LUND UNIVERSITY

SCHOOL OF ECONOMICS AND MANAGEMENT

LIFE BELOW ZERO
Zombie Firms and Low Interest Rates

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Graduate Thesis II, Master of Economics

15 Credits

April 2021

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Dedikeret til min far
Finn Berling

LIFE BELOW ZERO:

Zombie Firms and Low Interest Rates*

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April 12, 2021

Abstract

This paper employs a zombie classification following (Storz et al., 2017) to examine the phenomenon of zombie firms and low interest rates in Denmark using a comprehensive harmonized firm-level micro dataset from ORBIS covering the period 2002-2019. Specifically, the questions addressed are whether the prevalence of zombie firms increased due to low interest rates and has surviving as a zombie become easier as interest rates have declined? The second point of this research investigates what other factors can help explain the comparatively low rate of zombie firms in Denmark, given the low interest-rate setting– i.e., the importance of financial stability. This study documents that throughout low and even negative interest rates, 2009-2019, the prevalence of zombie shares declined substantially. Moreover, a linear probability model approach is used to show that the risk of surviving as a zombie did not increase dramatically over the period of cheap financing. Overall, the analysis suggests that zombie shares have not increased in the low interest rate setting. Pointing towards the importance of structural factors and the presence of a well-functioning financial system and efficient insolvency regime in Denmark has kept the zombification of the economy in check.

Keywords: *zombie firms, real economy and financial stability, low interest rate environment*

JEL Classification: *D22, D24, E43, E44, G32*

*This paper is meant as a graduate thesis in fulfillment of the requirements for the degree of Master of Science in Economics at Lund University - School of Economics and Management

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1 Introduction

In the aftermath of the "Great Recession" of 2008, central banks worldwide adopted accommodative monetary policy to foster economic recovery and help support the economy. Conventional monetary policy tools began to fail as central banks neared the zero-lower bound (ZLB) in 2008. The subsequent euro area sovereign debt crisis gave further impetus for European central banks in implementing ultra-easy monetary policy; specifically, resorting to negative rates, quantitative easing, and forward guidance. Simultaneously, most developed economies experienced a rise in the share of distressed, low-productivity, conceivably non-viable firms with high levels of corporate debt.

These persistently weak firms with a tendency to drag along —firms that are not able to earn enough to cover debt obligations but still manage to roll over their debts and limp along —are commonly referred to as "zombie firms". Current firm-level research suggests that a high prevalence of zombie firms is detrimental to the economy (Adalet McGowan et al., 2017b; Banerjee & Hofmann, 2018; Osterhold & Gouveia, 2020). Notably, as zombie firms are associated with a decline in aggregate productivity (Adalet McGowan et al., 2017b; Adalet McGowan et al., 2017a), the decline in business dynamism (Adalet McGowan et al., 2017a; Decker et al., 2016) and rising resource misallocation (Adalet McGowan et al., 2017b; Acharya et al., 2019; Gopinath et al., 2017; Andrews & Petroulakis, 2019).

Furthermore, the current empirical research also suggests an upwards trend in the share of zombie firms over time across many advanced economies and that the rise in the number of zombie firms is linked to two sources. First, the declining interest rates could allow zombie firms to prevail longer than they would otherwise in functioning market economies due to lower financing costs or bank forbearance. Lower financing costs create incentives for greater risk-taking as lower rates reduce the opportunity costs for creditors of rolling over non-performing loans because the alternative would be to invest in the money market at a lower rate (Andersen et al., 2019; Banerjee & Hofmann, 2018). The second source is forbearance due to capital bank shortages. The bank forbearance may be symptomatic of weakly capitalized banks that are incentivized to avoid recognizing losses (evergreening[1]) to evade falling below their minimum regulatory capital requirements (Andrews & Petroulakis, 2019; Caballero et al., 2008; Hoshi & Kashyap, 2004; Peek & Rosengren, 2005; Schivardi et al., 2020).

Thus, suggesting that part of the zombie problem stems from reduced financial pressure following the decline in the level of interest rates. Resulting in a fear of zombie firms and adverse consequences for the real economy and financial stability. This observed correlation is undoubtedly interesting for policymakers and economists alike in examining the

[1] The phenomenon of "evergreening" in this context is where banks engage in zombie lending to non-viable firms. This has been attributed to institutional incentives to engage in balance sheet cosmetics through a reluctance of write-downs on claims and realizing losses or forming provisions in order to make reported capital closer to regulatory requirements (Peek & Rosengren, 2005).

unintended consequences of ultra-easy monetary policy and preparing for the economic outcome of the current Covid-19 pandemic that could lead governments to prolong the life of the living dead.

Arguably, the accommodative monetary policy direction following the fallout from the Great Recession created a conducive environment for zombie firms. The use of unconventional tools was particularly evident in Denmark, as Danmarks Nationalbank (DNB) lowered rates into the negative territory in 2012 and has sustained the negative rates since.[2] Accordingly, making Denmark a good case in examining ultra-easy monetary policy and its link with firm dynamism.

As such, this study aims to assess the impact of low interest rates[3] on the prevalence of zombie firms. This link will be investigated by looking at the prevalence of zombie firms and the role of zombies on firm dynamics in a low interest-rate environment in Denmark. Specifically, the main questions are: has the prevalence of zombie firms increased due to low interest rates, and has surviving as a zombie become easier as interest rates have declined? Additionally, the second point of this research is to investigate what other factors can help explain the comparatively low rate of zombie firms in Denmark, given the low interest-rate setting– i.e., the importance of financial stability. Given that recent strands of literature from institutions such as the Bank for International Settlements (BIS) and the Organisation for Economic Co-operation and Development (OECD) have pointed to low interest rates, perhaps causing increased prevalence of zombie firms (Adalet McGowan et al., 2017b; Banerjee & Hofmann, 2018); how come prevalence is relatively low in a low interest environment such as Denmark (Andersen et al., 2019)? The paper presents a thoroughly descriptive analysis to address this question. The challenge is to undertake this inquiry in a more causal sense, contrary to a *cum hoc ergo propter hoc* approach.

To this end, this study applies a zombie classification following Storz et al. (2019) to examine the relationship between interest rates and zombie firm prevalence using firm-level microdata from ORBIS covering the period 2002-2019.[4] Unlike recent literature from Banerjee and Hofmann (2018) that has connected low interest rates with an increased zombie prevalence in advanced economies using only information on listed companies, this dataset is predominantly comprised of private firms.[5] In order to identify the mechanisms wherein interest rates affect firm dynamics, this paper divides the empirical approach into two steps.

[2] This provides for the most data-points out of potential economies with negative interest rates. Additionally, DNB alongside the Swiss National Bank have had the lowest interest rates post-Great Recession as -0.75%.

[3] Low and negative will be used interchangeably throughout the paper when addressing the nominal interest rate.

[4] Specifically, zombie firms are identified as firms that for two consecutive years have low debt service capacity, negative return on assets and negative net investments.

[5] (Banerjee & Hofmann, 2018)suffers from a key deficiency. Primarily, that it only examines listed firms that tend to be large enterprises and as such disregards the presence of small and medium-sized enterprises (SME) that are zombies. In fact, SMEs tend to represent the majority of businesses in advanced economies – for example, SMEs accounted for 98.2 per cent of all firms in Denmark (OECD, 2020).

In the first step, a difference-in-difference approach is undertaken to test for the potential drivers of zombie firms while controlling for unobserved influences that could raise the prevalence of zombie firms. This is conducted through the lens of capital sunk in zombie firms across industries and examines whether low interest rates and distressed banks could be a factor. The addition of a financial health measure is considered as empirical evidence suggests that distressed banks may be a potential cause of zombie emergence (Caballero et al., 2008; Storz et al., 2017; Schivardi et al., 2017). Using the BvD's BankFocus database, a bank health measure is constructed following Andrews and Petroulakis (2019). The second step is assessing zombie persistence in Denmark through a basic linear probability model (LPM) to investigate whether distressed firms have survived longer during the era of ultra-easy monetary policy.

The results of the difference-in-difference model indicate that the role of interest rates and bank health on zombie shares is not clearly visible given the current data. Despite not yielding any usable inferences on the drivers of zombie firms, this inquiry highlights the conundrum when investigating interest rates in a fixed effect model and proves why the empirical literature investigating this matter is scant. The LPM model shows that during the period of low interest rates, the probability of surviving as a zombie firm did not dramatically increase, as suggested by the existing literature.

The remainder of this paper is organized as follows. Section 2 reviews the literature on zombie firms and how zombie firms are identified in the literature. Section 3 provides an overlook of the data in general; specifically, how zombies are identified in the data and a detailed descriptive inquiry to the evolution of zombie firms in Denmark. The empirical framework is presented in section 4. Section 5 describes the results and analysis. Section 6 concludes.

2 Literature Review on Zombie Firms

2.1 A Prior on the Zombie Firm Definition

When is a firm a zombie? In economic terms, zombie firms are non-viable firms that would typically exit or be forced to restructure in a competitive market. The basic idea is that they are in distress because they lack profitability over an extended period, and as such are likely to have insufficient funds to service their debts – only kept alive by bank loans and continuing subsidies, both direct and indirect. When such firms survive and continue to exist, they are referred to by the literature as zombies (Kane, 1987).[6]

The literature has presented various definitions of the zombie concept, as there are currently no objective criteria for when a firm is non-viable and should exit the market. As

[6] The notion of a zombie firm was first coined by Kane (1987) in his study on the US savings and loan crisis of the 1980s and 1990s. However, the use of the term as an economic descriptor first gained traction when it was studied in context of the Japanese macroeconomic stagnation of the 1990s.

such, multiple methodologies in identifying zombie firms have been employed depending on a given research question.

Caballero et al. (2008) define zombie firms as distressed firms that receive financial help from their creditors to survive. Specifically, the authors identify zombie firms by comparing the interest rate paid of firms that are considered the highest quality borrowers (firms with AAA-ratings) with the interest paid of other firms (listed firms with information loan and debt information available). Firms with a negative interest rate gap (i.e., firms that pay an interest rate below that of the AAA-rated reference firms) are thus receiving subsidized credit and are classified as zombie firms. The basic idea of their criterion is that receiving subsidized credit is an indication of viability (or lack thereof) under regular market conditions. However, it has various drawbacks, as it only captures firms that are kept alive by subsidized lending. This ignores firms that have other reasons to exit the market.[7] To go along with the potential pitfalls of the method, it is also very data demanding since it requires detailed information on each firm's debt distribution.[8]

Other authors have developed methodologies that rely on operating characteristics, such as profitability-based zombie definitions, in order to avoid the potential difficulties and data demands of Caballero et al. (2008) seminal approach. Bank of Korea (2013) characterizes companies at risk of being zombie firms by assessing if firms have had three consecutive years of insufficient operating income (using EBIT) to cover interest expenses; specifically, an interest coverage ratio (ICR) below 100%.[9] Recent strands of zombie literature by the Organisation for Economic Co-operation and Development (OECD) (see Adalet McGowan et al. (2017a); Adalet McGowan et al. (2017b) and Andrews and Petroulakis (2019) builds upon Bank of Korea (2013) approach of using the ICR definition but adds an age criterion – firms are required to be older than ten years as a measure to avoid classifying start-up companies as zombie firms. This approach has been widely utilized in the recent zombie firm literature due to its data accessibility, cross-country comparability, and its ability to encompass channels other than subsidized credit (e.g., misdirected loans, government guarantees and bankruptcies) – see (Andersen et al., 2019; Banerjee & Hofmann, 2018; Cella, 2020; Deutsche Bundesbank, 2017; Osterhold & Gouveia, 2020).[10]

[7] The basic idea is that banks may give subsidized credits due to good bank-firm relationship and not just to keep firms alive. The authors also mention that when interest is persistently very low, then subsidized lending rates would also be very low or negative and that is not the case in practice. See Banerjee and Hofmann (2020) for further discussion.

[8] In some contexts, the approach is useful and has its advantages despite its strenuous data demands. See Giannetti and Simonov (2013) and Acharya et al. (2019). Notwithstanding, the influential definition, some scholars have pointed towards it being insufficient in indicating zombie firms as it is exposed to Type I and Type II errors– See Fukuda and Nakamura (2011) and Nakamura and Fukuda (2013) for further details.

[9] Bank of Korea (2013) also identifies companies as "marginal" as those who have had three consecutive years of negative cash flows from operating activities

[10] Some are extending the ICR zombie classification further by adding more restrictions. Osterhold et al., 2020, adds a more stringent time criteria by imposing a five-year restriction. Banerjee and Hofmann (2018) uses

Alternative approaches relying on further operating characteristics include Storz et al. (2017), who classify a firm as a zombie firm if its net investments and its return on assets are negative, and a debt-servicing capacity – EBITDA to total financial debt - lower than 5% for two consecutive years. The authors argue by accounting for negative investments; they avoid including young expanding enterprises as zombie firms. Furthermore, the use of debt-servicing capacity is put in place to avert classifying zombie firms with highly subsidized credit as healthy firms, and the year restriction accounts for business cycle effects. Schivardi et al. (2017) characterize zombie firms by using two criteria – the return on assets (three-year moving average of EBITDA over total assets) below the cost of capital for the safest borrowers and financial debt to assets (leverage) above 40%. Despite the various methodologies employed in capturing zombie firms, results are usually robust across the alternative definitions (see (Andrews & Petroulakis, 2019; Schivardi et al., 2017). This paper employs a zombie identification method following Storz et al. (2017).

2.2 Existing results on zombie firms

2.2.1 The Japanese macroeconomic stagnation of the 1990s

The empirical analysis of the zombie firm phenomenon largely builds on the experience from the Japanese macroeconomic stagnation of the 1990s, known as the "lost decade."[11] A large strand of literature documents the role of misdirected bank lending in the Japanese lost decade. Hoshi (2000) being the first to address the phenomenon of forbearance lending and its ramifications in the crisis. Peek and Rosengren (2005) provide matched Japanese bank-firm evidence for 1993 through 1999 to further expand on bank forbearance – whereby under-capitalized banks were most likely to engage in "evergreening" to the most unproductive firms during the Japanese crisis.[12] Specifically, the evergreen lending was attributed to a reluctance of banks to write off loans in order to avoid the realization of losses on their balance sheets, which resulted in creating a misallocation of credit. Cultural incentives were also a factor in the misallocation of credit to the weakest firms as intermediaries had an implicit obligation (moral suasion) to support distressed firms and favor strong bank-firm

(Adalet McGowan et al., 2017b) measure as their "broad" measure while also defining a "narrow" measure with the additional requirement of expectations of low future profitability inferred from the firm's stock market valuation. Deutsche Bundesbank (2017) also looks at an alternative way of characterizing zombies: firms whose cash flow has been negative for three consecutive years.

[11] Wherein, the collapse of Japan's bubble economy in the early 1990s was subsequent followed by a decade of economic stagnation and financial crisis. See Hoshi and Kashyap (2010) for a detailed survey of the three phases of the Japanese macroeconomic crisis.

[12] "Evergreening" meaning loans provided by banks to distressed firms allowing them to keep serving debt obligations.

relationships, which may have had a role in exacerbating the problem (Peek & Rosengren, 2005).[13]

Relatedly, the seminal work by Caballero et al. (2008) further explores and documents the phenomenon of "zombie lending" and the malefic role of zombie firms in the Japanese case[14] – particularly by investigating the distortionary effects of zombie firms on healthy firms based on matched bank-firm data for up to 2500 listed Japanese firms between 1981 and 2002. Showing evidence of zombie lending - whereby weak banks lent too much to non-viable firms at excessively low rates; nearly one-third of their firm sample received subsidized credit in the late 1990s and early 2000s. As a result, the increase of zombies created distortionary effects for healthy firms and prolonged the crisis in Japan. Specifically, the authors find a link between the percentage of zombie firms (applying the definition discussed in the previous subsection) in an industry and lower productivity, depressed job creation and investments, and greater excess capacity for healthy firms over their sample period.[15]

Subsequent studies investigating the zombie lending phenomenon have shed further light on the nuances of the Japanese lost decade, with mixed results. Some authors suggest that the impact of zombie lending on the Japanese economy has been somewhat overstated (Ahearne & Shinada, 2005; Fukuda & Nakamura, 2011).[16] While Okamura (2011) further builds upon the results of Peek and Rosengren (2005) by showing that undercapitalization of banks was the principal driver behind zombie firms in the Japanese crisis using Japanese firm-level data covering the period 1997 to 2003. Recent work by Giannetti and Simonov (2013) examines the real effects of bank bailouts on the supply of credit via a linear probability model (LPM) using Japanese firm-bank data from 1998 to 2004. Their findings point towards that too small capital injections fail to increase the supply of credit and concurrently encourage misdirected bank lending and zombie firms.

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[13] Hoshi et al. (1990) describes the structure of bank-firm relationships and shows that a firm's main bank takes a leading role in the restructuring process for firms in financial distress. Japanese firms usually have a close relationship to theirs banks in the form of bank shareholdings and board seats for bank representatives.

[14] Zombie lending is defined as lending by financial intermediaries to otherwise insolvent firms. Zombie lending can take various forms – interest rate concessions, moratoriums, "evergreening" of loans and debt forgiveness (Kwon et al., 2015).

[15] Their approach is considered important as they avoid the definitional issues of the previous aggregate investigations conducted on the distortionary effects of zombie firms in Japan's lost decade. Specifically, the problem of an aggregate investigation is that firms that are in sectors with low productivity and employment growth can be classified as distressed firms (zombies) because they simply are in sectors with low productivity and employment growth (Okamura, 2011). This allowed the authors to explicitly assess the effects of zombies in Japan – showing sectors with high zombie presence lowered investment and employment growth in their competitors by impeding the reallocation of human and capital resources.

[16] Wherein Fukuda and Nakamura (2011) specifically, states that Caballero et al. (2008) criterion overestimated the zombie congestion in the early 2000s due to misidentifying healthy firms as zombie firms under the quantitative easing monetary policy.

2.3.2 The emergence of zombie firms after the Great Recession

The Japanese experience with zombie lending and the emergence of zombie firms impacting long-term stagnation has not been unique to the Japanese economy but has also become a cautionary account for other economies. Zombie firms have garnered significant concern in much of the developed world in the wake of the global financial crisis and the European debt crises due to their perceived deleterious effects on financial stability and the economic recovery process (Acharya et al., 2019; Adalet McGowan et al., 2017a).[17]

This spectre has raised the question of how to corral zombie firms effectively by policymakers in economies around the world. Former US Treasury Secretary Larry Summers raised concern over the costs of zombie firms in a low interest environment and proposed mitigating it by raising the level of demand (Summers, 2014). While the Bank of England (2012) connected the situation in the aftermath of the global financial crisis with the decade-long stagnation in Japan during the 1990s and noted that a number of lessons can be drawn from the Japanese experience. An additional concern was raised by the top economic advisor to Chinese President Xi Jinping; - Liu He, as he expressed the need for shutting down zombie firms in order to reform the Chinese economy (Stevenson, 2018). The increased attention by pivotal economic policy voices has insinuated that the occurrence of zombie firms is seen as a latent threat to economies following the recent economic turmoil – global financial crisis, European debt crisis, and the latest Covid-19 pandemic.

Building on the Japanese experience and echoing the concerns of prominent officials' international organizations and institutions such as the OECD and the Bank for International Settlements (BIS) have increasingly become devoted in analyzing the issue as well. Consequently, increased research output and focus from the OECD came after the global financial crisis and the subsequent euro area sovereign debt crisis that documented a rise in the proportion of zombie firms to healthy firms across OECD economies. Adalet McGowan et al. (2017b) highlights that the increase in zombie prevalence in a sample of nine OECD countries[18] during the period 2003-2013 is coupled with a drag on aggregate productivity. In particular, their results show that zombie firms are increasingly surviving (or delaying restructuring) and congest markets and stifle the growth of healthy incumbent firms. In other words, harming the process of resource allocation by crowding out growth opportunities for healthy firms - creating a congestion effect that consequently creates a decline in potential output growth in the OECD. This increased prevalence of zombie firms in OECD countries, predominantly in European countries and a steady decrease in ICRs since 2011 have occurred despite the low interest rate setting, which is somewhat unexpected as interest costs should have decreased as well (Mahtani et al., 2018; IMF, 2017).

Another plausible explanation is presented by Adalet McGowan et al. (2017a) and Andrews et al. (2017c), who points towards structural policy weaknesses as an important

[17] Additionally, it has also gained exponential attention in the public debate as of late. See Figure B.1 in Appendix B.

[18] Belgium, Finland, France, Italy, Korea, Slovenia, Spain, Sweden and the United Kingdom.

factor in explaining the increased zombie prevalence in the OECD. The authors connect the rise of zombie firms and ineffective insolvency regimes as it explains weak market selection. This connection is investigated in the ensuing data section with the use of indicators of insolvency regimes to show that regimes that reduce barriers to restructuring and the cost associated with corporate failure may reduce the share of capital sunk in zombie firms.[19]

Another strand of recent zombie literature explores whether the prevalence of zombie firms is a symptom of financial constraints – specifically, showing that financial frictions promote the survival of non-viable firms via bank forbearance and that firms on the margin of exit are associated with weak banks. Distressed banks are more likely to delay deleveraging of non-viable firms and, as such, increase the indebtedness of these firms further at the expense of viable firms. Showing that, alike the Japanese experience, this inclination in lending to distressed firms is conducted as weak banks face increased regulatory scrutiny and due to moral suasion from their domestic governments who seek to avoid increases in firm bankruptcies and unemployment rates which ultimately leads to voter dissatisfactions (Acharya et al., 2019; Arrowsmith et al., 2013; Blattner et al., 2019; Schivardi et al., 2017; Storz et al., 2017). Andrews and Petroulakis (2019) uncover similar findings as the aforementioned literature and presents that one-third of capital misallocation spurred by zombie congestion is directly associated with bank health or the lack thereof. Moreover, the authors add to the discussion by suggesting that improvements in bank health increase the likelihood of zombie prevalence reduction in countries where insolvency regimes do not constrain corporate restructuring. In contrast, using a difference-in-difference method on 14 advanced economies, Banerjee and Hofmann (2018) do not find a link between zombie firm prevalence and bank health. Instead, the authors partly credit the uptick in zombie shares to reduced financial pressure.

Another plausible factor of the rise in zombie prevalence that has been highlighted in the recent literature is government support. Recently, literature examining zombie firms from a Chinese perspective has inquired about the impact of government intervention in the matter. Chang et al. (2021) present that a greater degree of government support in terms of subsidies, resource support, financial support and taxes; increases the risk that a firm will become a zombie firm in China. Furthermore, Tan et al. (2016) show that government intervention enhances the performance of zombie firms which subsequently crowd-out the growth of private firms. Along those lines, it has been shown that a large share of zombie firms is among state-owned firms, and this linkage contributes directly to debt vulnerabilities and low productivity for private firms (Lam et al., 2017). Additionally, empirical evidence in the Chinese experience indicates that government subsidies have a negative effect on capacity utilization of zombie firms and that these subsidies distort the investment behaviors of subsidized distressed firms and are more pronounced in state-owned zombie firms (Liu et al., 2019).

[19] See McGowan and Andrews (2018) for details on the design of the insolvency policy indicators.

2.3.3 The influence of unconventional monetary policy on zombie firms

In conjunction with the aforementioned potential factors contributing to the emergence of zombie firms, the zombie conundrum nowadays is also characterized by the low interest rate setting that was adopted through unconventional monetary policy measures in order to combat the downturn following the global financial crisis. The global financial crisis and the zero-lower bound (ZLB) problem that emerged in its aftermath put an increased re-focus on monetary economics and has since been heavily debated. The ZLB and, subsequently, a further lowing of rates into negative territory for some economies brought forth doubts about the effectiveness of monetary policy and, specifically, the interest rate channel. Conventional monetary policy tools began to fail as central banks neared the ZLB in 2008, which made them resort to setting negative rates, quantitative easing, and forward guidance.[20]

In 2009, the Swedish Riksbank temporarily implemented a negative interest rate policy (NIRP) below zero in 2009.[21] Which was soon followed by DNB in 2012 and the Swiss National Bank (SNB) in 2014.[22] The European Central Bank (ECB) and other central banks also followed suit in 2014 and the subsequent years (Arteta et al., 2018).[23] Effectively, meaning that central banks charge a "tax" for excess reserves held by commercial banks. As a result, through the interest rate channel, a lowering in interest rates on the interbank market will lead to lowered rates for the consumers of those banks and as such, boost aggregate demand. In other words, this will encourage households to save less and companies to invest more as the discount rate has been reduced, which in turn will boost demand for loans, aggregate demand and ultimately economic growth (Arteta et al., 2018).[24] This assumes that monetary policy works in the traditional sense. Conventionally, monetary policy has been seen as neutral – the idea that in the long run, money and monetary policy have no effect on real economic variables. However, the times of loose and unconventional monetary policy has shown that it affects not only the price of risk but also the level of risk taken. As such, contrary to traditional views, monetary policy does not only change aggregate demand but also encompasses resource -allocation effects (Sieroń, 2020).[25]

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[20] The underlying reasons of lowering rates into negative territories varied. DNB and SND was motivated by the need for combating capital inflow pressure and currency appreciation, while others such as the ECB and the Swedish Riksbank was to stabilize inflation expectations (Arteta et al., 2018).

[21] Specifically, the main refinancing rate which is equivalent to the deposit rate.

[22] Though the Swedish Riksbank was the first to set negative rates, it was only temporarily. Denmarks Nationalbank was the first to implement NIRP and sustain the negative rate for a long period of time. Sweden revisited the negative rate in February 2015.

[23] See Arteta et al. (2018) for an early survey of which central banks employed NIRP and an assessment of its implications.

[24] From the bank's perspective, the NIRP works through the transmission channel of affecting credit facilitation as NIRP encourages banks to use excess reserves to increase lending. This is also known as the credit channel or bank lending channel (Arteta et al., 2018).

[25] For a fuller discussion and analysis on monetary policy after the Great Recession and the unintended

Thus, it seems like easy monetary policies in the current environment cannot be fully viewed through the traditional lens and that perhaps there exist several unintended channels of monetary policy. Notably, the concern of inadvertent consequences of accommodative policies has been voiced before, mainly by the Austrian school of economics. The Austrian business cycle theorists (primarily Hayek and von Mises) examined the effects of credit expansion and the decline in the market interest rate below the natural rate through the lens of malinvestments. Ultimately, warning that a credit-driven expansion would lead to misallocation of real resources in the long run. Indicating that easy monetary policy may lead to malinvestments (Sieroń, 2020; von Hayek, 2012; White, 2012).[26] Along these lines, there have been several theoretical inquiries as of late into accommodative monetary policy and its unintended channels, such as zombie emergence. White (2012) outlines several unintended consequences of ultra-easy monetary policies. Pointing towards it not being a "free lunch" as they create malinvestments in the real economy, have adverse effects on the health of financial institutions and on the functioning of financial markets and worsen income and wealth distribution.

Borio (2018) further hypothesizes on the link between resource misallocation and macroeconomic outcomes while also stating that there is a tight relationship between zombie firm occurrence and low interest rates. He postulates that, "*…the impact of low interest rates is unlikely to be uniform across the economy. Sectors naturally differ in their interest rate sensitivity. And so do firms within a given sector, depending on their need for external funds and ability to tap markets. For instance, the firms' age, size and collateral availability matter."* Suggesting that there occurs a resource shift and that low interest rates reduce the pressure for these companies to reduce debt. Low borrowing costs keep zombie companies alive in certain sectors. As such, this paper also controls for unobserved sector influences, firm age and size in the ensuing empirical investigation.

Sieroń (2020), theoretically examines monetary policy after the Great Recession in a thorough manner in his book. Specifically, he investigates how accommodative monetary policy disrupts the process of reallocating resources and considers the zombie channel of monetary policy—arguing that holding interest rates for too long could hurt growth. Concluding that a monetary-liquidity trap wherein the low interest rates contribute to an increased zombie occurrence which in turn slows down economic growth.

Despite the increased theoretical focus of the unintended consequences of accommodative monetary policies and particular their link with firm dynamism and the process of resource allocation; there is still a need for a better understanding of the link. Part of the empirical literature indicates that that accommodative monetary policy in the incidence of zombies is a main driver (Adalet McGowan et al., 2017b; Banerjee & Hofmann, 2018). While, other perspectives from DNB and Deutsche Bundesbank have found no

consequences of ultra-easy monetary policies, see Sieroń (2020) and White (2012).

[26] See Laidler and David (1999) chapter 2 for a more encompassing explanation of the Austrian theory and its Wicksellian origins.

increase in the percentage share of zombie firms in a low interest setting (Andersen et al., 2019; Deutsche Bundesbank, 2017). Specifically, Andersen et al. (2019) examine the phenomenon covering the period of 2001 to 2016 using firm-level microdata from Statistics Denmark; the authors find that zombie firms constitute a small share of all firms measured by balance sheet totals and has been declining since 2011. Moreover, they also point towards the fact that zombie firms are distributed equally across industries and that there is an unchanged prevalence of zombie occurrence despite the low interest rates. Similarly, Deutsche Bundesbank investigates the spectacle in Germany for the years 2000, 2007 and 2015 using firm-level microdata from the Bundesbank's own financial statement data pool. Their results follow the perspective of DNB and show that zombie firms make up a small percentage of all firms in Germany. Their findings also show that the share has not increased in a time of low interest rates and is unlikely to have any dampening effect on productivity and economic growth in Germany.

Much of the literature reviewed here has shown that zombie firms are detrimental to the economy through various channels. Some of which include loan portfolio deterioration of banks, leading to reduced financial stability; forbearance lending that makes inefficient firms drag along and induce moral hazard; and crowding out more productive and creditworthy companies, ultimately distorting market competition. Overall, showing that zombie firms may result in a perverted banking sector that promotes misallocation of credit and resources and impeded firm dynamics as firm entry and exit is curtailed. This zombification of the economy may even be further exacerbated by the current accommodative monetary policy setting.

3 Data

3.1 Data

3.1.1 Firm-level Data

The baseline econometric analysis utilizes a harmonized micro-level dataset, where the underlying comprehensive firm-level data stems from ORBIS over the period 2000-2019. ORBIS is a commercial database provided by the publishing firm Bureau van Dijk (BvD), covering a large number of countries worldwide. This dataset is unique as it provides firm-level accounting data for public and private limited liability companies, partnerships and sole proprietorships distributed across all industries.[27] It is based on questionnaires and tax

[27] The database is restricted in this paper to cover all private non-primary and non-financial firms in Denmark that would fall into the national industrial classification: NACE Rev.2 codes 10-82, excluding 64-66. Which are: Manufacturing (C: 10-33); Electricity and Water supply services (D: 35-39); Construction (F: 41-43); Wholesale and retail services (G: 45-47); Transportation (H: 49-53); Accommodation and Food services (I: 55- 56); Information and Communication services (J: 58-63); Real estate services (L: 68); Professional, Scientific and

reporting's – compiled and published at both enterprise and establishment level, including distributions according to kind of activity, form of ownership, size group and region.

It is assumed that the firms in the sample are representative of the entire population of firms in Denmark. Accordingly, a sound basis for analyzing firm dynamics in Denmark (Statistics Denmark, 2018). Since the information is collected for use in the private sector with the aim of financial benchmarking, a number of steps need to be implemented before the data can be used for analysis. This paper adopts rigorous data cleaning and harmonization steps closely following suggestions by Kalemli-Ozcan et al. (2015) and Gal (2013) to overcome inherent data limitations. This involves the use of procedures such as keeping accounts that refer to the entire calendar year, dropping observations with missing information on key variables and winsorizing the data at the five-percent level by year and sector. Additionally, monetary variables are deflated using industry-specific deflators to adjust for price changes over time.[28]

The final unbalanced harmonized dataset is driven by the data availability that is necessary to construct the main zombie measures and is based on unconsolidated accounts in order to avoid double counting of firms.[29] This results in a total of 1,993,504 firm observations spanning from 2000 to 2019.

As the focus of this investigation is on zombie firms in a low interest rate environment, the firm-level data is coupled with the nominal short-term interest rate (i.e., the 1-week certificate of deposit rate: "indskudsbevisrenten").[30] Specifically, the end-year observations are extracted from Danmarks Nationalbank Statbank and utilized in the ensuing analysis.[31]

3.1.2 Data on Insolvency Proceedings and Bank Health

A second point of the research is to investigate what other factors can help explain the comparatively low rate of zombie firms in Denmark, given the low interest rate setting. To further substantiate the analysis, additional drivers of zombie firm emergence are introduced, and a set of insolvency indicators developed by the OECD (see (Adalet McGowan et al., 2017a; Andrews & Petroulakis, 2019; McGowan & Andrews, 2018) are adopted into the

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Technical Activities (M: 69-75); Administrative and support service activities (N: 77-82). A complete overview can be found in Table B.1 in Appendix B.

[28] Appendix A provides a detailed description of the data limitations, data cleaning and harmonization process and presents summary statistics of the relevant variables utilized in the analysis.

[29] Double counting could occur if the consolidated accounts of the parent (including all its subsidiaries) and the unconsolidated account of the parent (no subsidiaries) are utilized. Furthermore, the use of unconsolidated accounts could induce a potential bias as it may affect corporate profit shifting strategies (Adalet McGowan et al., 2017a); however, for this exercise I assume this is not the case.

[30] Thus, "interest rate" or "rate" refers to the official deposit policy rate and will be used interchangeably henceforth.

[31] The data is obtained from: Nationalbankens Statbank - statistikbank.dk/nbf/98214 : "*DNRENTA: Danmarks Nationalbank's official interest rates and money and capital market interest rates by item, country and methodology (yearly observations) – The Nationalbank's official rates – Certificates of deposit*"

dataset. The indicators are de jure measures ranging from 0 to 1 available for 2010 and 2016 – wherein a lower value indicates efficient insolvency proceedings. This measure will solely be used in the descriptive data section as it is not viable to examine time series variation in the indicator.

In addition to the insolvency measure, the paper makes use of a bank health indicator to analyze the connection between zombie firms and financial sector health. A holistic bank health measure is constructed following Andrews and Petroulakis (2019). The bank balance sheet data come from BvD's BankFocus database[32], which contains bank data for over 46,000 banks going back to the 1990s (BankFocus, 2021). The financial information from BankFocus is matched with the harmonized ORBIS firm-level dataset based on the banker variable in ORBIS.[33] This is possible as it is assumed that a firm's bank relationship reflects its borrowing relationship according to the literature (Chodorow-Reich, 2014; Kalemli-Ozcan et al., 2015). Some firms report more than one bank relationship, and, in such a case, the largest bank (in terms of total assets in 2019) among reported banks is assigned as the main one.

3.2 Descriptive Data

3.2.1 How to define and statistically capture zombie firms

A common approach in much of the recent literature is to utilize interest coverage ratio (ICR) as a proxy of firm viability and thus as a way of identifying zombie firms (e.g., (Adalet McGowan et al., 2017b; Andrews & Petroulakis, 2019; Banerjee & Hofmann, 2018).[34] This choice of identification method is driven by the fact that ICR accounts for channels other than subsidized credit (e.g., government guarantees, weak insolvency regimes and non-performing loans), increased cross-country comparability and is less endogenous to productivity than a measure solely based on negative profits (Adalet McGowan et al., 2017b). Similar other recent literature has used the same method in categorizing zombie firms in order to draw comparisons with the results presented by the OECD and BIS, see for example, Andersen et al. (2019) and Cella (2020).

Despite its widespread application, the ICR measure has a few drawbacks. Storz et al. (2017) cite that the indicator contradicts the postulation by Caballero et al. (2008) that

[32] Formerly known as BankScope

[33] As ORBIS does not provide an identifier for the firms' banks, I match based on bank names.

[34] There are currently no objective criteria for when a firm is non-viable and should exit. However, the consensus in the recent zombie firm literature, mainly by the OECD and the BIS, is that persistent negative profits are a good criterion. Specifically, a firm is considered a zombie if for three consecutive years $ICR = \frac{EBIT}{Interest\ Payments} < 1$. This definition generally captures non-viable firms that should either be closed down or restructured – but it should be noted that it may also capture some firms that should not necessarily be closed down. For instance, firms with negative profits for a number of years while developing new products that may generate future profits (e.g., technology firms that focus on R&D).

zombie firms receive subsidized credit. As such, zombie firms should be connected with low interest payments and would therefore be difficult to identify through ICRs. Furthermore, in the current ultra-easy monetary policy environment, lower rates could reduce the measure of zombie firms as they improve ICRs by reducing interest expenses, all else equal. Thus, a mechanical issue may arise when investigating zombies in a low interest environment.[35] Another drawback is that the data on interest payments is often sporadically reported for some countries – In Denmark's case, it is sparsely reported due to BvD's contractual agreements with the previous information provider.

To better identify non-viable firms in the data, avoid classification errors and avoid the pitfalls of data limitations inherent in ORBIS, this paper employs a definition following Storz et al. (2017) in categorizing the zombie firms in the baseline analysis.[36]

Specifically, this paper identifies zombie firms as follows:

1. Low debt service capacity – measured as a ratio of EBIT to total financial debt (sum of loans and long-term debt) below 5% for at least two consecutive years[37]
2. Return on assets is negative for at least two consecutive years
3. Net investments are negative for at least two consecutive years

The first condition will ensure that only highly indebted firms are captured – and is utilized instead of interest coverage in order to avoid misclassifying zombies with highly subsidized credit as healthy firms. The paper closely follows Storz et al. (2017) in defining the debt servicing capacity threshold at 5%. This implies that a median firm in the sample which pays approximately 5% interest on its outstanding debt has an ICR of one.[38] The second condition is intended to capture firms that are persistently not profitable. The third condition is put in place to ensure that the measure identifies firms that do not invest beyond the value of their depreciation. This restriction is imposed to avoid classifying younger firms, as it could be difficult to distinguish actual zombie firms from start-ups when examining profitability measures.[39] In combination, all three conditions are put in place in order to capture firms that are persistently not profitable enough to cover debt payments and

[35] According to Andersen et al. (2019): "*Mechanically, lower interest rates mean that meeting the zombie criteria becomes more difficult (interest payments higher than operating profits). But the impact is very small and may be ignored as interest payments as a percentage of the balance sheet total tend to be low.*"

[36] According to Andrews & Petroulakis (2019) this measure is highly correlated (around 0.7) to the ICR based measure but avoids some of its downfalls.

[37] This paper differs from Storz et al. (2017) in utilizing EBIT instead of EBITDA. This is mainly done due to data availability. See Rodano and Sette (2019) on the benefits and downfalls of using either EBIT or EBITDA.

[38] The implied interest rate for firms in the sample is calculated as interest payments divided by total debts.

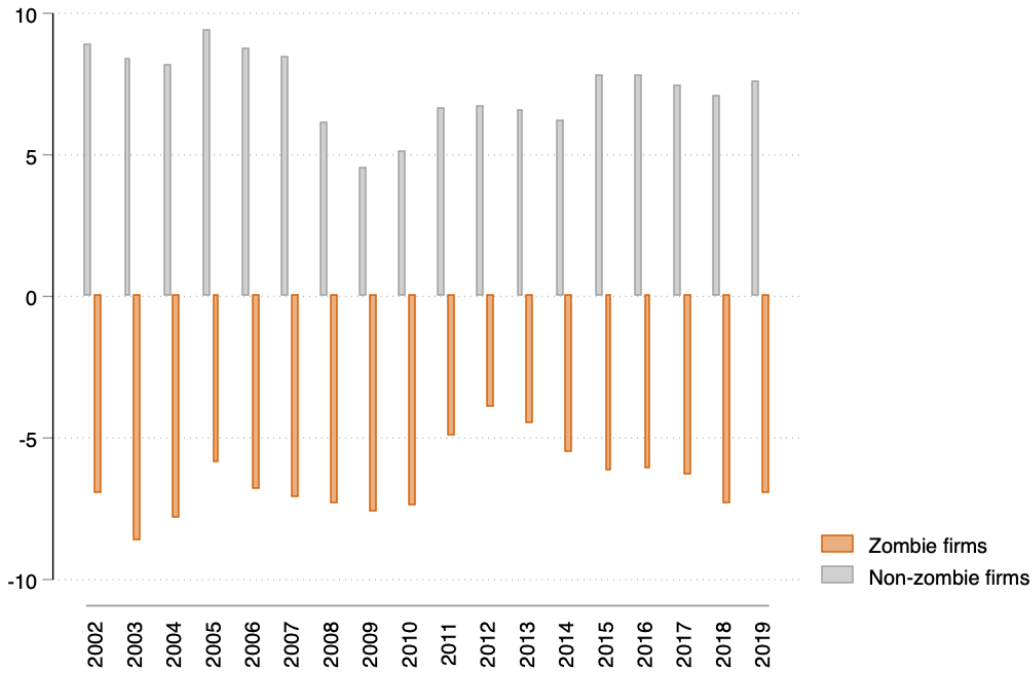
[39] It must be noted that there could be more reasons to why a firm have persistently negative profits. One being that a firm is a young firm in the start-up phase and as such have negative profits in the starting phase of their business life cycle. Another potential reason could be state-owned enterprises that are not profit driven per se.

therefore are on the margin of exit in a competitive market. It also addresses the concerns regarding a business cycle effect as a two-year window is imposed onto all the conditions of the measure.[40]

Data are available as of 2000; as such, the zombie classification can be applied from 2002, as that is the first year that a firm could fulfill the two consecutive year window that is imposed on the measure.

Subsequently – a binary variable is created; wherein, a set of firms are defined as zombie firms (equal to 1) when the individual firm fulfills criteria (1), (2) and (3) for (t, t-1) and non-zombies (equal to 0) when the criteria remain unfulfilled.

Figure 1: Median debt service capacity ratio



Note: The Figure reports the median debt service capacity ratio for zombie firms (orange bars) and non-zombie firms (grey bars) in the sample over the period 2002-2019. The median debt service capacity is measured as a ratio of EBIT to total financial debt (sum of loans and long-term debt). The sample median debt service capacity for the full period is 7.17% for non-zombie firms and -6.38 for zombie firms.

Source: Own calculations based on firm-level data from ORBIS

[40] This effect will also be addressed using a dif-in-dif including a fixed effect structure in the forthcoming analysis

Figure 1 displays the median debt service capacity ratio for each of the years in the period 2002-2019 for firms that are classified as zombie firms and non-zombie firms.[41] As expected, a striking difference between zombie firms and non-zombie firms in producing profits to service their debts is apparent. The sample median debt service capacity for non-zombie firms for the whole duration of the sample is 7.17%, while it is -6.38% for zombie firms (unreported). This suggests that while the median viable firm has no issue creating profits to service the interest on their debts; the median zombie firm, on the other hand, is falling in creating sufficient income to cover annual interest payments on their debt obligation without drawing on outside sources.

3.2.2 The characteristics of zombie firms and zombie share evidence

The debt service capacity ratio is not the only measure wherein there are differences between zombie firms and non-zombie. To investigate the various differences of zombie firms from non-zombie firms, this section examines the characteristics of zombie firms and investigates the share of zombie firms in Denmark.

In Table 1 various firm characteristics are reported in order to depict what distinguishes zombie firms from other firms.[42] Specifically, Table 1 highlights sample averages, as well as the results of Kolmogorov-Smirnoff (KS), tests for each variable to test for equality of distribution. The non-parametric KS test is utilized to further test whether zombies are different than non-zombies without making any assumptions about the underlying distributions.[43]

[41] The median ratio is reported in order to avoid the influence of extreme outliers on the distribution.

[42] The current measure of zombie firms gives equal weight to all firms in terms of characteristics such size. The following sub-sections will introduce a measure that captures their economic relevancy with the use of measures that incorporate the share of resources they capture across the included sectors.

[43] Since the KS test is a non-parametric test, it is possible to compare any two distributions without making assumptions about the underlying distribution of the data. This makes it effective in distinguishing a sample from another sample. This particular test is especially suitable for big samples (Massey Jr, 1951).

Table 1: Zombie firms' anatomy

Means[1] and difference in distribution test – KS Stat

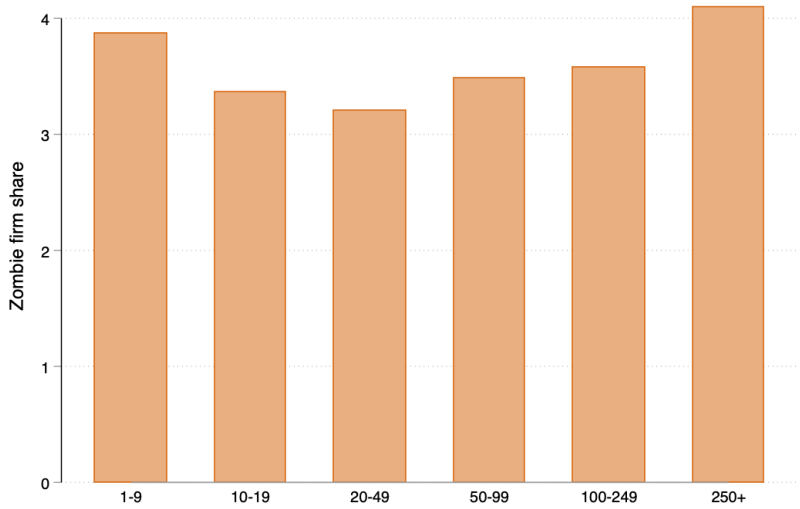
	Zombie firms[2]	Non-zombie firms	Kolmogorov-Smirnoff stat[3]
Total Assets	106376.43***	124918.89	0.07
Tangible Fixed Assets	56177.417***	68099.754	0.14
Number of employees	14.745***	15.681	0.03
Firm Age	12.9***	10.2	0.17
ROA (%)	-13.199***	5.117	0.715
Net Investments	-7678.698***	920.926	0.438
Cash Flow	601.77***	11645.436	0.522
Net Income	-4820.587***	4851.511	0.677
Provisions	4116.043***	6117.329	0.222
Long-term Debt	39210.785***	40341.119	0.104
Gross profits	19602.299***	31799.281	0.112

Note: [1] ***/**/* indicates significant difference in the means of zombie firms compared to non-zombie firms after controlling for sector and year fixed effects. Means are reported in either Danish Kroners or percentages. [2] Zombie firms are defined as firms with low debt service capacity below five percent for at least two consecutive years and negative return on assets and net investments for at least two consecutive years. [3] All tests reject the null hypothesis that the data is drawn from the same distribution as the one-percent critical value of the Kolmogorov-Smirnoff test is 0.002, and the p-values for each two-way sample tests are 0.000.
Source: Own calculations based on ORBIS firm-level data.

Zombie firms are characterized by being smaller on average than non-zombies in terms of assets and number of employees. The data also depicts that zombie firms have less tangible fixed assets than viable firms on average. Additionally, zombie firms are older and much less profitable in terms of gross profits, ROA and net income. Specifically, ROA is roughly 18 percentage points lower than non-zombie firms. Distressed firms in Denmark are further characterized by very low cash flow compared to their counterparts. Moreover, Zombie firms have negative net investments, which points to the fact that they are so highly indebted that they cannot afford to invest in plant, property and equipment.

The results differ slightly when investigating the median values as such, they are reported in **Table B.2** in Appendix A; wherein, the median zombie firm is larger than non-zombie firms in terms of total assets, tangible fixed assets and long-term debt.

Figure 2: The share of zombie firms in each size category (number of employees)



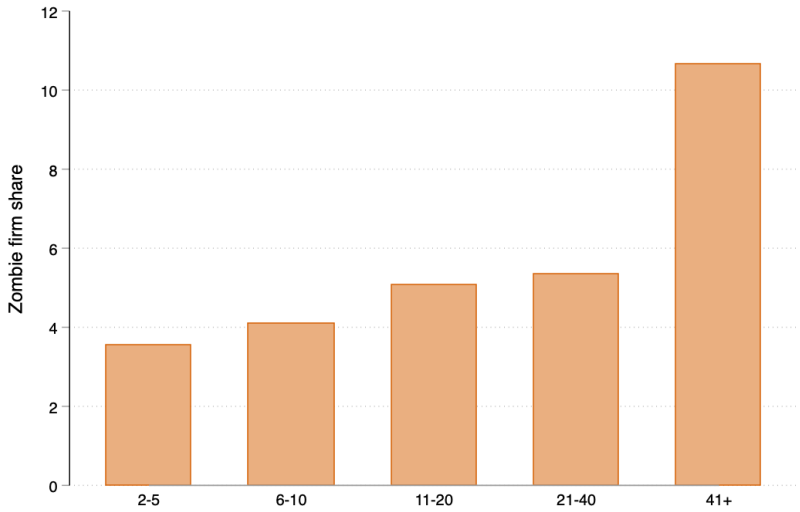
Note: The Figure shows the share of zombie firms in each size category based on the number of employees. See section 3.2.1 for precise definition of zombie firms.

Source: Own calculations based on firm-level data from ORBIS

Diving deeper down into certain characteristics, specifically, firm age and firm size can ascertain zombies further. Shares of zombie firms in each size category and each firm age category à la Adalet McGowan et al. (2017b) are calculated. The estimates shown in **Figure 2** and **Figure 3** are created by taking the unweighted average across zombie firms in the sample period in focus. The findings are somewhat consistent with existing literature pointing towards the likelihood of being a zombie firm increases with size and firm age (Adalet McGowan et al., 2017b). Specifically, **Figure 2** depicts that there is a bigger likelihood of being a zombie firm for small firms (1-9 employees) and for the largest category (250 plus employees). The relatively larger presence of zombie shares in the small size category (1-9) could be due to the fact that many small firms have many challenges in accessing capital in order to grow their businesses.[44] They are usually too small to access public debt, equity markets and attract venture capitalists; and as such, are forced to be heavily reliant on subsidized credit. A reasoning for a moderately higher zombie firm share for the largest size category could be that banks might have incentives to keep large firms alive due to bank forbearance, perhaps due to a prior firm-bank relationship. Another reasoning could be that larger firms are more likely to receive government subsidies due to the preferences of avoiding the high social costs that would incur if a large firm exited the market.

[44] In practice not all privately held firms have the objective of growth in terms of size. Some firm are small firms that intend to remain small and others have the intention of continued growth and profitability.

Figure 3: The share of zombie firms in each firm age category



Note: The Figure shows the share of zombie firms in each firm age category. Firm ages are calculated by taking the differences between accounting year and incorporation date. See section 3.2.1 for precise definition of zombie firms.

Source: Own calculations based on firm-level data from ORBIS

Figure 3 depicts that the share of zombie firms is higher for older firms. Specifically, firms that are above 41 years in firm age have approximately a 11% zombie share. It can be hypothesized that older firms have a larger number of employees and thus receive subsidies from banks, as discussed in the previous paragraph.

3.2.3 Zombie prevalence over time

Beyond the characteristics of distressed firms, the evolution of zombies in Denmark is important in order to understand zombie firms' effect on the real economy and its dynamics. The above table and figures outline the firm dynamics and characteristics of zombie firms compared to non-zombie firms. However, little is revealed about the presence of zombie firms in Denmark and whether that presence has increased after a change in interest rates following the aftermath of the global financial crisis.

Figure 4 examines the evolution of zombie firms in Denmark since 2002 and suggests that despite findings in existing literature, the prevalence of zombie firms has not increased significantly in the past years (Figure 4, orange line). From the start of the sample period in 2002 to around the onset of the global financial crisis zombie shares decreased, on average, from around 4% in 2002 to 2% in 2007. Unsurprisingly, the aftermath of the crisis created an uptick in zombie firm shares in Denmark, with approximately 6.3% of firms being zombie firms in 2010. As a response to the crisis, ultra-easy monetary policies were announced, and negative deposit rates were introduced in 2012. Despite this, the zombie rate continued to

decline to around 2.9% in 2017 before increasing once again to about 4.1% in 2019. This suggests that the upward shifts in shares are linked to economic downturns and are somewhat reversed in subsequent years. The current Covid-19 pandemic and its ensuing economic aftermath could foster a possible further upward shift, as seen in the last global financial crisis.

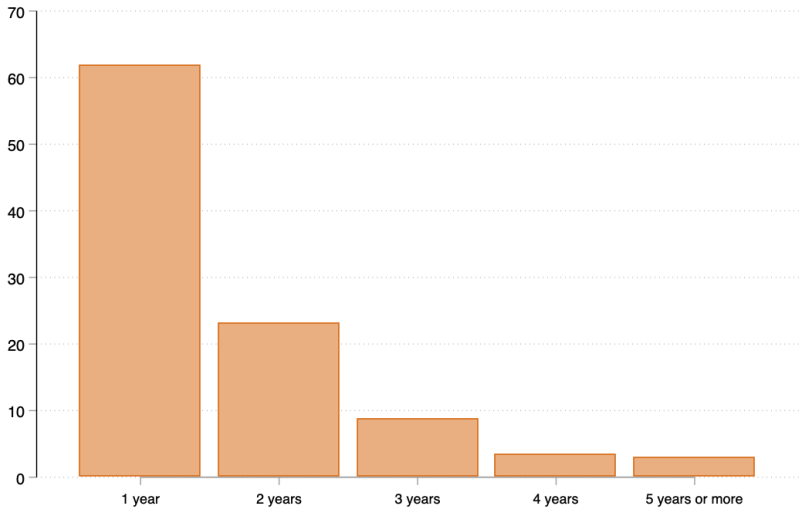
Figure 4: Zombie shares over the years and the probability of remaining a zombie

Note: The figure depicts the unweighted share of zombie firms over the sample period 2002 to 2019 (orange line). Additionally, both the probability of remaining a zombie one year later and two years later are depicted in the figure. The probability of remaining a zombie firm the next year is calculated as the number of firms that are classified as a zombie in year t and that remain a zombie in year t+1 divided by the number of firms that are classified as a zombie in year t. Moreover, the probability of remaining a zombie firm two years later is calculated as the number of firms that are classified as a zombie in year t and that remain a zombie in year t+2 divided by the number of firms that are classified as a zombie in year t (Banerjee and Hofmann, 2020). See section 3.2.1 for precise definition of zombie firms.

Source: Own calculations based on firm-level data from ORBIS

Additionally, the figure also depicts the persistence of zombie firms and whether surviving as a zombie firm has become easier since the decline in interest rates. The risk of persisting in a zombie state is not constant over time; however, it is evident from the figure that there is a marginal increase in remaining a zombie. Specifically, the probability of remaining a zombie in the following year rose from 43% in 2003 to 51% in 2019. Moreover, the probability of remaining a zombie two years later was 18% in 2004 and rose to 25% in 2019. This depicts that while there has been a small rise in the risk of remaining a zombie firm rather than exiting, it has not increased significantly during the years of negative interest rate policies.

Figure 5: Number of years classified as zombie firms



Note: The figure depicts the distribution of the number of years classified as a zombie firm. Aggregated for the years 2002 to 2019. Only the longest-lasting period is included for firms with multiple non-consecutive zombie classification periods. See section 3.2.1 for precise definition of zombie firms.

Source: Own calculations based on firm-level data from ORBIS.

Figure 5 shows the distribution of how long firms remain non-viable after being classified as a zombie firm. For firms that are reclassified as zombie firms numerous times, the figure depicts the longest-lasting period. Figure 5 indicates that the majority of zombie classification periods are relatively short; wherein, about 85% of firms are zombies for two years or less. While only 2.9% remain zombie firms for a long-extended period of five years and more. There is a noticeable share of firms that had multiple non-consecutive zombie classification periods; specifically, one-year periods which point to firms that are on the margin of exit but do not stay there for long.

As seen in Table 1 and Table A.2 in Appendix A, zombie firms have various distinct features different from non-zombie firms, one important feature being that they are larger – in terms of assets when comparing medians to their healthier counterparts. Additionally, zombie firms are also older and have a similar size in terms of labour.[45]

Therefore, in order to reflect their economic relevance, a share of resources that they capture is essential. Following the methods of Caballero et al. (2008), two size-weighted measures are created – based on labour and based on capital. Given potential sectorial heterogeneity, the two size-weighted zombie measures are aggregated by sectors.[46] For both

[45] It can be inferred that these characteristics make it easier for such firms to obtain access to credit as they have more tangible assets – collateral and perhaps a longer bank-firm relationship than their counterparts. Furthermore, Adalet McGowan et al. (2017b) argues that being larger in terms of employment increases the likelihood of receiving government subsidies as it implies high social costs from failure. This is particularly the case during recessions.

[46] This is described and investigated by Caballero et al. (2008). See Table B.1 of Appendix B for industry

size-weighted shares, the paper identifies the baseline number of zombie firms (based on the definition specified in section 3.2.1). The tangible capital stock[47] is then aggregated across zombie firms in a given two-digit industry and divided by the total industry tangible capital stock for each year to construct the zombie industry capital share.[48] The paper also considers a different specification of zombie industry capital stock, utilizing total assets as it is slightly broader and thus, is also included in the analysis[49] – when this variant is utilized in the econometric analysis, this will be explicitly stated to avoid any confusion.

A zombie capital sunk measure is vital as it reflects zombie congestion from an allocation standpoint in each given industry. The number infers that the share of industry capital sunk in zombies takes away from viable firm investments (i.e., the percentage of capital that resides in zombies in a given industry).

The second size-weighted measure is based on labour. As such, the total number of employees is aggregated across zombie firms in a given two-digit industry and divided by the total number of employees in all firms in the same industry for each year to construct a zombie industry labour stock measure. The ensuing econometric analysis will be using the size-weighted zombie share (capital) and the equal-weighted number of zombie firms' measure. The labour stock measure will be utilized in robustness checks.

Based on these measures, a more thorough investigation of the prevalence of zombie firms over time and their economic importance (through the lens of labour and capital sunk in the given industries) can be conducted. **Figure 6** depicts the shares of zombie firms over the period 2002 to 2019 for the three proxies: Number of firms (equal weight is given to each firm), labour and capital sunk.

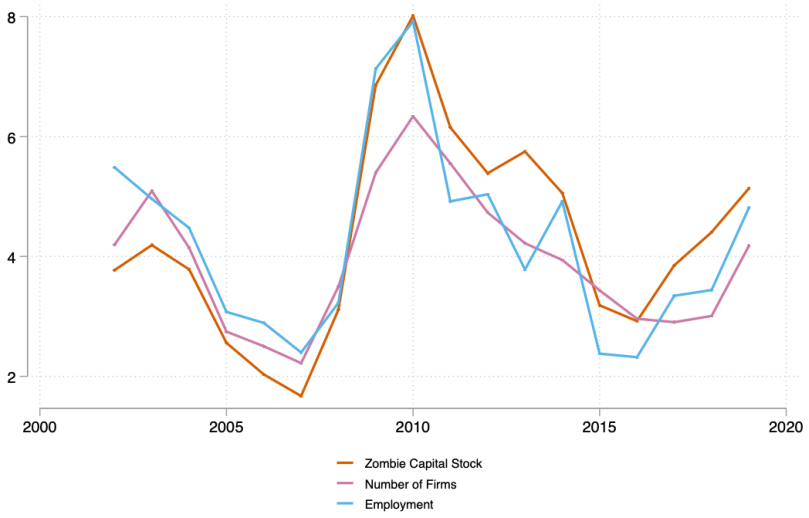
classifications.

[47] Physical or tangible capital is utilized as the main capital measure since it is considered collateral in both a bank – lending perspective and in the corporate insolvency process. Additionally, this provides a baseline for comparison to key zombie literature (i.e., Andrew and Petroulakis (2019); Adalet McGowan et al. (2017a); Osterhold and Gouveia (2020)).

[48] Interchangeably referred to as zombie capital share or capital sunk in zombie firms.

[49] This also considered in order to draw comparison to the other half of the key literature, which includes seminal work by Caballero et al. (2008), Adalet McGowan et al. (2017b) and Andersen et al. (2019).

Figure 6: Evolution of zombie firms in Denmark



Note: The figure shows the shares of zombie firms over the period 2002 to 2019 for three different proxies: Number of firms (unweighted), labour and capital sunk. See section 3.2.1 for precise definition of zombie firms.

Source: Own calculations based on firm-level data from ORBIS

Figure 6 suggests that the evolution of the share of firms classified as zombies for all three proxies have fluctuated with the business cycle - shifting upwards during economic downturns and declining in the subsequent recovery periods. Evidently, from the start of the sample period in 2002, which was the trough phase of the dot-com bubble, the share of zombie firms for the zombie capital stock, the number of firms and employment measure was 3.8%, 4.2% and 5.5%, respectively. Thereafter, there was a fairly big decline in zombie firm shares, and the figure illustrates that from 2005 to 2007, all three measures were at or below 3%. With the zombie capital share accounting for the lowest percentage of zombie share measures in the whole sample at 1.7%. Consequently, all three proxies increased after the financial crisis peaking in 2010 at 8%, 6.3% and 7.9% for zombie capital share, unweighted zombie share and zombie labour share, respectively. The ensuing years after the global financial crisis brought forth low zombie prevalence (in line with levels before the crisis). This suggests that despite a low interest rate environment, the zombie share fell and firms that were zombie firms during the crisis either reclassified as non-zombie firms or exited the sample. It is worth noting that all three proxies were somewhat fluctuating in the same manner before the global financial crisis; however, after the crisis became slightly more decoupled. Particularly, the zombie capital share had a hike in 2013 that could be a direct result of the lowering of the rates in 2012 below zero. In the latter years of the sample, zombie shares rose again to around 4%-5% for all three measures.

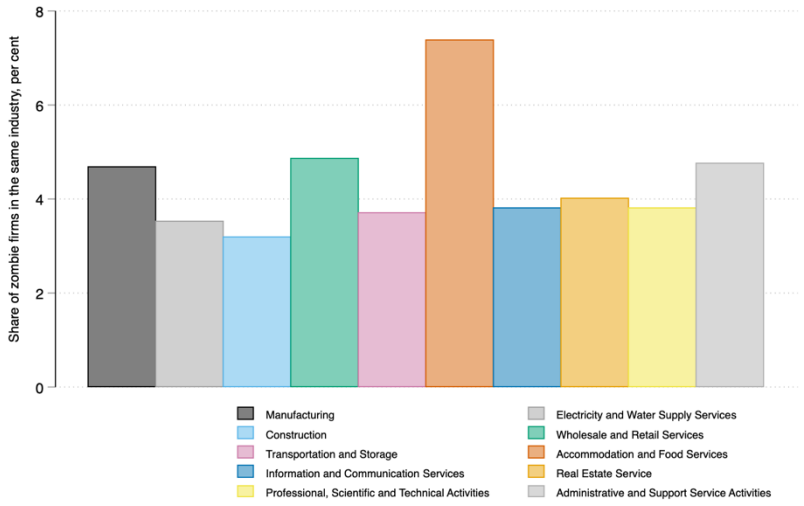
3.2.4 Industry distribution of zombie firms

This section explores the sectoral asymmetries in the zombie capital share in Denmark. As evident in **Figure 7A**, there are a few variations in the zombie capital shares at the sectoral level as zombies are distributed somewhat evenly across industries. The largest presence of zombie firms is found in the accommodation and food services sectors, followed by the second largest presence of zombie firms in the wholesale and retail service sectors. Specifically, it shows that for the full sample period from 2002 to 2019, 7.4% of zombies were in the accommodation and food service industries. **Figure 7B** further explores the distribution of zombie firms at the sectoral level with the difference of examining the years: 2007, 2012 and 2019. 2007 is chosen as it was a boom period, during the time of the overheating of the economy before the global financial crisis – 2012 is selected as this is the first year with negative interest rates from DNB – 2019 is picked because it is the most recent year available in the data.

As expected, this points towards low zombie capital shares during the boom period and higher shares in years after. This also depicts that the overweight of zombie firms in the accommodation and food services sectors stem from the later years of the sample, with a share of 15.8% of zombies residing in that sector in 2019. In contrast, most other industries had similar or lower levels when compared to 2012. According to the data, the accommodation and food service industries did not have a significant amount of assets available to meet their short-term liabilities, pointing towards the fact that they might have seized on low interest rates in taking out big loans and becoming over-leveraged. Consequently, as markets slide further due to the coronavirus pandemic, the accommodation and food service industries have the prospect of falling into a heavy debt load tailspin.

Another interesting observation from **Figure 7B** is that the real estate service sector decreased capital sunk in zombie firms substantially from 2012 to 2019. This can be attributed to the healthy and booming real estate market in Denmark.

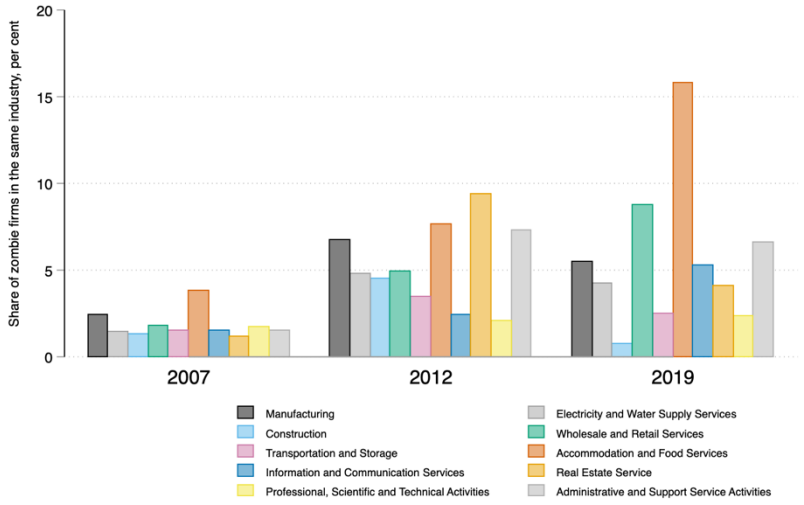
Figure 7A: Zombie shares by sector



Note: The figure depicts the distribution of capital sunk in zombie firms across the one-letter NACE Rev. 2 industries (see Table A1 in Appendix B) for the full sample. Note that this does not include the primary industries.

Source: Own calculations based on firm-level data from ORBIS

Figure 7B: Zombie shares by sector – selected years



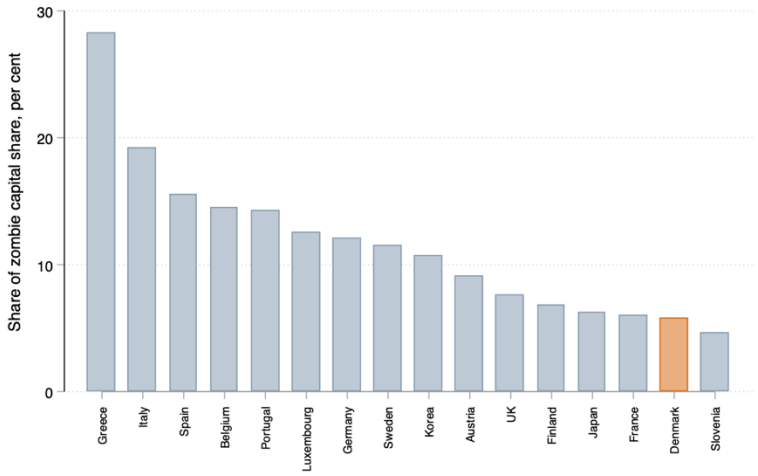
Note: The figure depicts the distribution of capital sunk in zombie firms across the one-letter NACE Rev. 2 industries (see Table A1 in Appendix B). Note that this does not include the primary industries.

Source: Own calculations based on firm-level data from ORBIS

3.2.5 Comparative evidence: Denmark vs. OECD counterparts

This section has thus far provided descriptive evidence on the evolution of zombie firms in Denmark and their characteristics in contrast to healthy firms. However, the question remains of how it compares to other countries. As seen in **Figure 4** and **6**, the average zombie share (regardless of proxy chosen) is fairly low. This assessment is also true when comparing to other countries. Specifically, as seen in **Figure 8**, the share of zombie firms is low compared to OECD counterparts.[50] It examines the capital sunk in zombie firms in 2013 in order to allow comparability to existing studies from the OECD (Adalet McGowan et al., 2017b). Moreover, it also helps paint a picture of zombie shares in low interest rate countries and Denmark which had negative interest rates at that point in time. Comparing with Sweden and Finland, zombies accounted for 11.4% and 6.8%, respectively, of total capital stock in 2013. The figure further substantiates the fact that the cyclical position has a vital influence on the prevalence of zombie shares. This is clear in the case of Greece still being in a protracted recession after the global financial crisis. Other factors such as a good insolvency framework and sound financial sector stability could also play a role in the relatively low zombie prevalence in Denmark compared to other countries.

Figure 8: The zombie shares in Denmark and in 15 OECD countries.



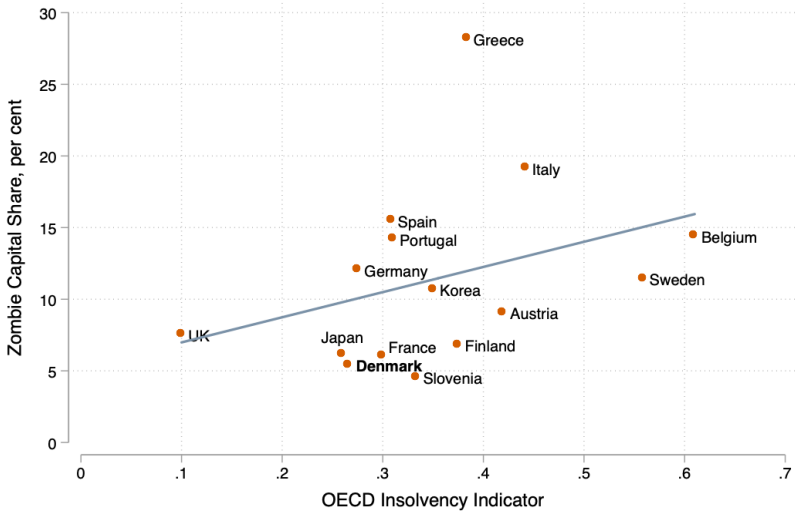
Note: Data for 2013. Zombie shares are measured in terms of capital (tangible assets)

Source: Adalet McGowan et al. (2017a) and own calculations based on firm-level data from ORBIS.

[50] This comparison is included for presentational purposes; however, cross-country comparisons bring forth some uncertainty since there are different legislative and accounting regimes. Additionally, the data on the zombie shares for the 15 OECD countries stemming from Adalet McGowan et al. (2017a) all utilize ICR in order to capture zombie firms. This paper is utilizing the debt service capacity in defining zombie firms as it is more comprehensive and avoids the pitfalls of the ICR measure (c.f supra section 3.2.1). It is important to note that according to Andrews and Petroulakis (2019) the two measures are highly correlated. Despite this, there a probably some differences given cross-country differences and the different use in capturing zombie firms. Nonetheless, the prevalence of zombie firms in Denmark over time and in this particular case is still presumed to be low compared to its OECD counterparts.

As suggested by the literature, factors of a more structural nature also play a role in the zombie emergence across OECD (Adalet McGowan et al., 2017a). **Figure 9** gives an overview of zombie capital share on the OECD insolvency measure (see Appendix A for more details on the measure). This suggests that Denmark has a relatively good framework for distressed firms on exit margin. This contributes to the resolution of non-viable firms and results in a fairly low zombie capital share in contrast with OECD counterparts.

Figure 9: Insolvency proceedings and zombie shares in 15 OECD countries.



Note: Each marker represents an OECD country. The zombie capital share is plotted against the OECD insolvency indicator, "Insol12"- This is a composite indicator of a country's insolvency regime. The indicator ranges from zero to one. A lower value denotes efficient insolvency proceedings. The slope of the linear regression line is 17.5 and has an explanatory power of R^2=0.12.

Source: Adapted from Andersen et al., 2019 with the use of data from Adalet et al., 2017a and own calculations based on firm-level data from ORBIS.

3.2.6 Financial Stability Perspective: Gauging Bank Health

An increased zombie prevalence across various countries has also potentially been attributed to weak banks (Caballero et al., 2008; Schivardi et al., 2017; Storz et al., 2017). Not all of the literature agrees with this link, as Banerjee and Hofmann (2018) find no such link using the price-to-book ratio as their bank health measure. Defining a bank measure is challenging as the underlying firm-level data is mainly composed of SMEs, which in turn may not rely on big banks. Therefore, a market-based measure is not viable. In this paper, an investigation of whether weak banks can be a source of change in zombie firms behavior is pursued in the second step of the empirical analysis by following the methodology of Caballero et al. (2008) and Storz et al. (2017) using bank sheet information from BvD's BankFocus database.[51]

[51] This particular measure of bank health is not perfect and faces a number of challenges – See *Box 2* in Adalet McGowan et al. (2017b). Notwithstanding, the bank traits that makes up the bank health index measure are picked based on the fact that they are commonly associated with bank health in the past literature (Caballero et

To gauge bank health, a continuous index is constructed from the first principal component (the largest eigenvalue) from a Principal Component Analysis of seven financial statement variables stemming from bank balance sheets. These include tangible common equity (TCE, a proxy for capital), NPLs, net income, net interest income, return on average assets (ROAA), Z-score and retail funding.[52] Specifically, the Z-score is given by the sum of ROAA and TCE over the standard deviation of returns on average assets. As such, it is an indicator of the bank's distance to bankruptcy. Retail funding is created by the ratio of retail deposits and total assets. This measures to what extent the bank relies on sticky retail deposits. The composite measure is increasing in bank health.

The holistic bank health measure is subsequently matched up with firms in the ORBIS dataset that provide information on their bank relationship. Some firms report several bank relationships, and, in such case, the largest bank in 2019 is assigned as the main bank in the firm-bank relationship. The coupling of firms and their respective banks produces a sample of 29,910 different firms linked up with 51 individual danish banks – totaling 198,229 observations from 2005 to 2019.

Figure B.2 of Appendix B details the evolution of bank health in Denmark over the period 2005 to 2019. It is clear from the figure that financial sector health declined in the global financial crisis, and as such, it aligns well with the development of the crisis and is expected to be a good proxy for bank health in Denmark in the ensuing empirical analysis.

3.2.7 Key takeaways

- The firm characteristics differ between zombie firms and non-zombie firms. Zombies tend to be smaller in size (number of employees and assets), older and less profitable.
- The zombie firm share in Denmark over the period 2002 to 2019 have fluctuated with the business cycle – shifting upwards during economic downturns and declining in the following recovery periods. Overall, it has remained relatively low when compared to its OECD counterparts.
- The risk of remaining a zombie has only seen a slight rise in the sample period and has not increased during the period of falling interest rates. Indicating that as far as the danish case, low interest rates have not increased zombie prevalence.
- Firms that are on the margin of exit tend to be classified as zombies for a one-year period, and most recover afterwards.
- Zombie firms are evenly distributed across industries, with the exception of a slight overweight of zombies in the accommodation and food service industries.
- The efficient insolvency regime that is in place in Denmark may help to limit the zombification of the economy.

al., 2008 and Storz et al., 2017) and also due to data availability.

[52] The index is given by the first principal component – the one connected with the largest eigenvalue. Summary statistics of the bank health measure and the parts that it is made up of is seen in Table A.3 in the Appendix A.

4 Empirical Framework

4.1 Zombie shares in a low interest-rate environment

The previous section has highlighted various firm dynamics and traits for zombie firms in Denmark while also depicting the zombie incidence in terms of their industry distribution, their relation to OECD counterparts and evolution over time. This descriptive inquiry shows that after 2010, where interest rates declined substantially, zombie firm presence in Denmark did not escalate further – in fact, the zombie firm share decreased over the period 2010-2016. Furthermore, zombie firm persistence is relatively low as few firms stay in the zombie state for several years. These observations are unlike empirical studies that have pointed to persistently low interest rates and weak bank health as potential key drivers in the overall increase of zombie firms at the country and at the sectoral level (Banerjee and Hofmann, 2018).

The descriptive inspection included in this paper does not explain a causal relationship that clarifies the observed correlation. Against this background, this section attempts to outline the empirical investigation which considers the zombie phenomenon in Denmark through the channel of ultra-easy monetary policy, namely, low interest rates – while also taking bank health into consideration. The idea is to investigate the potential drivers of the zombie phenomenon and whether after the financial crisis in 2008, a period of low interest rates, more firms that were classified as zombies remained in that state.

4.1.1 Interest rates, bank health and capital sunk in zombie firms

To estimate the connection between zombie share emergence and its drivers, a cross-sectional test is implemented.[53] Specifically, a difference-in-difference method popularized by Rajan and Zingales (1998) will be adopted as it is possible to better address the lack of variation in the main interest variable as well as omitted common variables. That is to say that the model allows to control for omitted time-invariant specific factors and common industry-specific factors. The model is based on the postulation that there exist industries that have naturally high exposure to a given policy (the treatment group), and those industries should be disproportionally more affected than other industries (the control group) if the policy is relevant to the outcome. Effectively, this approach tests whether the effect of lower interest rates or weaker bank health is more pronounced in industries that are more dependent on external funding. The intuition behind using external funding is that industries that are more dependent on external funding are also more sensitive to financial pressure.

[53] This approach follows Banerjee and Hofmann (2018) who conducted this test on panel data across 48 industries for 14 advanced economies in the period 1987-2016.

To this end, a connection between the share of industry capital sunk in zombie firms for 62 industries, low interest rates and bank health are estimated in a difference-in-difference framework for the following specification, over the period 2002-2019:[54]

$$\begin{aligned} \textit{Zombie Share}_{st} = \beta_1(\textit{External finance dependence}_s * \textit{Interest rate}_{t-1}) + \\ \beta_2(\textit{External finance dependence}_s * \textit{Bank health}_{t-1}) + \gamma_{st} + \varepsilon_{st}, \end{aligned} \tag{1}$$

where the dependent variable, $\textit{Zombie Share}_{st}$ denotes the share of capital sunk in zombie firms in industry s, and year t [55]. $\textit{External finance dependence}_s$ in sector s is measured as the median firm's share of capital expenditures that are not financed from operating income.[56] This inclusion follows the literature in utilizing the measure as to proxy for industry exposure to interest rates and bank health (Rajan and Zingales, 1998; Banerjee and Hoffman, 2018). Interest rate refers to the nominal short-term interest rate with a one-year lag (t-1).[57] Bank health denotes the health of a bank associated with firm i in sector s. The bank health measure enters the model with a one-year lag (t-1). A fixed effects structure is utilized, denoted by γ_{st}. Wherein a two-way fixed effects structure ($\gamma_{st} = \theta_s^1 + \theta_t^2$) is included to control for unobserved influences. Specifically, the industry fixed effects are added to control for unobserved differences in characteristics between industries (e.g., productivity levels, etc.). Additionally, year fixed effects are added to control for unobserved cyclical influences and other time-varying factors. To account for potential serial correlation, robust standard errors are clustered at the industry level. This assessment will be conducted for the baseline measure of zombie firms described in section 3.2.1. It should be mentioned that this approach yields a differential impact and as such do not inference about the average effect of interest rates and bank health on zombie share.

4.2 Survival of zombie firms in a low interest-rate environment

The potential drivers of zombie shares across different industries are just one part of the phenomenon. Another investigation that could help assess the effect of interest rate channel on zombie firms is a simple LPM model evaluating the probability of remaining a zombie

[54] The measure of bank health links 29,910 firms with 51 individual banks for the period 2004 to 2018.

[55] See Table B.1 in Appendix B for the two-digit NACE Rev. 2 industry classifications. Furthermore, the Zombie share is based on the tangible capital stock (c.f. section 3.2.3).

[56] Specifically, this is defined as the difference between capital expenditures on fixed assets and cash flows from operations divided by capital expenditures. As ORBIS does not include sufficient data on depreciation for Denmark – this paper utilizes net investments as a proxy for capital expenditures.

[57] Following the same reasoning as Andrews and Petroulakis (2019), the interest rate enters the model with a one-year lag (t-1). This is done in order to capture it at the start of the time window utilized in the zombie definition – wherein firms are classified as zombie firms if they fulfil the criteria in section 3.2.1 for two consecutive years. Additionally, it is also indicated as the better-fit model when examining the Bayesian Information Criterion (BIC) against models with more lags.

firm over time. This approach is somewhat similar to Cella (2020), who investigated zombie firms and their implication in Sweden, with the difference that this paper will examine the probability of remaining a zombie firm in contrast to the probability of becoming a zombie firm.

4.2.1 Zombie firm persistence

The zombie firm persistence in Denmark is explored during the period where interest rates were constantly lowered by the DNB, 2009-2019 and is compared to the prior period, 2002-2008. The following LPM model for Denmark is estimated over the period 2002-2019:

$$Zombie\ Persistence_{ist} = \alpha_0 + \alpha_1(years_{ist}) + X_{ist-1}\Theta + \gamma_{it} + \varepsilon_{ist}, \tag{2}$$

where the unit of observation is firm i, sector s, and year t. The dependent variable, $Zombie\ Persistence_{ist}$ takes the value of 1 if a firm in time t will be classified as a zombie firm in the ensuing years and 0 otherwise. Specifically, zombie persistence is the probability that a zombie firm in time t will remain in the zombie state next year, two years later and three years later. $\mathsf{years}_{\mathsf{ist}}$ is a dummy variable equal to 1 over the years 2009-2019 and equal zero over the period 2002-2008. The matrix X_{ist} indicates relevant firm-level controls depending on the specification, such as firm size, debt service capacity and firm age.[58] A two-way fixed effects structure ($\gamma_{st} = \theta_s^1 + \theta_t^2$) is included to control for unobserved influences. Specifically, the firm fixed effects are added to control for firms' time-invariant characteristics Additionally, year fixed effects are added to control for unobserved cyclical influences and other time-varying factors. To improve the efficiency of the model and account for potential serial correlation, robust standard errors are clustered at the firm level. The estimation of the model will be with OLS (via the LPM) for ease of interpretation. [59]

As the dependent variable takes two values, the output coefficients cannot be interpreted as the effect on y for a one-unit change in x, ceteris paribus. Instead, it provides the probability that y=1 for a one-unit change of the independent variable of interest, holding everything else constant. The advantages of utilizing a LPM are that it allows for large numbers of fixed effects and ease of interpretation. Disadvantages include the fact that the error term is by definition heteroscedastic, but this is solved by using robust standard errors. Furthermore, OLS is not bound by the predicted probability within the range [0,1]; however, this is only a concern in forecasting probabilities (Hsiao, 2014). Given its

[58] Firm age and firm size are included as controls given the results in the Data Section – suggesting an effect on the likelihood of a firm remaining a zombie. Both Hoshi and Kashyap (2004) and Andrews and Petroulakis (2019) have also included these controls utilizing the same reasoning found in this paper.

[59] Given the very large number of N and consequently large number of fixed effects, it is not possible to estimate a probit or logit model. These binary models are not well-suited for its use due to incidental parameters problem (see Heckman (1987) for further insight). As such, the paper utilizes the LPM.

advantages, the model is used to identify which factors increase or decrease the likelihood of remaining a zombie firm for an extended period of time in Denmark.

5 Empirical Results and Discussion

5.1 Zombie firms and low interest rates

In light of the descriptive results presented in this paper and findings from existing literature, this section begins with investigating the potential drivers of zombie shares (**Figure 10**). Panel A shows the relationship between zombie shares and the policy rate in Denmark over the period 2002 to 2019. The visual evidence suggests that up until the global financial crisis, there was a tight negative relationship between the two[60], followed by a break in the link in the ensuing years. The close correlation leading up to the financial crisis could have been due to less pressure to deleverage for firms. As noted by Borio (2018), a reason for the tight relationship in the immediate years following the crisis could be reverse causality – as a decline in productivity and profitability could induce central banks to adopt accommodative policy and cut rates. This would explain the zombie trend following cyclical movements but does not clarify the overall persistent increase across advanced economies since the 1980s (Banerjee & Hofmann, 2018). Notwithstanding, this close correlation came to a halt in the immediate recovery in Denmark and decoupled as the ZLB was reached. It is a priori reasonable to expect that lower rates lighten the debt burden but at the same time may propagate zombie lending as the opportunity cost is lower – pointing to a deeper link between policy rates and distressed firms. As such, a rudimentary visual inspection does not explain a propagation mechanism that explains the observed correlation. Furthermore, the seemingly structural break occurring around the same time the DNB lowered rates into the negative territory, could also point towards the relationship is purely coincidental and that other factors may help explain the observed relationship.[61]

One potential factor as mentioned in the literature (Andrews & Petroulakis, 2019; Banerjee & Hofmann, 2018; Storz et al., 2017) is weak banks. Panel B depicts the correlation between zombie shares and bank health. The zombie shares are negatively correlated to bank health for most of the sample period. However, this appears to be episodic in nature, as it is decoupled before the economic boom leading up to the global financial crisis and again in 2016.

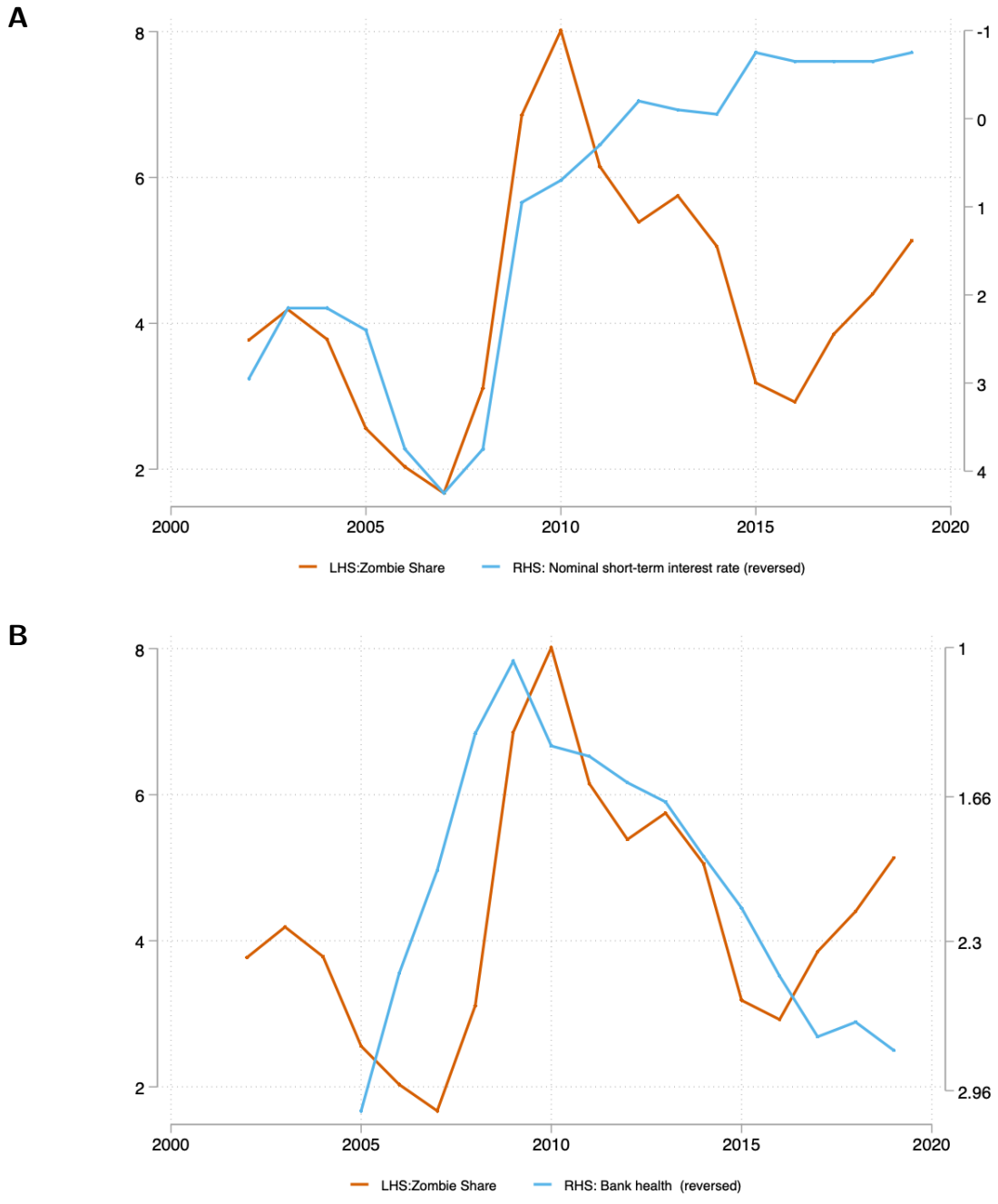
Although this visual inspection builds upon the descriptive results, a more robust inquiry of the factors leading to zombie firm emergence is warranted in order to answer the principal research question. Specifically, whether the reduced financial pressure following the

[60] This is the case regardless of which proxy for zombie firms is used.

[61] This observed break is merely an eyeball observation and has not been conducted through tests (i.e., xtbreak and Chow test)

decline in the level of interest rates is pushing up zombie shares or is it attributed to other factors.

Figure 10: Potential drivers of zombie shares



Note: Panel A shows the average capital sunk in zombie firms (orange line) and the nominal short-term interest rate (blue line – right axis). Panel B shows the average capital sunk in zombie firms (orange line) and the average bank health (blue line– right axis). See Section 3.2.1 for precise definition of zombie firms and see Section 3.2.6 for details on the construction of the bank health measure.

Source: Own calculations based on firm-level data from ORBIS and BankFocus.

Table 2: Drivers of zombie shares

Dependent variable: Zombie capital shares	(1)	(2)	(3)
External finance dependence$_s$ × Interest rate	-0.281		-0.027
	(0.207)		(0.270)
External finance dependence$_s$ × Bank health		0.001	0.001
		(0.003)	(0.004)
Observations	1,158	120	120
R2 (adjusted)	0.240	0.513	0.506
Industry-FE	Yes	Yes	Yes
Year-FE	Yes	Yes	Yes

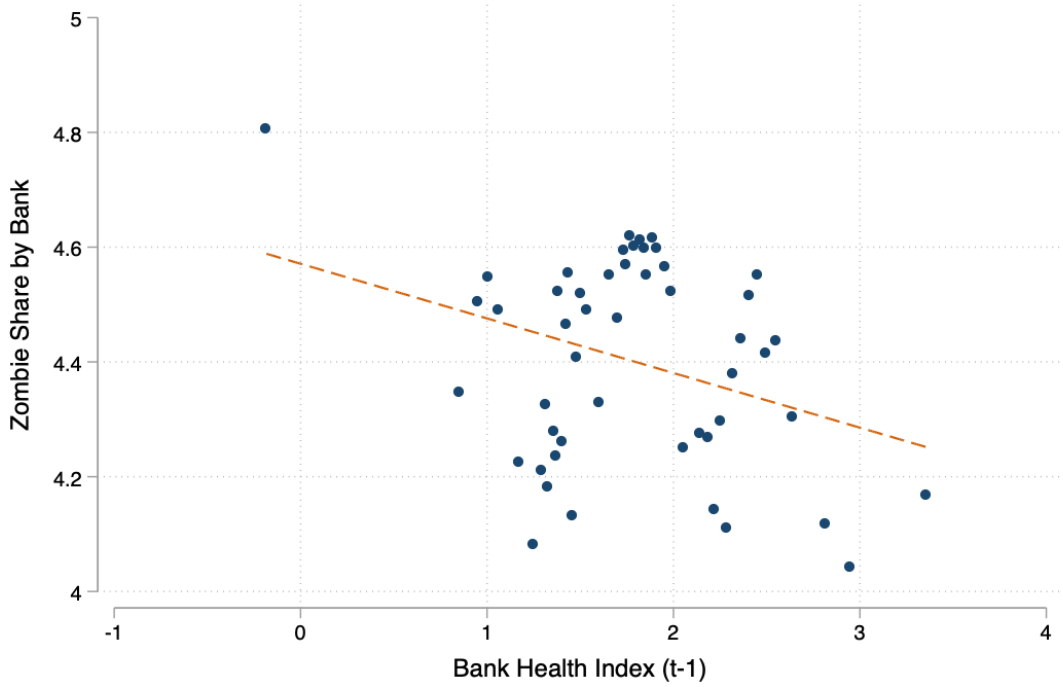
Note: The dependent variable is the share of industry capital sunk (based on tangible assets) in zombie firms. Industry refers to NACE Rev. 2. at the two-digit level. The regressions are based on 62 industries when including interest rate only. There are 53 industries when bank health is entered. Robust standard errors are clustered by industries in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 2 attempts to assess whether the impact of low interest rates and low bank health is stronger in industries that are more dependent on external funding as these industries would inherently be more exposed to financial pressure (equation 1). However, as seen in the table the role of interest rates or bank health is not visible as insignificant measures are shown for both. Specifically, the interaction between external finance dependence and interest rates shows the expected sign, which would point towards lower values of nominal interest rates are associated with disproportionately higher zombie capital share in highly exposed industries (i.e., those that depend more on external funding) than low-exposed industries (depend less on external funding). However, this relationship is statistically insignificant. The same observation of lack of statistical significance is seen with bank health. Thus, it is not possible to examine the causal relationship between interest rates, bank health and the prevalence of zombie firms within this framework using microdata. Given the in-variant nature of the nominal interest rate, investigating bank health unaccompanied could serve as a rejoinder.

Following Andrews and Petroulakis (2019), **Figure 11** depicts the relationship between zombie firms and bank health. Specifically, the figure illustrates the share of zombie firms at the industry-year level associated with each bank and plots it against the one-year lag of the constructed bank health measure. A linear regression fitted line is displayed and shows zombie share on bank health with interacted industry-year fixed effects. This is included to control for the business cycle at the industry level. For simplicity of representation, the sample of the bank health measure is divided into 50 bins of equal size, and each point in the scatter plot gives the sample mean of zombie share for each bin (after controlling for industry-year fixed effects). Evidently, a negative relationship between bank health and the zombie firm share is present, this can be interpreted as evidence that zombie firms are more likely to be connected to weak banks in Denmark. This substantiates the basic findings in

Figure 10 (Panel B) as it yields similar result but accounts for the business cycle at the industry level. Furthermore, it is similar to Andrews and Petroulakis (2019) finding, however the negative relationship is not as pronounced in this paper. Figure B.3 in Appendix B depicts corresponding graphs for the seven individual bank variables that are used to make up the composite bank health measure.

Figure 11: Zombie firm share for each bin of bank health



Note: The graph depicts the mean share of zombie firms for each bin of bank health (50 bins of equal size) with the inclusion of interacted industry-year fixed effects. The relationship is significant at the one percent level with a slope of -0.095 and is based on 223,652 firm-bank observations for the period 2004 to 2019.

Source: Own calculations based on firm-level data from ORBIS and BankFocus.

5.2 The risk of remaining a zombie in a low interest rate setting

The lack of statistically significant results in the previous section does not rule out anything. It merely opens new questions for the research and leads the paper to ascertain the second research question posed: whether the risk of surviving as a zombie firm in Denmark has increased since the lowering of the interest rates.

Table 3: Linear Probability Model: Risk of remaining a zombie

Dependent variable: Zombie Persistence (binary)	(1) Probability of remaining a zombie firm next year	(2) Probability of remaining a zombie firm two years later	(3) Probability of remaining a zombie firm three years later
Years (2009-2019)	0.052***	0.077***	0.134***
	(0.001)	(0.001)	(0.001)
Firm age	0.045***	0.224***	0.389***
	(0.000)	(0.001)	(0.001)
Size	0.000	0.020***	0.024***
	(0.000)	(0.000)	(0.000)
Debt Capacity	0.000***	-0.000***	-0.000**
	(0.000)	(0.000)	(0.000)
Observations	1,417,098	1,417,098	1,417,098
R2 (adjusted)	0.041	0.271	0.510

Note: The dependent variable is a binary indicator of zombie persistence, based on the probability of remaining a zombie in the ensuing years (see Section 3.2.3). Column 1-3 depicts the probability of remaining a zombie one, two and three years later, respectively. The following control variables are included: Firm age, size and debt service capacity. Firm age is the one-year lag of a firm's age (measured as ln); Size is the one-year lag of a firm's size based on the ln of total assets. Debt capacity is a firm's one-year lagged debt service capacity. Robust standard errors are clustered by firms in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

To further investigate zombie firms in a low interest environment, **Table 3** reports results pertaining to the LPM model (equation 2) on the risk of surviving as a zombie firm as rates have declined. In order to account for the monetary policy change following the financial crisis and to better understand the link of zombification in a low interest setting, the sample split via a dummy variable. Particularly, the period where interest rates were constantly lowered in Denmark, 2009-2018 will be investigated and put in contrast to the prior period in 2002-2008. To reduce omitted variables bias, a fixed effects two-way structure at the firm and year level is included to eliminate firm-invariant and time-invariant confounders.

In **Table 3**, column 1 shows that the probability that a firm stays a zombie firm next year is higher over the period 2009-2019 than the prior period. This suggests that after the global financial crisis and the ensuing lowering of policy rates, the one-year zombie persistence increased marginally in contrast to before the crisis, consistent with findings in **Figure 4**. This finding is expected given the descriptive analysis; however, it illustrates the probability more precisely. Furthermore, column 1 also depicts that older firms and firms with better debt service capacity have a higher probability of remaining a zombie firm one year later. The age link follows the intuition depicted in **Figure 3**, while the increase of debt capacity (which is considered as an improvement in the ability to service debts) is somewhat counterintuitive. At first glance, it would be expected to have a negative sign,

however it could be due to the fact that an improvement in debt service capacity takes time to materialize in terms of balance sheet improvements. Results in column 2 and column 3 also indicate that the probability of remaining classified as a zombie firm increased in Denmark over the period when interest rates were reduced significantly. Though this increase was minimal, in context of comparing it to the evidence of Banerjee and Hofmann (2018), it is expected given **Figure 4** (the three-year zombie persistence is unreported in the figure). Investigating the controls for both column 2 and column 3, it is evident that older firms, firms with a lower ability to their service debt obligations and bigger firms in terms of total assets and are more likely to survive as zombie firms after one year. This corresponds with the economic intuition and firm-level descriptive results shown in section 3.

In conclusion, **Table 3** reveals clear and comprehensible results regarding the zombie persistence in Denmark during the years of low and even negative interest rates. Mainly showing that while there has been a marginal increase in the risk of surviving as a zombie firm rather than exiting, it has not increased significantly during the years of accommodative monetary policy in Denmark. This is in contrast to findings by Banerjee and Hofmann (2018) that find that zombie persistence has been on the rise in advanced economies since the 1980s. Indicating, as far as Danish firms are concerned, that the effect of low interest rates on the risk of surviving as a zombie firm for many years is minimal. Following the sentiment of Andersen et al. (2019) it can be presumed that there has not been a negative impact on productivity through the interest rate channel during years of low rates.

6 Conclusion

There is widespread evidence of the negative consequences of zombie firms on the real economy and financial stability across advanced economies. Zombie firms have garnered significant concern in much of the developed world in the aftermath of the global financial crisis and the European debt crisis; not to mention the ensuing potential economic fallout from the current covid-19 pandemic. Despite this increased attention, the empirical evidence looking at the unintended consequences of ultra-easy monetary policy on firm dynamism and the process of resource allocation is few and far between. The aim of this paper is to shed light on the relationship of low interest rates on the prevalence of zombie firms and its effect on the likelihood of survival of these distressed firms.

In particular, this paper exploits comprehensive firm-level microdata to explore the link between low interest rates and the zombie phenomenon in Denmark. Denmark is a rich case study, as it has had persistently low and even negative interest rates since the global financial crisis. Thus, it is well suited for an assessment in the matter. This study documents several main results. First, the zombie share (across three proxy utilized) decreased significantly over the period of 2010 and 2019. Pointing towards that firms that were classified as zombie firms during the global financial crisis either reclassified as non-zombie firms or exited the sample. It also indicates that the prevalence of zombies fluctuates with the business cycle.

Second, over the period of consistently low and negative interest rates (2009-2019), the probability of remaining a zombie firm only increased marginally. Indicating that the cheaper financing provided by the low interest rates did not result in over-leveraged firms and ultimately zombie firms. Third, the industry distribution of zombie firms is fairly homogenous for the full sample period. This paper also attempts to undertake this inquiry in a more causal sense. However, with the applied data and method, the empirical results cannot point to whether low interest rates and weak banks are a driver in the relatively low zombie share in Denmark. Notwithstanding, when examining bank health, it points towards a negative relationship between bank health and zombie firm share. Suggesting that the low prevalence of zombie firms in Denmark can be attributed to more structural factors such as strong banks and an effective insolvency regime.

Overall, the analysis highlights the importance of structural factors. Specifically, the role of sound insolvency proceedings and a well-functioning financial system in Denmark has assisted in keeping zombie firm prevalence in check and limited the risk of surviving in the zombie state. Despite that these results are only pertinent for Denmark, they could be indicative of the importance of regulatory and governmental settings that foster the timely exit and recovery for companies and subsequently may provide useful information to governments, in particular in the context of policy making. Moreover, setting up future debates into the remedies of zombies and the link between zombie congestion and monetary policy – whether accommodative policy should be a focus or other cures are necessary for the widespread "zombification" infesting economies around the world. This is especially vital in the wake of the current pandemic and the economic consequences still to be seen. Undoubtedly, this phenomenon deserves further study.

Acknowledgments

I would like to express my sincere gratitude to my supervisor, Thomas Fischer, for his valuable input and supervisory contributions throughout the thesis process and I would also like to thank my co-supervisor, Ovidijus Stauskas, for his helpful insights and guidance.

In addition, I would like to extend my gratitude to Erik Sonne for his valuable help in regard to the Orbis dataset; Dr. Şebnem Kalemli-Özcan for providing an industry correspondence table and to Senior Economist at Danmarks Nationalbank, Andreas Kuchler, for being helpful early in the thesis process by answering questions and pointing me in the right direction. Lastly, I would like to thank Eric Berling – Michael Engmose – Johann Grøndahl – for their helpful comments.

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APPENDIX A | Construction of the dataset

Appendix A provides a detailed description of the construction of the nationally representative harmonized firm-level dataset utilized in this study – describing the data selection, the exporting process, the merging between various disks and the data cleaning process. The paper follows suggestions by Kalemli-Ozcan et al. (2015) and Gal (2013) in constructing the dataset. Further descriptions of supplemental data additions (i.e., insolvency regime indicators and bank health indicators) are also included to present the underlying data and features of the additions.

A Data Collection and Exporting Process

The data collection process follows the practical steps prescribed in Kalemli-Ozcan et al. (2015) with a focus on maximizing the coverage for Denmark over the selected time period; while also avoiding certain issues and pitfalls of the database itself [62]. The data is extracted through BvD's historical disks – "ORBIS Historical" as this product is superior to others from a time-series perspective.[63] The data extraction from BvD's historical disks is a rather comprehensive and tedious task, as it is only available through external hard drives connected to licensed, stand-alone computers in select locations. However, this method is better in terms of mitigating the potential pitfalls of the database itself. Some of the issues of the ORBIS database include: inconsistent reporting of some variables throughout the various disks and as such missing variables could be an issue – e.g., variables such as "Added-Value" and "Interest Coverage" may be missing from some disks depending on year and country.[64] This occurs since firms are not required to report information. Furthermore, ORBIS automatically deletes non-reporting firms from the database after a certain time period – this creates an artificial survivorship bias in the data. Specifically, ORBIS reports data for the five most recent years in each disk and will keep the firm if they are active in the business register. Single disks may often over-represent larger firms and underrepresent smaller firms due to this survivorship bias and this issue can potentially be mitigated by re-weighing the data with the intention of increasing the representativeness of smaller firms. According to Kalemli-Ozcan et al. (2015), there is less of a need doing so if their guidelines are followed and as the use of "ORBIS Historical" avoids a majority of these issues.

[62] See Bajgar et al., (2020) for a detailed discussion on coverage, representativeness and pitfalls of the ORBIS data.

[63] ORBIS Historical have historical data (contains data beyond the latest 10 years) linked to companies that are still operating and includes regular and ongoing updates that accounts for various data considerations such as ratio calculations. The online version of ORBIS only contains data for the last 5 years for private firms and the last 10 years for listed firms. This paper solely makes use of BvD's historical product, ORBIS Historical – but refers to it as ORBIS throughout the paper.

[64] This is true for both the Online version of ORBIS and the historical version of ORBIS.

Thus, to combat these issues, the paper relies on the comprehensive data cleaning method prescribed by Kalemli-Ozcan et al. (2015) as described in the following sub-section and with the use of ORBIS Historical.

In order to maximize the coverage of firms and variables in Denmark over time, the paper makes use of several disks from ORBIS. Specifically, the underlying dataset combines different BvD disks: ORBIS 2020 June disk, ORBIS 2020 disk, ORBIS 2016 disk, ORBIS 2012 disk, ORBIS 2010/2009 disk and ORBIS 2006 disk. The choice of disks has been made to ensure a time overlap that complements earlier ones and hence, helps to get around reporting rules in ORBIS and retains as much information as possible. Particularly, there is a reporting lag of financial data of usually two years – i.e., the 2020 ORBIS disk's latest available coverage year is from 2018. The exact structure of each disk is described in **Table A.1** underneath. The data selection in a given BvD disk is based on industrial companies to ensure that banks and insurance companies are excluded. The set of selection criteria utilized in each given disk are combined by the "and" expression which then results in a unique set of firms satisfying all the criteria selected. Particularly, the set of selection criteria includes only choosing firms from Denmark – Active firms – firms that fall into the industry classification of NACE Rev. 2: 10-63 and 68-82[65] and firms that are underneath the umbrella of consolidations codes C1, C2/U2 and U1.

In combining the various vintages, the paper utilizes the overlaps that are from the most recent year as the information is most likely to be updated and discards the older overlaps. This update could entail the value of variables that were not available in an earlier disk that subsequently have been made available in later disks. As described in the main part of the paper, the database covering all private non-primary and non-financial firms in Denmark falls under the statistical classification of economic activities in the European Community: NACE[66]. The current version, NACE Rev. 2, is a revised version of the NACE Rev. 1 system. There was a change in sectoral classification in 2008, going from NACE Rev. 1.1 to NACE Rev. 2. Accordingly, older disks (in this case, ORBIS 2006 disk) uses a NACE Rev. 1.1. system to depict the different industries. **Table A.2** describes the details of the supplement NACE Rev. 1.1 codes (the ones that are not included in the range 15-64 and 70-74) used when setting up the data extraction criteria's in ORBIS. The specific conversion of each individual industry section from NACE Rev.1.1 to NACE Rev. 2 included in the final harmonized dataset is described in the following section.

[65] For earlier vintages using NACE Rev. 1 - the following two-digit NACE Rev. 1.1. codes are used: 15-64, 70-74 & extra - See details in Table A.2

[66] NACE is an acronym for "Nomenclature statistique des activités économiques dans la Communauté européenne"

Table A.1: Review of ORBIS vintages

ORBIS Disk	Years Included	Active Firm Count[1]	Industry Classification
2020 June	[2019]	159,654	NACE 2 (10-63, 68-82)
2020	[2018, 2017, 2016, 2015, 2014]	156,822	NACE 2 (10-63, 68-82)
2016	[2014, 2013, 2012, 2011, 2010]	125,932	NACE 2 (10-63, 68-82)
2012	[2010, 2009, 2008, 2007, 2006]	112,247	NACE 2 (10-63, 68-82)
2010	[2008, 2007, 2006, 2005, 2004]	106,937	NACE 2 (10-63, 68-82)
2006	[2004, 2003, 2002, 2001, 2000]	91,740	NACE Rev. 1 (15-64, 70-74 & others included – See Table A.1: "Others Included")

Note: The information in the brackets depicts the actual years included in the respective original ORBIS disks. A black highlight signifies the participation of that year in the final harmonized dataset, while a red highlight describes no participation.
[1]The active count encompasses firms that fall into the following consolidation codes: C1/C2/U1/U2 – the final harmonized dataset retains U1 and U2 in order to avoid double counting (cf. supra. note 29 in data section) as such, the final firm count for each disk will differ than the reported.

Table A.2: "Others Included" NACE Rev. 1.1. Classification - 2006

Conversion – NACE Rev. 1.1. to NACE Rev. 2	Description (NACE Rev. 1.1.)
NACE Rev. 1.1: 92.11, 92.20, 92.12 and 92.13 ⇔ NACE Rev.2: 59.11-14 and 59.20	Motion picture, video and television programme activities
NACE Rev. 1.1: 01.41 ⇔ NACE Rev.2: 10.12 & 81.30	Agricultural service activities; landscape gardening
NACE Rev. 1.1: 92.40 ⇔ NACE Rev.2: 63.91	News agency activities
NACE Rev. 1.1: 92.32, 92.34, 92.62 and 92.72 ⇔ NACE Rev.2: 79.90	Operation of art facilities; Other entertainment activities; Other sporting activities and Other recreational activities – respectively.

Note: Not all possible conversions are included as they could end up capturing more than intended. An example is the conversion of NACE Rev. 2 – 16.10: "Sawmilling and planning of wood" which is converted to NACE Rev.1.1 – 02.01: "Forestry and logging" - and is intended to capture "production of split poles, pickets and similar products" but could end up accounting for more firms than just those that are working with "production of split poles, pickets and similar products". As such, a miniscule loss of information may occur between the conversion of the two classification systems.
Whenever possible this paper has prioritized the use of NACE Rev. 2 classifications as it is the most recent and is generally used as the primary industry classifier in the previous literature.

The detailed data collection process gives a basis for exporting the data. In each of the given disks, the data is extracted using the five latest relative years, and the output is subsequently transformed to a Stata file using *STAT/TRANSFER*. The data comes in a wide format in Stata and various steps are needed in order to clean up the data before merging the various disks.

B Data Limitations

Firm-level data from ORBIS is widely used in the zombie firm literature and, more generally, in firm dynamic literature. Despite this, the dataset is not flawless, and coverage differs from country to country and across years. This is due to the fact that the data collection method varies for each country – some are based on questionnaires or tax reporting's or both. As pointed out by Bajgar et al. (2020) there are various limitations one should be aware of when using the dataset. A mentioned limitation is that often firms in ORBIS only represent a portion of the entire firm population; as such, they do not qualify as a representative sample of the firm population and are typically older and larger than the average firm. Despite the *a prior* assumption of the data being representative of the firm population in Denmark; the appearance and disappearance of firms in the data throughout the years could be due to valid entry and exit but could also be due to changes in data coverage. As such, ORBIS could over-represent larger firms and under-represent smaller firms stemming from this survivorship bias. Another inadequacy that Bajgar et al. (2020) point towards is the presence of rounded values for some variables that could have a large impact when making any form of data inferences. Further limitations also present themselves in the construction of a zombie measure.[67] There is currently not a single objective measure that is agreed upon – rather, there are several measures with various approaches. As such, classifications error such as type I (misclassifying a zombie firm as a non-zombie firm) and type II (misclassifying a healthy firm as a zombie firm) errors could be of concern.[68] This paper employs a classification scheme of zombie firms based on a stringent profitability and debt servicing criterion using ratios based on accounting data. Thus, any bias (overestimation or underestimation) that affects the input variables in the classification scheme could also induce a bias in the number of firms classified as zombie firms. Despite these apparent data limitations, ORBIS has the advantage of being flexible and covers a lot of ground, and thereby succeeds as the best data option available when it comes to studying firm dynamics. Comprehensive data cleaning, harmonization and choice of zombie identification method that address the shortcomings of the data is utilized in order to make these limitations innocuous.

[67] One example of this, is the lack of data on interest paid in order to construct a complete ICR zombie measure. This severely limits the ability to draw direct comparisons as the ICR zombie identification method is widely used in recent literature. This will be further addressed in the subsequent section.

[68] According to Caballero et al. (2008) good firms could be mistakenly classified as zombies because they can borrow at a better interest rate than the prime rate or if a firm pays off a loan in an accounting year. However, (Hoshi, 2006) concluded that these errors are not a serious problem if a profitability criterion is added.

C Data Cleaning and Merging Process

The paper undertakes various steps in setting up the data, merging and cleaning the data, closely following the suggestions by Kalemli-Ozcan et al. (2015) and OECD research experiences (Gal, 2013).

Before discussing the concrete cleaning steps for the full dataset, each vintage is constructed into viable financial panel datasets. This is done by cleaning up each vintage prior to consolidating them. The data in the disks are reshaped in order to go from a wide format to a long format to create full panels and observations that have missing account identifiers – *BvD ID numbers* are deleted. Duplicates in terms of year and the main account identifier, *ID NUMBER* is dropped – these occur due to wrongly coded year information. Observations with no financial information (examined by looking at if the variable *Closing_Date* is missing), observations where the country code (created based on the BvD ID numbers) does not correspond to the BvD's own country ISO code and observations with missing currency information are all dropped. It is important to note that all financial variables are vetted in terms of consistency in the units expressed. Thus, they are expressed in the same integer power of ten to create harmonized units.

As mentioned earlier, there is a minor complication when combining ORBIS disks over a wide time span as there is a change in sectoral classifications in 2008 from NACE Rev 1.1 to NACE Rev 2. by Eurostat. The paper incorporates a correspondence table between NACE Rev 1.1 and NACE Rev 2 (one-to-one match for every sector) in order to update older sector classifications into the most recent in the various disks.[69] Another issue that could arise is firms changing firm identifiers over time; as such, a table with official identifiers changes provided by BvD is also used to address this issue. Subsequently, all six disks are merged (i.e., stacked with the *append* command in Stata) to create one large firm-level panel dataset.

C.1 Cleaning and Filtering Data

The following steps are successively implemented to the merged firm-level panel dataset in order to retain the accounts with relevant and valid information:

a. Firm-year observations that have missing information on total assets and operating revenue and sales and employment are dropped.
b. Firms are dropped from the consolidated dataset if total assets are negative in any year, or if employment is negative or greater than 2 million in any year, or if tangible fixed assets are negative in any year.
c. Unconsolidated accounts are retained – As such, accounts with the consolidation codes of C1 and C2 are dropped.

[69] This correspondence table was provided by Dr. Şebnem Kalemli-Özcan upon requesting it.

C.2 Winsorizing the data

Further data harmonization is made by winsorizing the data by year and sector. Specifically, winsorization at the five percent level (i.e., the 5 and 95 percentile) is conducted for the following key variables: interest paid, total assets, fixed assets, tangible fixed assets, intangible fixed assets, operating revenue (turnover), cash flow, gross profit, non-current liabilities, current liabilities, total shareholders liability, net income, provisions, long-term debt, depreciation, EBITDA, EBIT and ROA. This operation is conducted to filter away the influence of extreme outliers in order to ensure that the results are not driven by a few small and large outliers.[70]

C.3 Deflating monetary values

To ensure the comparability of monetary variables over time, adjusted for price change, all monetary firm-level data are deflated using the same industry-specific deflators from an external source. This is done as ORBIS contains firm-level nominal variables and therefore, the paper follows the standard practice and utilizes two-digit industry deflators from the OECD STAN database to make sure variables are not distorted by price changes. The latest available year for gross output price deflator data is 2018; therefore, the 2019 data is imputed from the 2018 values.

Following the set up by Gal (2013), each relevant variable X_{it} for firm i and year t are deflated with gross output price indices at the two digits industry level:

$$X_{it}^{DKK_{Real},t_0} = \frac{X_{it}^{DKK_{Nominal}}}{P_{jt}^{t_0}}$$

Where $X_{it}^{DKK_{Nominal}}$ refers to each relevant variable in the local nominal currency value (Danish Kroner – DKK) for firm i and year t. $P_{jt}^{t_0}$ refers to the gross output price deflator from OECD STAN in year t with reference year t_0 in industry j. The reference year is 2015.

C.4 Representativeness issues - Excluding weights

Reweighting data is a common method utilized in order to ensure the aggregate representativeness of a sample of firms. In regard to ORBIS, the improvement of representativeness comes in the form of correcting for the under-representation of small firms, which ensures a more balanced coverage and enhances international comparability (Gal, 2013). Building on the work of Gal (2013), the recent zombie literature strands from the OECD (Adalet McGowan et al., 2017a/b) address potential issues stemming from underrepresentation of small and young firms and of certain sectors by applying a post-

[70] Common practice within the field is either winsorizing at the 1 percent level or the 5 percent level; as such, this paper winsorized the variables at the five percent level for each tail.

stratification method of re-weighing the sample based on the number of employees from the OECD Structural Demographic Business Statistics (SDBS). They use it as a robustness check and find that using resampling weights are robust to their baseline results.[71]

However, according to a recent study by Bajgar et al. (2020) the inclusion of reweighing the sample with firm size as a remedy for ORBIS representativeness issues is troublesome. They conduct a thorough analysis and find that reweighing does not solve the issue of under-representativeness in ORBIS other than the mechanic effect on the firm size distribution and could essentially further complicate the problem by adding more weight on small firms.[72]

As stated earlier, Kalemli-Ozcan et al. (2015) discuss that if ORBIS Historical is utilized and their guidelines are followed there is less of a need to reweigh the data to obtain a nationally representative firm-level dataset. This assertation is in line with the recent literature (i.e., Bajgar et al. (2020)) and as such, this paper refrains from utilizing weights in the baseline approach and as a robustness extension. As described earlier, winsorization and other harmonization methods are implemented to combat the representativeness issue. In spite of not adding weights, this discussion has been included as it addresses a seemingly superfluous exercise that has been prescribed in much of the recent firm-level research using the ORBIS dataset, particularly stemming from the OECD (see (Adalet McGowan et al., 2017a; Adalet McGowan et al., 2017b; Gal, 2013).

C.5 Summary Statistics

Table A.3 presents summary statistics for the firm- (Panel A) and bank-level (Panel B) variables prior to harmonization and the final dataset utilized in the analysis. The initial raw dataset is without basic cleaning, winsorization and price change adjustments. Only selected variables are included as the underlying raw dataset includes many non-relevant variables. The means and standard deviations are calculated for each year. The information in the table displays the means and the standard deviations averaged across the sample period – 2000 to 2019. All financial variables are expressed in Danish Kroner (DKK).

[71] The difference between the results where weights are included, and the baseline results are minimal.

[72] See Bajgar et al. (2020) for a comprehensive discussion on the weighing aspect of ORBIS.

Table A.3: Summary statistics

	Raw Full Dataset			Harmonized Full Dataset		
Statistic	N	Mean	SD	N	Mean	SD
Panel A. Firm-level variables						
Total Assets	2,053,126	1.26e+09	1.23e+12	1,991,045	124224.4	562193.6
Tangible Fixed Assets	1,775,244	2.39e+07	2.39e+09	1,714,982	67581.34	411715.8
Number of employees	945,446	38.02957	1836.634	920,284	15.64664	112.0195
Debt Service Capacity (%)	1,833,090	.1211556	23.33541	1,788,998	.1721688	24.95495
ROA (%)	1,961,666	3.881935	28.35816	1,900,655	4.39795	18.35129
Net Investments	1,532,167	2454136	1.77e+09	1,488,921	490.2174	104961.1
Zombie Capital Share [NRI] (%)	2,057,285	3.075746	5.494652	1,993,504	4.24232	4.352819
Panel B. Bank-level variables						
Bank Health				178,415	1.833447	.6637983
Tangible Common Equity (% assets)				198,229	5.327322	3.195485
Net Income (% assets)				198,229	.4200634	.4728515
Net Interest Income (% assets)				198,229	1.514926	.7169957
ROAA (%)				198,229	.4320974	.4953261
Z-score				198,229	208.1261	125.4398
Retail Funding (% assets)				198,229	34.83084	17.28958
NPLs (% assets)				178,415	2.535207	2.645704

Note: The "raw" full dataset is the full sample dataset prior to data harmonization. Specifically, it is without basic cleaning, filtering, winsorization and deflation of monetary variables. Variables with no information and firm duplicates are however still dropped. Consequently, the harmonized dataset includes cleaning, price change adjustments and winsorization at the five percent level for all financial variables.

D Supplementary Data Additions

D.1 Insolvency Regime Indicators

This section provides an overview and further detailed descriptions of the insolvency framework design utilized to test the effect of the insolvency framework on the relationship between bank health and zombie firms in the analysis. This includes a presentation of the underlying data that is used in order to create the various composite indicators included in the analysis and also includes various figures for both the compiled composite indices and the individual features that the indices are made up of.

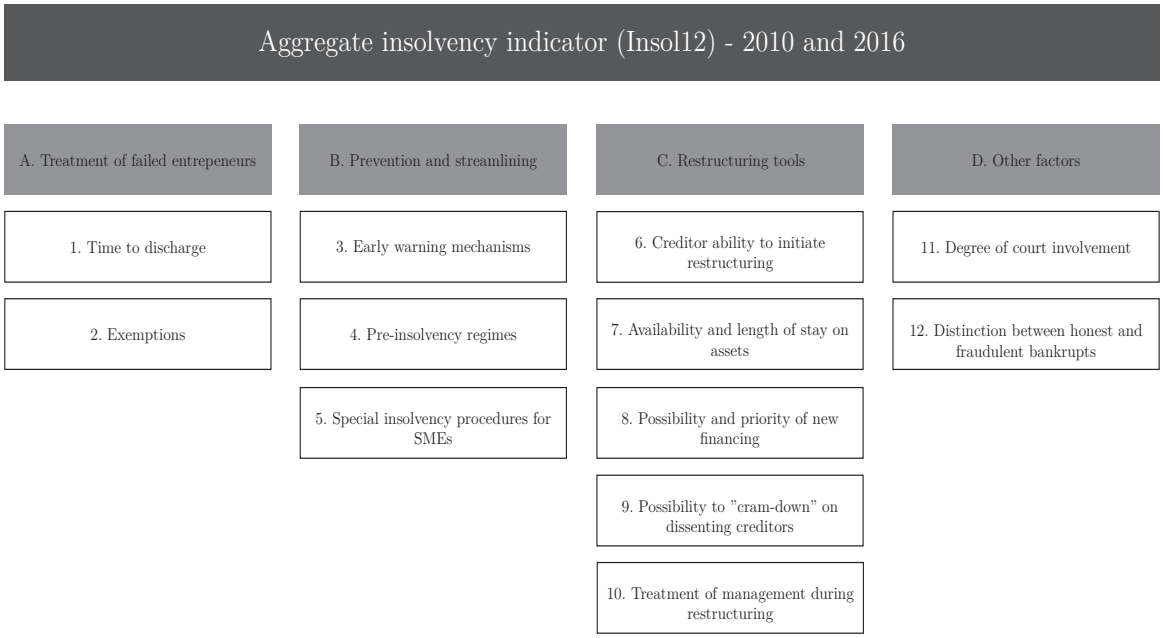
The original set of insolvency indicators have been developed by the OECD (see Adalet McGowan and Andrews, 2018) and covers 13 distinct insolvency framework features for 35 OECD members and 11 non-member countries. An aggregate indicator, *insol12,* is created. *Insol12* is an unweighted average of 12 of the original 13 components for 2016 – see **Figure A.1** Individual features that are used to comprise the composite index are also included in the extension of the analysis. The details of the composite index and individual indicators are described in **Table A.4**.

Table A.4: OECD insolvency indicators: Framework

Area	Indicator	Description
Insolvency Indicator	Insol-12	Composite indicator based on 12 components of the Insolvency indicator, for Denmark, 2010 and 2016
Treatment of failed entrepreneurs	Personal costs to failed entrepreneurs	Composite indicator based on the 2 components "Time to discharge" and "Exemption of assets"
	Time to discharge	If discharge is not available, 40 years are allocated as a proxy for the working life of a typical worker following Armour and Cumming (2008). If discharge is available, based on the number of years to discharge, a composite index is created using thresholds, which takes the value 0 if the time to discharge is less than or equal to one year, 0.5 if the time to discharge is between one and three years and 1 if the time to discharge is greater than three years.
	Exemption of assets	The indicator takes the value 0 if exemptions (pre-bankruptcy assets which are exempted from the bankrupt estate) are more generous than modest personal items and working equipment (e.g. the debtor's house is exempted), 0.5 if exemptions are restricted to only modest personal items (e.g. assets or income required to cover the debtor's subsistence) and working equipment and 1 if exemptions are less generous than modest personal items and working equipment (e.g. the assets or property of the spouse of the debtor can be included in the bankrupt estate).
Prevention and streamlining	Lack of Prevention and streamlining	Composite indicator based on the 3 components "Early warning mechanisms", "Pre-insolvency regimes" and "Special procedures for SMEs."
	Early warning mechanisms	The indicator is a dummy variable equal to 0 if countries have early warning mechanisms (e.g., on-line self-test, training) in place and 1 otherwise.
	Pre-insolvency regimes	The indicator is a dummy variable equal to 0 if pre-insolvency regimes exist and 1 otherwise.
	Special procedures for SMEs	This indicator is a dummy variable, which takes the value 0 if special insolvency procedures exist for SMEs and 1 otherwise.
Restructuring tools	Barriers to Restructuring	Composite indicator based on the 5 components "Initiation of restructuring by creditors", "Length of stay on assets in restructuring", "Possibility and priority of new financing", "Possibility to cram-down on dissenting creditors", "Dismissal of management during restructuring"
	Initiation of restructuring by creditors	This indicator is a dummy variable equal to 0 if creditors can initiate both liquidation and restructuring and 1 if creditors can initiate only liquidation.
	Length of stay on assets in restructuring	All countries in the sample have the option of a stay on assets in restructuring. This indicator is a dummy variable equal to 0 if the length of stay has a limit and 1 if the length of stay is indefinite.
	Possibility and priority of new financing	This indicator is equal to 0 if the new financing has priority over only unsecured creditors; 0.5 if the priority of new financing has priority over both secured and unsecured creditors; and 1 if new financing has no priority.
	Possibility to "cram-down" on dissenting creditors	This indicator takes the value 0 if there is cram-down, with the provision that dissenting creditors receive as much under restructuring as in liquidation; 0.5 if cram-down exists in the absence of this provision; and 1 if there is no cram-down.
	Dismissal of management during restructuring	This indicator takes the value 0 if management is not dismissed during the restructuring process and 1 if management is dismissed.
Other factors	Degree of court involvement	The questionnaire asks if courts are involved in the different stages of both liquidation and restructuring processes (i.e., the launch of the insolvency procedure, appointment of an insolvency practitioner, voting on a restructuring plan by creditors, confirmation and declaration of the restructuring plan as binding or enforceable and other stages). The indicator adds the number of stages for restructuring (ranging from 0 to 5) and number of stages for liquidation (ranging from 0 to 5), and then rescales the values to be between 0 and 1.
	Distinction between honest and fraudulent bankrupts	The indicator takes the value 0 if there is a distinction between the treatment of honest and fraudulent entrepreneurs in the insolvency process (e.g., a fraudulent entrepreneur may be ineligible for debt write-off or discharge from debt) and 1 otherwise.
	Rights of employees (Not available for DNK)	Not available for Denmark

Source: Adapted from McGowan, M.A., & Andrews, D. (2018))

Figure A.1: The structure of the OECD insolvency indicator – 2010 and 2016



Note: Shows the structure of the OECD insolvency indicator for the years 2010 and 2016

Sources: Adapted from McGowan, M.A., & Andrews, D. (2018))

The composite indicators range from 0 to 1; wherein, an increase in the indices depicts the extent of how the insolvency regime feature may delay the initiation and resolution of proceedings. The various scores are displayed in **Table A.5** underneath. An overview of the composite indices, sub-component indices and individual features are provided in **Figure A.2**, **Figure A.3** and **Figure A.4**, respectively.

Table A.5: OECD insolvency indicators (Denmark): Scores

Area	Indicator	Indicator Scores	
		2010	2016
Insolvency Indicator	Insol-12	n/a	0,266
Treatment of failed entrepreneurs	Personal costs to failed entrepreneurs	0,5	0,5
	Time to discharge	0,5	0,5
	Exemption of assets	0,5	0,5
Prevention and streamlining	Lack of Prevention and streamlining	0,33	0,33
	Early warning mechanisms	0	0
	Pre-insolvency regimes	0	0
	Special procedures for SMEs	1	1
Restructuring tools	Barriers to Restructuring	n/a	0,1
	Reduced Barriers to Restructuring[1]	0,5	0,25
	Initiation of restructuring by creditors	1	0
	Length of stay on assets in restructuring	n/a	0
	Possibility and priority of new financing	n/a	0
	Possibility to "cram-down" on dissenting creditors	0	0,5
	Dismissal of management during restructuring	n/a	0
Other factors	Degree of court involvement	n/a	0,7
	Distinction between honest and fraudulent bankrupts	0	0
	Rights of employees (Not available for DNK)	n/a	n/a

Note:[1]This is the reduced version and is only based on "cram-downs" and "Initiation". This is created in order to have a barriers of restructuring measure that encompasses both available years. n/a meaning that the scores are not available due to lack of survey replies for Denmark.
Source: McGowan, M.A., & Andrews, D. (2018)) and own calculations.

Figure A.2: Insol12: Composite indicator based on 12 components; Denmark - 2016

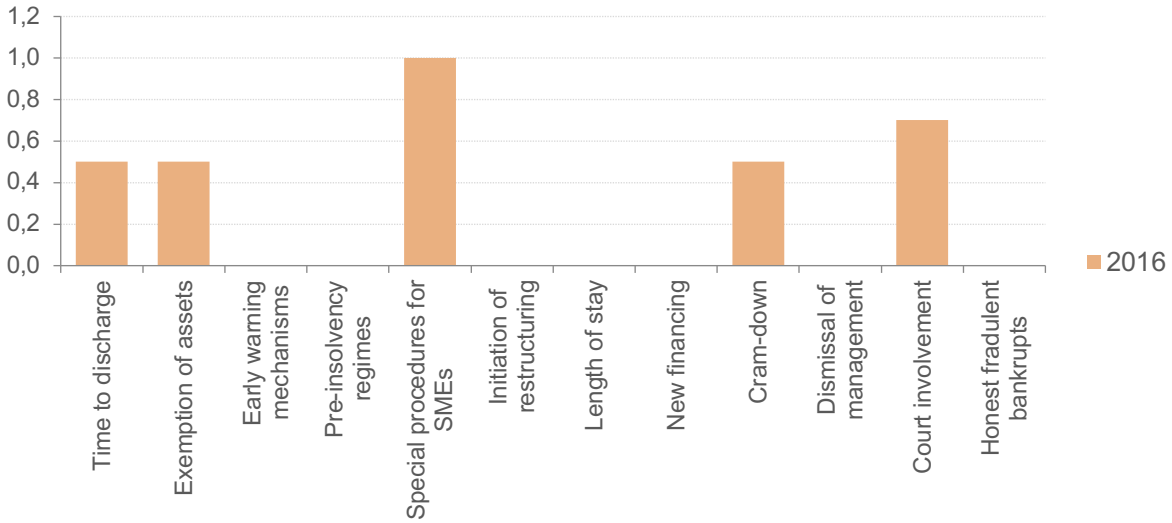


Figure A.3: Composite insolvency indicator: sub-components;Denmark-2010 and 2016

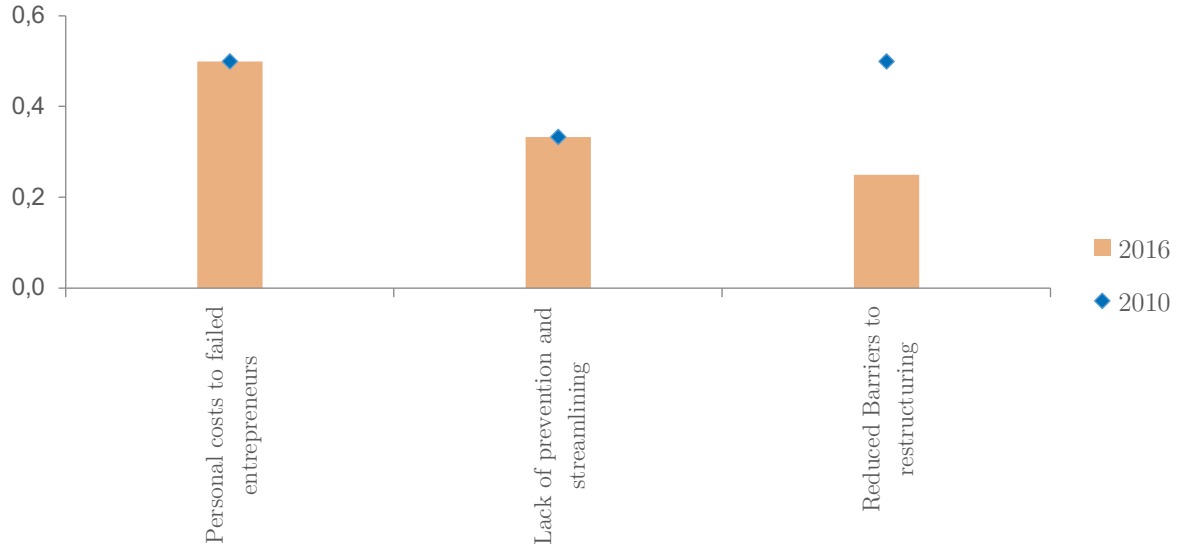
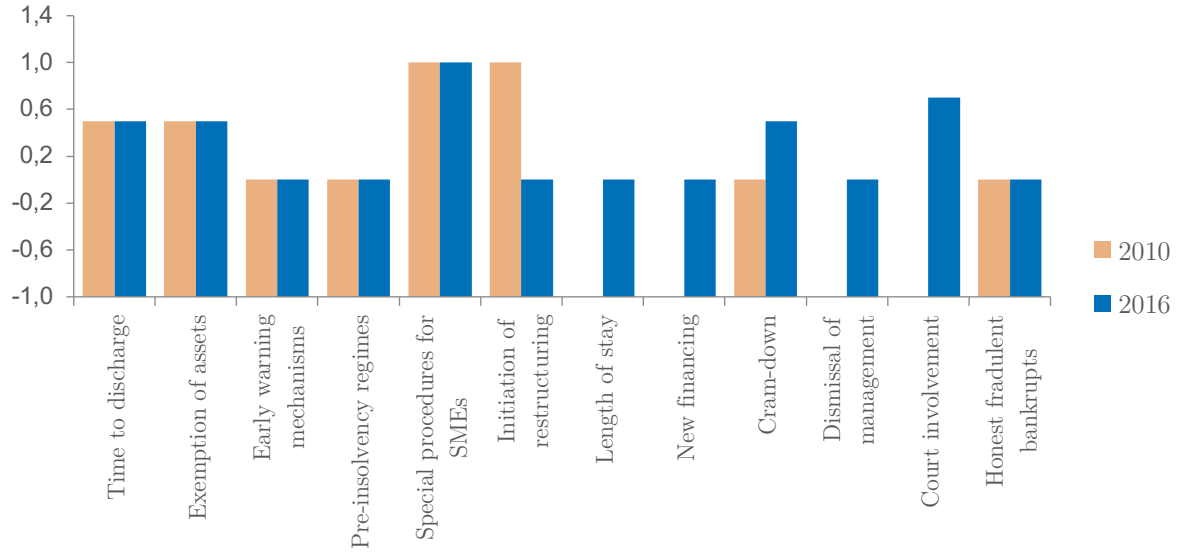


Figure A.4: Individual features of the insolvency indicators; Denmark - 2010 and 2016



Note: Vertical axis lower bound is -1,0 in order to better illustrate values at zero. The index does not contain negative values. Following individual features contain no data for 2010 as Denmark did not provide answers: Length of stay, New financing, Dismissal of management and Court involvement.

APPENDIX B | Additional Tables and Figures

A Additional Tables

Table B.1: Industry classifications by NACE revision 2 codes and descriptions

Two-digit NACE Rev. 2 Industries		One-letter NACE Rev. 2 Sections	
10	Manufacture of food products	C	Manufacturing
11	Manufacture of beverages		
12	Manufacture of tobacco products		
13	Manufacture of textiles		
14	Manufacture of wearing apparel		
15	Manufacture of leather and related products		
16	Manufacture of wood and of products of wood and cork, except furniture, etc.		
17	Manufacture of paper and paper products		
18	Printing and reproduction of recorded media		
19	Manufacture of coke and refined petroleum products		
20	Manufacture of chemicals and chemical products		
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations		
22	Manufacture of rubber and plastic products		
23	Manufacture of other non-metallic mineral products		
24	Manufacture of basic metals		
25	Manufacture of fabricated metal products, except machinery and equipment		
26	Manufacture of computer, electronic and optical products		
27	Manufacture of electrical equipment		
28	Manufacture of machinery and equipment n.e.c.[1]		
29	Manufacture of motor vehicles, trailers and semi-trailers		
30	Manufacture of other transport equipment		
31	Manufacture of furniture		
32	Other manufacturing		
33	Repair and installation of machinery and equipment		
35	Electricity, gas, steam and air conditioning supply	D	Electricity and Water Supply Services
36	Water collection, treatment and supply		
37	Sewerage		
38	Waste collection, treatment and disposal activities; materials recovery		
39	Remediation activities and other waste management services		
41	Construction of buildings	F	Construction
42	Civil engineering		
43	Specialised construction activities		
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	G	Wholesale and Retail Services
46	Wholesale trade, except of motor vehicles and motorcycles		
47	Retail trade, except of motor vehicles and motorcycles		
49	Land transport and transport via pipelines	H	Transportation and Storage
50	Water transport		
51	Air transport		
52	Warehousing and support activities for transportation		
53	Postal and courier activities		
55	Accommodation	I	Accommodation and Food Services
56	Food and beverage service activities		
58	Publishing activities	J	Information and Communication Services
59	Motion picture, video and television programme and music publishing activities		
60	Programming and broadcasting activities		

61	Telecommunications		
62	Computer programming, consultancy and related activities		
63	Information service activities		
68	Real estate activities	L	Real Estate Service
69	Legal and accounting activities	M	Professional, Scientific and Technical Activities
70	Activities of head offices; management consultancy activities		
71	Architectural and engineering activities; technical testing and analysis		
72	Scientific research and development		
73	Advertising and market research		
74	Other professional, scientific and technical activities		
75	Veterinary activities		
77	Rental and leasing activities	N	Administrative and Support Service Activities
78	Employment activities		
79	Travel agency, tour operator reservation service and related activities		
80	Security and investigation activities		
81	Services to buildings and landscape activities		
82	Office administrative, office support and other business support activities		

Note: This table provides an overview of the NACE Revision 2, Level 2 Classifications (two-digit) and their corresponding one-letter sections. For space considerations, this paper does not report the 4-digit industry classification. For a detailed structure of NACE Rev. 2 see Eurostat, (2008). NACE Rev. 2 – Statistical classification of economic activities in the European Community. Methodologies and Working papers.
[1] n.e.c.: not elsewhere classified

Source: Eurostat, (2008). NACE Rev. 2 – Statistical classification of economic activities in the European Community. Methodologies and Working papers.

Table B.2: Zombie firms' anatomy – reported medians

Medians[1] of zombie firms and non-zombie firms

	Zombie firms[2]	Non-zombie firms
Total Assets	29354.5 ***	25922
Tangible Fixed Assets	6549.259***	3392.644
Number of employees	3***	3
Firm Age	9***	7
ROA (%)	-8.33***	3.64
Net Investments	-953.683***	-71.716
Cash Flow	-553.941***	2727.407
Net Income	-2038.528***	746.268
Provisions	0 ***	310
Long-term Debt	5329.336***	350.833
Gross profits	4201.92***	7826.793

Note: [1] ***/**/* indicates the statistically significant difference in the median value of zombie firms compared to non-zombie firms. A Kruskal-Wallis H test was conducted to determine whether the medians for the selected variables where different for zombie firms and non-zombie firms. Medians are reported in either Danish Kroners or percentages. [2] Zombie firms are defined as firms with low debt service capacity below five percent for at least two consecutive years and negative return on assets and net investments for at least two consecutive years.

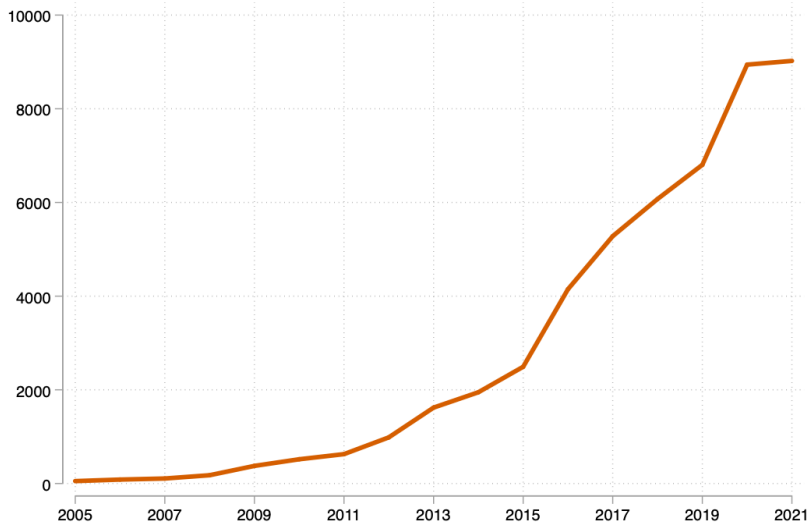
Table B.3: Drivers of zombie shares – Zombie capital shares based on total assets

Dependent variable: Zombie capital shares	(1)	(2)	(3)
External finance dependence$_s$ × Interest rate	0.005		-0.014
	(0.166)		(0.305)
External finance dependence$_s$ × Bank health		-0.002	-0.002
		(0.003)	(0.003)
Observations	1,101	120	120
R2 (adjusted)	0.284	0.661	0.661
Industry-FE	Yes	Yes	Yes
Year-FE	Yes	Yes	Yes

Notes: The dependent variable is the share of industry capital sunk (based on total assets) in zombie firms. Industry refers to NACE Rev. 2. at the two-digit level. The regressions are based on 62 industries when including interest rate only. There are 53 industries when bank health is entered. Robust standard errors are clustered by industries in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

B Additional Figures

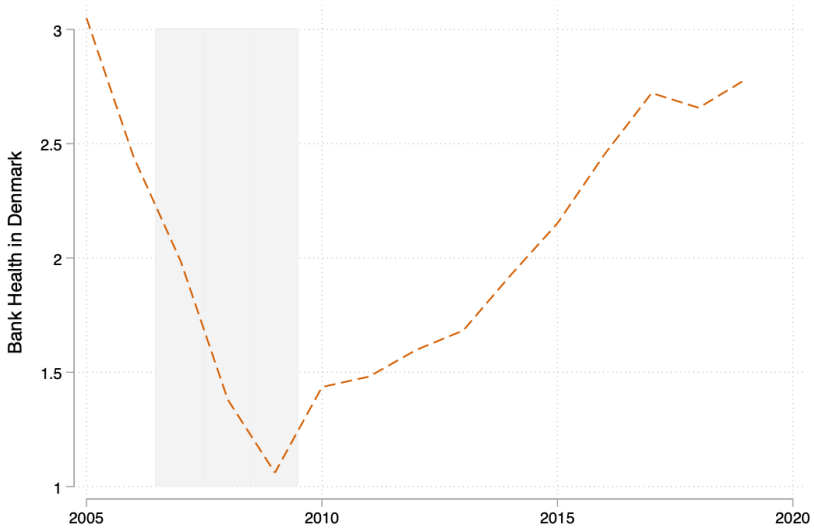
Figure B.1: The public debate about zombie firms



Note: Cumulative count of how many times the words "zombie firm" or "zombie company" or zombie firms" or "zombie companies" are mentioned in Danish, English, French, German, Italian, Swedish and Norwegian - language newspapers and news magazine as well as in blog or board entries.

Sources: Authors' own search in Factiva

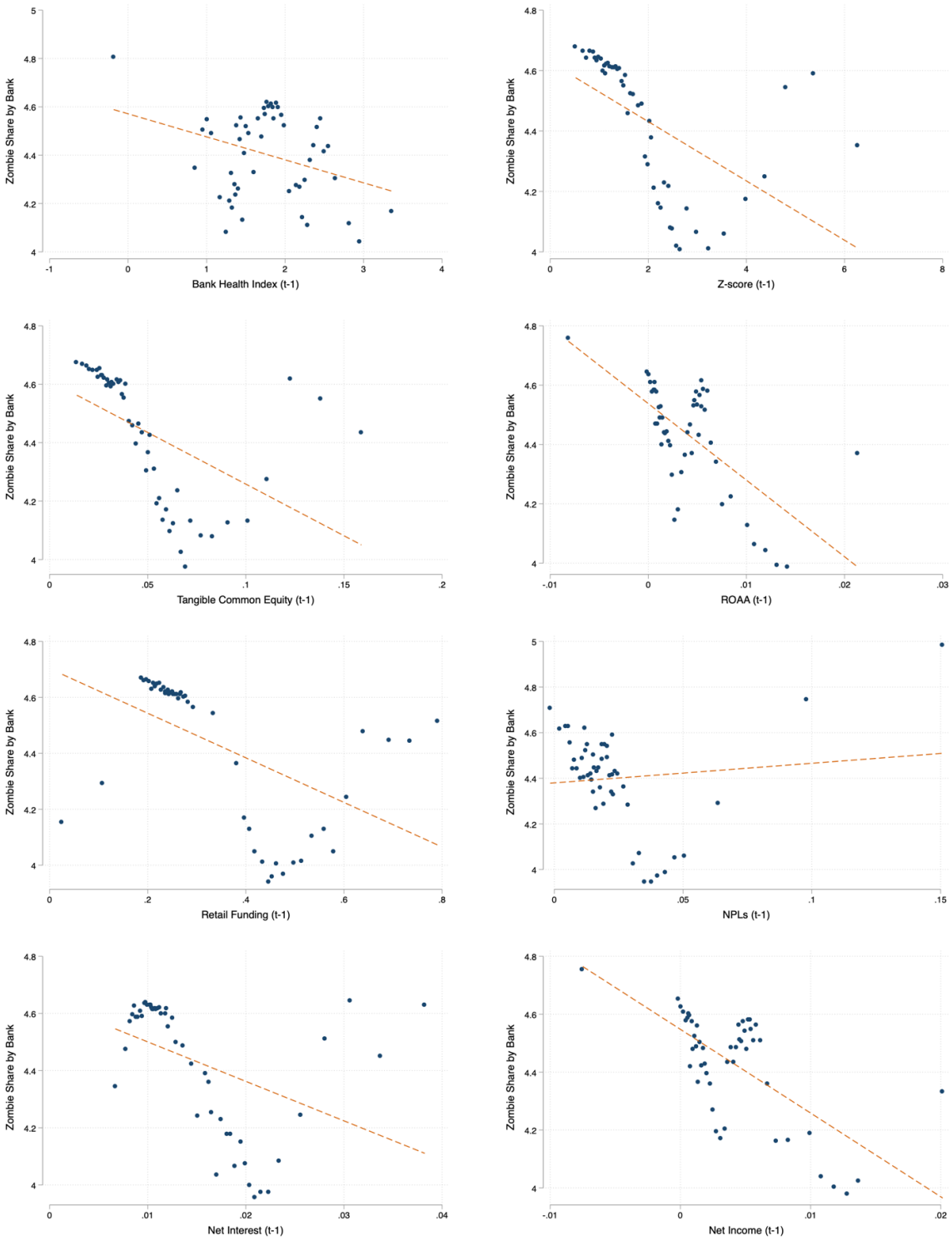
Figure B.2: The evolution of bank health in Denmark



Note: The figure depicts the evolution of bank health in Denmark over the period 2005 to 2019 for 51 individual banks. This provides the average bank health for banks in Denmark weighted by the number of firms for which a bank is considered to be their main bank. Bank health is given by the first principal component from a principal component analysis of seven financial statement variables from danish bank balance sheets. These include tangible common equity (TCE, a proxy for capital), NPLs, net income, net interest income, return on average assets (ROAA), Z-score and retail funding. The grey band illustrates the global financial crisis.

Sources: Own calculation with the use of data from BankFocus

Figure B.3: Weak banks and zombie firms – additional figures



Note: The figures depict the average share of zombie firms (connected to a bank) for each bin of bank health. For ease of observation the bins are divided into 50 bins of equal size purged of industry x year fixed effects. Bank health is given by the first principal component from a principal component analysis of seven financial statement variables from danish bank balance sheets. These include tangible common equity (TCE, a proxy for capital), NPLs, net income, net interest income, return on average assets (ROAA), Z-score and retail funding.

Sources: Own calculation with the use of data from BankFocus