_{it}^{v} \equiv \frac{\partial Q(\cdot)}{\partial V_{it}}\frac{V_{it}}{Q_{it}} = \frac{1}{\lambda_{it}}\frac{P_{it}^{V} V_{it}}{Q_{it}}. \tag{A4}$$

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:

$$\mu_{it} = \theta_{it}^{v}\frac{P_{it}Q_{it}}{P_{it}^{V} V_{it}}. \tag{A5}$$

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):[13]

$$q_{it} = \beta_{v1} v_{it} + \beta_{k1} k_{it} + \beta_{v2} v_{it}^2 + \beta_{k2} k_{it}^2 + \omega_{it} + \epsilon_{it}. \tag{A6}$$

where lower cases denote logs.[14] 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-specific deflator.

We follow the literature and control for the simultaneity and selection bias, inherently present in the estimation of Eq. (A6), 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:

$$q_{it} = \phi_{it}(v_{it}, k_{it}) + \epsilon_{it}. \tag{A7}$$

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

$$\omega_{it} = g_t(\omega_{it-1}) + \varepsilon_{it}. \tag{A8}$$

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

[13]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).

[14]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:

$$E\left(\varepsilon_{it}(\beta)\begin{pmatrix} v_{it-1} \\ k_{it} \\ v_{it-1}^2 \\ k_{it}^2 \end{pmatrix}\right) = 0, \tag{A9}$$

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:

$$\theta_{it}^v = \widehat{\beta}_{v1} + 2\widehat{\beta}_{v2} v_{it}, \tag{A10}$$

which allows us to calculate the markup of firm i.

Appendix C. Additional Tables

	EBITDA	EBITDA	EBITDA	EBITDA	EBITDA
Δ Share Zombie	-0.093***	-0.101***	-0.094***	-0.102***	-0.105***
	(0.018)	(0.021)	(0.018)	(0.021)	(0.021)
Industry Sales Growth					-0.012***
					(0.003)
Observations	3,171	3,171	3,171	3,171	3,171
R-squared	0.864	0.883	0.873	0.892	0.894
Country-Industry FE	✓	✓	✓	✓	✓
Year FE	✓				
Industry-Year FE		✓		✓	✓
Country-Year FE			✓	✓	✓

Table C.1: EBITDA Margin: Industry-Country Evidence. This table presents industry-country-year level regressions. The dependent variable is the turnover-weighted EBITDA Margin in an industry-country. ΔShare Zombie measures the increase in the asset-weighted share of zombie firms in an industry-country pair from $t-1$ to t. *Industry Sales Growth* represents measures the growth in aggregate sales at the industry-country level from $t-1$ to t. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details). Standard errors clustered at the industry-country level. *** p<0.01, ** p<0.05, * p<0.1

	Default	Default	Default	Default	Default
Δ Share Zombie	-0.012***	-0.016***	-0.009**	-0.013***	-0.013***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Industry Sales Growth					-0.001
					(0.001)
Country-Industry FE	✓	✓	✓	✓	✓
Year FE	✓				
Industry-Year FE		✓		✓	✓
Country-Year FE			✓	✓	✓
Observations	2,595	2,595	2,595	2,595	2,595
R-squared	0.821	0.845	0.860	0.885	0.885

Table C.2: Firm Defaults: Industry-Country Evidence. This table presents industry-country-year level regressions. The unit of observation is industry-country-year. The dependent variable is the share of firm defaults. Δ*Share Zombie* measures the increase in the asset-weighted share of zombie firms in an industry-country pair from $t-1$ to t. *Industry Sales Growth* is the growth in aggregate sales at the industry-country level from $t-1$ to t. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details). Standard errors clustered at the industry-country level. *** p<0.01, ** p<0.05, * p<0.1

	Tradable	Non-Tradable
	Markup	Markup
Non-Zombie	0.048***	0.063***
	(0.001)	(0.008)
Non-Zombie	-0.111***	-0.258***
×Industry Share Zombies	(0.014)	(0.057)
Observations	901,699	2,878,641
R-squared	0.687	0.570
Industry-Country-Year FE	✓	✓
Firm-Level Controls	✓	✓

Table C.3: Tradable vs Non-Tradable Industries: Firm-Level Evidence. This table presents firm-year level regressions, separately for firms operating in tradable and non-tradable industries. The dependent variables are a firm's markup. *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 3.2 for more details). Standard errors clustered at the industry-country level. *** p<0.01, ** p<0.05, * p<0.1.