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Abstract

We develop a simple model of financial intermediation with search and matching frictions between banks and firms. The model links credit market tightness –encapsulating the abundance of credit– to the search and opportunity costs of credit intermediation. Search costs generate lending to unprofitable firms (i.e., zombies) and the opportunity costs of searching exert countervailing forces on the incentives for banks and firms to participate in zombie lending, generating an *inverted U-shaped* relationship between credit market tightness and the share of zombie lending. High bargaining power of firms decreases the opportunity cost of firms foregoing credit relationships, reduces the share of zombie firms and increases the efficacy of capital injections to reduce zombie lending. Using data for 31 industries in Japan over the period 2000-2019, we test and corroborate our theoretical predictions by constructing theory-consistent measures of credit market tightness and bargaining power. Consistent with our theory, the findings reveal that capital injections are more effective in industries with higher credit market tightness and greater bargaining power of firms.

JEL codes: E22, E23, E32, E44.

Keywords: Zombie firms, bank lending, credit market tightness.

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1. Introduction

Zombie firms –unprofitable enterprises kept in existence through external borrowing– are pervasive in several economies. In fact, a growing number of studies link them to the abundance of credit that incentivizes bank lending to unprofitable firms.[1] Despite the prevalent connection between credit conditions and zombie firms, there is no theoretical or empirical work that directly links zombie firms to the availability of credit to validate or disprove this hypothesis. We fill this gap in the literature by developing the first theoretical model linking the costs of credit intermediation and the availability of credit with the share of zombie firms. We use our theory to construct a new measure of credit market tightness that allows us to test and empirically validate the link between credit abundance and zombie firms using industry-level data from Japan. Consistent with our theory, we show that during the Japanese banking crisis of early 2000 the effectiveness of credit injections was stronger in industries with higher credit market tightness and firm's bargaining power.

Our study examines the idea that the costs of credit intermediation are central to the share of zombie firms in an economy. The costs we have in mind go well beyond completing contractual arrangements and regulatory procedures and also comprise the *search* and *opportunity costs* of forming a credit relationship.[2] Our framework formalizes the idea that the avoidance of search costs fosters the lending to unprofitable firms (zombies) since banks and firms decrease lending standards to forgo costly search. At the same time, the abundance of credit generates distinct opportunity costs of forming credit relationships between bank and firm. Specifically, for a bank, credit abundance decreases the likelihood of finding borrowing firms and increases the opportunity costs of forgoing credit relationships, thus inducing the bank to lower lending standards. For a firm, the incentives are reversed. This is because credit abundance increases the likelihood of finding lending banks, thereby reducing a firm's opportunity costs of forming a new credit relationship and providing incentives to the firm's ownership to exit lending relations to avoid

[1]See Acharya et al. (2022) and references therein for an overview of the empirical relevance of zombie firms across countries. Several policy articles address the issue of zombie lending and credit market (see, for instance, Storz et al., 2017; Banerjee and Hofmann, 2018; Adalet McGowan et al., 2018; Favara et al., 2022; Albuquerque and Iyer, 2023).

[2]In our framework, search costs also encompass the legal and contractual penalties sustained by the bank to terminate a credit agreement. Those penalties are mandatory in several jurisdictions (for instance, the Code of Federal Regulations, 2024, Title 12 regulates debt cancellation contracts and debt suspension agreements in the U.S.) and they stimulate the bank's incentive to continue to supply credits to weak firms.

losses. Accordingly, search costs generate zombie lending and the abundance of credit provides countervailing incentives to the firm's owners and the bank for the formation of weak credit relations and the proliferation of zombie firms.

We formalize these ideas in a parsimonious model of frictional financial intermediation between banks and firms. We assume that the costs of financial intermediation arise from search and matching frictions that obstruct the costless meeting between banks and firms in the credit market. Firms have different levels of productivity and each firm receives a new productivity draw in each period. Zombie firms have insufficient productivity to be profitable in the current period but they receive credit and may become profitable in the future with a new draw of high productivity. The threshold of firm-specific productivity necessary to achieve positive profits is endogenous to the costs of financial intermediation and the abundance of credit.

Search frictions entail two distinct forces on the proliferation of zombie firms. First, they decrease the threshold of idiosyncratic productivity needed for the firm to obtain credit. This is because the bank optimally maintains a credit relationship with low-productivity firms having negative profits so as to forgo the costs of searching, thereby generating the increase of zombie firms in equilibrium. Second, search frictions make the opportunity costs of financial intermediation endogenous to the degree of abundance of credit in financial markets. The degree of abundance of credit exerts two countervailing forces for the creation of zombie firms. On the one hand, credit abundance increases the competition across banks and raises the *tightness* in the credit market faced by banks –encapsulated by the ratio between the supply and demand of loans. The rise in credit market tightness and the resulting increase in competition across banks generate countervailing opportunity costs for the bank and the firm. In a tight financial market with abundant credit, the bank encounters elevated search and opportunity costs and optimally lends to low-productivity firms to avoid such costs, thus stimulating the proliferation of zombie firms. On the other hand, when credit is abundant and the credit market is tight, firm owners face lower opportunity costs for staying in a credit relationship that generates negative profits. They can terminate the relationship and find with low search costs a new lending bank upon receiving a new draw of productivity, hence discouraging the proliferation of zombie firms. Thus, the increase in credit market tightness incentivizes bank lenders and disincentivizes firm equity holders to maintain a weak credit relationship.

These two countervailing forces generate an *inverted U-shaped* relationship between credit market tightness and the share of zombie firms. A rise in credit market tightness that increases the bank's opportunity costs of forgoing a credit relationship decreases the level of firm-specific productivity that the bank requires to establish and maintain a credit relationship. This situation allows low-productivity firms to remain in the market, thereby increasing the share of zombie firms. However, as tightness continues to rise, the owners of low-productivity firms are more likely to end the relationship to avoid negative profits, especially because search costs for a new lender are low and firm owners may improve their outcome with a new productivity draw. As a result, the share of zombie firms decreases. Our model shows that, beyond a sufficiently high level of credit market tightness, the firm owner's incentive to terminate the credit relationship outweighs the bank's incentive to remain in the credit relationship. Therefore, the share of zombie firms decreases with the rise in credit market tightness.

The bargaining power between the bank and firm in sharing the profits from the relationship –reflected by the interest rate applied to the loan– is critical to the prevailing force and the link between the share of zombie firms and credit market tightness. If the firm has high bargaining power and retains a large fraction of profits from bargaining a low interest rate, then the bank has a reduced incentive to form a credit relationship with the low-productivity firm. Thus, a high firm's bargaining power reduces the proliferation of zombie firms for any level of credit market tightness. Similarly, capital injections to banks result in a decrease in lending to zombie firms owing to the abundance of credit and high credit market tightness that incentivizes the firm to forgo unprofitable credit relationships.

To summarize, based on the search and opportunity costs of credit intermediation, our model shows that zombie firms exist in equilibrium and that credit market tightness exerts countervailing forces on the share of zombie firms, positing three testable predictions:

1. Credit market tightness has an inverted U-shaped relationship with the share of zombie firms.

2. An increase in firm's bargaining power strengthens the reduction in the share of zombie firms when credit market tightness rises.

3. The efficacy of capital injections to reduce zombie lending increases with higher credit market

tightness and firm's greater bargaining power.

We empirically test our theoretical predictions using a dataset we construct from industry-level data across 31 industries in Japan. The dataset is derived from different data sources over the period 2000-2019. Japan is the ideal testing ground for our theory, since the country has an established history of zombie lending, and the cross-sectional variation of credit market tightness, bargaining power, and financial conditions across industries allows powerful econometric identification. We define zombie firms as per Caballero et al. (2008) using the universe of enterprises in the Nikkei Financial Quest database. We construct theory-consistent measures of credit market tightness using data on the supply and demand of loans from the Loan Officer Opinion Survey on Bank Lending Practices at Large Japanese Banks, as well as from the Tankan Survey, administered by the Bank of Japan.

We study the empirical relevance of our first prediction on the inverted U-shaped relationship between credit market tightness and the share of zombie firms by estimating threshold and quadratic regression models and applying the formal test from Lind and Mehlum (2010). We establish that the share of zombie firms maintains an inverted U-shaped relationship with credit market tightness, thus corroborating the first prediction of our theory. Our results are robust across several specifications of our regression model and the inclusion/exclusion of several variables.

The systematic differences in bargaining power between firms and banks across industries in our data allow us to test the negative relationship between the share of zombie firms and firms' bargaining power established by our second prediction. Zombie firms are concentrated in industries where banks have high bargaining power (e.g., shipping and power industries) while they are scarce in sectors where firms have high bargaining power (e.g., pharmaceutical and mining industries). Our industry-level data confirms our second prediction: higher firm bargaining power reduces the incidence of zombie firms.

Finally, we use our theory to study the effect of exogenous capital injections on the share of zombie firms during the banking crisis in Japan in the late 1990s. Our theory predicts that an exogenous capital injection to banks decreases the share of zombie firms. For sufficiently large credit injections, credit abundance and high tightness in the financial market strengthen the firm's incentive to forgo unprofitable credit relationships relative to the bank's incentive to maintain unprofitable relationships to avoid high search costs, reducing the share of zombie firms on balance. We test the theoretical prediction by constructing a novel index of exposure of the firms to capital injections and show that the effectiveness of capital injections to reduce the zombie share increases with tightness in the credit market, thereby corroborating our third prediction of our theory.

Related literature. Our work is closely related to Caballero et al. (2008)'s seminal study on zombie lending. They establish the nexus between credit supply and the proliferation of zombie firms during the banking crises in Japan in the late 1990s. Recent studies show how credit allocation and policy actions shape aggregate outcomes, hence evincing a complex interplay between credit markets, economic policies and zombie firms (Acharya et al., 2020 and Acharya et al., 2021). Related to our research are also the studies on bank lending and collateral constraints for the presence of low-productivity firms in the economy (Faria-e-Castro et al., 2024, González et al., 2024, and Tracey, 2024). Unlike those studies, however, we focus on the interplay between credit market tightness and the distinct incentives of banks and firms to participate in zombie lending, focusing on Japan.

Our work also relates to the empirical research that studies the drivers of zombie lending. Prominent drivers are firm competition (Brunner et al., 2024), the capitalization of banks (Peek and Rosengren, 2005; Schivardi et al., 2021), capital-market conditions (Favara et al., 2022), and the size of capital injections (Giannetti and Simonov, 2013). Compared to these studies, however, we focus on the abundance of credit, encapsulated by the measure of tightness in the credit market. We show that tightness in credit market has a non-monotonic relationship with the share of zombie firms, resulting from the opposing forces of the opportunity costs of financial intermediation.

Finally, our results relate to the literature that studies the sources of boom-bust cycles, showing that those are linked to either price swings in the housing market (Jermann and Quadrini, 2012; Burnside et al., 2016; Mian et al., 2017; Garriga et al., 2019), dispersed information that generates phases of optimism and pessimism (Beaudry and Portier, 2004; Benhima, 2019), credit constraints under self-fulling expectations (Liu and Wang, 2014), the interplay of the economy and monetary policy (Christiano et al., 2008; Schularick and Taylor, 2012), or the revisions of the expectations about future growth (Brianti and Cormun, 2024; L'Huillier et al., 2024). Our analysis shows that credit market tightness may also generate phases with low and high shares of unprofitable firms that are consistent with boom-bust cycles.

Outline. The remainder of the paper is organized as follows. Section 2 develops our parsimonious model of frictional financial intermediation and formulates testable empirical predictions. Section 3 presents novel measures of credit market tightness, tests our theoretical predictions using industry-level data, and studies the effect of capital injections during the banking crisis in Japan in the early 2000s. Section 4 concludes.

2. A model of zombie firms

We develop a parsimonious model with search frictions in the credit market between banks and firms. The simple framework transparently shows that financial frictions lead banks to form relationships with unprofitable, low-productivity firms (zombies) that would not occur in a frictionless credit market. The model establishes three testable predictions: (i) the share of zombie firms has an inverted U-shaped relation with credit market tightness, (ii) an increase in the firm's bargaining power strengthens the reduction in the share of zombie firms when credit becomes abundant, and (iii) the effectiveness of capital injections to reduce the share of zombie firms increases with credit market tightness and elevated firm's bargaining power.. We will test these predictions empirically in Section 3.

Environment. The economy lasts two periods, $t = 1, 2$, and payoffs in the second period are discounted at the rate $\beta < 1$. In the first period, the economy starts with a large number of firms, indexed by $i \in (0, 1]$. Each firm has idiosyncratic productivity $z_{i,t}$ with cumulative density function $G(z)$ and draws a new idiosyncratic productivity in each period. At the beginning of each period, firms receive a random draw of idiosyncratic productivity $z_{i,t}$ from the distribution $G(z)$ and start production upon obtaining a loan from the bank. To manufacture output the firm incurs a fixed cost f. At the beginning of the first period, firms are matched with a bank, and each firm pays the interest rate $r_{i,t}$ for the loan. Output $\pi_{i,t}$ increases with the firm idiosyncratic productivity and the aggregate process A_t (that represents factors determining aggregate productivity), and decreases with the fixed costs of production, hence implying the following: $\partial\pi(z_{i,t}, A_t, f)/\partial z_{i,t} > 0$, $\partial\pi(z_{i,t}, A_t, f)/\partial A_t > 0$ and $\partial\pi(z_{i,t}, A_t, f)/\partial f < 0$.

Each bank posts a loan at the cost κ, and the probability of finding a firm depends on the *tightness* in the credit market θ, defined as the ratio between the number of loans offered by banks and the number of firms seeking to secure a loan. A high credit tightness (i.e., a large supply relative to the demand of loans) decreases the probability for banks to find a firm while it increases the probability for the firm of finding a bank. More formally, we assume that the probabilities of matching for firms and banks are strictly concave functions of credit market tightness. We define the matching probability for firms as $p(\theta)$, such that $p'(\theta) > 0$ since the availability of credit increases the firm's probability of forming a match. Similarly, the matching probability for banks is equal to $q(\theta)$, such that $q'(\theta) < 0$. We assume that matching happens in period 1 and credit market tightness is known to the bank and firm.

Upon forming a match, the interest rate on the loan $r_{i,t}$ splits the joint surplus of matching that accrues to the firm and the bank. The interest rate is set according to Nash bargaining, as we describe after defining the joint surplus.

Frictionless credit markets. We begin by deriving the equilibrium in the economy with a frictionless credit market, where the firm and the bank can form a relationship in each period at no cost. Firms and banks maintain relationships that yield a positive surplus that requires positive profits. The surplus for the firm comprises the income from the profits in each two periods, net of the costs for the loan, amounting to $\pi(z_{i,1}, A_1, f) - r_{i,1}$ for the first period, and $\pi(z_{i,2}, A_1, f) - r_{i,2}$ for the second period. The surplus for the bank comprises the income from the interest rate paid by the firm over the initial period: $r_{i,1}$.[3] Thus, the total surplus of the match is equal to $\pi(z_{i,1}, A_1, f)$ in the first period. To obtain an analytical solution for the productivity threshold that defines mutually profitable relationships associated with a non-negative total surplus, we assume that output is equal to productivity net of the fixed cost, $\pi(z_i, A_t, f) = z_i A_t - f$.[4] Thus, the threshold of idiosyncratic productivity below which a firm will decide to terminate production in the first period is equal to:[5]

$$\tilde{z}_{\text{no frictions},1} = \frac{f}{A_1}, \tag{1}$$

Equation (1) shows that the productivity threshold consistent with a non-negative joint surplus is equal to the effective fixed costs (i.e., the fixed cost in units of aggregate productivity) in the

[3] Without loss of generality, the determination of the interest rate becomes irrelevant for this frictionless economy.

[4] Without loss of generality we assume this function to be $\pi(z_{i,t}, A_t, f) = z_{i,t} A_t - f$. This production function arises in a firm dynamics framework as in Melitz (2003); Bilbiie et al. (2012); Hamano and Zanetti (2017) (see Appendix A). Alternative production functions with $\frac{\delta \pi}{\delta z_i} > 0$ and $\pi_i \in [-f, \infty)$ have the same implications.

[5] A similar condition holds for the cutoff level productivity in the second period.

frictionless economy. The intuition is straightforward: the bank provides the loan to the firm whose productivity is sufficiently high to cover the fixed costs of production, which ensures that the firm operates with non-negative profits. Unlike the frictional credit market that we consider in the next paragraph, the firm and bank only consider the current period in setting the threshold of productivity since the formation of a relationship is costless.

Frictional credit markets. We now consider an economy with search frictions between firms and banks in the credit market. As in the frictionless economy, the firms and banks establish a loan whenever the joint surplus from the match is non-negative. The frictions in the credit market are relevant to determine the threshold of idiosyncratic productivity. The joint surplus of maintaining a match is the sum of the value of the match for the firm and the bank, but it also accounts for the respective opportunity cost (or outside option) of remaining unmatched[6]. To obtain an analytical expression for the threshold of idiosyncratic productivity, we need to consider the value of being in and out of a financial relationship between firms and banks. We start by defining the value functions for the firm and the bank that constitute the joint surplus and then derive the threshold of idiosyncratic productivity in the frictional credit market that generates a non-negative joint surplus.

The value for a firm of matching with a bank, denoted with $v^m_{1,i}$, is equal to:

$$v^m_{1,i} = \pi(z_{i,1}, A_1, f) - r_{i,1} + \beta E(\pi(z_{i,2}, A_2, f) - r_{i,2}), \tag{2}$$

which is the sum of the discounted profits net of the interest paid to the bank for staying in the match for periods one and two. The value of an unmatched (idle) firm is equal to:

$$v^u_{1,i} = \beta p(\theta) E(\pi(z_{i,2}, A_2, f) - r_{i,2}), \tag{3}$$

where the unmatched firm gains zero payoffs in period one but finds a bank with probability $p(\theta)$ and earns the discounted profits $\beta(\pi(z_{i,2}, A_2, f) - r_{i,2})$ in period 2. The value of a loan for the bank ($v^l_{1,i}$) is equal to:

$$v^l_{1,i} = r_{i,1} + \beta E(r_{i,2}), \tag{4}$$

which is the sum of the interest rates earned by the bank in periods one and two. The value of

[6]Note here that we are assuming here, that the owners of the firm can repay the capital received from the bank when the relationship is severed in period 1 and then mothball the current firm to the next period to avoid current period losses, or find a new equivalent firm.

an unmatched bank is equal to:

$$v^{\pi}_{1,i} = -\kappa + \beta q(\theta)\beta E(r_{i,2}), \tag{5}$$

where the unmatched bank posts a loan offer at the cost κ in the first period, and finds a firm with probability $q(\theta)$ that pays the interest rate $r_{i,2}$ in the second period.

The interest rate splits the profits of production between the firm and the bank and is set according to the Nash bargaining rule. The bargaining weight for the firm is $\eta \in (0, 1)$ and the bargaining weight for the bank is $1-\eta$. In the second period, the firm and bank split the value of production according to Nash bargaining and therefore the interest rate is equal to the share of profits accruing to the bank that are equal to: $r_{i,2} = (1-\eta)\pi(z_{i,2}, A_2, f)$.[7] Zombie lending arises from the draw of new productivity that may enhance the profits of currently unprofitable firms, encapsulated by the assumption that the expected profits are positive in the second period (i.e., $E(\pi(z_{i,2}, A_2, f)) > 0$).[8]

The joint surplus of forming a match ($v^s_{1,i}$) is equal to:

$$\begin{aligned} v^s_{1,i} &= \underbrace{(v^m_{1,i} - v^u_{1,i}(\theta))}_{\text{Firm Surplus}} + \underbrace{(v^l_{1,i} - v^{\pi}_{1,i}(\theta))}_{\text{Bank Surplus}} && (6) \\ &= \pi(z_{i,1}, A_1, f) + \beta E(\pi(z_{i,2}, A_2, f)) + \kappa - \beta E(\pi(z_{i,2}, A_2, f))[q(\theta)(1-\eta) + p(\theta)\eta]. && (7) \end{aligned}$$

Equation (6) shows that the outside options for the firm and bank, $v^u_{1,i}(\theta)$ and $v^{\pi}_{1,i}(\theta)$, respectively, are critical to the effect of credit market tightness on the total surplus. Equation (7) is derived by substituting the values functions $\{v^m_{1,i}, v^u_{1,i}, v^l_{1,i}, v^{\pi}_{1,i}\}$ in equation (6) using equations (2)-(5) and the Nash bargaining rule for the interest rate.

Equation (7) shows that the joint surplus of forming a lending relationship is equal to the sum of the profits in the two periods, plus the saving of search costs accruing to the bank if the match is preserved (represented by the term κ in the equation). It is reduced by the expected profits of the firm and bank in the second period, which depends on the tightness in credit markets. The latter

[7] Though not necessary for our results, we can also solve for the first-period interest rate $r_{i,1} = (1-\eta)\pi(z_{i,1}, A_1, f) - \eta\kappa + \eta(1-\eta)\beta(q(\theta) - p(\theta))E(\pi(z_{i,2}, A_2, f))$.

[8] This assumption is consistent with firms operating in a monopolistically competitive goods market with stochastic and non-auto regressive productivities in equilibrium. The assumption captures the idea that, though the current profit of a firm could be negative, the expected present discounted value of the future profits is positive, which is needed for the firm to desire continued operation. We empirically demonstrate in Section X that zombie firms do indeed hold such positive expectations about future profits.

term represents the outside options for the firm and bank to leave the current lending relationship and obtain credit by forming a new match.

By setting the joint surplus equal to zero, we derive the threshold of productivity. Firms with idiosyncratic productivity above the threshold generate positive profits from the match; otherwise, the match is unprofitable. To obtain an analytical solution for the threshold, we assume, as in the frictionless economy, that the output is equal to $\pi(z_{i,t}, A_t, f) = z_{i,t}A_t - f$, and we derive the productivity threshold by setting the total surplus equal to zero ($v^s_{1,i} = 0$), yielding:[9]

$$\tilde{z}_{\text{frictions},1} = \frac{f - \kappa - \beta E\left\{\pi(z_{i,2}, A_2, f)[1 - (1-\eta)q(\theta) - \eta p(\theta)]\right\}}{A_1}. \quad (8)$$

Equation (8) shows that search frictions exert two distinct forces on the threshold of idiosyncratic productivity compared to the frictionless economy in equation (1). First, the *search costs* (κ) decrease the productivity threshold since the bank is prepared to match with a firm with a low productivity level to avoid a costly search. Thus, search costs generate zombie firms by lowering the threshold of idiosyncratic productivity compared to the case of the frictionless economy.

Second, the different *opportunity costs* for the bank and firm to forgo the match move the threshold in opposite directions. For the bank, the opportunity cost of being unmatched increases with tightness in the credit market, since high credit availability reduces the probability for the bank to find a loan-seeking firm. Therefore, the bank optimally decreases the required idiosyncratic productivity to increase the probability of matching. This effect is represented by the term $(1-\eta)\pi(z_{i,2}, A_2, f)q(\theta)$ (recall $q'(\theta) < 0$), thereby capturing the decrease in the share of profits accruing to the bank with tightness in the credit market. For the firm, the opportunity cost of not being in a loan contract decreases with tightness in the credit market since credit abundance ameliorates the probability of finding credit in the next period when the firm receives a new draw of idiosyncratic productivity. This second effect is captured by the term $\eta\pi(z_{i,2}, A_2, f)p(\theta)$ (recall $p'(\theta) > 0$), which shows that the share of profits accruing to the firm increases with tightness in the credit market. Thus, the opportunity costs for the firm and the bank exert opposing forces on the threshold value, generating a non-monotonic relationship between the threshold of idiosyncratic productivity and tightness.[10]

[9] Because there is no third period, the cutoff level productivity in the second period becomes the same as the one found in the frictionless economy.

[10] It is straightforward to verify that the threshold of idiosyncratic productivity in equation (8) nests the value

To derive analytical solutions and formulate testable implications for the effect of financial frictions on the share of zombie firms, we normalize aggregate productivity to 1 ($A_1 = A_2 = 1$) and assume independence between aggregate productivity and tightness in the credit market.[11] With these simplifying assumptions, the expectations of the firm's profits are constant and we label them $\bar{\pi}_2$ to ease notation.[12] In our new notation, the productivity threshold in equation (8) is:

$$\tilde{z}_{\text{frictions},1} = f - \kappa - \beta\bar{\pi}_2[1 - (1-\eta)q(\theta) - \eta p(\theta)]. \tag{9}$$

The next proposition summarizes the differences in the threshold of idiosyncratic productivity between the frictional and frictionless credit markets.

Proposition 1 (Productivity thresholds in frictional and frictionless credit markets)**.** *The threshold of idiosyncratic productivity needed by the firm to obtain a loan in frictional credit markets is lower than the threshold of idiosyncratic productivity in the frictionless credit market. Search frictions allow low-productivity firms with negative profits to receive credit and produce.*

Proof. Direct implication from $\tilde{z}_{\text{no frictions}} > \tilde{z}_{\text{frictions}}$, as implied by equations (1) and (9). Because $q(\theta)$ and $p(\theta)$ are between 0 and 1, $\pi(z_{i,1}) < 0 \ \forall \ z_{i,1} = \tilde{z}_{\text{frictions}}$. □

Zombie firms, credit market tightness, and bargaining power. The model allows us to study the extent to which the share of zombie firms is determined by: (i) the tightness in the credit markets (θ), and (ii) the bargaining power of firms (η).

Credit market tightness is critical to the firm's productivity threshold since it determines the matching probabilities and therefore the incentives for the bank and firm to form a credit relationship. The effect of a change of credit market tightness on the threshold of idiosyncratic

in the frictionless economy in equation (1) once we remove financial frictions by setting $\kappa = 0$ and $q = p = 1$.

[11] As shown in Appendix A.4, the results hold when we relax this assumption, although at the expense of involved analytical results.

[12] The survival of the firm across the two periods relies on the fact that $\bar{\pi}_2 > 0$, such that firms that have negative profits in the first period have expectations of positive profits in the second period. This assumption is satisfied in the model, as the domain of idiosyncratic productivity is R^+. We show in Appendix C that the expectation of positive profits is empirically validated.

productivity ($\tilde{z}_{\text{frictions}}$) is equal to:[13]

$$\frac{\partial \tilde{z}_{\text{frictions}}}{\partial \theta} \begin{cases} < 0, & \text{if } \eta p'(\theta)\bar{\pi}_2 < -(1-\eta)q'(\theta)\bar{\pi}_2 \;\; \Rightarrow \text{Zombie share increases in } \theta, \\ > 0, & \text{if } \eta p'(\theta)\bar{\pi}_2 > -(1-\eta)q'(\theta)\bar{\pi}_2 \;\; \Rightarrow \text{ Zombie share decreases in } \theta, \end{cases} \tag{10}$$

where $\bar{\pi}_2 > 0$, $q(\theta) > 0$, $p'(\theta) > 0$ and $q'(\theta) < 0$.

Condition (10) shows that tightness in the credit market exerts a non-monotonic influence on the threshold of idiosyncratic productivity. Tightness decreases the threshold when the marginal increase in the share of profits accruing to the firm is lower than the marginal increase in the share of profits accruing to the bank, as in the top inequality in condition (10). However, tightness increases the threshold when the marginal increase in the share of profits accruing to the firm exceeds the respective marginal increase to the bank's profits, as evidenced in the bottom inequality in condition (10).

The relative change in the probabilities of forming a relationship for the firm and bank determines the effect of tightness in financial markets on the threshold of idiosyncratic productivity. An increase in tightness results in a reduction in the threshold when tightness in the credit market is low and there is an abundance of firms searching for loans. In such a case, the share of profits accruing to the bank from the increase in tightness is larger than those to the firm. Since the bank has the incentive to maintain financial relationships with low-productivity firms to forgo search costs, the share of zombie firms increases when this effect prevails in the economy.

However, an increase in tightness results in a rise of the threshold when tightness is high and there is an abundance of banks searching for firms. In such an instance, the increase in profits accruing to the firm is larger than those to the bank so the share of zombie firms decreases.[14]

The next proposition summarizes the relationship between tightness in the financial markets and the share of zombie firms.

Proposition 2 (Credit market tightness and the share of zombie firms)**.** *Credit market tightness*

[13]The condition is obtained by differentiating equation (9) with respect to credit market tightness. When the productivity threshold increases the share of zombie firms decreases.

[14]The decrease in share of zombie firms is driven by the firm's incentives to avoid the high cost of borrowing when there is a high probability of forming a new match in the next period, and a new draw of idiosyncratic productivity may make the firm profitable and reduce the cost of borrowing.

has an inverted U-shaped relationship with the share of zombie firms. The increase in credit market tightness has two opposing effects on the share of zombie firms: (i) it provides incentives to the bank to lower the threshold of productivity to forgo the high search costs, raising the share of zombie firms, and (ii) it provides incentives to the firm to forgo the match, receive a new draw of idiosyncratic productivity, and seek to form a match in the next period when credit is abundant and search costs are low.

Proof. Direct implication from condition (10). □

Condition (10) also shows that bargaining power is critical to changes in the share of zombie firms in response to tightness in credit market. The next corollary establishes the link between bargaining power and the share of zombie firms.

Corollary 2.1. (Bargaining power and the share of zombie firms). *The change in the firm's bargaining power decreases the share of zombie firms when the probability of forming a match for the firm is higher than the probability for the bank (i.e., $p(\theta) > q(\theta)$). Otherwise, the share of zombie firms increases.*

Proof. Differentiating the threshold of idiosyncratic productivity in condition (10) with respect to the bargaining power yields:

$$\frac{\partial \tilde{z}_{\text{frictions}}}{\partial \eta} \begin{cases} > 0, & \text{if } p(\theta) > q(\theta) \Rightarrow \text{Zombie share decreases in } \eta, \\ < 0, & \text{if } p(\theta) < q(\theta) \Rightarrow \text{Zombie share increases in } \eta. \quad \square \end{cases} \tag{11}$$

The intuition from Corollary 2.1 is straightforward. Specifically, in a tight credit market with an abundance of credit and a high probability for the firm to form a match, the firm's surplus of forming a match significantly increases, thereby incentivizing the low-productivity firm to forgo costly financial intermediation while waiting to receive a new draw of productivity in the next period. Accordingly, the share of zombie firms decreases.

The next corollary shows that as tightness rises, the threshold of idiosyncratic productivity increases for any given level of the firm's bargaining power, thereby reducing the share of zombie firms in the economy since firms with low productivity forgo borrowing.

Corollary 2.2. (Interplay between bargaining power and tightness for the share of zombie firms).

An increase in the level of bargaining power amplifies the increase of the threshold of idiosyncratic productivity and therefore reduces the share of zombie firms in response to the rise in credit market tightness.

Proof. Direct implication from differentiating condition (11) with respect to tightness:

$$\frac{\partial^2 \tilde{z}_{\text{frictions}}}{\partial \eta \partial \theta} > 0 \quad \text{since} \quad p'(\theta) - q'(\theta) > 0. \quad \square \tag{12}$$

Corollary 2.2 states that the increase in the firm's bargaining power always raises the threshold of idiosyncratic productivity for an increase in credit market tightness, as shown by the positive sign of $\partial \tilde{z}_{\text{frictions}}/\partial \theta$ in condition (10). Corollaries 2.1 and 2.2 imply that a firm's high bargaining power increases the contribution of a change in credit market tightness to the threshold.

Corollary 2.2 underpins our empirical test aimed at establishing the relevance of bargaining power for the relationship between tightness and the share of zombie firms. In particular, we test whether an increase in credit market tightness exerts a higher decrease in the share of zombie firms in industries with high bargaining power compared to industries with low bargaining power.

2.1. A numerical illustration

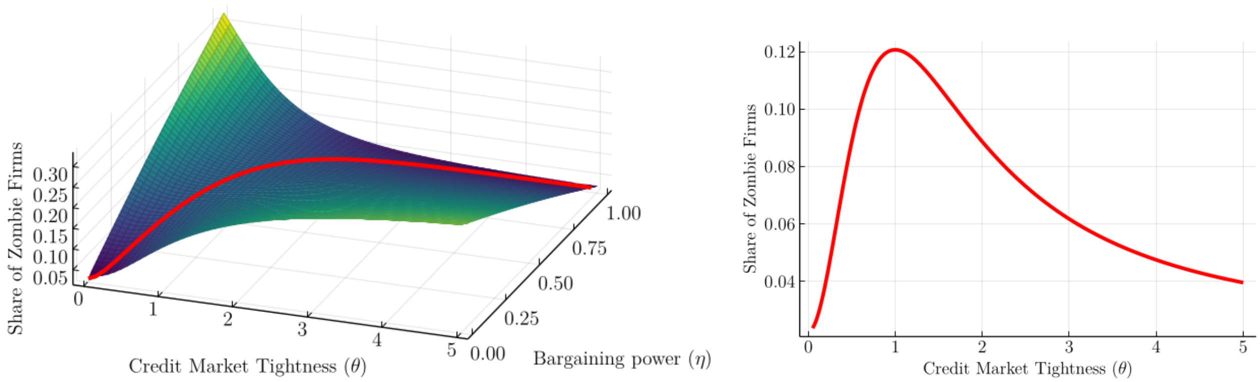
To show the quantitative relevance of our mechanisms, we simulate our model to study the inverted U-shaped relationship between the share of zombie firms and credit market tightness. We also study the interplay between bargaining power and credit market tightness resulting in the reduction in the share of zombie firms.

We assume that the matching function has constant elasticity of substitution (CES): $\mu V/(1 + \theta^l)^{\frac{1}{l}}$, such that the probabilities for the firm and bank of forming a match are equal to $p(\theta) = \theta(1 + \theta^\zeta)^{-1/\zeta}$ and $q(\theta) = (1 + \theta^\zeta)^{-1/\zeta}$, respectively, where V is the number of loans offered by banks to firms.[15] We calibrate the parameter ζ to the conventional value of 0.5 and set $\eta = \theta^l/(1 + \theta^l)$ such that the equilibrium satisfies the Hosios (1990) condition.[16] We assume a standard Pareto distribution for the idiosyncratic productivity shocks with cumulative distribution function: $G(z_{i,t}) = (\underline{z}/z_{i,t})^k$ where $\underline{z}$ is the lower cutoff of the distribution and $z_{i,t} > \underline{z}$. This

[15] As shown in Appendix A, our results continue to hold with the standard Cobb-Douglas matching function.

[16] For a CES matching function this strictly speaking introduces another dimension where bargaining power is as well a function of tightness. Appendix A shows that this assumption only strengthens the U-shaped relationship.

standard assumption for the distribution of firm productivity allows us to derive the closed-form solution for the share of zombie firms equal to $1 - (z_s/z_{zo})^k$, where z_{zo} is the threshold of idiosyncratic productivity in the frictionless credit markets (determined by equation 1) and z_s is the threshold of idiosyncratic productivity in the frictional credit markets (determined by equation 9). We set the distribution parameter k equal to 3.4 to replicate the standard deviation of the firm turnover (see Ghironi and Melitz, 2005; Bilbiie et al., 2014; Hamano and Zanetti, 2017, 2022). We set the discount factor β to the standard value of 0.99, the cost of posting a loan κ to 0.01, and the fixed cost of production f to 1.5.[17] In Figure 1, we consider values for credit market tightness and bargaining power within ranges $\theta \in [0.01, 5]$ and $\eta \in [0.01, 0.99]$.



(a) Zombie share, credit market tightness and bargaining power.

(b) Zombie share and credit market tightness when bargaining power is efficient.

Figure 1: Numerical illustration of the share of zombie firms

Notes: Shown in Figure (a) are the zombie share (z-axes) against credit market tightness (θ, x-axes) and the firm's bargaining power (η, y-axes) under a CES matching function. The red line shows the share of zombie firms when the Hosios (1990) condition holds. Shown in Figure (b) is the share of zombie firms under the Hosios condition.

Figure 1a shows the variation in the share of zombie firms (z-axes) with respect to credit market tightness (θ, x-axes) and the firm's bargaining power (η, y-axes). The red line shows the points that satisfy the Hosios condition. Consistent with Proposition 1, the increase in credit tightness significantly raises (decreases) the share of zombie firms for the levels of tightness that satisfy condition (10). Consistent with Corollary 2.1, the share of zombie firms is high for firms with low bargaining power. Figure 1b shows the variation in the share of zombie firms and credit market tightness under the Hosios condition. The figures show a significant inverted U-shaped relationship between credit market tightness and the share of zombie firms.

[17] These values are chosen to generate positive expected profits in the second period ($\bar{\pi}_2 = (1/f)^{\zeta}[f(\zeta/(\zeta-1)) - f]$).

The numerical simulations show that the theoretical predictions are quantitatively impactful. The next section empirically appraises these theoretical predictions using industry-level data from Japan.

3. Empirical analysis

This section begins with constructing our new data. It studies the effect of changes in credit market tightness on the share of zombie firms to test the inverted U-shaped relationship between the share of zombie firms and tightness in the credit market (Prediction 1). It then tests whether the increase of firm's bargaining power reduces the share of zombie firms in response to a rise in credit market tightness (Prediction 2). Finally, it studies the link between credit market tightness and the effectiveness of capital injections during the Japanese banking crisis in the late 1990s.

3.1. Data

Our main variables of interest are the measure of zombie firms, the theory-consistent measures of credit market tightness, bargaining power, and industry-level productivity. We construct measures for these variables by combining several different sources drawn across 31 industries in Japan for the period 2000-2019.[18]

We construct the share of zombie firms ($\texttt{ZombieRatio}_{it}$) for industry i in period t using the Nikkei Financial Quest dataset that provides information on the annual financial statements of listed firms in Japan. We classify zombie firms at the firm level using the criterion from Caballero et al. (2008) (CHK, hereafter). They define a lower-bound rate of interest payments for high-quality-borrowing firms and classify zombie firms as those charged with an interest rate below the lower-bound. Using the same criterion, we construct the share of zombies for each industry using the classification in the Nikkei dataset.[19] Panels (a) and (b) in Figure 2 show the aggregate measure of the share of zombie firms and the industry-level share of zombie firms, respectively.

We construct theory-consistent measures of credit market tightness from the difference between

[18] Appendix B provides a detailed discussion of the data sources. The data from the Demand for Loans DI starts in 2000, which constrains the beginning of our sample period.

[19] Our theoretical characterization of zombie firms is consistent with the empirical definition. In our model, zombie firms have negative profits in the first period, as stated in Proposition 1. Despite the negative profits, zombie firms remain in the economy and produce with the financial support from the bank.

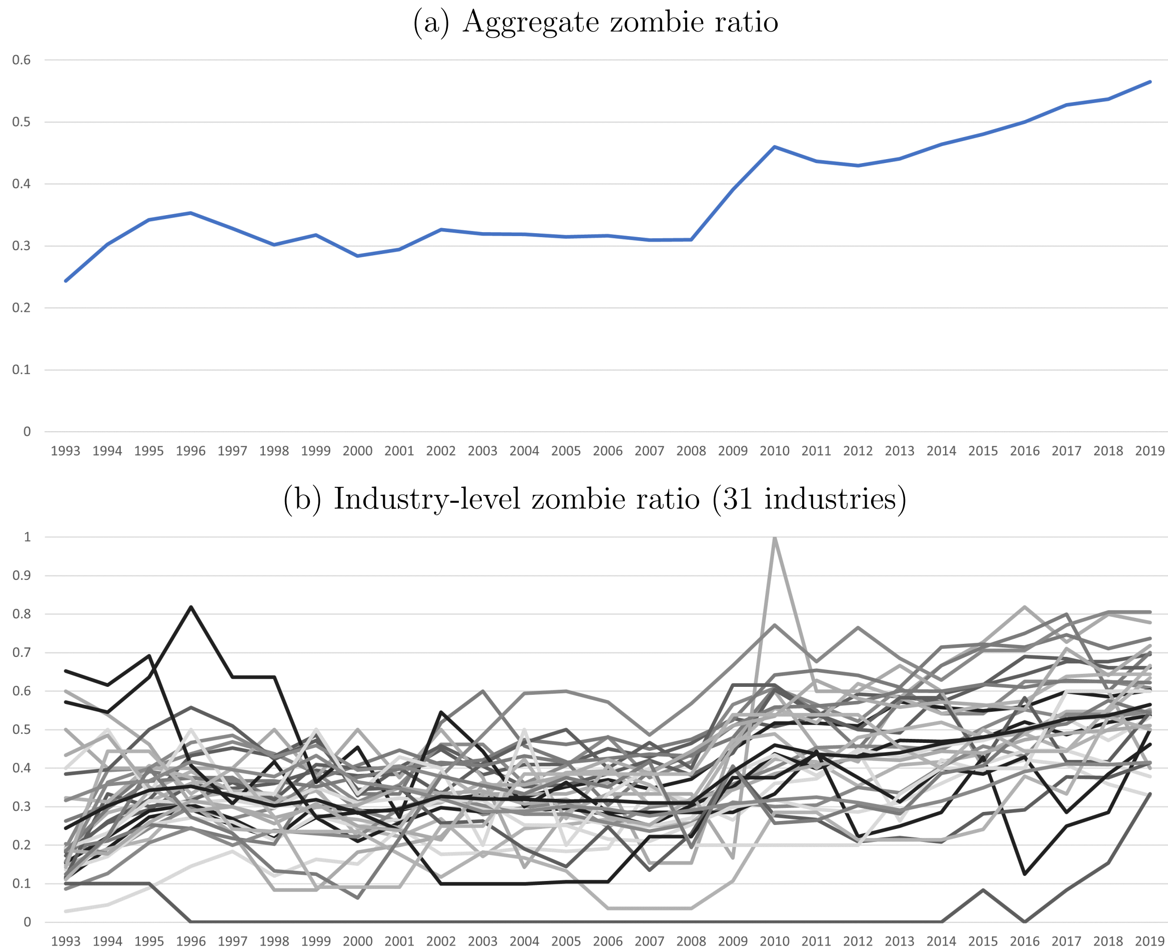


Figure 2: Time series plot of the zombie ratio (`ZombieRatio`)

the supply of and demand for loans. The demand for loans is from the Loan Survey or the Tankan Survey and the supply of loans is from the Tankan Survey. The Bank of Japan administer both of these surveys. We construct industry-level credit market tightness measures using the classification of the Bank of Japan and convert them into the measures based on the Nikkei industry classification that are consistent with our classification. We construct two indices of credit market tightness. The first index of credit market tightness –that we refer to as `Tightness1`– is defined as follows:

$$\texttt{Tightness1} = \text{Lending Attitude DI} - \text{Demand for Loans DI},$$

where the Lending Attitude DI is from the Tankan Survey and the Demand for Loans DI is from the Loan Survey. Our second and alternative index of credit market tightness –that we refer to as Tightness2– is defined as follows:

$$\texttt{Tightness2} = \text{Lending Attitude DI} - \text{Financial Position DI},$$

where the Lending Attitude DI and the Financial Position DI are from the Tankan Survey. The Index Tightness1 is our preferred index since the Demand for Loans DI in the Loan Survey measures accurately the firm's demand for loans. The Financial Position DI in the Tankan Survey is less accurate, though, as it also includes characteristics unrelated to loan demand.[20] We convert the series to annual frequency to make them consistent with the annual frequency of the zombie ratio. Panels (a) and (c) of Figure 3 show aggregate measures of Tightness1 and Tightness2, respectively, across the 31 industries for the period 2000-2019. We observe a small drop in 2003 and a large decline in 2008 for Tightness1. In contrast, we observe two small decreases: one during the 2002-2003 period and the other during the 2008-2009 period for Tightness2. Panels (b) and (d) of Figure 3 show industry-level measures of Tightness1 and Tightness2, respectively, for all the 31 industries. For Tightness1, a common drop in 2008 is noteworthy. On the whole, there is a large dispersion across the 31 industries for both measures of tightness.

Since we need to control for the firm performance at the industry level in the estimations, we construct a measure of the productivity from two vintages of the Japan Productivity Database, JIP2014 and JIP2023, which respectively covers the period of 1970-2011 and 1994-2020. For our analysis we employ JIP2014 for 2000-2011 and JIP2023 for 2012-2019. [21] We obtain a measure of nominal labor productivity from the ratio of nominal value added produced in industry i to labor-hours in the same industry.

We construct the series for bargaining power using data from the Nikkei Financial Quest. We measure the firm's bargaining power as follows:

$$\texttt{BP1} = \frac{\text{operating profits} - \text{interest payment}}{\text{operating profit}}, \quad \text{and} \quad \texttt{BP2} = \frac{\text{operating profits} - \text{interest payment}}{\text{total sales}}. \tag{13}$$

The variables BP1 and BP2 encapsulate the fact that firms with high bargaining power retain a

[20]Demand for Loans DI primarily contains information on the demand for loans. Financial Position DI reflects a firm's judgment on the following three different aspects of its financing: the level of its liquidity holdings, the lending attitude of financial institutions, and the terms and conditions of a firm's financing, some of which are unrelated to its loan demand.

[21]See Appendix B for details on the series.

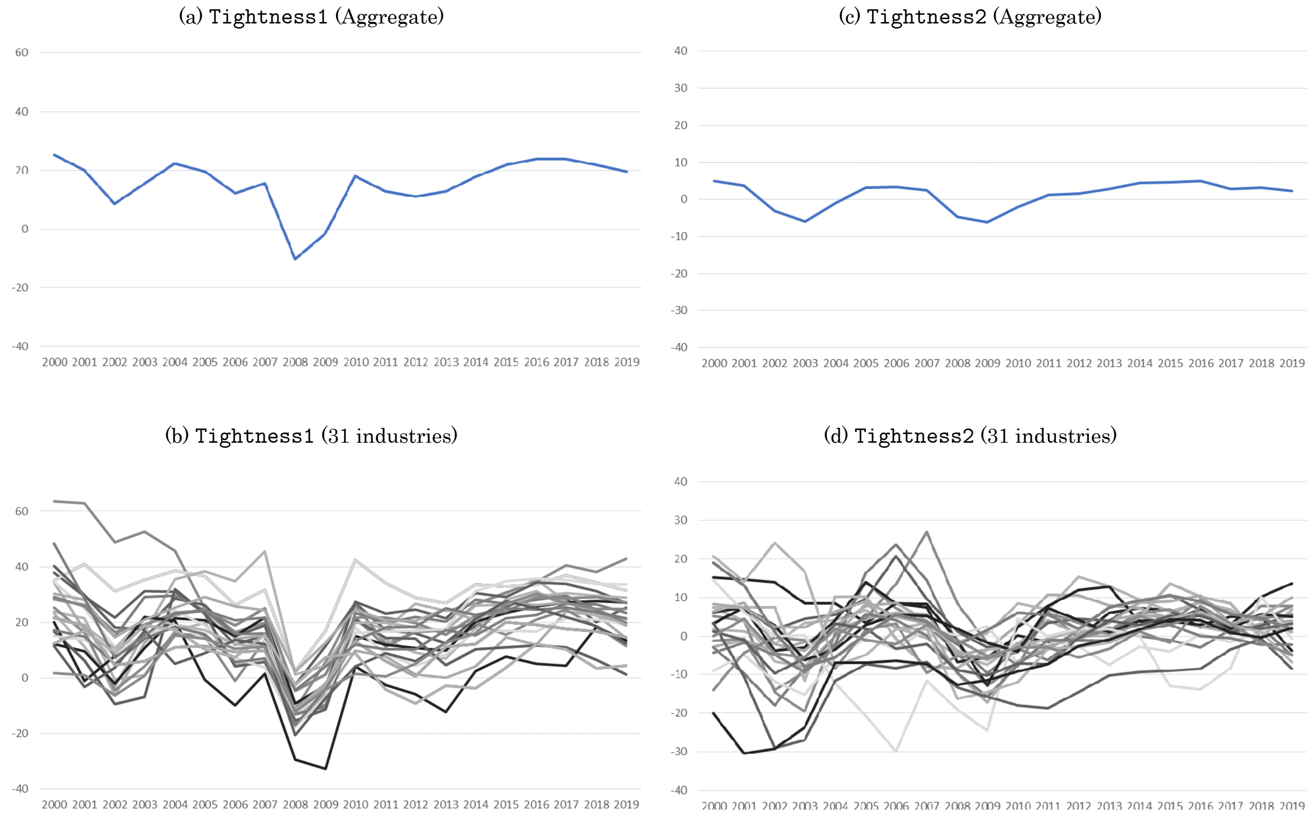


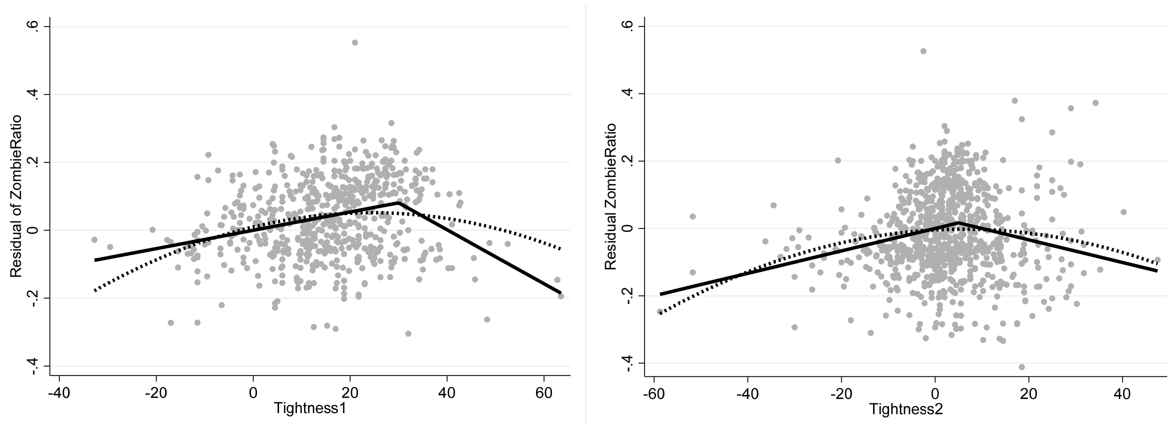
Figure 3: Time series plot of the credit market tightness

large differential between operating profits and interest payments. We construct an annual dataset of these variables for the 31 industries using the Nikkei Industry Classifications for our sample period.

3.2. Credit market tightness and zombie firms

We first focus on the link between credit market tightness and the share of zombie firms and test the inverted U-shaped relationship between the share of zombie firms and credit market tightness.

Preliminary evidence. Figure 4 shows the scatterplot of the share of zombie firms and our measures of credit market tightness `Tightness1` (left panel) and `Tightness2` (right panel), fitting a quadratic polynomial (dotted line) and a kinked line (solid line). The fitted lines show an inverted U-shaped relationship between credit market tightness and the share of zombie firms. Consistent with our theory, the share of zombie firms initially increases with the rise in credit market tightness and it decreases past a level of credit market tightness. We test the relationship empirically using the two alternative econometric approaches based on: (i) the threshold, and (ii) quadratic regression models.



Notes: The left panel shows the scatter plot for credit market tightness (`Tightness1`) and the share of zombie firms (`ZombieRatio`), after controlling for other determinants, along with fitted quadratic (solid line) and kinked (dotted line) polynomials. The left panel shows the scatter plot for our alternative measure of credit market tightness (`Tightness2`) and the share of zombie firms (`ZombieRatio`), after controlling for other determinants, along with fitted quadratic (solid line) and kinked (dotted line) polynomials.

Figure 4: Credit market tightness and share of zombie firms

Threshold regression model. To test the inverted U-shaped relationship and the non-monotonicity between credit market tightness and the share of zombie firms, we estimate the following threshold regression model:

$$\texttt{ZombieRatio}_{it} = \beta_0 + \beta_1\theta_{it} + \beta_2(\theta_{it} - \theta^*) \times I(\theta_{it} > \theta^*) + \beta_3 A_{it} + \phi_i + \varepsilon_{it}, \tag{14}$$

where $\texttt{ZombieRatio}_{it}$ is share of zombie firms, θ_{it} is credit market tightness (measured by one of our variables, either `Tightness1`, or `Tightness2`), θ^* is the threshold value for credit market tightness, A_{it} is the labor productivity, ϕ_i is the industry-specific effect, and ε_{it} is the error term. We select the threshold value of credit market tightness (θ^*) that generates the highest fit of the regression and is within the range of values for tightness in our sample.[22] We test the inverted U-shaped relationship between the zombie ratio and credit market tightness from the values of the parameters β_1 and β_2. To validate empirically the inverted U-shaped relationship between credit market tightness and the share of zombie firms we need a positive estimate for β_1 and a negative estimate for $\beta_1 + \beta_2$. With those estimates, the rise in credit market tightness increases

[22] The threshold value of credit market tightness, θ^*, is estimated by searching for a value over the entire range of sorted observations θ_{it} that minimizes the sum of the squared residuals. We estimate the model following the procedure in Hansen (1999). The range for the threshold value θ^* in `Tightness1` is between -32.75 and 63.50 and that for `Tightness2` is between -30.50 and 27.00, as shown in Table B.1 in Appendix B.

the share of zombie firms when tightness is below the estimated threshold θ^*. However, it reduces the share of zombie firms when tightness exceeds the threshold.

Table 1: Zombie ratio and tightness: threshold regression model

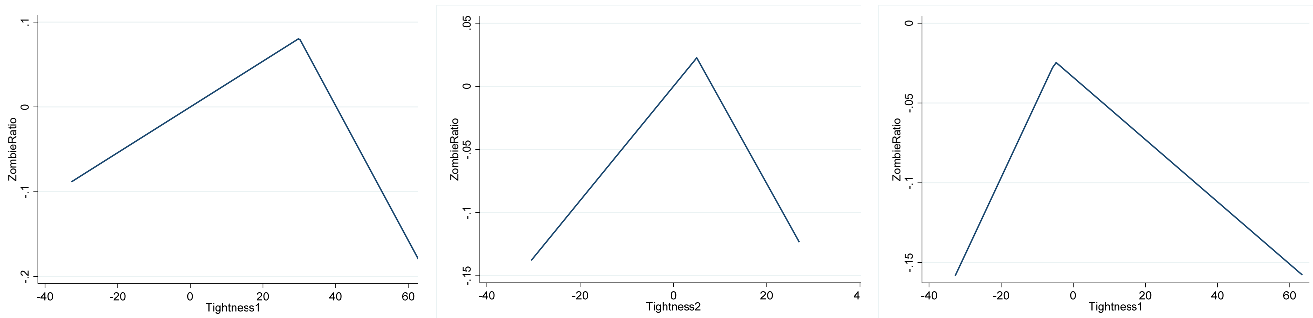
Dependent variable: `ZombieRatio`				
	(1)	(2)	(3)	(4)
CMT measure:	`Tightness1`	`Tightness1`	`Tightness2`	`Tightness1`
β_1	0.00270***	0.00327***	0.00436***	0.00524***
	(0.000476)	(0.000471)	(0.000937)	(0.00113)
β_2	-0.0106***	-0.0110***	-0.0118***	-0.00716***
	(0.00202)	(0.00205)	(0.00207)	(0.00143)
Control	Yes	No	Yes	Yes
θ^*	30.00	29.00	5.75	-5.75
Sample period	Full	Full	Full	2000-2009
Observations	620	620	620	310
R-squared	0.550	0.527	0.540	0.692

Notes: Standard errors are in parentheses. The symbols ***, ** and * denote statistical significance at the one percent, five percent and ten percent levels, respectively. The estimation period is from 2000 to 2019, except for column (4) where the estimation period is from 2000 to 2009.

Column (1) of Table 1 shows the baseline results when we control the regression with labor productivity.[23] The entries reveal that the coefficient β_1 on `Tightness1` is positive for values below the estimated threshold value of 30, thereby establishing that the zombie ratio increases by 0.27 percentage points in response to a one-point increase in our tightness index when tightness is lower than the estimated threshold. Consistent with our theoretical results, the change in tightness above the threshold negatively contributes to the share of zombie firms, thus reducing it by a 0.79 percentage points for a one-point increase in the tightness index ($-0.0079 = 0.00270 - 0.0106$). These estimates establish that an increase of one standard deviation in credit market tightness *increases* the zombie ratio by about 3.5 percentage points when the tightness is lower than the estimated threshold but that the same increase in tightness *decreases* the share of zombie firms by about 10 percentage points when tightness is higher than the threshold. Central to our results, the magnitude of the changes in the share of zombie firms is statistically significant and economically relevant. Figure 5 (left panel) shows the relationship between the zombie share and credit market tightness from our estimates in column 1 of the table. The positive slope below the threshold of tightness is determined by the estimate of β_1, the negative slope above the threshold is determined

[23] We obtain similar results using the real labor productivity or nominal unit labor costs as control variables.

by the sum of the estimates of β_1 and β_2, and the value at the kink is from the estimated threshold θ^*.



Notes: The left, middle and the right panels show the relationship between the share of zombie firms using the estimates in columns (1), (3) and (4) of Table 1, respectively. The positive slope before the threshold of tightness is from the estimate of β_1, negative slope after the threshold is sum of the estimates of β_1 and β_2, and the maximum value of the zombie ratio is obtained by setting tightness at the estimated threshold θ^*.

Figure 5: The credit market tightness and the zombie ratio in the threshold specification

Columns (2) of Table 1 shows the estimates for the regression that omits the control variables. The estimates are similar to our benchmark estimation in column (1), showing same significance and magnitude for the coefficients β_1 and β_2 that capture the effect of credit market tightness on the zombie share. These findings corroborate the central result of the inverted U-shaped relation between tightness and the zombie ratio. The estimated threshold of the tightness is equal to 29 and is slightly lower than the benchmark estimation.

Column (3) shows the results when we use the alternative measure of credit market tightness `Tightness2`. The estimated threshold value is 5.75 and the relationship between credit market tightness and the zombie ratio robustly remains an inverted U-shape. A one standard deviation increase in tightness generates a 3.5 percentage point rise in the share of zombie firms when tightness is lower than the threshold. The same rise in tightness generates a 5.1 percentage point decrease in the share of zombie firms when tightness exceeds the threshold. The middle panel of Figure 5 shows the estimated inverted U-shaped relation for the alternative tightness measure `Tightness2`.

Finally, column (4) in Table 1 shows the estimates for the shorter period 2000-2009, which excludes the second half of the sample period when the zombie ratio rose steadily in response to the global financial crisis. The estimates show that the inverted U-shaped relationship between credit market tightness and the zombie ratio is robust and that the estimated threshold is equal to -5.75. The lower estimate for the threshold is expected. This is because the share of zombie firms is substantially higher in the second half of the sample as a result of the financial crisis. The right panel of Figure 5 shows that the estimates for the shorter sample period are similar to the benchmark results.

Quadratic regression model. To ensure that our results are independent from the econometric approach and the specification of the threshold regression model, we use a quadratic regression model that allows us a direct econometric test for the inverted U-shaped relationship between credit market tightness and the share of zombie firms. To formally test the inverted U-shaped relationship formally, we estimate the following regression:

$$\texttt{ZombieRatio}_{it} = \beta_0 + \beta_1\theta_{it} + \beta_2\theta_{it}^2 + \beta_3 A_{it} + \phi_i + \varepsilon_{it}. \tag{15}$$

To interpret the results of our estimation, we rewrite the equation (15) as follows:[24]

$$\texttt{ZombieRatio}_{it} = \beta^* + \beta_2(\theta_{it} - \theta^*)^2 + \beta_3 A_{it} + \phi_i + \varepsilon_{it} \tag{16}$$

where $\beta^* = \beta_0 - \beta_2(\theta^*)^2$ and $\theta^* = -\beta_1/(2\beta_2)$. Both equations (15) and (16) provide exactly the same model with the same degree of freedom. We estimate equation (15) but reparametrize the estimated equation to equation (16), which is more informative on the shape of the nonlinear function. For example, the presence of the industry-specific effect ϕ_i in equation (16) implies that the extremum of (the predicted) zombie ratio varies across industries, which corresponds to $\beta^* + \phi_i$. We are particularly interested in the estimate for θ^* that maximizes, or minimizes, the share of zombie firms. The estimate for θ^* in equation (16) is the empirical counterpart to the threshold of credit market tightness in our threshold regression model in equation (14). However, in principle, it can also be negative, thereby implying a U-shaped (instead of an inverted U-shaped) relationship between share of zombie firms and credit market tightness. Thus, our empirical test is agnostic on whether the non-monotonic relationship has a U- or an inverted U-shape.

[24]We derive the equation as follows:

$$\begin{aligned}\beta_0 + \beta_1\theta_{it} + \beta_2\theta_{it}^2 &= \beta_0 - \beta_2 2(-\beta_1/(2\beta_2))\theta_{it} + \beta_2\theta_{it}^2 = \beta_0 - \beta_2 2\theta^*\theta_{it} + \beta_2\theta_{it}^2 = \beta_0 + \beta_2(\theta_{it}^2 - 2\theta^*\theta_{it}) \\ &= \beta_0 - \beta_2(\theta^*)^2 + \beta_2(\theta_{it}^2 - 2\theta^*\theta_{it} + (\theta^*)^2) = \beta_0 - \beta_2(\theta^*)^2 + \beta_2(\theta_{it} - \theta^*)^2 = \beta^* + \beta_2(\theta_{it} - \theta^*)^2\end{aligned}$$

More practically, if the estimate for β_2 in equation (15) is positive, the model implies that the share of zombie firms is a (strictly) convex function of credit market tightness. In this case, the estimate θ^* corresponds to the minimum point, evincing a U-shaped relationship between the share of zombie firms and credit market tightness. In contrast, if the estimate for β_2 is negative, the estimate θ^* corresponds to the maximum point. Equations (15) and (16) infer that the share of zombie firms is a (strictly) concave function of credit market tightness. In this case, the share of zombie firms and credit market tightness have an inverted U-shape relationship, as our theory predicts. We test the hypothesis of the inverted U-shape using the test in Lind and Mehlum (2010) that requires the following: (i) a positive coefficient for β_1, (ii) a negative coefficient for β_2, and (iii) the estimate for θ^* to be within the range of values for tightness in our sample.[25]

Table 2: Zombie ratio and tightness: quadratic regression model

Dependent variable: `ZombieRatio`				
	(1)	(2)	(3)	(4)
CMT measure:	`Tightness1`	`Tightness1`	`Tightness2`	`Tightness1`
β_1	0.00323***	0.00381***	0.00128*	4.61e-05
	(0.000725)	(0.000785)	(0.000737)	(0.000517)
β_2	-6.52e-05***	-7.15e-05**	-0.000142***	-4.75e-05***
	(2.64e-05)	(2.80e-05)	(6.59e-05)	(1.90e-05)
Control	Yes	No	Yes	Yes
θ^*	24.758	26.635	4.495	0.485
U-shape test	2.52***	2.55***	2.47***	2.49***
Sample period	Full	Full	Full	2000-2009
Observations	620	620	620	310
R-squared	0.539	0.508	0.530	0.688

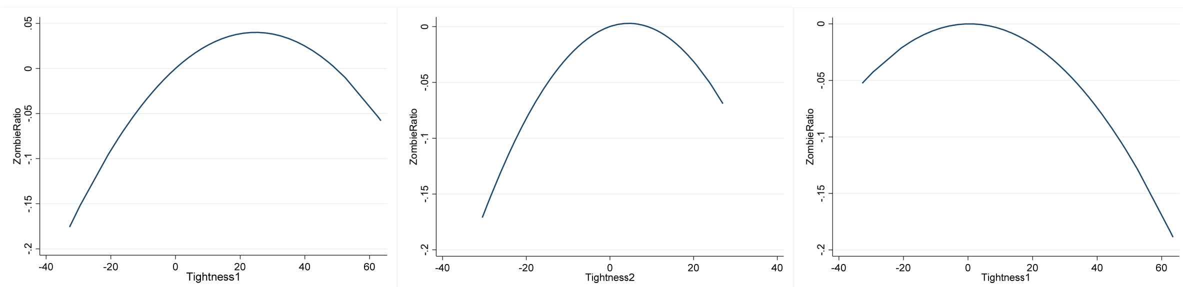
Notes: Standard errors are in parentheses. ***, ** and * denote statistical significance at the one percent, five percent and ten percent levels, respectively. The estimation period is from 2000 to 2019, except for column (4) where the estimation period is from 2000 to 2009. The U-shape test of Lind and Mehlum (2010) shows t-test statistic for the null hypothesis of monotone or U-shaped function against the alternative hypothesis of an inverted U-shaped function.

Table 2 shows the estimates for equation (15). Column (1) shows that the test satisfies the conditions for the inverted U-shape since the coefficient on the linear term β_1 and the square term β_2 are positive and negative, respectively, and the estimates for θ^* is within the range of values

[25] To establish the inverted U-shape relation, Lind and Mehlum (2010) propose a test for the null hypothesis of a non-positive slope at the lower end of the explanatory variable and/or a non-negative slope at the higher end of the explanatory variable against the combined alternative hypothesis of a positive and a negative slope at the lower and higher end of the explanatory variable, respectively.

for tightness in the sample. The last row, labeled 'U-shape test,' reports the statistics for the Lind and Mehlum (2010) test. It shows that the null hypothesis that the relationship between tightness and zombie share is U-shaped is strongly rejected against the alternative hypothesis that the relationship is the *inverted* U-shape, consistent with our theory. Columns (2)-(4) consider alternative specifications of the regression, showing that findings of the test robustly support the inverted U-shaped relationship between credit market tightness and share of zombie firms.

Figure 6 shows the estimated inverted U-shaped relation between credit market tightness and the zombie ratio from the estimates of the quadratic regression model. The left, middle and right panels show the plots from estimates in column (1), (3) and (4) of Table 2, respectively.



Notes: The left, middle and right panels show the function from the estimates in columns (1), (3) and (4) of Table 2, respectively.

Figure 6: The credit market tightness and the zombie ratio in the quadratic specification

3.3. Bargaining power and zombie firms

We now test our theoretical prediction to establish whether an increase in a firm's bargaining power strengthens the reduction of the share of zombie firms when credit market tightness rises.

We test the link between zombie firms and firm's bargaining power by exploiting the cross-sectional variation in the bargaining power of firms across the different industries in our sample. We do so by studying the statistical differences in the relationship between credit market tightness and share of zombie firms between industries with high and low firm bargaining power. We pool observations belonging to the highest tail of the bargaining power above the 90th percentile and those belonging to the lowest tail below the 10th percentile and estimate the following regression model:

$$\texttt{ZombieRatio}_{it} = \beta_0 + \beta_1\theta_{it} + \beta_2\theta_{it} \times I(\texttt{BP}_{it} = High) + \beta_3 I(\texttt{BP}_{it} = High) + \beta_4 A_{it} + \phi_i + \varepsilon_{it}, \quad (17)$$

where $\mathtt{BP}_{it}$ is one of our measures `BP1` or `BP2` of the firm's bargaining power. For our prediction to hold empirically, the industries with high firm bargaining power have a negative relationship with credit market tightness while industries with low firm bargaining power have a positive relationship with the credit market tightness. Thus, the estimate of β_2 is negative if share of zombie firms declines in response to an increase of tightness in industries with high bargaining power.

Table 3: Zombie ratio regression results: impact of bargaining power in the linear specification

Dependent variable: `ZombieRatio`				
	(1)	(2)	(3)	(4)
CMT measure:	`Tightness1`	`Tightness1`	`Tightness2`	`Tightness2`
BP measure:	`BP1`	`BP2`	`BP1`	`BP2`
β_1	0.00358***	0.00459***	0.00588***	0.00610**
	(0.00120)	(0.00132)	(0.00224)	(0.00266)
β_2	-0.00165	-0.00327*	-0.00606*	-0.00427
	(0.00186)	(0.00187)	(0.00316)	(0.00347)
β_3	0.0388	0.0565	0.0694	0.0643
	(0.0692)	(0.0644)	(0.0627)	(0.0588)
Observations	124	124	124	124
R-squared	0.796	0.634	0.788	0.611

Notes: Standard errors are in parentheses. ***, ** and * denote statistical significance at the one percent, five percent and ten percent levels, respectively. Estimation period is from 2000 to 2019.

Table 3 shows the estimation results. Tightness has a positive and significant relation with share of zombie firms across the different degrees of the firm's bargaining power, as shown by the positive coefficients for `Tightness1` and `Tightness2` in columns (1)-(4). The coefficient of the interaction terms, β_2, is negative and significant in columns (2) and (3), which is consistent with our theoretical prediction that high firm's bargaining power is associated with a lower share of zombie firms. Thus, industries with high firm's bargaining power have a lower incidence of zombie firms for an increase in credit market tightness than industries with low firm bargaining power.

To summarize, the empirical results corroborate our theory. Specifically, they reveal: (i) an inverted U-shaped relationship between credit market tightness and the share of zombie firms, and (ii) the magnitude of an increase in the zombie ratio consequent to the increase in credit market tightness is smaller for industries with high firm bargaining power. These results empirically verify our Predictions 1 and 2.

3.4. Capital injections and zombie firms

In this final section, we study the effect of exogenous capital injections – an increase in credit market tightness – on the share of zombie firms. We are interested in testing whether the effectiveness of an exogenous capital injection to reduce the share of zombie firms depends on the level of credit market tightness. Our theory predicts that capital injection successfully reduces the share of zombie firms for a sufficiently high level of tightness. However, it increases the share of zombie firms when tightness in the credit market is low. We test the theoretical prediction with granular firm-level data, studying the numerous capital injections during the banking crisis in Japan in the late 1990s and early 2000s.

During the crisis, the Japanese government recapitalized several banks with targeted policy interventions.[26] The size of the recapitalizations and the financial conditions differed considerably among the beneficiary banks. This heterogeneity in the policy intervention allows us to identify the impact of capital injections on share of zombie firms. We interpret the recapitalization of banks as an exogenous shock that relaxes the banks' financial constraint and increases the availability of credit to firms while raising credit market tightness.

We use data on bank relationships and the amount of outstanding loans for the universe of Japanese-listed firms from the Nikkei Financial Quest dataset. To study the effect of bank recapitalization on firms, we identify the firms that transacted with the recapitalized banks and quantify the exposure of those firms to the capital injection. We test whether the increase in credit market tightness induced by the capital injections to banks had a significant impact on the share of zombie firms.[27]

We test our theory by estimating the following regression:

$$\begin{aligned} \texttt{ZombieDum}_{it} &= \beta_0 + \beta_1 \texttt{Injection}_{ikt} \times \theta_{jt} + \beta_2 \texttt{Injection}_{ikt} + \beta_3 \theta_{jt} \\ &\quad + \texttt{IndustryFE}_j + \texttt{YearFE}_t + u_{ikt}, \end{aligned} \tag{18}$$

where $\texttt{ZombieDum}_{it}$ is an indicator variable for the zombie status that takes the value of one if firm

[26]See Appendix D for the list of banks that received capital injections.

[27]Though Giannetti and Simonov (2013), Nakashima (2016), and Montgomery and Shimizutani (2009) examine the effect of bank capital injections on bank lending in Japan, we are the first to study the link between the effectiveness of capital injection to credit market tightness and zombie lending.

i is identified as a zombie firm according to the CHK criterion and zero otherwise, $\texttt{Injection}_{ikt}$ represents the exposure of firm i to a capital injection to the partner bank k at time t. In equation (18), we use the indicator variable that is equal to one if the bank receives a capital injection in year t and zero otherwise. The variable θ_{jt} is our measure of tightness in the firm-specific industry j, described in Section 3. We use the measure of tightness `Tightness2` since the sample period for the variable covers the major capital injections in Japan during 1998-2003.

Consistent with Prediction 1, we expect the capital injection to reduce the share of zombie firms when credit market tightness is elevated. However, the same capital injection increases the share of zombie firms when credit market tightness is low. From the lens of our regression equation (18), we expect coefficients β_1 and β_2 to be negative and positive, respectively, for our theory to hold empirically.

Table 4: Zombie firms, tightness and capital injection

Dependent variable: `ZombieDum`				
	(1)	(2)	(3)	(4)
CMT measure:	`Tightness2`	`Tightness2`	`Tightness2`	`Tightness2`
Injection lag:	0	0	1	1
β_1	-0.00130***	-0.000810***	-0.000713**	-0.000754***
	(0.000237)	(0.000187)	(0.000307)	(0.000243)
β_2	0.0152***	0.00334	0.0340***	0.0155***
	(0.00439)	(0.00347)	(0.00381)	(0.00298)
β_3	0.000229**	0.000565***	0.000384***	0.000587***
	(0.000102)	(8.57e-05)	(0.000109)	(9.11e-05)
Industry FE	Yes	No	Yes	No
Firm FE	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	565,421	565,421	492,642	492,642
R-squared	0.085	0.445	0.092	0.459

Notes: Standard errors are in parentheses. The symbols ***, ** and * denote statistical significance at the one percent, five percent and ten percent levels, respectively. The estimation period is from 1998 to 2019.

Column (1) of Table 4 shows a high and significant relationship between the firm's exposure to capital injections and zombie status. The coefficient β_2 on the indicator variable for the firm's exposure to the capital injection –which indicates that the bank with which a firm deals receives a capital injection in the year– is positive and significant. The results show that a firm is more likely to become a zombie when linked to a bank that is a beneficiary of capital injection. The coefficient β_1 on the interaction term between exposure and credit market tightness is negative and significant, indicating that the increase in credit market tightness weakens the link between capital injection and the proliferation of zombie firms. These findings corroborate our theory. In particular, they demonstrate that the effectiveness of the capital injection in reducing the share of zombie firms increases in a tight credit market when firms have easy access to credit. Our results are consistent with Acharya et al. (2021) who show that strong capital injections are needed to decrease the incidence of zombie firms.

To ensure that our results are robust, columns (2)-(4) show the estimates for alternative specifications of the model that control for firm-fixed effect and the inclusion of a one-year lag for the variable $\texttt{Injection}_{ikt}$. Results are robust and consistent across the different specifications.

4. Conclusion

We develop a framework of financial intermediation with search and matching frictions between banks and firms which explains the co-existence of bank lending to unprofitable firms with low productivity (zombie firms). The incidence of zombie firms depends on credit market tightness that encapsulates the abundance of credit provision in financial markets. An increase in credit market tightness initially increases the share of zombie firms due to the bank's incentive to forgo costly separation. In contrast, the firm's incentive to terminate an unprofitable relationship rises with an increase in credit market tightness, which decreases the share of zombie firms. These countervailing forces generate an inverted U-shaped relationship between credit market tightness and the share of zombie firms. A high firm bargaining power magnifies the firm's incentive to terminate unprofitable relationships and decreases the share of zombie firms. We test our theory by constructing measures of credit market tightness and bargaining power for 31 industries in Japan. We find that capital injections during the Japanese banking crisis of the early 2000s had stronger efficacy in reducing the share of zombie firms in sectors with high firms' bargaining power, consistent with the predictions of our theoretical framework.

Our results suggest several interesting directions for future research. First, the model shows that the different opportunity costs of the bank and firm are central to the incidence of zombie firms. When the discount on future payoffs is low –like during the period of ultra-low interest rates in Japan since the late 1990s– the incidence of opportunity costs weakens, suggesting the strengthening of our mechanism with the departure of monetary policy from the zero lower bound of the interest rate.[28] Second, our simple model can be extended to a fully dynamic system to study the cyclical variation of the share of zombie firms over the business cycle and investigate the interplay between credit injections and business cycle fluctuations. The extended framework will also enable the study of the optimal provision of credit and the role of credit market tightness on the effectiveness of credit market policies and the incidence of boom and bust cycles originating from financial markets.[29] Third, we tested our theory on Japan, which has experienced a high and persistent level of zombie lending since the banking crises. It would certainly be interesting to construct measures of credit market tightness for other economies like the US or Europe where zombie firms are less prevalent and the lending rates sensitive to economic conditions. Fourth, our analysis abstracts from the issues of over-indebtedness of firms and under-capitalization of banks that several studies find are important for the proliferation of zombie firms and, in principle, they may interact with credit market tightness. We plan to pursue some of these extensions in future research.

[28]Ikeda et al. (2024) provide an overview of the monetary policy framework in Japan, showing that the effectiveness of monetary policy weakens in a zero-interest rate environment, consistent with the role of discounting in our theoretical framework.

[29]Bai et al. (2025), Ghassibe and Zanetti (2022), Eichenbaum et al. (2022) and Liu et al. (2019) show that the effectiveness of fiscal and monetary policies depend on the state of the economy which is linked to credit market policies.

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Not Intended for Publication. Appendix for "Credit Market Tightness and Zombie Firms: Theory and Evidence from Japan"

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A. Model Appendix

In this Appendix, we outline model details and extensions. In Section A.1 we provide details on how the production function of the firm $\pi = Az_i - f$ relates to the standard production function in general equilibrium models with firm dynamics. In Appendix A.2 we provide an extension in which bargaining power is an endogenous function of credit market tightness. In Appendix A.3 we show that the model predictions are robust to different types of matching functions. In Appendix A.4 we demonstrate that the relationship between zombie share and credit market tightness remains an inverse U-shape when future expected firm profits are a function of current credit market tightness. We also discuss the consequences of a positive relationship between the expectations of future profits and credit market tightness for the inverse U-shape. The positive relationship incetivizes the continuation of the credit relationship between the bank and the firm, which is supported by high future profits. Thus, the share of zombie firms increases since the firm has weaker incentives to terminate the relationship in the expectations of high profits. This force "extends" the left slope of the inverse U-shape.

A.1. Firm Production Function

We show that our assumption about the production function of the firm in Section 2, $\pi = Az_i - f$, can be nested within common tractable models of firm dynamics. To illustrate the case, we start with the conventional firm profit function in Melitz (2003) and Hamano and Zanetti (2017):

$$\pi_i = CP(\frac{PZ}{W} z_i \frac{\sigma - 1}{\sigma})^{\sigma-1} \frac{1}{\sigma} - \tilde{f} \frac{W}{PZ} \ , \tag{19}$$

$$\pi_i = CP(\frac{\sigma - 1}{\sigma} \nu)^{\sigma-1} z_i^{\sigma-1} - \tilde{f} \nu \ . \tag{20}$$

Using the concise notation $\psi \equiv (\frac{\sigma-1}{\sigma}\frac{1}{\nu})^{\sigma-1}$ and $f \equiv \tilde{f}\nu$ yields

$$\pi_i = CP\psi z_i^{\sigma-1} - f. \tag{21}$$

Finally, assume $\sigma = 2$ and $A \equiv CP\psi$, then

$$\pi_i = A z_i - f. \tag{22}$$

Equation 22 shows that firm profit can be conveniently written as a linear function of aggregate factors influencing firm productivity, idiosyncratic firm productivity and fixed cost.

A.2. Tightness and Bargaining Power

In this Appendix section, we discuss the case where bargaining power is a function of credit market tightness.

Proposition 3 (Credit market tightness and zombie firms)**.** *The relationship between credit market tightness and zombie firms has an inverted U-shape at the efficient level of firm bargaining power. When efficient bargaining power is a (positive) function of tightness as is the case of the CES matching function, high bargaining power magnifies the inverted U-shape. The bargaining power and credit market tightness increase simultaneously, eroding the incentive for the bank to stay in a credit relationship while increasing the incentive for the equity holder of the firm to terminate the lending relationship and find a new match.*

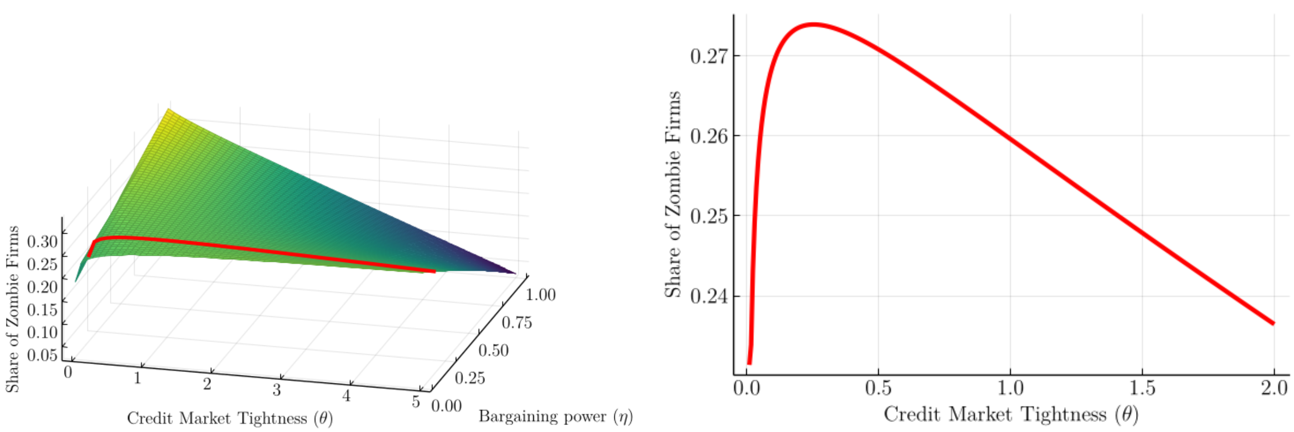
Assuming $\eta(\theta)$, where $\eta'(\theta) > 0$, it yields:

$$\frac{\partial \tilde{z}_{\text{frictions}}}{\partial \theta} \begin{cases} < 0, & \text{if } \eta(\theta)p'(\theta) + \eta'(\theta)p(\theta) < \eta'(\theta)q(\theta) - (1 - \eta(\theta))q'(\theta) \ \Rightarrow \text{Zombie share increases in } \theta, \\ > 0, & \text{if } \eta(\theta)p'(\theta) + \eta'(\theta)p(\theta) > \eta'(\theta)q(\theta) - (1 - \eta(\theta))q'(\theta) \ \Rightarrow \text{Zombie share decreases in } \theta. \end{cases} \tag{23}$$

Note that for a CES matching function firm bargaining power is efficient when $\eta(\theta) = \frac{\theta^l}{1+\theta^l}$. In this case $\eta'(\theta) = \frac{l\theta^{l-1}}{(1+\theta^l)^2} > 0$. Equation (23) shows that even keeping $p(\theta), q(\theta)$ and their derivatives constant, $\eta'(\theta)$ decreases at a faster rate at the level of the efficient bargaining power in the CES matching case in θ than η. This shows that when we endogenize firm bargaining power and make it a positive function of θ –as efficient bargaining would require for many conventional matching functions like the CES matching function– the inverted U-shape continues to hold. Even more, efficient bargaining will lead to a powerful strengthening of the non-linear inverse U-shaped forces driving the zombie firm share.

A.3. Cobb-Douglas Matching Function

Our results on the relationship between zombie share and credit market tightness based on the CES matching function (Section 2) hold to the Cobb-Douglas (CD) matching function. In the CD case, the matching probability for firms finding loans is $p(\theta) = \min(\mu\theta^{1-\zeta}, 1)$ and the matching probability for banks finding firms is $q(\theta) = \min(\mu\theta^{-\zeta}, 1)$. We calibrate $\zeta = 0.66$ and $\mu = 0.25$ in the CD case. Different from the CES matching function, the efficient degree of bargaining power is constant and equal to the elasticity of the matching function Hosios (1990). The Hosios condition implies that $\eta = \zeta$. Other parameters remain unchanged. The relationship between the zombie firm share, credit market tightness, and firm bargaining power is shown in Figure 1.



(a) Zombie firm share, credit market tightness and the bargaining power.

(b) Zombie firm share and credit market tightness when bargaining power is efficient.

Figure 1: Numerical illustration of the share of zombie firms, Cobb-Douglas matching function

Notes: Figure (a) shows the zombie share (z-axis) against credit market tightness (θ, x-axis) and the firm's bargaining power (η, y-axis) assuming a Cobb-Douglas matching function. The red line shows the zombie firm share when bargaining power is such that the Hosios (1990) condition holds. Figure (b) shows the relationship between the zombie share and credit market tightness when the bargaining power is set to the efficient level, which in the Cobb-Douglas case is just $\eta = \zeta$.

A.4. Relaxing the Independence Assumption between Tightness and Firm Profits

If we think of credit market tightness as being driven by monetary and macroprudential policies, then future firm productivity and credit market tightness may be correlated. To show that our results are robust, we relax the assumption $\delta E(A_2)/\delta\theta = 0$ that the aggregate component in future profits is uncorrelated with current credit market tightness. More concretely, we assume that future expected aggregate productivity is a function of credit market tightness $E(A_2(\theta))$.

We can then solve $E(\pi(z_{i,2}, A_2(\theta)))$ to find $\tilde{z}_{\text{frictions}}$. To do so, we need to calculate the expectations for current idiosyncratic *and* aggregate productivity $E(z_{i,2}, A_2(\theta))$, given current credit market tightness θ. Hence, future expected profits in the second period are a function of current credit market tightness $\bar{\pi}_2(\theta)$. Whether profits rise or fall with tightness depends on whether $\frac{\delta E(A_2)}{\delta\theta}$ is positive or negative. Equation (9) in the main text then changes to the following:

$$\tilde{z}_{\text{frictions}} = f - \kappa - \beta\bar{\pi}_2(\theta)[1 - (1-\eta)q(\theta) - \eta p(\theta)]. \tag{24}$$

Profits become a function of credit market tightness conditions, and condition (11) changes to the following:

$$\frac{\partial \tilde{z}_{\text{frictions}}}{\partial\theta}\begin{cases} < 0, \text{ if } & \eta[\frac{\bar{\pi}_2'(\theta)}{\bar{\pi}_2(\theta)}p(\theta) + p'(\theta)] < \frac{\bar{\pi}_2'(\theta)}{\bar{\pi}_2(\theta)}(1-(1-\eta)q(\theta)) - (1-\eta)q'(\theta) \Rightarrow \text{X increases in } \theta, \\ > 0, \text{ if } & \eta[\frac{\bar{\pi}_2'(\theta)}{\bar{\pi}_2(\theta)}p(\theta) + p'(\theta)] > \frac{\bar{\pi}_2'(\theta)}{\bar{\pi}_2(\theta)}(1-(1-\eta)q(\theta)) - (1-\eta)q'(\theta) \Rightarrow \text{X decreases in } \theta. \end{cases} \tag{25}$$

The new terms $\frac{\bar{\pi}_2'(\theta)}{\bar{\pi}_2(\theta)}p(\theta)$ and $\frac{\bar{\pi}_2'(\theta)}{\bar{\pi}_2(\theta)}(1-(1-\eta)q(\theta))$ enter in the condition. These terms, have similar properties to $p'(\theta)$ and $-q'(\theta)$ in that both increase in θ when $\frac{\delta A_2}{\delta\theta}$ is positive. Similarly, both terms decrease in θ when $\frac{\delta A_2}{\delta\theta}$ is negative. Which term dominates depends on bargaining power and the shape of the matching function as in equation (10).

Note that the relationship between tightness and the next period's expected profits determines the sign of $\frac{\bar{\pi}_2'(\theta)}{\bar{\pi}_2(\theta)}$. When this relationship is positive then $\frac{\partial \tilde{z}_{\text{frictions}}}{\partial\theta} < 0$ for high levels of credit market tightness. This means that for higher levels of tightness, the bank's and firm's incentive to subsidise the match will dominate the incentive to destroy the match. Mapping this into zombie firm share-credit market tightness space means that the left slope of the inverted U-shape becomes longer as shown by the brown line in Figure 2. This is the result of the positive correlation between credit market tightness and aggregate productivity, which means that for each level of credit market tightness the prospects of future expected match profits increase. The risk of losing out on this future expected matched profits in the next period increases the incentive to maintain unproductive matches in the current period.

The reverse is true when aggregate productivity A_2 is a negative function of θ and hence $\frac{\bar{\pi}_2'(\theta)}{\bar{\pi}_2(\theta)} < 0$. In this case, the incentive to maintain an unproductive match becomes weaker when credit market tightness increases. Higher credit market tightness enables equity holders to form new productive matches outside the current match with a high likelihood. At the same time the payoff of maintaining and financing a match into the next period is reduced and the risk of not matching successfully in the next period and missing out on production is less. Consequently, zombie firm share increases less in credit market tightness and peaks sooner. This results in a "flatter" inverse U with a longer right slope in credit market tightness-zombie firm share space as shown by the yellow line in Figure 2.

When the next period's profits are a function of credit market tightness and hence the predictions above hold, conditions (11) and (12) remain unchanged.

Relaxing the relationship between credit market tightness θ and the future aggregate component in firm profits A_2 such that $\frac{\delta A_2}{\delta \theta} \neq 0$ thus provides one additional empirical prediction. When A_2 and future expected profits $E(\pi(\theta, A_2))$ are a positive function of θ, then an increase in credit market tightness will lead to a further reduction of the minimum cutoff under financial frictions and share of zombie firms will increase by more. In other words, the left slope of the inverted U-shaped relationship between credit market tightness and the share of zombie firms is extended. In contrast, when the aggregate component A_2 is a negative function of credit market tightness θ –and hence firm future expected profits and future expected profits $E(\pi(\theta, A_2))$ are lower when credit market tightness is higher– then the incentive to sever the match becomes stronger as credit market tightness increases. This is because the benefit from staying in the match for the next period declines. As a result, the share of zombie firm share will peak at a lower level. Graphically, the right slope of the inverted U-shape in zombie share- credit market tightness space will become more pronounced for the same credit market tightness space.

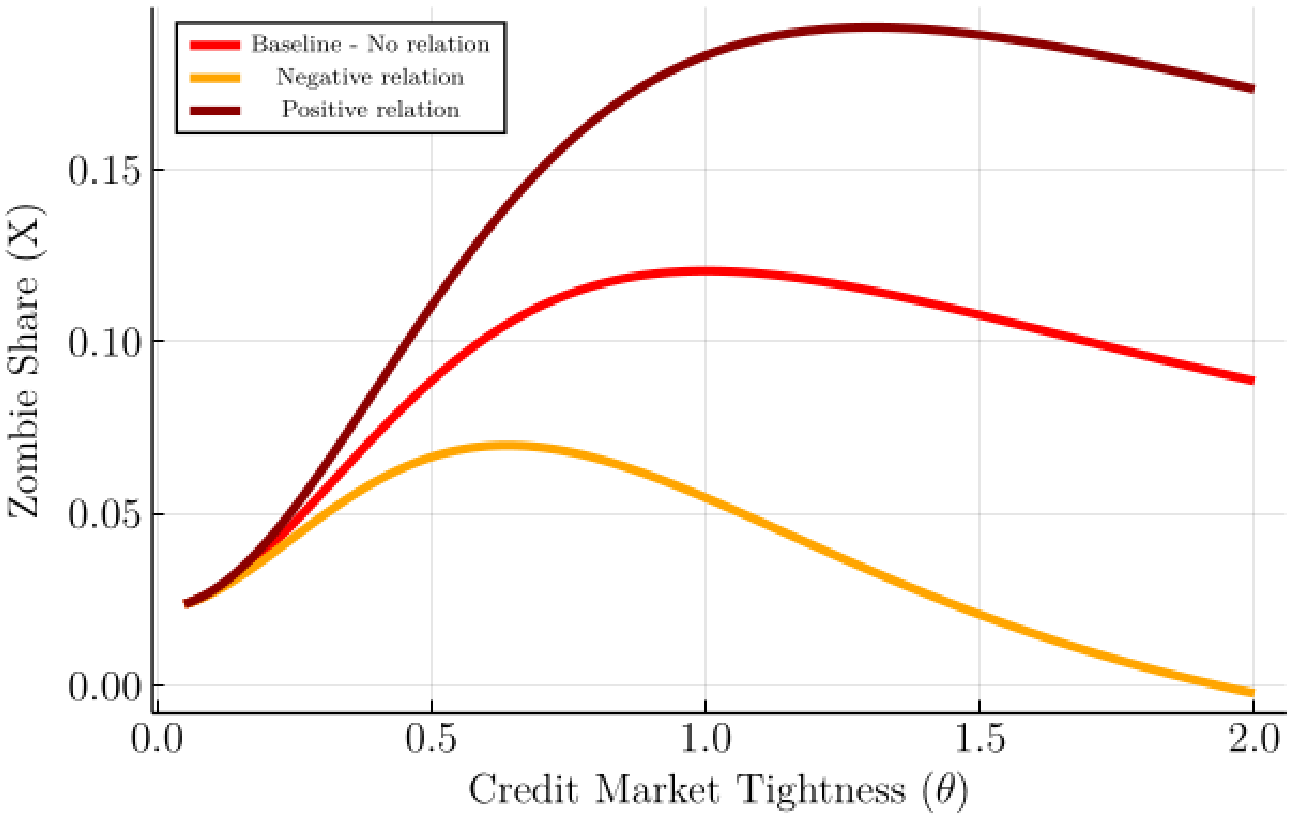


Figure 2: The zombie firm share and credit market tightness for different functional relations between A_2 and θ.

Notes: The figure shows the relationship between credit market tightness and the zombie firm share for a positive, none, and a negative functional relation between firm profits and credit market tightness. For each scenario, firm bargaining power is set to the efficient level.

Figure 2 plots the relationship between the share of zombie firms and credit market tightness for the cases of positive, zero, or negative functional relationships between current credit market tightness and future firm profits. As explained, the positive relationships increases the zombie firm share for every level of credit market tightness and lengthens the left slope of the inverted U-shape. The opposite is true for a negative relationship. Finally, when future expected profits react very strongly positively (negatively) to changes in credit market tightness, then the right (left) slope of the inverted U may disappear and the relationship between credit market tightness and share of zombie firms may be monotonically positive (negative).

B. Data Appendix

In this Appendix, we discuss data sources and construction of our variables of interest.

Nikkei Financial Quest

For the construction of the zombie ratios, we follow the procedure of Caballero et al. (2008). Specifically, we use financial statement information on listed firms in Japan from the Nikkei Financial Quest. The database covers all companies submitting annual securities reports (Yuka-shoken-Houkokusho).

The Loan Survey

For the construction of the variable that measures credit market tightness, we employ the Senior Loan Officer Opinion Survey on Bank Lending Practices at Large Japanese Banks (i.e., the Loan Survey) that the Bank of Japan (BOJ) reports. The Loan Survey is a quarterly statistical survey undertaken in January, April, July, and September of each year. This survey aims to quantitatively measure the perspectives of senior loan officers at major Japanese banks regarding the loan market. A multiple-choice questionnaire is utilized to gather information on respondents' views regarding the demand for loans from firms and other borrowers, as well as standards and terms of loans, among other considerations. Respondents consist of senior loan officers at 50 large private banks. Bank size is determined by lending volume. The combined loan size of these banks represents approximately 75 percent of the loan market among Japanese private banks, including city banks, regional banks, regional banks II, trust banks, long-term credit banks, and shinkin banks (cooperative regional financial institutions serving small and medium enterprises and local residents).

In the Loan Survey, the Demand for Loans Diffusion Index (DI) captures the trend in responses to questions regarding changes in loan officers' perspectives compared to the previous quarter's survey. Specifically, the survey asks respondents about the changes in demand for loans from borrowers (i.e., firms, local governments, and households) over the past three months, excluding normal seasonal variations. The DI is calculated as the sum of the percentage of respondents selecting "substantially stronger" and those selecting "moderately stronger" to the survey item, with the latter weighted by 0.5. This sum is then subtracted from the sum of the percentage of respondents selecting “substantially weaker” to the survey item and those selecting “moderately weaker,” also with the latter weighted by 0.5.

The Demand for Loans DI is reported for the following five industries: (1) manufacturing, (2) non-manufacturing, (3) construction and real estate, (4) finance and insurance, and (5) other non-manufacturing. It is also reported by three firm size categories: large, medium-sized, and small firms.

The Tankan Survey

We also employ the Short-Term Economic Survey of Enterprises in Japan (i.e., the Tankan Survey) for construction of the tightness measure. The Tankan Survey is a quarterly statistical survey conducted by the BOJ in March, June, September, and December each year. The BOJ solicits responses from selected private enterprises in Japan with a capital of 20 million yen or more.

In the Tankan Survey, one important variable for our analysis is the Lending Attitude (of Financial Institutions) Diffusion Index (DI). It reports the respondents’ judgments of financial institutions’ attitude toward lending, as perceived by responding enterprises. Respondents are required to select one of three options: (1) “accommodative,” (2) “not so severe,” and (3) “severe.” The Lending Attitude DI is calculated by subtracting the percentage share of those responding with “severe” from those responding with “accommodative.” This index is reported by industry (about 40 industries) and by firm size.

Another useful variable in the Tankan Survey is the Financial Position DI. It captures respondents’ judgments of the overall cash position of the participating enterprises in terms of three potential responses: “easy,” “not so tight,” and “tight.” This index is also reported by industry (about 40 industries) and by firm size.

The JIP Database

For the productivity of firms that are aggregated at the industry level, we use the JIP Database (Japan Industrial Productivity Database). The JIP database contains annual data on 108 sectors from 1970 that can be used for total factor productivity analyses. These sectors cover the entire Japanese economy. The database includes detailed information on sectoral capital service input indices and labor service input indices. It includes annual information from input-output tables on the real capital stocks and the nominal cost of capital by type of capital and by industry, in nominal and real units. The statistics are regularly updated. Therefore, we use JIP2023 that covers the period 1994-2020 and JIP2014 that covers the period 1970-2011.

Descriptive Statistics

We present descriptive statistics of the variables that we use in our industry-level analysis in Table B1.

Table B.1: Descriptive statistics

	N	T	mean	sd	min	p25	p50	p75	max
`ZombieRatio`	31	20	0.40	0.17	0.00	0.29	0.4	0.52	1.00
`Tightness1`	31	20	15.55	13.05	-32.75	7.75	16.75	24.25	63.50
`Tightness2`	31	20	1.13	7.67	-30.50	-3.00	2.00	5.75	27.00
`BP1`	31	20	0.78	0.43	-7.11	0.78	0.90	0.94	0.99
`BP2`	31	20	0.06	0.05	-0.09	0.03	0.05	0.08	0.30
Productivity	31	20	8.90	12.87	1.33	3.41	4.90	8.88	81.59

Notes: Mean, standard deviation (sd), minimum (min), 25th percentile (p25), median (p50), 75th percentile (p75), and maximum (max). Sample period is from 2000 to 2019.

C. Firms' Profit Forecasts

As shown in Section 2, we assume that the incentive to maintain a zombie firm relationship is a bid for resurrection. Hence, stakeholders involved in the firm's financial performance have a positive expectation about future profitability. We find that these positive expectations of future firm profits of firms currently classified as zombie firms can be readily observed in our data. In Appendix A.4 we discuss the consequences of a correlation between current credit market tightness and future expected firm profits. We show that a positive correlation between current credit market tightness and future expected profits expands the range of values for credit market tightness in which the share of zombie firms increases. Within this range, on the left side of the inverted U-relationship between credit market tightness and zombie firm share, the incentive to forbear on loans and maintain relationship dominates the option to sever the relationship and for the matching parties to be dormant in the current period and search in the next period. Our empirics indicate that our baseline measure of credit market tightness is positively correlated with future firm profits.

We use the Nikkei Financial Quest for profitability forecasts, which also provides information on listed companies' own forecasts for their annual current profits. Most listed companies in Japan customarily announce their forecasts for their sales, operating profits, current profits, net income, and dividends per share for the next fiscal year when they officially present their financial statements. Among the forecasts, we use the initial ones for each firm-fiscal year, most of which are announced one year in advance. Based on the theoretical prediction presented in the previous section, we examine whether firms issue positive earnings forecasts and whether the correlation between profitability forecasts and credit market tightness is positive.[1]

First, we examine whether listed firms in Japan make positive profitability forecasts. For the fiscal years 2000-2019, we calculate the ratio of firms that reported negative current profits to those that reported profit forecasts. We also calculate the ratio of firms that ended up reporting negative actual current profits to those that reported actual profits. We perform the same exercise by aggregating the information at the industry level. Tables C.1 and C.2 show the results. Table C.1, which depicts summary statistics at the firm level, shows that only a small fraction of firms forecast negative current profits, but a larger fraction of firms actually reported negative current profits. For example, in fiscal year 2000, 1.6 percent of firms forecast negative current profits, yet 7.2 percent of them actually report negative current profits. Throughout the period, less than 3 percent of firms report negative current profits except in fiscal year 2009 when the Global Financial Crisis hit the economy. These findings are consistent with the theoretical model's assumption of the positive expected profits. We have a similar result in Table C.2. Specifically, as shown in the table, statistics aggregated at the industry level, indicate that a very limited number of industries forecast negative current profits.

[1] To the best of our knowledge, we are the first to use empirically the information of firm profitability forecasts and their relation to zombie firm status.

Table C.1: Current profit at firm level: forecast and actual

Fiscal year	Forecast		Actual	
	Number of firms	Ratio of firms with negative profit	Number of firms	Ratio of firms with negative profit
2000	1520	1.6%	1605	7.2%
2001	1645	1.6%	1687	15.4%
2002	1734	1.8%	1755	9.9%
2003	1795	1.3%	1842	6.1%
2004	1875	1.1%	1935	5.2%
2005	1891	1.0%	1954	5.7%
2006	2082	1.5%	2114	7.4%
2007	2147	1.6%	2164	8.6%
2008	2178	1.8%	2191	20.0%
2009	2196	9.1%	2205	18.7%
2010	2213	2.4%	2231	8.4%
2011	2248	2.3%	2282	9.0%
2012	2282	2.3%	2320	9.3%
2013	2333	1.8%	2398	6.5%
2014	2377	1.3%	2471	6.6%
2015	2446	1.5%	2527	7.1%
2016	2505	1.6%	2603	6.8%
2017	2563	1.8%	2679	5.6%
2018	2623	1.7%	2765	7.0%
2019	2691	2.2%	2851	9.6%

Notes: In the majority of cases, firm forecasts are made one year prior to the end of the fiscal year.

Second, we examine whether the correlation between credit market tightness and expected profits is positive. Because tightness is measured at the industry level, we aggregate expected profits at the industry level to estimate the correlations. Table C.3 shows the results. When we use `Tightness1` for the tightness measure –which is our main tightness variable– the correlations are always positive. However, that they are insignificant or negative when we use `Tightness2`.

All of these results indicate that the first assumption of positive profitability forecasts is satisfied and that the second assumption of positive covariance between tightness and forecasts is also generally met.

Table C.2: Sum of current profits at industry level: forecast and actual

Fiscal year	Forecast		Actual	
	Number of industries	Ratio of industries with negative profit	Number of industries	Ratio of industries with negative profit
2000	31	0.0%	31	0.0%
2001	31	0.0%	31	6.5%
2002	31	0.0%	31	6.5%
2003	31	0.0%	31	0.0%
2004	31	0.0%	31	0.0%
2005	31	0.0%	31	0.0%
2006	31	0.0%	31	0.0%
2007	31	0.0%	31	0.0%
2008	31	0.0%	31	6.5%
2009	31	3.2%	31	6.5%
2010	31	0.0%	31	0.0%
2011	31	3.2%	31	6.5%
2012	31	3.2%	31	3.2%
2013	31	3.2%	31	3.2%
2014	31	0.0%	31	3.2%
2015	31	0.0%	31	3.2%
2016	31	0.0%	31	3.2%
2017	31	0.0%	31	0.0%
2018	31	0.0%	31	3.2%
2019	31	0.0%	31	9.7%

Notes: In the majority of cases firm forecasts are made one year prior to the end of the fiscal year.

Table C.3: Correlation coefficients between tightness measures and profit forecasts

	CMT measures	
	Tightness Measure 1	Tightness Measure 2
Profit Forecasts	0.2534	-0.0004
	(0.0000)	(0.9925)
Profit Forecasts/Assets	0.1159	-0.1197
	(0.0049)	(0.0036)

Notes: Tightness measure of an industry is for year t. Profit forecast is the sum of the current profit forecast for year $t+1$ in an industry. Asset is the sum of assets in an industry in year $t+1$. The numbers in parentheses are p-values.

D. List of bank capital injections in Japan

Table D.1: List of bank capital injections in Japan

Year	Bank	Injection amt (billion yen)	Injection size
1998	Industrial Bank of Japan	100	0.0036079
1998	Long-term Credit Bank of Japan	1766	0.0895211
1998	Nippon Credit Bank	600	0.0616973
1998	Dai-ichio Kangyo Bank	99	0.0024016
1998	Sakura Bank	100	0.0026666
1998	Fuji Bank	100	0.0026483
1998	Tokyo Mitsubishi Bank	100	0.0017391
1998	Asahi Bank	100	0.0049092
1998	Sanwa Bank	100	0.0026345
1998	Sumitomo Bank	100	0.002443
1998	Daiwa Bank	100	0.0089524
1998	Tokai Bank	100	0.0045907
1998	Ashikaga Bank	30	0.0066851
1998	Yokohama Bank	20	0.0025702
1998	Hokuriku Bank	20	0.0036784
1998	Mitsui Trust Bank	100	0.0107042
1998	Mitsubishi Trust Bank	50	0.0038284
1998	Yasuda Trust Bank	150	0.023966
1998	Toyo Trust Bank	50	0.0073057
1998	Chuo Trust Bank	60	0.0206714
1998	Sumitomo Trust Bank	100	0.0083929
1999	Industrial Bank of Japan	600	0.0207862
1999	Dai-ichio Kangyo Bank	900	0.0254108
1999	Sakura Bank	800	0.0239526
1999	Fuji Bank	1000	0.0242909
1999	Asahi Bank	500	0.0253502
1999	Sanwa Bank	700	0.0198145
1999	Sumitomo Bank	501	0.0128186
1999	Daiwa Bank	408	0.0381935
1999	Tokai Bank	600	0.0290798
1999	Ashikaga Bank	105	0.0264497
1999	Yokohama Bank	200	0.0267355
1999	Hokuriku Bank	75	0.0173054
1999	Ryuku Bank	40	0.0445931
1999	Mitsui Trust Bank	400.2	0.0512979
1999	Mitsubishi Trust Bank	300	0.0252978
1999	Toyo Trust Bank	200	0.0322839
1999	Chuo Trust Bank	150	0.0374873
1999	Sumitomo Trust Bank	200	0.0186623
1999	Hiroshima Sogo Bank	40	0.0269784
2000	SBI Shinsei Bank	240	0.0416719
2000	Aozora Bank	260	0.0625982
2000	Hokkaido Bank	45	0.0213814
2000	Chiba Kogyo Bank	60	0.049347
2000	Kumamoto Family Bank	30	0.0319097
2000	Yachiyo Bank	35	0.0340267
2001	Kinki Osaka Bank	60	0.0220456
2001	Higashinihon Bank	20	0.018564
2001	Gifu Bank	12	0.0321132
2001	Kansai Sawayaka Bank	12	0.0140996
2002	Wakayama Bank	12	0.0477173
2002	Fukuoka City Bank	70	0.0350522
2002	Kyushu Bank	30	0.0401151
2003	Risona Bank	1960	0.0850727