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Zombie Firms and Total Factor Productivity: Evidence from Portugal

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Abstract

This dissertation examines whether pre-pandemic zombie status influenced the productivity evolution of Portuguese manufacturing firms following the COVID-19 shock. Zombie firms are generally characterised as financially distressed firms that remain active through continued access to external financing and that are typically associated with lower productivity and weaker economic performance. Despite the growing attention devoted to zombie firms, limited evidence exists on how these firms respond to external shocks.

Using data from the SABI database for the period 2017–2022, zombie firms are identified as firms exhibiting negative equity for two consecutive years prior to the pandemic. Firm productivity is measured through Total Factor Productivity (TFP), and the analysis combines Propensity Score Matching with a Difference-in-Differences framework to compare productivity changes between zombie and comparable non-zombie firms before and after the pandemic shock.

Given their lower productivity and greater financial fragility, zombie firms would be expected to experience a less favourable productivity response to the COVID-19 shock. However, the baseline Difference-in-Differences estimates suggest a small positive productivity differential between the pre- and post-pandemic periods for zombie firms relative to comparable non-zombie firms. Nevertheless, the estimated effect is economically modest, statistically significant only at the 10% level, and disappears when a stricter definition of persistent zombie firms is adopted.

Overall, the findings provide no robust evidence that zombie status significantly influenced firms' productivity response to the pandemic shock. Although zombie firms remained less productive than non-zombie firms throughout the pre-pandemic period, both groups exhibited broadly similar productivity trajectories during the post-pandemic period.

These findings contribute to the literature on zombie firms by providing evidence on whether pre-pandemic zombie status influenced firms' productivity adjustment during an economic disruption.

Keywords: Zombie Firms; Total Factor Productivity (TFP); COVID-19; Difference-in-Differences (DiD); Propensity Score Matching; Portuguese Manufacturing Firms

Resumo

Esta dissertação analisa se a condição de empresa zombie pré-pandemia influenciou a evolução da produtividade nas indústrias transformadoras portuguesas após o choque da COVID-19. As empresas zombie são caracterizadas por menor produtividade e fraco desempenho económico, permanecendo em atividade através do acesso continuado a financiamento externo. Apesar da crescente atenção dedicada a estas empresas, continua a existir evidência limitada sobre a forma como respondem a choques externos.

Com recurso à base SABI para o período 2017-2022, as empresas zombie são identificadas por apresentarem capital próprio negativo durante dois anos consecutivos antes da pandemia. A produtividade é medida através da Produtividade Total dos Fatores, e a análise combina Propensity Score Matching com um modelo de Diferenças-em-Diferenças para comparar as variações de produtividade entre empresas zombie e não zombie comparáveis, antes e depois do choque.

Dada a sua maior fragilidade, seria expectável um ajustamento da produtividade menos favorável das empresas zombie à COVID-19. No entanto, as estimativas de Diferenças-em-Diferenças sugerem um ligeiro diferencial positivo na variação da produtividade das empresas zombie face aos pares não zombie comparáveis. Contudo, este efeito é modesto em termos económicos, significativo apenas a 10%, e desaparece ao adotar uma definição mais restritiva de empresas zombie persistentes.

Em termos gerais, os resultados não fornecem evidência robusta de que a condição de empresa zombie tenha influenciado significativamente o ajustamento da produtividade ao choque pandémico. Embora as empresas zombie permanecessem menos produtivas no período pré-pandemia, ambos os grupos exibiram trajetórias globalmente semelhantes após o choque.

Estes resultados contribuem para a literatura sobre empresas zombie ao fornecer evidência sobre a influência da condição de empresa zombie pré-pandemia no ajustamento da produtividade durante um choque económico.

Palavras-chave: Empresas zombie; Produtividade Total dos Fatores (PTF); COVID-19; Diferenças-em-Diferenças; Propensity Score Matching; Indústrias Transformadoras Portuguesas

Table of Contents

List of Figures

List of Tables

1. Introduction

Productivity growth is a key driver of economic growth and depends on the ability of economies to direct resources from less efficient to more efficient firms. Under normal market conditions, financially fragile and inefficient firms are expected to exit the market, allowing resources to be reallocated towards more productive firms. Through this process of resource reallocation, competitive markets contribute to aggregate productivity growth (Caballero & Hammour, 1994; Hopenhayn, 1992).

However, this cleansing effect does not always operate effectively. As a result, increasing attention has been devoted to a group of firms that remain active under conditions that would normally lead to market exit. Commonly known as zombie firms, these firms are artificially kept alive despite persistent financial fragility and weak economic performance.

Although there is no universally accepted definition of zombie firms, the literature generally characterises them as financially distressed firms that remain active through continued access to external financing rather than through sustainable profitability. Previous studies also associate zombie firms with lower productivity, higher leverage and weaker overall performance compared to healthy firms (Albuquerque & Iyer, 2024; Banerjee & Hofmann, 2022; Carreira et al., 2022; Tracey, 2025).

The concern surrounding zombie firms extends beyond their survival. By remaining active, these firms may absorb capital, labour and credit that could otherwise be allocated to more productive firms. Furthermore, their presence may distort competition, reduce investment incentives and hinder the growth of healthy firms. As a result, zombie firms may contribute to lower productivity growth and weaker economic performance (McGowan et al., 2018).

For these reasons, zombie firms have become an increasingly important topic in both the academic and policy debate. Understanding how these firms behave during periods of economic disruption is therefore important not only from a firm-level perspective but also for assessing their broader implications for productivity and resource allocation.

Despite the extensive literature on zombie firms, limited evidence exists on how these firms adjust following a major external shock. In particular, it remains unclear whether zombie firms experience a different productivity evolution relative to comparable non-zombie firms when exposed to a negative economic disruption. This question is particularly relevant

because productivity is one of the characteristics most consistently associated with zombie firms and plays a central role in economic growth and resource allocation.

To address this gap, this dissertation investigates whether pre-pandemic zombie firms reacted differently from comparable non-zombie firms to a major economic shock. More specifically, it examines whether zombie status influenced firms' productivity adjustment following the COVID-19 shock.

The COVID-19 pandemic provides a unique setting to analyse this question. Unlike previous crises, the COVID-19 shock originated from a public health emergency rather than from the financial system itself. As a result, firms were affected regardless of their initial financial conditions, creating an opportunity to examine how zombie firms and healthy firms adjusted to an exogenous shock.

To examine this question, the analysis relies on firm-level data from the SABI database covering Portuguese manufacturing firms. Zombie firms are defined as firms classified as zombies in 2019 based on two consecutive years of negative equity. To identify the effect of zombie status, a Difference-in-Differences approach is combined with Propensity Score Matching to compare the evolution of productivity, measured by the Total Factor Productivity (TFP), between zombie and non-zombie firms before and after the pandemic. This empirical strategy allows the comparison of firms that shared similar size, firm age, and productivity levels prior to the shock. To ensure the reliability of the baseline results, the analysis incorporates a robustness check using a stricter 'persistent zombie' definition, classifying firms that exhibit negative equity for at least four consecutive years (from 2015 to 2018).

Contrary to the predictions derived from the zombie-firm literature, the findings do not provide evidence that zombie firms experienced a less favourable productivity evolution following the COVID-19 shock. Instead, the results suggest that zombie firms experienced a slightly less pronounced decline in productivity relative to comparable non-zombie firms. However, this estimated effect is economically modest, being significant only at the 10% level and disappearing under a stricter zombie definition. Importantly, zombie firms remained less productive on average throughout the pre-pandemic period, but the productivity gap between the two groups narrowed substantially following the COVID-19 shock. This pattern is illustrated in Figure 1, which presents the annual evolution of average

TFP for zombie and non-zombie firms. As shown in the figure, both groups exhibited broadly similar productivity trajectories throughout the post-COVID period.

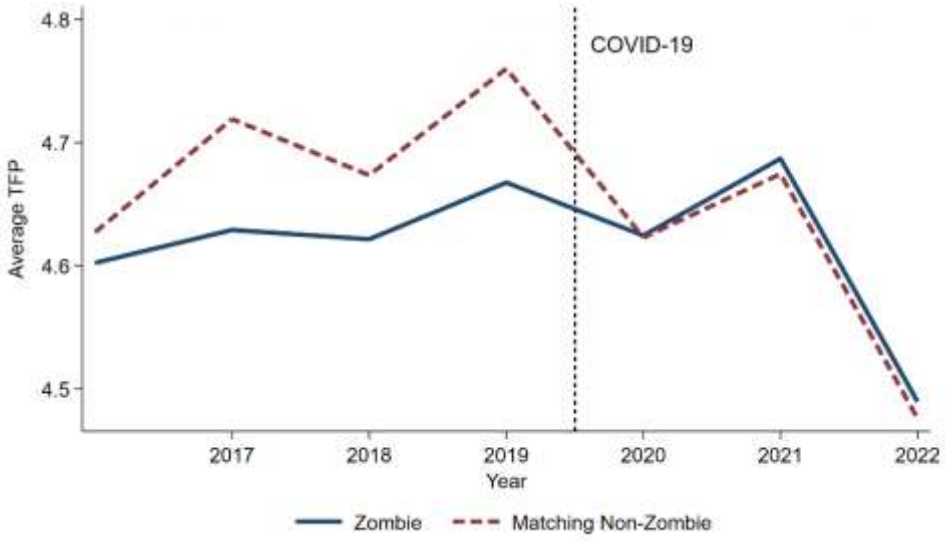

Figure 1. Evolution of Average Total Factor Productivity Before and After the COVID-19 Shock

Note: Average TFP corresponds to the annual mean of log TFP for zombie and matched non-zombie firms. The figure is based on the matched estimation sample (N = 2,556). **Source:** Author's calculations using SABI data.

These findings contribute to the existing literature by providing firm-level evidence on whether pre-existing zombie status influenced firms' productivity adjustment to an exogenous shock. By comparing the productivity evolution of zombie and comparable non-zombie firms before and after the pandemic, this dissertation contributes to the limited evidence on how zombie firms respond to severe economic disruptions.

The remainder of this dissertation is organised as follows. Chapter 2 reviews the relevant literature on zombie firms. Chapter 3 describes the data, variable construction, and sample selection process, while Chapter 4 presents the empirical methodology. Chapter 5 presents and discusses the empirical results, including the robustness analysis, study limitations, and avenues for future research. Finally, Chapter 6 concludes.

2. Literature Review

The efficient allocation of resources is a fundamental determinant of aggregate productivity and economic growth. In particular, productivity gains depend on the ability of the economy to reallocate resources from less efficient to more productive firms. This process is supported by continuous technological progress, which enables the adoption of more efficient production methods and the replacement of outdated ones (Caballero & Hammour, 1994; Hopenhayn, 1992).

Within this framework, competitive markets are characterised by a 'cleansing effect', whereby inefficient firms exit the market because they are unable to remain profitable when competing with more productive firms. This occurs because firms continuously face productivity shocks and only those that remain sufficiently productive survive, while less efficient firms eventually exit. As a result, the resources previously employed by these firms become available for reallocation towards more productive competitors (Caballero & Hammour, 1994; Hopenhayn, 1992).

However, the cleansing effect does not always operate as predicted in theory, particularly during economic downturns. During these periods, competitive market forces may weaken, significantly lowering the productivity threshold required for survival. As a result, inefficient firms may remain active despite their low productivity and weak financial performance, rather than exiting the market as predicted by the cleansing effect (Caballero & Hammour, 1994; Hopenhayn, 1992).

Empirical evidence supports this argument, suggesting that the cleansing effect may weaken during major economic downturns. In these circumstances, inefficient firms often remain active in the market despite their low productivity and profitability. For instance, major economic downturns, such as the Great Recession, the Global Financial Crisis, and the COVID-19 pandemic, have been associated with a rising prevalence of these low-productivity and financially fragile firms, raising concerns about the effectiveness of the market selection process (Albuquerque & Iyer, 2024; Banerjee & Hofmann, 2022; McGowan et al., 2018).

This evidence points to the growing presence of firms that remain active despite weak performance. If these firms are unable to survive through productivity and profitability, they are likely to rely on alternative mechanisms. In this context, the literature has devoted

increasing attention to a particular group of such firms: zombie firms. Although no consensual definition exists, zombie firms are generally described as financially distressed firms that remain active despite conditions that would normally lead to market exit, often through continued access to external financing (Albuquerque & Iyer, 2024; Carreira et al., 2022; Hoshi, 2006; Kane, 1987; Shome & Verma, 2025; Yu et al., 2021).

Zombie Definitions Despite the growing attention devoted to zombie firms, identifying zombie firms is far from straightforward. Distinguishing firms that are persistently unproductive and financially unsustainable from those experiencing only temporary financial distress remains a major challenge in the literature, and no single consensual definition has emerged. As a result, researchers have developed several alternative approaches to identify zombie firms.

The earliest approaches to identifying zombie firms focused on their relationship with the banking sector. The literature argues that the process of cleansing inefficient firms from the market is disrupted by the continuous provision of credit, which allows such firms to survive artificially (Ahearne & Shinada, 2005; Albuquerque & Iyer, 2024; Caballero et al., 2008). Under this perspective, zombie firms are not merely firms with fragile financial conditions, but firms that are artificially kept alive through continued bank financing (Álvarez et al., 2023; Caballero et al., 2008; Hoshi, 2006). Consequently, some authors attempt to identify zombie firms through the characteristics of the credit they receive.

Caballero et al. (2008) define a zombie firm as a firm receiving subsidised credit, where the interest paid falls below a relevant benchmark or hypothetical lower bound. Since this benchmark already reflects highly favourable lending conditions, firms paying even lower interest rates are interpreted as benefiting from explicit or implicit bank support. Under this framework, preferential credit conditions signal that banks are artificially sustaining firms that would otherwise exit the market. Along similar lines, Hoshi (2006) also classifies zombie firms as firms whose interest payments are substantially lower than what their debt levels would normally imply, suggesting that they benefit from preferential lending conditions.

Despite being based on different measures of preferential lending, these approaches rely on information about firms' access to bank credit and lending conditions. This creates important empirical challenges. First, it is difficult to observe and measure whether firms are actually benefiting from favourable credit conditions. Second, detailed information on lending

conditions and bank-firm relationships is rarely available in large firm-level databases, limiting the implementation of cross-country analyses (Acharya et al., 2022; McGowan et al., 2018).

Consequently, the literature gradually shifted its focus towards more observable metrics, particularly firms' financial performance. One of the most common approaches is the interest coverage ratio (ICR). The ICR captures a firm's immediate ability to service its debt through internally generated earnings. If the ICR is below one, the firm cannot generate enough cash flows to pay its interest expenses and therefore depends on refinancing to avoid firm default. The ICR is particularly useful for cross-country analysis, as it allows for easier comparability (Albuquerque & Iyer, 2024; Banerjee & Hofmann, 2022; McGowan et al., 2018).

Several studies refine the ICR-based approach by incorporating additional criteria aimed at capturing firms' long-term viability and reducing the risk of misclassifying firms experiencing temporary distress. Banerjee and Hofmann (2022) complement the ICR criterion with a measure of future growth prospects based on Tobin's q below the sector median, while McGowan et al. (2018) instead impose a minimum firm-age requirement. Although they rely on different indicators, both approaches seek to distinguish persistently weak firms from those experiencing only temporary financial difficulties.

Following a similar logic, Albuquerque and Iyer (2024) extend the ICR-based definition by incorporating negative real sales growth and above-median leverage, aiming to distinguish persistently unprofitable firms from those experiencing temporary distress.

However, not all performance-based definitions rely on the interest coverage ratio. For instance, Carreira et al. (2022) define zombie firms as highly leveraged firms whose return on assets remains below a low-risk interest rate for at least three consecutive years, indicating that they consistently fail to generate returns sufficient to cover their financing costs. This criterion is combined with above-median leverage and a minimum firm-age requirement. Other authors identify zombie firms based solely on persistent negative profits over multiple consecutive years (Chang et al., 2021; Yu et al., 2021).

Ultimately, whether using the ICR, ROA, or net profits, the majority of these performance-based definitions require conditions to hold over multiple years to mitigate the inclusion of firms experiencing temporary financial distress due to short-term fluctuations in prices or profits (Albuquerque & Iyer, 2024; Banerjee & Hofmann, 2022; McGowan et al., 2018).

The absence of a consensual definition has important implications for empirical research, as different definitions can yield different results (Acharya et al., 2022; Schivardi et al., 2020; Nurmi et al., 2022). In particular, definitions based solely on contemporaneous financial performance, such as profits or returns, may create important causal identification problems. During periods of adverse economic conditions, otherwise viable firms may temporarily satisfy the zombie criteria, not because they are structurally unproductive, but because they are affected by the same negative shock. Consequently, an increase in the measured prevalence of zombie firms may simply reflect a broad deterioration in economic conditions rather than a genuine rise in the number of structurally unviable firms, potentially biasing empirical estimates of the economic effects of zombie congestion (Schivardi et al., 2020).

In response to these limitations, part of the literature has shifted its attention from firms' current financial performance to the strength of their underlying balance-sheet position. Rather than identifying zombie firms through persistently low profitability, these approaches focus on firms whose financial position suggests that they should no longer be able to remain active in the market (Blažková & Dvouletý, 2022; Bonfim et al., 2023; San-Jose et al.,2022).

The economic rationale behind these definitions is that firms continue to operate despite being technically insolvent, a condition commonly measured through negative equity. A firm with negative equity has accumulated losses to the point where its liabilities surpass its assets, leaving no remaining shareholders' capital. This implies that creditors are unlikely to recover their loans even after liquidation. Consequently, the continued survival of firms with negative equity may be interpreted as evidence that creditors are tolerating or supporting firms despite their technical insolvency (Blažková & Dvouletý, 2022; Bonfim et al., 2023; San-Jose et al.,2022).

While profitability-based measures primarily capture firms' ability to generate sufficient earnings in the short run, negative equity reflects a deeper and more persistent form of financial distress resulting from the accumulation of losses over time. For this reason, the literature often characterises firms with negative equity as representing one of the most severe forms of zombification (San-Jose et al., 2022). This measure became particularly relevant following the COVID-19 pandemic, since it was difficult to distinguish unviable firms from otherwise viable firms affected by a temporary shock (Bonfim et al., 2023).

The required number of consecutive years of negative equity varies across studies, depending on the level of severity that the authors aim to capture. Bonfim et al. (2023) consider a single year of negative equity sufficient to indicate technical insolvency, whereas Blažková and Dvouletý (2022) and San-Jose et al. (2022) require longer periods to identify more persistent and severe cases of zombification.

Zombie Characteristics Although there is no single consensual way to identify zombie firms, the literature consistently finds that firms classified as zombies share several common characteristics, including persistent underperformance and financial fragility.

The most consistent finding concerns productivity. Across different countries and definitions, zombie firms systematically exhibit lower levels of total factor productivity (TFP) and labour productivity than healthy firms, suggesting that they are less efficient. This lower productivity is reflected in weaker operating performance, including lower sales, profitability, and returns on assets (Albuquerque & Iyer, 2024; Banerjee & Hofmann, 2022; Carreira et al., 2022; Nurmi et al., 2022; Tracey, 2025).

These operational difficulties are accompanied by fragile financial conditions. The literature characterises zombie firms by higher leverage, weaker balance sheets, lower liquidity, and a greater risk of default. These constraints are associated with lower investment in both tangible and intangible capital, limiting future growth opportunities and reinforcing persistent underperformance (Albuquerque & Iyer, 2024; Banerjee & Hofmann, 2022; Carreira et al., 2022; Chang et al., 2021; El Ghoul et al., 2021).

Persistence of Zombie Status Taken together, these characteristics suggest that zombie firms suffer from structural rather than temporary weaknesses. This naturally raises an important question regarding the dynamics of zombification: once firms enter zombie status, are they able to recover, or does the condition tend to persist over time?

The evidence suggests that zombie status tends to be highly persistent and can last for several years (Albuquerque & Iyer, 2024; Carreira et al., 2022). Rather than converging towards the performance of healthy firms, zombie firms often experience a progressive deterioration in their financial and economic conditions, with gaps in assets, capital, productivity, and employment widening over time (Albuquerque & Iyer, 2024).

Even when firms exit zombie status, recovery is often fragile. Former zombie firms face a significantly higher probability of relapsing into zombie status than firms that were never

zombies. Moreover, relapse rates have increased substantially over the last decade. This pattern is partly attributed to the fact that former zombie firms continue to invest less and exhibit lower productivity than their healthy counterparts, suggesting that the underlying weaknesses associated with zombification often persist beyond the initial recovery (Banerjee & Hofmann, 2022).

Nevertheless, recovery is possible. Nurmi et al. (2022) document cases of zombie recovery, mainly driven by downsizing strategies. In response to weak performance, some firms reduce employment and sell assets to regain profitability (Carreira et al., 2022; Nurmi et al., 2022). More broadly, successful recovery often requires both operational and financial restructuring. Larger and older firms also appear more likely to recover, possibly due to a greater capacity to implement such adjustments (Carreira et al., 2022).

Overall, although recovery is possible, the literature indicates that zombie status is predominantly a persistent condition. Even when firms succeed in escaping zombie status, recovery often remains fragile and accompanied by a significant risk of relapse.

Drivers of Zombie Persistence But what makes zombie firms so persistent? If zombie firms are characterised by weak productivity and fragile financial conditions, one might expect them to eventually exit the market. To explain this persistence, the literature identifies several mechanisms that contribute to their persistence. Among these, banks play a central role in enabling the survival of financially weak and unviable firms, thereby disrupting the cleansing mechanism of the market (Acharya et al., 2019; Acharya et al., 2022; Albuquerque & Iyer, 2024; Bonfim et al., 2023; Bruche & Llobet, 2014; Caballero et al., 2008; Faria-e-Castro et al., 2024; Hoshi, 2006).

The main mechanism through which banks sustain zombie firms is commonly referred to as 'evergreening'. Evergreening describes the practice whereby banks continuously refinance distressed firms by extending existing loans or granting new credit, allowing them to meet outstanding financial obligations and avoid default. Rather than allowing inefficient firms to exit the market, banks renew existing loans and maintain their access to financing (Acharya et al., 2019; Albuquerque & Iyer, 2024; Bonfim et al., 2023; Chang et al., 2021; Faria-e-Castro et al., 2024). The literature also refers to this behaviour as "extending and pretending", highlighting the fact that banks continue to provide credit to firms that are no longer viable, instead of recognising the associated losses (Acharya et al., 2022; Bruche & Llobet, 2014; Hu

& Varas, 2021). For this reason, evergreening is closely associated with "zombie lending", as it enables firms to survive despite their weak financial performance (Albuquerque & Iyer, 2024; Bonfim et al., 2023; Tuuli, 2024).

In practice, these strategies may involve not only the extension of new credit, but also more favourable lending conditions, such as lower interest rates, debt forgiveness, debt-for-equity swaps, and payment moratoria. Rather than restoring firm viability, these practices allow financially weak firms to continue operating despite their low efficiency (Acharya et al., 2019; Caballero et al., 2008; Faria-e-Castro et al., 2024).

While these practices help explain how zombie firms survive, they do not explain why banks are willing to sustain these potentially insolvent firms. Understanding the incentives behind these practices is therefore crucial to explain the persistence of zombie firms. The main incentive to continue granting new loans is to avoid recognising losses and preserve capital (Acharya et al., 2019; Acharya et al., 2022; Albuquerque & Iyer, 2024; Bonfim et al., 2023). If a bank recognises that a loan is unlikely to be repaid, it must record a loss, reducing both its profits and its book equity. In addition, banking regulation requires financial institutions to maintain minimum capital buffers to absorb unexpected losses and ensure financial stability. Consequently, recognising loan losses reduces these reserves and may force banks to raise additional capital, placing further pressure on their balance sheets and potentially constraining future lending activity (Acharya et al., 2019; Bonfim et al., 2023).

Importantly, these incentives are stronger for weakly capitalised banks, that is, banks with relatively low capital reserves available to absorb potential losses. Such institutions are therefore more likely to engage in zombie lending to avoid violating regulatory capital requirements (Acharya et al., 2019; Albuquerque & Iyer, 2024; Bonfim et al., 2023; Bruche & Llobet, 2014).

Rather than immediately recognising losses, banks may choose to continue financing distressed firms in the hope that their financial condition will eventually improve, allowing outstanding loans to be repaid. This behaviour is commonly referred to as a "gamble for resurrection", as banks effectively gamble on the future recovery of troubled borrowers to avoid immediate losses and the deterioration of their own balance sheets (Acharya et al., 2022; Bruche & Llobet, 2014). Such behaviour is often supported by overly optimistic expectations regarding the recovery of zombie firms (Albuquerque & Iyer, 2024).

Beyond regulatory capital concerns, banks are also driven by broader systemic risks, including the need to avoid fire-sale externalities. Jaskowski (2015) argues that banks may continue evergreening loans to prevent sharp declines in collateral values. If banks stop financing zombie firms, they may be forced to liquidate their assets to recover outstanding loans. However, large-scale liquidation increases the supply of similar assets in the market, leading to price declines. Since banks often hold similar types of collateral across multiple firms, this decline in prices reduces the value of their entire collateral portfolio. As a result, the recovery value of loans may fall below their outstanding debt, generating further losses. In this context, rolling over loans may be a more attractive strategy to avoid these negative spillovers and contain losses (Jaskowski, 2015).

The nature of the bank–firm relationship further amplifies the likelihood of zombie lending. This behaviour arises from banks' aim to protect the funds they have already lent to these firms (Acharya et al., 2019; Albuquerque & Iyer, 2024; Álvarez et al., 2023; Bonfim et al., 2023; Caballero et al., 2008). Furthermore, lenders may continue extending and renewing loans in an attempt to restore the firm's viability, or even to create the appearance of financial stability, which can help attract less-informed external investors or additional sources of financing, ultimately increasing the likelihood that banks recover at least part of their previous loans (Acharya et al., 2022).

This incentive dynamic is particularly relevant when a bank acts as the sole creditor. When multiple lenders are involved, the risk of default is shared. In contrast, when a single bank holds most or all of the firm's debt, it internalises the full cost of default, which increases the incentive to continue lending and offer more favourable loan conditions to prevent firm exit (Faria-e-Castro et al., 2024).

These explanations implicitly assume banks are aware of the financial conditions of the zombie firms. This raises another important question: are banks knowingly sustaining unviable firms, or are they simply unable to distinguish accurately between zombie and healthy firms? A large body of literature suggests that banks are often aware that these firms face structural and persistent financial problems, rather than temporary distress, but still choose to continue lending. This is supported by evidence showing that, under stricter supervisory scrutiny, banks reduce zombie lending, indicating that they are able to distinguish between viable and non-viable firms (Acharya et al., 2019; Acharya et al., 2022; Bonfim et al., 2023; Bruche & Llobet, 2014; Herweg & Kähny, 2025; Jaskowski, 2015).

However, other studies highlight that banks may not always be able to accurately distinguish between zombie and healthy firms due to information asymmetries. In some cases, firms may manipulate financial information to conceal their deterioration, making it harder for lenders to correctly assess their viability (Albuquerque & Iyer, 2024; Chang et al., 2021; Tracey, 2025).

Although banks are the primary drivers of zombie persistence, other sources of financing may also contribute. Shareholders, for instance, may continue funding weak firms when they expect future recovery and hope to recover part of their investment (Tuuli, 2024).

The macroeconomic environment also plays an important role in zombie survival. Low interest rates reduce debt-servicing costs, improving firms' ability to meet their financial obligations and, therefore, making banks more willing to continue extending credit. Although the long-term effects may be more nuanced, empirical evidence generally associates both low-interest-rate environments and periods of abundant liquidity with a higher prevalence of zombie firms and zombie lending (Acharya et al., 2019; Acharya et al., 2022; Banerjee & Hofmann, 2022; Herweg & Kähny, 2025; You et al., 2025).

In addition to financing conditions, the institutional environment also plays a crucial role in determining whether zombie firms survive, recover, or exit the market. If the legal framework does not adequately protect creditors, enforcing debt claims becomes more difficult. In such circumstances, banks may recover only a small fraction of their loans if a distressed firm is liquidated. As a result, banks may prefer to continue financing zombie firms rather than recognise losses on their balance sheets. Similarly, the insolvency framework may constitute a barrier to resource reallocation, preventing the market exit of zombie firms. When insolvency procedures are slow or inefficient, financially distressed firms may remain active for prolonged periods, delaying both restructuring and liquidation. Empirical evidence supports these mechanisms: countries with efficient restructuring and liquidation procedures experience a faster decline in zombie firms following recessions, while reforms that accelerate insolvency processes can both facilitate the exit of unviable firms and support the recovery of more productive ones (Jordà et al., 2022; Nieto-Carrillo et al., 2022).

Unlike creditor protection and insolvency procedures, labour protection regulation may increase the likelihood of zombie firm exit**.** High levels of employment protection make restructuring more difficult and costly, limiting firms' ability to restore profitability through

labour adjustments. Since the literature identifies downsizing and restructuring as important mechanisms of zombie recovery, stricter employment protection may reduce the likelihood of successful recovery. As recovery prospects weaken, banks may become less willing to continue extending credit, thereby increasing the likelihood of firm exit (Zhaxi & Yasuda, 2025).

Finally, direct government intervention also plays a significant role in zombie firm survival. Governments often intervene to prevent firm default in order to preserve employment and limit the economic costs associated with firm failure. While these interventions may generate important short-run benefits, they also introduce moral hazard. Since this support is mainly implemented through subsidies and financial assistance, zombie firms may choose to survive based on continuous public funding rather than trying to restructure and become viable (Chang et al., 2021; Tan et al., 2016). Consequently, while public intervention may help preserve firms in the short run, it can also contribute to the long-run persistence of zombie firms by reducing incentives to restructure and improve performance (Meng et al., 2025).

Internal Determinants of Zombie Survival However, zombie firm survival is not only driven by external factors. Internal characteristics and corporate governance structures may also affect firms' incentives to remain active despite weak performance. Firms operating under limited liability have stronger incentives to continue operating because shareholders cannot lose more than their invested capital, effectively transferring part of the downside risk to creditors (Blažková & Dvouletý, 2022). Similarly, weaker governance structures may increase the likelihood of zombification. Firms with a single board member are more likely to become zombies, as they benefit from less oversight and monitoring than firms with more diversified boards. Similarly, when the CEO is also the company's owner, the likelihood of zombification increases due to moral hazard. In such cases, the CEO-owner may engage in riskier decisions in an attempt to recover the firm, while effectively transferring the downside risk to creditors (San-Jose et al., 2022).

Overall, the persistence of zombie firms is not driven by a single factor, but rather by a combination of external and internal mechanisms. Together, these factors shape the incentives of firms, creditors, investors, and policymakers, determining whether financially distressed firms are restructured, liquidated, or allowed to survive.

Spillover Effects The importance of studying zombie firms lies not only in their ability to survive despite being economically unviable, but also in the distortions their survival creates for the rest of the economy. By remaining active in the market, zombie firms affect the functioning of several markets, generating spillover effects that extend well beyond the firms themselves.

A key distortion created by zombie firms occurs in the credit market. Given that the supply of credit is limited, continued financing of zombie firms generates a crowding-out effect, leaving less credit available for viable and productive firms. At the same time, the presence of zombie firms increases industry credit risk, as lenders become more exposed to potential defaults and face greater uncertainty regarding firms' financial conditions. This leads to a higher risk premium and more expensive credit conditions for all firms. Moreover, zombie firms do not use this credit efficiently. Instead of allocating funds towards productive investment or expansion, they primarily use them to service existing debt and sustain ongoing operations, without generating improvements in productivity or performance (Acharya et al., 2019; Acharya et al., 2022; Ahearne & Shinada, 2005; Tracey, 2025; You et al., 2025; Yu et al., 2021).

As a result, credit misallocation significantly harms healthy firms by constraining their access to financing, thereby reducing investment and overall economic growth (Acharya et al., 2019; Acharya et al., 2022; Faria-e-Castro et al., 2024). This mechanism is further supported by evidence showing that when stricter bank supervision limits zombie lending, zombie firms become more likely to default and exit the market. The resulting reallocation of resources facilitates firm entry and improves industry-level productivity (Bonfim et al., 2023).

While these effects originate in the credit market, zombie firms also affect the allocation of resources in product and factor markets. In a frictionless setting, inefficient firms would scale down their activity, release resources, and allow more productive firms to expand and gain market share. However, continuous financing prevents this adjustment process and allows zombie firms to remain active in the market. As a result, these firms continue to supply goods, often at artificially low prices, in an attempt to generate short-term liquidity. This behaviour puts downward pressure on industry prices and decreases profit margins for more efficient firms. Consequently, healthier firms may struggle to expand and, in some cases, may even be forced to exit the market despite being more productive. At the same time, the lower expected profitability reduces incentives for new firms to enter the market, weakening

competitive pressure and slowing the process of resource reallocation (Acharya et al., 2019; Acharya et al., 2022; Hoshi, 2006; Albuquerque & Iyer, 2024; Ascani & Nair, 2025; Banerjee & Hofmann, 2022; Caballero et al., 2008; Nieto-Carrillo et al., 2022).

Similar distortions emerge in labour markets. Zombie firms also tend to retain labour, reducing the supply of available workers to healthy firms. This tighter labour market contributes to higher wages and limits job creation among healthy firms. Together, these spillover effects weaken the profitability and growth potential of more productive firms (Acharya et al., 2019; Acharya et al., 2022; Albuquerque & Iyer, 2024; Ascani & Nair, 2025; Banerjee & Hofmann, 2022; Caballero et al., 2008; Hoshi, 2006; Nieto-Carrillo et al., 2022)

Ultimately, the costs of zombie firm survival extend far beyond the firms themselves, as distortions across credit, labour, and capital markets accumulate into significant macroeconomic consequences. As the negative impacts on employment growth, investment, firm productivity, and market entry translate into a decline in aggregate productivity, the overall value-added in the economy inevitably drops**.** In addition, the downward pressure exerted by zombie firms on prices may generate disinflationary effects (Acharya et al., 2019; Acharya et al., 2024; Bruche & Llobet, 2014; Carreira et al., 2022; Faria-e-Castro et al., 2024; McGowan et al., 2018). Together, these mechanisms may contribute to deeper recessions and slower economic recoveries when zombie firms become more prevalent (Jordà et al., 2022).

Causal Identification However, establishing a causal relationship between zombie prevalence and these spillover effects is not straightforward, particularly during periods of severe economic disruption. Some studies argue that the observed relationship between zombie prevalence and other firms' weak performance may partly reflect the impact of negative aggregate shocks. In such contexts, both the increase in zombie firms and the deterioration of healthy firms may occur simultaneously, rather than one directly causing the other (Schivardi et al., 2020). In a similar vein, Tracey (2025) does not find strong evidence that zombie firms directly harm the performance of healthy incumbents. Instead, the author attributes the macroeconomic consequences primarily to reduced market dynamism, particularly through lower rates of firm entry, rather than to direct spillover effects.

These alternative interpretations highlight an important challenge in the zombie firm literature. If adverse aggregate shocks can simultaneously increase zombie prevalence and

weaken the performance of healthy firms, distinguishing between genuine zombie spillovers and the broader effects of economic crises becomes particularly difficult. However, they do not rule out the possibility that firms with pre-existing financial fragilities respond differently to adverse economic shocks. Consequently, these periods provide a valuable setting to assess whether firms with pre-existing financial fragilities are more vulnerable to adverse shocks than their healthier counterparts.

As previously discussed, earlier crises, such as the Great Recession and the Global Financial Crisis, were associated with significant increases in zombification (Acharya et al., 2022; Albuquerque & Iyer, 2024; McGowan et al., 2018). Building on this premise, the unprecedented economic shock of the COVID-19 pandemic has renewed concerns regarding the persistence of financially weak firms, making it a particularly relevant setting for the study of zombie firms and market selection mechanisms (Acharya et al., 2022; Shome & Verma, 2025).

Zombie Firms and the COVID-19 Shock Unlike previous crises, the COVID-19 shock was initially non-financial, arising from a public health emergency. As a result, its economic consequences extended even to viable sectors and productive firms. These effects were largely driven by lockdown measures, which forced firms to suspend operations, adopt remote work arrangements, and adjust to sudden shifts in consumer demand. At the same time, firms were unable to immediately adjust their productive factors to the abrupt fall in demand, leading to a sharp decline in revenues and profitability. Furthermore, the literature suggests that the pandemic shock was not primarily related to firms' underlying characteristics, but rather to the sudden liquidity shortages generated by the crisis (Faria-e-Castro et al., 2024; Guerini et al., 2024). This perception shaped the policy response adopted in many countries, including Portugal.

In Portugal, since the crisis was largely perceived as a temporary liquidity shock, the government implemented unprecedented support measures aimed at preserving firm liquidity and preventing widespread bankruptcies (Kozeniauskas et al., 2022; Nogueira, 2022). As a consequence, firm default rates reached historically low levels during the pandemic, contrasting with the patterns typically observed during recessions. These interventions also raised concerns that liquidity support policies may have weakened the cleansing effect, artificially sustaining inefficient and zombie firms (Acharya et al., 2022; Faria-e-Castro et al., 2024; Guerini et al., 2024).

The empirical evidence regarding the effects of these interventions on zombification remains mixed across countries. Guerini et al. (2024) find that public support primarily benefited healthy firms experiencing temporary liquidity difficulties, without evidence that less productive French firms received disproportionate support. In contrast, Kozeniauskas et al. (2022) find evidence for Portugal that less productive firms were more likely to seek government subsidies, consequently increasing the survival probability of inefficient firms. Therefore, the literature does not provide a consensual conclusion regarding the effects of government support during the COVID-19 pandemic on the survival of zombie firms. Nevertheless, the Portuguese evidence illustrates a broader concern that emerged during the pandemic: support measures may have contributed to the survival of financially fragile firms.

More broadly, the unprecedented scale of public support measures implemented during the pandemic renewed concerns that government intervention could weaken the cleansing mechanism and artificially sustain financially fragile firms, bringing the phenomenon of zombie firms back to the centre of both the academic and policy debate (Acharya et al., 2022; Albuquerque & Iyer, 2024).

While the extensive literature on zombie firms has thoroughly documented their characteristics, determinants, and overall role in resource misallocation, a critical empirical gap remains. There is little research on how zombie firms reacted to an exogenous shock compared to their healthy peers. In particular, much of the recent research on the pandemic focuses on the relationship between government support and fragile firms. However, much less attention has been given to understanding how zombie and non-zombie firms actually adjusted to the shock itself (Shome & Verma, 2025).

To address this gap, this dissertation contributes to the literature by analysing how zombie and non-zombie firms in Portugal responded to the COVID-19 shock, particularly in terms of productivity. More specifically, it examines whether pre-pandemic zombie status influenced firms' productivity dynamics following the COVID-19 shock.

Focusing on productivity is especially relevant given that it is one of the characteristics most consistently associated with zombie firms and plays a central role in economic growth and resource allocation. Moreover, the literature consistently portrays zombie firms as financially fragile and less productive than healthy firms. As a result, one would expect these firms to be particularly vulnerable to a severe economic disruption such as the COVID-19 pandemic.

Lacking financial flexibility and internal buffers, zombie firms are theoretically less equipped to absorb sudden disruptions compared to healthy firms. Consequently, one would expect their overall production efficiency to deteriorate more severely following a major exogenous shock.

However, the unprecedented policy response to the COVID-19 pandemic complicates this expectation. By alleviating liquidity constraints and supporting firms' survival, government interventions may have altered the productivity adjustment of financially fragile firms, making the overall effect of the pandemic on zombie firms an empirical question rather than a theoretical certainty.

Examining whether this expected disadvantage materialised therefore provides additional insights into how pre-existing zombie status shaped firms' productivity adjustment following a major economic shock. By comparing the evolution of zombie and non-zombie firms before and after the pandemic, this dissertation provides new evidence on whether the structural weaknesses commonly associated with zombie firms translated into a different productivity adjustment during a period of severe economic disruption.

3. Data and Variables

This chapter describes the data, variables, and sample construction procedures used to analyse the post-pandemic productivity adjustment of zombie and non-zombie firms. It begins by presenting the data source and the estimation sample, before describing the estimation of firm-level productivity and the criteria used to identify zombie firms. Finally, it explains how the treatment and control groups are constructed and matched to improve comparability prior to estimation.

3.1. Data and Sample Construction

The data were collected from the SABI database, which contains firm-level accounting and financial information for Portuguese firms. The analysis covers the period from 2017 to 2022, while additional information from 2015 and 2016 is used to construct the zombie classification. The sample was restricted to private corporate firms, namely private limited companies ('Sociedades por Quotas'), single-member private limited companies ('Sociedades Unipessoais por Quotas'), and public limited companies ('Sociedades Anónimas'). Other legal forms, such as cooperatives, associations, public sector entities, and foreign establishments, were excluded to ensure greater comparability across firms and consistency in accounting information.

Additionally, the analysis focuses exclusively on the manufacturing industry, restricting the sample to firms with CAE codes between 10 and 32 (CAE Rev.3). This restriction improves comparability across firms, as more homogeneous production processes and input structures allow for a consistent estimation of total factor productivity. Furthermore, the manufacturing sector provides a particularly interesting setting to analyse the COVID-19 shock. Unlike contact-intensive sectors like tourism or hospitality, which faced mobility restrictions and mandatory closures, the pandemic's impact on manufacturing was highly heterogeneous. While some firms experienced severe disruptions in supply chains and demand, others continued operating with comparatively fewer interruptions. This variation creates an opportunity to examine whether pre-existing financial fragilities, namely zombie status, influenced firms' productivity dynamics during the crisis.

To facilitate the empirical analysis, manufacturing firms were further aggregated into five broader sector groups based on the Portuguese CAE classification: (1) Food and Beverages (CAE 10–12); (2) Textiles (CAE 13–15); (3) Wood, Paper and Furniture (CAE 16–18 and 31); (4) Chemicals, Metals and Other Manufacturing (CAE 19–25 and 32); and (5) High-

Technology Manufacturing (CAE 26–30). The aggregation was inspired by the rationale underlying the OECD technological classification and aims to capture broad differences in technological intensity, production processes, and input structures across manufacturing industries (Hatzichronoglou, 1997). At the same time, broader sector groups facilitate the empirical analysis by reducing excessive fragmentation across industries.

At the firm level, the sample was restricted to firms with revenues above 1,000 euros to ensure that only economically active firms were included in the analysis. In addition, only firms with at least two employees and a positive capital stock were considered. These restrictions were necessary to ensure the feasibility and consistency of total factor productivity estimation. Similar sample restrictions are commonly adopted in the firm-level productivity literature (Silva et al., 2010). At this stage, the sample consists of an unbalanced panel of 19,456 firms covering the period from 2017 to 2022.

3.2. Total Factor Productivity

To analyse whether zombie and non-zombie firms adjusted differently to the COVID-19 shock, a productivity measure that captures changes in firms' overall production efficiency is required. For this purpose, this dissertation uses Total Factor Productivity (TFP) because it captures differences in production efficiency that cannot be explained solely by observable factors of production. Unlike measures based on a single productive factor, such as labour productivity, TFP considers the joint contribution of multiple inputs, including labour and capital. Therefore, firms are not considered more productive solely because they use higher levels of a specific productive input (Syverson, 2011).

For instance, firms may display different levels of labour productivity not because they are necessarily more efficient, but because some firms rely more heavily on capital-intensive production processes than others. TFP overcomes this problem by capturing the efficiency with which firms transform productive inputs into output beyond the simple quantity of inputs used (Syverson, 2011).

To estimate firm-level TFP, it is first necessary to specify a production function that relates output to the productive inputs used by the firm. Following Levinsohn and Petrin (2003), this dissertation adopts a Cobb-Douglas production function (Cobb & Douglas, 1928), in which output depends on observable inputs such as labour, capital and intermediate inputs,

as well as an unobserved productivity component capturing differences in production efficiency across firms.

$$Y_{it} = A_{it}\, K_{it}^{\alpha} L_{it}^{\beta}\, M_{it}^{\gamma} \tag{3.1}$$

where i denotes firms and t denotes years, Y_{it} represents gross output, K_{it} is the capital input, L_{it} is the labour input, M_{it} represents intermediate inputs, and A_{it} represents the unobserved productivity component, reflecting firm-specific production efficiency. Taking natural logarithms, Equation (3.1) can be expressed in linear form as:

$$\ln Y_{it} = \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln M_{it} + \ln A_{it} \tag{3.2}$$

The term A_{it} represents the firm-specific productivity component of the production function. After accounting for the contribution of the observable productive inputs (labour, capital, and intermediate inputs), the remaining variation in output is attributed to A_{it}. Taking natural logarithms, $\ln A_{it}$ corresponds to Total Factor Productivity (TFP) (Levinsohn & Petrin, 2003; Solow, 1957; Syverson, 2011).

While Equation (3.2) provides a conceptual representation of Total Factor Productivity through the unobserved term $\ln A_{it}$, this component cannot be observed directly and must therefore be estimated. In principle, this requires estimating the production function and recovering the remaining unobserved productivity component as the residual of the estimated production function.

However, estimating the production function raises an important econometric challenge. Specifically, Ordinary Least Squares (OLS) fails to provide unbiased and consistent estimates due to the simultaneity problem. This arises because firms observe their own productivity levels ($\ln A_{it}$), when making production decisions, while the econometrician does not. When firms experience a positive productivity shock, they immediately increase their use of freely variable inputs, such as labour and intermediate inputs. In contrast, capital is typically considered a state variable that adjusts only gradually over time, since investment decisions involve planning and adjustment costs and cannot be changed instantaneously. Consequently, firms cannot immediately alter their capital stock in response to unexpected productivity shocks. Since the econometrician does not observe the productivity shock, it becomes part of the regression error term. Consequently, firms choose their input levels based on information that is contained in the error term, generating a correlation between

the explanatory variables and the error term and violating the exogeneity condition required for OLS (Levinsohn & Petrin, 2003).

This raises the question of how productivity can be estimated consistently when it is observed by firms but not by the econometrician. To address this simultaneity problem, Levinsohn and Petrin (2003) use intermediate inputs as proxy variables for unobserved productivity. The rationale behind the method is to infer unobservable productivity through observable firm behaviour. The method relies on the monotonicity assumption, which states that, for a given level of capital stock, firms experiencing higher productivity are expected to use larger amounts of intermediate inputs. Since capital cannot be adjusted immediately, differences in the use of intermediate inputs can be interpreted as reflecting differences in unobserved productivity. This allows the unobserved productivity component to be expressed as a function of observable variables, removing the correlation between the explanatory variables and the error term.

Furthermore, the remaining production function parameters are identified by exploiting the fact that capital adjusts more slowly over time than freely variable inputs. Since investment decisions are typically made in advance and involve adjustment costs, firms cannot immediately change their capital stock in response to unexpected productivity shocks in the current period. Consequently, the existing level of capital is assumed not to be correlated with contemporaneous productivity shocks, allowing the capital coefficient to be consistently estimated (Levinsohn & Petrin, 2003).

Accordingly, following Levinsohn and Petrin (2003), the production function estimated in this dissertation is represented as:

$$y_{it} = \beta_L l_{it} + \beta_k k_{it} + \beta_M m_{it} + \omega_{it} + \eta_{it} \quad (3.3)$$

where y_{it} , l_{it} , k_{it} ,and m_{it} represent the natural logarithms of gross output, labour input, capital input, and intermediate inputs, respectively; ω_{it} is the unobserved productivity component observed by firms but not by the econometrician; and η_{it} is a random error term assumed to be independently and identically distributed.

In this specification, the unobserved productivity component (ω_{it}) corresponds to the theoretical productivity term ($\ln A_{it}$) introduced in Equation (3.2). As in the theoretical production function, it represents the portion of output that cannot be explained by observable productive inputs and therefore corresponds to firm-level Total Factor

Productivity (TFP). Since this productivity component cannot be observed directly, Levinsohn and Petrin (2003) recover it indirectly by using firms' intermediate input choices as proxy variables for unobserved productivity. Under the monotonicity assumption, firms' demand for intermediate inputs contains information about their underlying productivity, allowing $\omega_{it}$to be consistently recovered. Consequently, the estimated values of ω_{it} provide the empirical measure of firm-level TFP used throughout the subsequent analysis. Further details regarding the recovery of the productivity term from the estimated production function are presented in Appendix A.

While Levinsohn and Petrin (2003) use intermediate inputs as proxies for unobserved productivity, alternative approaches instead rely on firms' investment decisions. However, firms do not necessarily invest in every period, meaning that investment may frequently take zero values. This makes it difficult to satisfy the monotonicity condition required for identification, as the proxy function is no longer invertible. As a result, firms with zero investment observations would need to be excluded from the analysis, leading to a more restricted sample. In contrast, intermediate inputs are used continuously in production and can be adjusted more rapidly in response to productivity shocks, whereas investment decisions are subject to adjustment costs. Consequently, intermediate inputs not only provide a better reflection of contemporaneous productivity shocks but also avoid the sample restrictions associated with zero investment observations.

These advantages are particularly important given the focus of this dissertation on manufacturing firms. Manufacturing firms rely heavily on intermediate inputs such as raw materials, energy and production supplies, which are used continuously throughout the production process. These intermediate inputs therefore provide a reliable proxy for unobserved productivity shocks while allowing a larger share of firms to be retained in the estimation sample (Levinsohn & Petrin, 2003).

Once the estimation method is established, the next step is to construct the variables for the production function using accounting information obtained from the SABI database. Following the approach adopted by Carreira et al. (2022), gross output was used as the output measure to better capture the firm's productive capacity. Gross output was calculated using the following formula:

$$Gross\ Output = Turnover + Variation\ in\ Production + Capitalized\ production + Supplementary\ income + Operating\ subsidies$$

This measure captures the total value generated through the production process and serves as the output variable in the estimation procedure (Silva et al., 2010).

Following Levinsohn and Petrin (2003), intermediate inputs are used both as production inputs and to recover the unobserved productivity component. In line with Carreira et al. (2022), intermediate inputs were constructed using the cost of goods sold and supplies and external services:

$$Intermediate\ Inputs = Cost\ of\ Goods\ Sold + Supplies\ and\ External\ Services$$

Labour input was measured using the number of employees, while capital input was measured using tangible fixed assets (Levinsohn & Petrin, 2003).

Once the production variables were constructed, it was necessary to ensure that they reflected real rather than nominal changes over time. Since the period under analysis includes years of relatively high inflation, particularly in 2022, the variables used in the TFP estimation were deflated in order to capture real changes in productive factors rather than nominal price variations (Eurostat, 2026b). Following the approach adopted by Carreira et al. (2022), the Producer Price Index (PPI) for the manufacturing industry was used to deflate the gross output variable by dividing nominal values by the corresponding annual PPI (Eurostat, 2026c). Intermediate inputs and capital variables were deflated using the GDP deflator (Eurostat, 2026a). Both deflators use 2015 as the base year and were obtained from Eurostat.

Following the standard production function literature, logarithmic transformations were applied to output, labour, capital, and intermediate inputs. The use of logarithms allows the Cobb-Douglas production function to be estimated in linear form, facilitating the econometric estimation of the model. In addition, the estimated coefficients can be directly interpreted as production elasticities (Levinsohn & Petrin, 2003).

Moreover, an unbalanced panel was used to estimate firm-level productivity, meaning that firms were not required to be observed in every year of the sample period. This avoids the potential selection bias associated with balanced panels, which exclude firms entering or exiting the market (Levinsohn & Petrin, 2003). This is particularly important in the present context, as zombie firms are characterised by low productivity and financial fragility, making

them more likely to default or exit during the sample period. Restricting the estimation to firms observed in all years could therefore disproportionately exclude zombie firms and bias the productivity estimates. The additional sample restrictions required for the propensity score matching and Difference-in-Differences analyses are introduced in the following sections.

Since firm-level productivity measures may be affected by extreme observations and accounting outliers, the logarithm of the total factor productivity variable was winsorized at the 1st and 99th percentiles. This procedure reduces the influence of extreme values while preserving the overall distribution of the data. The winsorized measure of the log TFP was subsequently used throughout the empirical analysis.

3.3. Zombie Definition

As discussed previously in the literature review, there is no unique and consensual definition of zombie firms. Nevertheless, the literature generally characterises zombie firms as financially distressed firms that remain active despite conditions that would normally lead to market exit, often through continued access to external financing.

Among the alternative definitions discussed in the literature, the negative equity criterion was selected because it captures persistent balance-sheet fragility and is particularly suitable for distinguishing structurally weak firms from those experiencing temporary financial distress (San-Jose et al., 2022). Accordingly, this dissertation defines zombie firms as firms that exhibit negative equity for two consecutive years.

The number of consecutive years of negative equity used to define zombie firms varies across the literature, depending on the level of severity the study aims to capture. Existing studies use requirements ranging from one to five consecutive years of negative equity, with longer periods generally associated with more severe zombie firms (Blažková & Dvouletý, 2022; Bonfim et al., 2023; San-Jose et al., 2022). Consequently, the requirement of two consecutive years of negative equity was adopted. Using only one year could include firms experiencing temporary financial distress rather than persistent financial fragility, while stricter requirements, such as three or five consecutive years, could excessively restrict the sample by capturing only the most severe cases of zombification.

Furthermore, negative equity indicates technical insolvency, meaning that liabilities exceed assets. Unlike profitability-based measures, it reflects the cumulative effect of financial losses

over time and therefore captures deeper balance-sheet fragility rather than temporary fluctuations in firm performance. As discussed in the literature review, this measure became more commonly used in studies conducted after the COVID-19 pandemic because it reduces the risk of classifying otherwise viable firms experiencing temporary pandemic-related losses as zombie firms (Bonfim et al., 2023; San-Jose et al., 2022).

3.4. Treatment and Control Groups

To implement the empirical strategy, firms were classified into treatment and control groups based on their zombie status in 2019, the last year before the COVID-19 shock. Firms classified as zombies in 2019 were assigned to the treatment group. Defining treatment immediately before the pandemic ensures that zombie status reflects firms' pre-pandemic financial condition and is not influenced by the shock itself, allowing the comparison of zombie and healthier firms entering the crisis.

Nevertheless, as a robustness check, a stricter definition of zombie firms was also considered to assess whether the estimated effects are sensitive to the specific definition of zombie firms adopted in the baseline specification. Under this criterion, firms were classified as zombies only if they satisfied the zombie condition throughout the entire pre-COVID period (2017–2019). Since this classification requires negative equity in the two preceding years, persistent zombie firms necessarily exhibit negative equity for at least four consecutive years (2015–2018), capturing more severe and persistent financial distress.

Accordingly, these firms are referred to as persistent zombie firms. Under the baseline definition, 1,577 firms were classified as zombies. Applying the stricter persistent zombie definition reduced this number to 1,224 firms, reflecting the more restrictive nature of the criterion.

3.5. Improving Comparability: Propensity Score Matching

However, an important limitation of the baseline Difference-in-Differences approach is that zombie and non-zombie firms may already differ systematically before the COVID-19 shock. In particular, literature frequently shows that zombie firms tend to be less productive and financially weaker than non-zombie firms. Consistent with this concern, a preliminary regression using the full pre-matching sample indicates that zombie firms exhibited significantly lower productivity levels before the pandemic, suggesting that treated and control firms were not fully comparable before matching (see Annex A, Table A.1).

To address these pre-existing differences and improve comparability between treated and control firms, a Propensity Score Matching (PSM) approach was implemented. Firms were matched using pre-pandemic characteristics measured in 2019, namely productivity, firm age, firm size (measured by the logarithm of total assets), and sector group. Importantly, rather than only relying on productivity in 2019, the matching procedure incorporated TFP levels across three pre-shock years (2017, 2018, and 2019). This ensures that treated and control firms not only shared comparable productivity levels immediately before the pandemic but also exhibited similar productivity patterns during the pre-shock period.

In addition, exact matching was imposed at the sector-group level to ensure that treated and control firms operated in broadly similar industrial environments. Broader sector groups were used instead of highly disaggregated CAE codes to avoid excessive fragmentation of the sample and ensure a sufficient number of comparable firms within each category.

To assess whether the matching procedure successfully improved comparability, a covariate balance test was conducted. The results indicate substantial improvements in the balance of pre-pandemic productivity and firm size. Although a minor difference remained for firm age ($p = 0.020$), this variable is controlled for in the subsequent Difference-in-Differences estimation (see Annex A, Table A.2).

Prior to matching, the sample was restricted to firms with sufficient productivity information to compute productivity changes between the pre-pandemic (2017–2019) and post-pandemic (2020–2022) periods. However, the estimation does not require a strictly balanced panel over the entire period. Firms are only required to have at least one valid observation in each period, which maximises sample retention while ensuring that productivity changes can be computed consistently.

After the matching procedure, the baseline sample comprised 2,556 firms (1,278 matched pairs), whereas the robustness specification based on the Persistent Zombie definition retained 2,010 firms (1,005 matched pairs).

3.6. Descriptive Statistics

Table 1 reports the sectoral distribution of zombie firms in the matched estimation sample. While zombie firms are present across all manufacturing activities, their distribution is not uniform. The Chemicals, Metals & Other Manufacturing sector accounts for the largest share of zombie firms (31.8%, corresponding to 406 firms), whereas High-Tech Manufacturing

represents the smallest share (3.4%). These differences suggest that zombie firms are more concentrated in some manufacturing activities than in others. Consequently, sector-group controls are included in the analysis to account for potential differences in productivity dynamics and financial structures across industries.

Table 1. Sectoral Distribution of Zombie Firms in the Matched Estimation Sample

	Matched Firms	Zombie Firms	Share of Zombie Firms (%)
Food & Beverages	650	325	25.4%
Textiles	518	259	20.3%
Wood, Paper & Furniture	488	244	19.1%
Chemicals, Metals & Other	812	406	31.8%
High-Tech Manufacturing	88	44	3.4%
Total	2556	1278	100%

Notes: Based on the matched estimation sample (N = 2,556). 'Matched Firms' includes zombie firms and their matched non-zombie counterparts. 'Share of Zombie Firms (%)' reports the percentage of all zombie firms in the matched estimation sample belonging to each sector. **Source:** Author's calculations using SABI data.

Table 2 presents descriptive statistics for the matched estimation sample in 2019. The results indicate that zombie and non-zombie firms exhibit similar levels of productivity, total assets, and revenue, as the differences between groups are not statistically significant. This suggests that the matching procedure was successful in improving comparability along key economic dimensions. However, zombie firms remain younger and display lower levels of capital stock and employment than their matched non-zombie counterparts. These remaining differences highlight that, although the matching procedure substantially improved comparability, some firm characteristics continue to differ across groups.

Table 2. Descriptive Statistics for Zombie and Non-Zombie Firms in the Matched Estimation Sample (2019)

	Mean Zombie	Mean Matched Non-Zombie	Difference	p-value
Log TFP	4.760	4.668	0.092	0.281
Firm Age	34.544	37.089	-2.545	0.039
Assets (€ thousands)	435.389	542.228	-106.839	0.249
Revenue (€ thousands)	498.930	497.181	1.749	0.985
Capital (€ thousands)	118.134	206.576	-88.442	0.028
Employees	8.496	10.865	-2.369	0.003
Observations	2556			

Notes: Based on the matched estimation sample in the baseline year (2019). Log TFP corresponds to the logarithm of Total Factor Productivity. Assets, revenue, and capital are expressed in thousands of euros. The table reports group means, mean differences, and p-values from two-sample t-tests. A p-value below 0.05 indicates that the difference in means between zombie and non-zombie firms is statistically significant. **Source:** Author's calculations using SABI data.

Overall, these descriptive statistics highlight the effectiveness of the matching procedure in enhancing comparability between zombie and non-zombie firms, while also justifying the inclusion of control variables in the subsequent Difference-in-Differences estimation.

4. Methodology

This chapter presents the methodology used to examine whether pre-pandemic zombie status influenced firms' productivity adjustment following the COVID-19 shock. To do so, this dissertation uses a Difference-in-Differences framework on a matched sample of zombie and non-zombie firms, allowing the comparison of productivity changes between zombie and comparable non-zombie firms before and after the pandemic shock.

To guide the reader through this empirical identification strategy, this chapter presents the Difference-in-Differences framework, the model specification, and the assessment of the parallel trends assumption.

4.1. Difference-in-Differences (DiD)

Having defined zombie firms, the following step is to analyse whether zombie and non-zombie firms reacted differently to an exogenous shock. To do so, a two-period Difference-in-Differences (DiD) approach was used to compare the behaviour of the treated group, zombie firms, and the control group, non-zombie firms, before and after the shock. This methodology allows the analysis to identify whether the productivity trajectory of zombie firms evolved differently from that of non-zombie firms following the COVID-19 shock. The exogenous shock considered was the COVID-19 pandemic, since it affected all firms simultaneously. Moreover, the pandemic provides an appropriate exogenous setting for the analysis, as firms were exposed to the shock regardless of their pre-existing zombie status.

The pre-COVID period corresponds to 2017–2019, while the post-COVID period covers 2020–2022. Both periods comprise three years, allowing the analysis to compare firms' productivity performance before and after the COVID-19 shock using symmetric time windows. This structure captures not only the immediate impact of the pandemic but also the subsequent adjustment process, as firms may require time to adapt their production processes, employment decisions, and investment strategies following an economic disruption.

The Difference-in-Differences approach consisted of collapsing the annual data into one observation per period for each firm, corresponding to the average value of the variables during the pre- and post-COVID periods. Rather than comparing productivity levels, the analysis focuses on changes in productivity. Accordingly, the dependent variable was

calculated as the difference between the average logarithm of post-COVID productivity and the average logarithm of pre-COVID productivity:

$$\Delta\, ln(TFP_i) = \overline{\ln TFP}_{i,post} - \overline{\ln TFP}_{i,pre} \quad (4.1)$$

where i indexes firms; $\overline{\ln TFP}_{i,post}$ represents the average logarithm of firm-level productivity during the post-COVID period (2020–2022), while $\overline{\ln TFP}_{i,pre}$ represents the average logarithm of productivity during the pre-COVID period (2017–2019).

By using the average value for each period, it is possible to capture the average effect of the shock while mitigating the impact of annual fluctuations or a specific outlier year, since productivity may have been affected by temporary disruptions that varied across years. Therefore, averaging productivity over each period provides a more representative measure of firms' underlying performance before and after the shock.

4.2. Model Specification

The model is estimated using an Ordinary Least Squares (OLS) regression on a collapsed dataset. The dependent variable is the change in average productivity, measured by Total Factor Productivity (TFP), for each firm between the two periods.

Although the matching procedure successfully balanced treated and control firms in terms of pre-pandemic productivity and firm size, a small imbalance remained with respect to firm age. Therefore, the final specification includes pre-pandemic firm age and sector-group controls to account for any residual differences between firms that may remain after matching. Firm age is particularly relevant because firms at different stages of their life cycle may exhibit distinct productivity dynamics and adjustment capacities following an external shock. In addition, industry fixed effects are captured through sector-group dummy variables.

Furthermore, standard errors were clustered at the CAE 2-digit industry level to account for potential correlation in productivity shocks among firms operating within the same industry.

Given that the dependent variable measures the change in productivity between the pre- and post-COVID periods, the coefficient of interest, β_1, associated with the treatment dummy, captures whether pre-pandemic zombie firms experienced a significantly different productivity adjustment relative to the matched control group.

Consequently, the following econometric regression was estimated for both the baseline and the robustness (Persistent Zombie) samples:

$$\Delta\, ln(TFP_i) = \beta_0 + \beta_1 \text{Treated}_i + \beta_2 \text{Firm Age}_i + \gamma_s + \varepsilon_i \quad (4.2)$$

where $\Delta\, ln(TFP_i)$ represents the change in the logarithm of firm-level total factor productivity between the pre- and post-COVID periods, $Treated_i$ is a dummy variable identifying firms classified as zombies in 2019, the last year before the COVID-19 shock, $Firm\ Age_i$ corresponds to firm age before the COVID-19 shock, γ_s denotes sector-group fixed effects that control for time-invariant differences across manufacturing industries, and ε_i is the error term.

4.3. Parallel Trends

The use of a Difference-in-Differences approach relies on the parallel trends assumption, according to which treated and control firms should exhibit similar productivity trajectories before the shock. Under this assumption, in the absence of the COVID-19 shock, the productivity gap between the two groups would be expected to evolve similarly over time.

To assess the plausibility of this assumption, Figure 2 presents the average TFP levels of zombie firms (treated firms) and matched non-zombie firms (control firms) during the pre-COVID period. As shown in Figure 2, zombie and matched non-zombie firms exhibit similar productivity trajectories during the pre-COVID period. Although productivity levels differ between the two groups, there is no evidence of systematic divergence prior to the pandemic. Therefore, the figure provides supporting evidence for the plausibility of the parallel trends assumption.

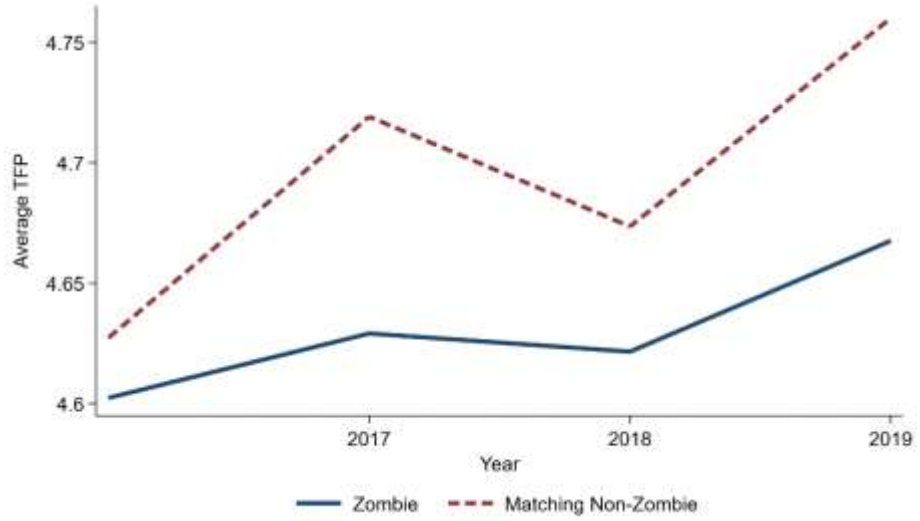

Figure 2. Pre-Treatment Trends in Total Factor Productivity

Notes: The figure reports the annual mean of log TFP for zombie firms and matched non-zombie firms during the pre-treatment period (2017–2019). The figure is based on the matched estimation sample (N = 2,556). **Source:** Author's calculations using SABI data.

Taken together, the methodological framework developed in this chapter provides the basis for evaluating whether pre-pandemic zombie status influenced firms' productivity adjustment following the COVID-19 shock. The next chapter presents and discusses the empirical results.

5. Results and Discussion

Building on the empirical strategy developed in the previous chapter, this chapter examines whether firms classified as zombies before the pandemic experienced a different productivity evolution following the COVID-19 shock relative to comparable non-zombie firms. It first presents and discusses the baseline Difference-in-Differences results and then assesses their robustness using a stricter definition of zombie firms. The chapter concludes with a discussion of the study's limitations and suggestions for future research.

5.1. Difference-in-Differences Results

Based on the existing literature, zombie firms would be expected to experience a less favourable productivity evolution following the shock, given their lower levels of productivity, structural financial fragility, and dependence on external financing. To test this hypothesis, the baseline Difference-in-Differences model was estimated using the propensity score matched sample. As described in Chapter 4, the dependent variable corresponds to the change in winsorized TFP between the pre-treatment (2017–2019) and post-treatment (2020–2022) periods. The baseline econometric specification presented in Equation (4.2) is reproduced below for ease of reference:

$$\Delta\, ln(TFP_i) = \beta_0 + \beta_1 \text{Treated}_i + \beta_2 \text{Firm Age}_i + \gamma_s + \varepsilon_i \qquad (4.2)$$

The specification includes a treatment dummy identifying firms classified as zombies in 2019, together with sector-group fixed effects and pre-pandemic firm age controls. Standard errors are clustered at the CAE 2-digit industry level, and the final estimation sample consists of 2,556 firms. Table 3 presents the estimation results.

Table 3. Difference-in-Differences Estimates of the Productivity Response to the COVID-19 Shock

	Δ Log TFP
Zombie Firm (Matched)	0.067*
	(0.036)
Firm Age	0.001**
	(0.0005)
Textiles	0.132**
	(0.048)
Wood, Paper & Furniture	0.189**
	(0.078)
Chemicals, Metals & Other Manufacturing	0.196***
	(0.046)
High-Tech Manufacturing	-0.133
	(0.084)
Observations	2,556
R-squared	0.009

Notes: The dependent variable is the change in winsorized log TFP between the pre-treatment period (2017–2019) and the post-treatment period (2020–2022). Results are based on the propensity score matched sample. The treatment group consists of firms classified as zombies in 2019. The omitted sector group is Food & Beverages. Standard errors clustered at the CAE 2-digit industry level are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. **Source:** Author's calculations using SABI data.

Contrary to the expectations derived from the zombie-firm literature, the estimated treatment coefficient is positive and statistically significant at the 10% level, suggesting that zombie firms experienced a slightly more favourable productivity response to the COVID-19 shock than comparable non-zombie firms. Since the dependent variable measures the change in productivity between the pre- and post-COVID periods, the positive coefficient indicates that zombie firms experienced a more favourable productivity adjustment, rather than higher productivity levels per se. However, given that the coefficient is statistically significant only at the 10% level and its magnitude remains modest, the results should be interpreted with caution.

In addition to the treatment effect, the control variables also provide insights into how productivity dynamics differed across firms and industries during the pandemic period. The coefficient associated with firm age is positive and statistically significant at the 5% level, but relatively small, suggesting that older firms experienced a more favourable productivity evolution during the post-pandemic period. This finding is consistent with the view that older firms may benefit from greater organisational experience, more established market positions, and stronger adjustment capacity during periods of economic disruption.

Regarding sectoral differences, firms operating in the Textiles sector, the Wood, Paper & Furniture sector, and the Chemicals, Metals & Other Manufacturing sector exhibited significantly stronger productivity growth relative to the Food & Beverages sector, which serves as the reference category. In contrast, no statistically significant differences were observed for firms operating in High-Tech Manufacturing. These results suggest that productivity adjustment following the COVID-19 shock differed across manufacturing sectors, potentially reflecting differences in production structures, supply-chain disruptions, or exposure to changing demand conditions during the pandemic.

Although the estimated treatment effect is relatively small, its positive sign is somewhat surprising given the predictions of the zombie-firm literature and therefore calls for further discussion.

One possible explanation for this result relates to the extensive support measures implemented during the COVID-19 period in Portugal, such as debt moratoria, government-guaranteed credit lines, tax deferrals, and the temporary suspension of insolvency obligations (Nogueira, 2022). Because the baseline zombie definition adopted in this dissertation identifies firms experiencing financial distress through negative equity, these firms are more likely to face greater financial constraints and a stronger dependence on external financing. Consequently, measures aimed at easing liquidity constraints may have been especially relevant for this group. It is therefore plausible that such measures may have helped alleviate liquidity constraints during the pandemic, although this mechanism cannot be directly assessed in the present analysis.

Consistent with this interpretation, empirical evidence shows that inefficient firms were more likely to resort to support measures in Portugal during the pandemic (Kozeniauskas et al., 2022). In this context, such measures may have helped attenuate some of the structural disadvantages typically associated with zombie firms, contributing to the absence of a substantial productivity disadvantage among zombie firms during the pandemic period. However, this interpretation should be regarded as a plausible explanation rather than as a direct empirical finding of the present study.

Additionally, the fact that the analysis focuses exclusively on manufacturing firms may also help explain the absence of stronger productivity deterioration among zombie firms. Compared to contact-intensive sectors, manufacturing activities were generally less exposed

to mobility restrictions and social distancing measures during the pandemic, potentially reducing the magnitude of productivity disruptions across firms.

While Table 3 reports the estimated treatment effect, it does not show how the productivity trajectories of zombie and non-zombie firms evolved over time. Figure 3 therefore complements the regression results by illustrating the annual evolution of average TFP before and after the COVID-19 shock.

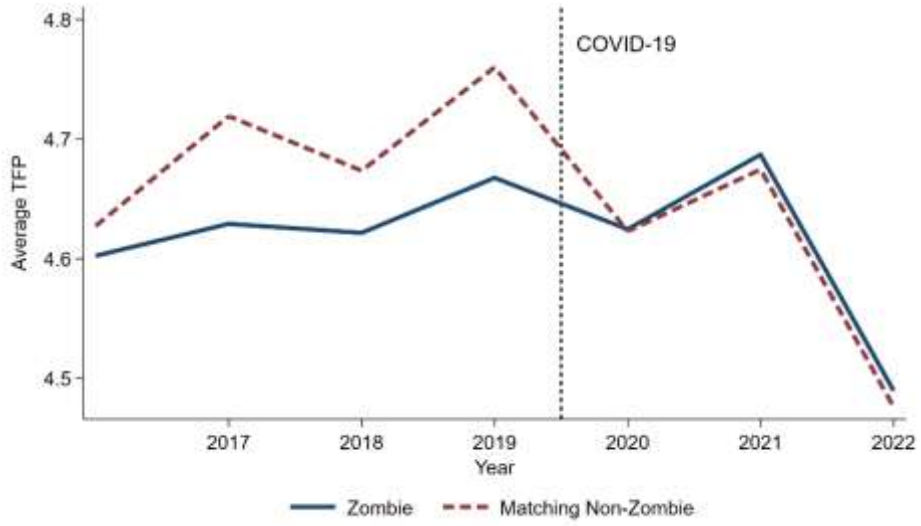

Figure 3. Evolution of Average Total Factor Productivity Before and After the COVID-19 Shock

Note: Average TFP corresponds to the annual mean of log TFP for zombie and matched non-zombie firms**.** The figure is based on the matched estimation sample (N = 2,556). ***Source:*** Author's calculations using SABI data.

The graph highlights that zombie firms exhibited lower average TFP levels before the shock, consistent with the existing literature. As expected, both groups experienced a decline in productivity in 2020, the first year affected by the COVID-19 shock. From that point onwards, the productivity trajectories of zombie and matched non-zombie firms became increasingly similar, with the initial productivity gap largely disappearing. Following the initial decline, both groups experienced a temporary recovery in 2021 before recording a further deterioration in 2022.

The deterioration observed in 2022 may reflect the gradual withdrawal of pandemic-related support measures, combined with broader macroeconomic disruptions affecting manufacturing firms during the post-pandemic recovery period. The deterioration coincides with a period characterised by the European energy crisis, elevated inflation, rising

production costs, and increased economic uncertainty following Russia's invasion of Ukraine (Banco de Portugal, 2022). Although the TFP estimates are based on deflated variables and therefore do not simply reflect nominal price increases, these factors may still have adversely affected firms' productivity by creating additional operational and cost pressures.

The convergence observed after the onset of the pandemic is consistent with the positive Difference-in-Differences coefficient reported in Table 3. Rather than reflecting a substantial improvement in the productivity of zombie firms, the results suggest that the productivity advantage previously exhibited by comparable non-zombie firms largely disappeared following the COVID-19 shock. One possible explanation is that the government support measures discussed above disproportionately benefited financially fragile firms by alleviating liquidity constraints during the pandemic, although this mechanism cannot be directly tested in the present analysis.

It is important to note that the Difference-in-Differences estimates may still be subject to survivorship bias arising from sample attrition. As previously discussed, the estimation of productivity changes requires firms to have available information in both the pre- and post-COVID periods. Consequently, firms that exited the market during or after the pandemic were necessarily excluded from the analysis.

Although the available data do not allow the characteristics of exiting firms to be directly observed, it is plausible that firms leaving the sample were disproportionately concentrated among the most financially fragile zombie firms. If so, the final estimation sample may overrepresent the relatively more resilient zombie firms that survived throughout the pandemic period. Consequently, the estimated treatment effect may primarily reflect the productivity dynamics of the most resilient zombie firms rather than those of the broader zombie population. Therefore, the positive coefficient should be interpreted with caution, as it may not fully capture the productivity response of zombie firms that did not survive the pandemic period.

Overall, the baseline results provide only limited evidence that zombie firms experienced a different productivity response to the COVID-19 shock. The robustness of this finding is examined in the following section.

5.2. Robustness Analysis: Persistent Zombie Firms

To assess the robustness of the baseline results, the analysis was re-estimated using a stricter classification criterion that captures firms experiencing persistent financial distress. Firms were classified only if they remained zombies throughout the entire pre-COVID period (2017-2019). Given that the zombie status adopted requires two consecutive years of negative equity, this criterion implies that firms exhibited negative equity for at least four consecutive years (2015–2018). Table 4 reports the results of the robustness analysis using the persistent zombie sample.

Table 4. Robustness Check: Difference-in-Differences Estimates under the Persistent Zombie Definition

	Δ Log TFP
Persistent Zombie (Matched)	0.021
	(0.045)
Firm Age	0.003***
	(0.0006)
Textiles	0.099**
	(0.046)
Wood, Paper & Furniture	0.157***
	(0.039)
Chemicals, Metals & Other Manufacturing	0.157***
	(0.033)
High-Tech Manufacturing	-0.095
	(0.109)
Observations	2,010
R-squared	0.009

Notes: The dependent variable is the change in winsorized log TFP between the pre-treatment period (2017–2019) and the post-treatment period (2020–2022). Results are based on matched sample. The treatment group consists of firms classified as persistent zombies, defined as firms that remained zombies throughout the entire pre-COVID period (2017–2019). The omitted sector group is Food & Beverages. Standard errors clustered at the CAE 2-digit industry level are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. **Source:** Author's calculations using SABI data.

Compared to the baseline specification, the estimated treatment coefficient becomes smaller under the persistent zombie definition and statistically insignificant at conventional significance levels. Although the estimated sign is consistent with the baseline estimation, the absence of statistical significance prevents any strong conclusion regarding this relationship. This suggests that the relationship between zombie status and post-pandemic productivity evolution may be sensitive to the degree of persistence of financial distress used to classify firms as zombies. While the baseline specification indicates a small positive productivity differential, it becomes statistically irrelevant when a stricter definition is adopted.

This finding is particularly relevant because the persistent zombie definition captures firms exhibiting negative equity for at least four consecutive years prior to the pandemic. Consequently, if zombie status were systematically associated with a different productivity response to the COVID-19 shock, such an effect would be expected to be even more pronounced among these persistently distressed firms. However, no statistically significant treatment effect is observed under this specification.

The coefficients associated with firm age and the sector-group variables remain broadly consistent with those obtained in the baseline specification. Although some differences in coefficient magnitudes are observed, the overall pattern of results remains qualitatively unchanged. This suggests that the adoption of the stricter zombie definition mainly affects the estimated treatment effect, while the relationship between the control variables and productivity dynamics remains broadly unchanged.

Overall, the robustness analysis suggests that the baseline results should be interpreted with caution. Although the baseline specification indicates a small positive treatment effect, this effect is no longer statistically significant when a stricter definition of zombie firms is adopted. Consequently, the findings provide no robust evidence that zombie firms experienced a substantially different productivity response to the COVID-19 shock.

5.3. Limitations

Although the empirical analysis provides useful evidence regarding the productivity response of zombie firms to the COVID-19 shock, several limitations should be acknowledged when interpreting the results.

The first limitation concerns the definition of zombie firms. As discussed in the literature review, there is no single consensual criterion for identifying zombie firms, and alternative definitions may lead to different empirical results. The baseline definition adopted in this dissertation was selected because it captures persistent balance-sheet fragility while remaining operational, given the available data. Nevertheless, the robustness analysis shows that the estimated treatment effect is sensitive to the identification criterion employed.

Another important limitation relates to survivorship bias. As discussed in the results section, the estimation sample includes only firms that survived throughout the observation period and for which productivity information is available in both the pre- and post-COVID periods. Consequently, more fragile zombie firms that exited the market during the pandemic

are excluded from the analysis. Therefore, the estimated results may disproportionately reflect the behaviour of relatively more resilient surviving zombie firms and may not fully capture the productivity dynamics of the broader population of zombie firms.

Finally, the post-treatment period overlaps with other major economic disruptions beyond the COVID-19 shock itself. In particular, the energy crisis, rising inflationary pressures, and increased uncertainty associated with the Russia–Ukraine war may have influenced firms' productivity dynamics during 2022. Consequently, it is difficult to fully isolate the effects of the pandemic from other contemporaneous macroeconomic shocks affecting Portuguese manufacturing firms. Nevertheless, the inclusion of 2022 was considered important, as firms' productivity adjustment to the COVID-19 shock may have unfolded gradually over several years rather than occurring immediately after the initial outbreak.

5.4. Future Research

The limitations identified in this dissertation suggest several avenues for future research. First, future research could explore alternative definitions of zombie firms and examine whether the estimated impact of zombie status varies across different identification criteria. Given the absence of a consensual definition in the literature, comparing alternative classification methods could provide a more comprehensive understanding of the relationship between financial distress and firm performance during periods of economic disruption.

Second, given the potential survivorship bias identified in this dissertation, future research should examine firm survival directly. While the present analysis focuses on surviving firms, zombie status may also influence the likelihood of firm exit during periods of economic distress. Investigating whether zombie firms were more likely to exit the market during or after the COVID-19 period would provide a more complete assessment of the consequences of zombie status and complement the evidence on productivity dynamics presented in this dissertation.

Finally, future research could extend the analysis to other sectors of the Portuguese economy, particularly those more directly affected by mobility restrictions during the pandemic, such as hospitality, tourism, and retail activities. Additionally, future studies could examine the role of public support measures in shaping the survival, adjustment capacity, and productivity performance of financially distressed firms during periods of economic crisis.

6. Conclusion

This dissertation examined whether pre-pandemic zombie status conditioned firms' productivity adjustment to the COVID-19 shock within the Portuguese manufacturing sector. Using firm-level data from 2017 to 2022, the analysis employed a two-period Propensity Score Matching combined with a collapsed Difference-in-Differences framework to compare changes in Total Factor Productivity (TFP) between zombie and non-zombie firms before and after the pandemic.

The motivation for this research derives from the literature portraying zombie firms as financially fragile, inefficient, and persistently less productive than healthy firms. Given these characteristics, the existing literature would lead one to expect zombie firms to exhibit a less favourable productivity adjustment following a severe economic disruption. However, the findings of this dissertation do not provide evidence consistent with this expectation.

The results suggest a slightly more favourable productivity adjustment following the COVID-19 shock among zombie firms. Although the baseline specification suggests that the decline in productivity was marginally smaller for zombie firms than for comparable non-zombie firms, this estimated effect is economically modest and significant only at the 10% level. Moreover, the effect is not robust to the adoption of a stricter definition of zombie firms, as the statistical significance disappears under the persistent zombie specification.

Importantly, these findings should not be interpreted as evidence that zombie firms outperformed healthy firms. Instead, the results suggest that both groups exhibited broadly similar productivity adjustments following the COVID-19 shock, with zombie firms experiencing a slightly less pronounced deterioration, thereby narrowing the productivity gap between the two groups.

One possible explanation for these findings relates to the unprecedented support measures implemented by the Portuguese government, such as credit moratoria and guaranteed loan lines. By preventing widespread firm defaults and alleviating liquidity constraints, these measures may have cushioned the shock for financially fragile firms, such as zombie firms, and may have reduced the pressures typically faced by weaker firms during periods of economic disruption. However, the present study does not directly evaluate the impact of these measures, and therefore, this interpretation should be viewed as a plausible explanation rather than a causal conclusion.

Nevertheless, these conclusions must be interpreted with caution due to certain limitations. First, the analysis is potentially subject to survivorship bias, as the estimation sample is restricted to firms that have observations across both the pre- and post-pandemic periods. Therefore, the estimated effects reflect only the behaviour of firms that survived throughout the study period and may not be representative of the broader population of zombie firms. In particular, if the most financially fragile zombie firms disproportionately exited the market during the pandemic, the estimated productivity dynamics may primarily capture the adjustment of relatively more resilient survivors. Second, the post-pandemic period encompasses the year 2022, which was affected by macroeconomic disruptions arising from the Russia–Ukraine war. Rising energy costs, inflationary pressures, and broader economic uncertainty may have influenced firms' productivity dynamics independently of the COVID-19 shock.

Overall, this dissertation contributes to the literature by providing firm-level evidence on whether pre-existing zombie status shaped firms' productivity adjustment following the COVID-19 shock in the Portuguese manufacturing sector. Unlike much of the existing literature, which primarily focuses on the determinants, characteristics, or prevalence of zombie firms, this dissertation examines how zombie and non-zombie firms adjusted to a major exogenous shock in terms of productivity. Contrary to the expectations derived from the existing literature, the findings provide no robust evidence that zombie firms experienced a substantially less favourable productivity adjustment than comparable non-zombie firms following the COVID-19 shock.

Appendix A. Estimation of Total Factor Productivity

To address the simultaneity bias, Levinsohn and Petrin (2003) use intermediate inputs (m_{it}) as a proxy for the unobserved productivity shock. According to this framework, the demand for intermediate inputs is written as a decision that depends on their state levels, the capital stock and the productivity shock:

$$m_{it} = m_{it}(k_{it}, \omega_{it})$$

The method relies on the monotonicity assumption, which states that, for a given level of capital stock, firms experiencing positive productivity shocks are expected to use more of intermediate inputs. Consequently, under this assumption, this intermediate demand function can be inverted to express the unobserved productivity as a function of observable variables.

$$\omega_{it} = \omega_{it}(k_{it}, m_{it})$$

As explained in section 3.2, assuming a Cobb-Douglas function, the gross output production in logarithms is given by

$$y_{it} = \beta_L l_{it} + \beta_k k_{it} + \beta_M m_{it} + \omega_{it} + \eta_{it} \quad (3.3)$$

where y_{it}, l_{it}, k_{it}, and m_{it}denote the logarithms of gross output, labour, capital, and intermediate inputs, respectively; ω_{it} is the unobserved productivity component observed by firms but not by the econometrician, and η_{it} is an i.i.d. error term. After estimating the production function, the productivity component is recovered as:

$$\hat{\omega}_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_m m_{it}$$

Since the production function is estimated in logarithms, the extracted residual $\hat{\omega}_{it}$ corresponds to the logarithm of TFP ($\ln A_{it}$), representing the portion of output that cannot be explained by observable productive inputs.

To obtain the absolute level of productivity (A_{it}) as defined in the original Cobb-Douglas production function in levels ($Y_{it} = A_{it}\, K_{it}^{\alpha} L_{it}^{\beta}\, M_{it}^{\gamma}$), the exponential transformation is applied to the estimated residual: $A_{it} = \exp(\hat{\omega}_{it})$

which is mathematically equivalent to: $A_{it} = \frac{Y_{it}}{L_{it}^{\hat{\beta}_l} \cdot K_{it}^{\hat{\beta}_k} \cdot M_{it}^{\hat{\beta}_m}}$

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Annex A. Additional Matching Diagnostics

This annex provides supplementary evidence on the comparability of treated and control firms before and after the propensity score matching procedure. It reports the pre-treatment regression used to assess initial differences between zombie and non-zombie firms, details of the matching strategy, and the covariate balance tests conducted after matching.

A.1. Pre-Matching Sample Diagnostics

To evaluate whether pre-treatment differences in the dependent variable analysed existed before the matching procedure, the following regression was estimated using the full pre-matching sample:

$$\text{TFP}_i = \beta_0 + \beta_1 \text{Treated}_i + \beta_2 \text{Firm Age}_i + \gamma_s + \varepsilon_i$$

The dependent variable corresponds to firm-level TFP, while the treatment variable is a dummy identifying zombie firms. The specification also includes sector-group fixed effects (γ_s), which control for time-invariant differences across manufacturing sectors, and firm-age controls. In addition, the winsorized measure of TFP is used to reduce the influence of extreme observations.

The regression results, reported in Table B.1, show that zombie firms exhibited significantly lower productivity levels relative to non-zombie firms before the COVID-19 shock. The coefficient associated with the treatment dummy is negative and statistically significant at the 1% level, suggesting that zombie firms were already less productive before the pandemic, consistent with the existing literature.

Table A.1. Pre-Treatment Productivity Differences Between Zombie and Non-Zombie Firms

	Log TFP
Zombie Firm	-1.456***
	(0.097)
Firm Age	
	-0.002
Observations	19456
R-squared	0.046

Notes: Standard errors clustered at the CAE 2-digit industry level are reported in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01 . **Source:** Author's calculations using SABI data.

These results suggest that treated and control firms were not fully comparable before the pandemic.

A.2. Matching Procedure

The matching procedure was performed using pre-pandemic firm characteristics measured in 2019. Firms were matched according to their pre-pandemic productivity level, firm age, firm size, and sector group.

Pre-pandemic TFP was included because productivity constitutes the central dimension of analysis in this dissertation, and pre-existing productivity differences could otherwise bias the DiD estimation. Rather than relying solely on productivity in 2019, the matching procedure incorporated TFP levels across three pre-shock years (2017, 2018, and 2019). This ensures that treated and control firms not only shared similar productivity levels immediately before the pandemic but also exhibited parallel productivity trajectories prior to the exogenous shock. Firm age prior to the COVID-19 shock was included because firms at different stages of their life cycle may exhibit distinct productivity dynamics, financial structures, and adjustment capacities (Carreira et al., 2022).

Firm size was proxied using the logarithm of total assets rather than revenue. Total assets were considered more appropriate in the context of zombie firms because they better reflect firms' structural and financial dimensions. In contrast, revenue may fluctuate more substantially due to short-term market conditions. Moreover, using the logarithm of total assets reduces the influence of extreme observations and improves comparability across firms of different sizes (Smyth et al., 1975).

Exact matching was imposed at the sector-group level. Broader sector groups were preferred to highly disaggregated CAE codes in order to avoid excessive fragmentation of the sample and ensure a sufficient number of comparable firms within each category.

A.3. Covariate Balance Diagnostics

To assess whether the matching procedure successfully improved comparability between treated and control firms, a covariate balance test was conducted. The results indicate that the matching procedure eliminated differences in firm size and pre-pandemic productivity between the two groups. Although a minor statistical difference remains for firm age ($p = 0.020$), this variable is included as a control in the subsequent Difference-in-Differences estimation. The results of the covariate balance tests are reported in Table A.2.

Table A.2. Covariate Balance after Propensity Score Matching

Variable (2019)	Mean Zombie	Mean Non-Zombie	Difference	p-value
Firm Age	34.544	37.089	-2.545	0.039
Log Assets	4.844	4.853	-0.010	0.851
Log TFP (2019)	4.760	4.668	0.092	0.281
Log TFP (2018)	4.674	4.622	0.052	0.525
Log TFP (2017)	4.719	4.629	0.090	0.298
Observations	2556			

Note: The table presents mean comparison tests (t-tests) between treated and control firms. The results suggest substantial improvement in covariate balance following the matching procedure, although some differences remain. p-values > 0.10 indicate no statistically significant difference between groups, confirming covariate balance.

Annex B. Additional Robustness Check: Parallel Trends under the Persistent Zombie Definition

As an additional robustness check, Figure B.1 illustrates the average log TFP of persistent zombie firms and matched non-zombie firms during the pre-treatment period. As shown in Figure B.1, both groups exhibit broadly similar pre-treatment trends. Although some differences in productivity levels are observed, the evolution of productivity is broadly similar across the two groups prior to the COVID-19 shock.

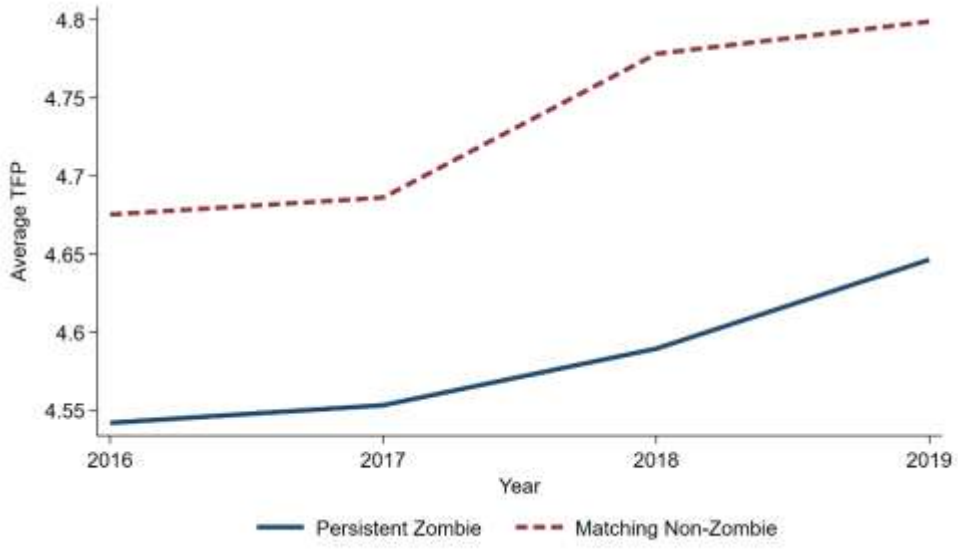

Figure B.1. Parallel Trends Assumption under the Persistent Zombie Definition

Note: The figure reports the annual mean of log TFP for persistent zombie firms and matched non-zombie firms during the pre-treatment period (2017–2019). The figure is based on the matched estimation sample used in the robustness analysis (N = 2,010). **Source:** Author's calculations using SABI data.

Annex C. SABI Variable Codes Used in the Analysis

Gross Output

Variable	SABI Code
Turnover	727
Variation in Production Inventories	39159
Capitalized Production	39160
Supplementary Income	39238
Operating Subsidies	39151

Intermediate Inputs

Variable	SABI Code
Cost of Goods Sold	726
Supplies and External Services	39165

Labour

Variable	SABI Code
Number of Employees	747

Capital

Variable	SABI Code
Tangible Fixed Assets	39010

Firm Age

Variable	SABI Code
Date of Incorporation	-204

Zombie Definition

Variable	SABI Code
Equity	707

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