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Exploring Corporate Capital Structure and Overleveraging in the Pharmaceutical Industry

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Abstract: This paper applies an empirical model of corporate capital structure, optimal debt, and overleveraging to estimate overleveraging measured as the difference between actual and optimal debt. Estimated using a sample of the twenty largest pharmaceutical firms, covering the time span from 2000 to 2018, the model sheds light on an industry-specific default risk. The analysis presented in this paper reveals a concerning trend in the pharmaceutical industry, with corporate excess debt steadily increasing over the past two decades, particularly peaking during the 2008 crisis and after 2013. These findings underscore the critical role of excess debt in exacerbating financial instability and highlight the pharmaceutical sector's unique challenges, including high R&D intensity and regulatory pressures. By quantifying overleveraging and linking it to financial risk, the paper offers valuable policy implications, emphasizing the need for proactive management of optimal debt levels to mitigate default risks and enhance macroeconomic resilience.

Keywords: corporate instability; pharmaceutical sector; credit flows; financial crisis; excess debt; early warning signals

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1. Introduction

The financial health and stability of corporations are pivotal not only for the individual entities but also for the broader macroeconomy. Corporations serve as the engines of economic growth, driving innovation, employment, and wealth creation. When a corporation's financial structure is robust, it enables the company to withstand economic shocks, invest in future growth, and contribute positively to the economy. Conversely, financial instability at the corporate level can lead to a series of negative effects, including reduced investment, layoffs, and, in extreme cases, bankruptcies, which can collectively worsen economic growth and stability.

In this context, the capital structure of firms, particularly their levels of debt, has emerged as a critical area of study. Capital structure decisions influence a firm's cost of capital, risk profile, and financial flexibility. A well-balanced capital structure can optimize a company's value, providing the necessary funds for growth while managing risk. However, an over-reliance on debt can lead to overleveraging, increasing the risk of default and financial distress, which can have broader implications for the economy. The 2008 global financial crisis, for instance, highlighted the dangers of excessive corporate debt, where the collapse of highly leveraged firms contributed to a severe economic downturn.

The pharmaceutical industry offers a particularly intriguing case for studying corporate capital structure due to its unique characteristics. High research and development (R&D) expenditures, long product development cycles, tough regulatory environments, and the increased adoption of artificial intelligence create significant financial pressures on pharmaceutical companies. These factors drive the need for substantial and sustained investment, often funded through debt. However, the high level of uncertainty and long-time horizons associated with bringing new drugs to market also increase the financial risk for these companies. This research aims to explore these unique dynamics and evaluate how excess debt and overleveraging trends affect pharma companies' financial health, specifically focusing on their high default risks associated with R&D failures.

Shahrour et al. (2024) examine how R&D investments influence U.S. firms' abilities to align environmental initiatives with financial performance. The study utilizes a sample of 229 firms from 2003 to 2021, employing multivariate panel regression models to analyze the data. The authors highlight a positive relationship between corporate performance (CP) and financial performance (ROA), with R&D enhancing this effect. However, the study mentions that the U.S. withdrawal from the Paris Climate Agreement weakens R&D's moderating influence, underscoring the need for stable climate policies. The findings emphasize the strategic importance of R&D for fostering green innovation, achieving sustainability, and maintaining long-term competitiveness in a regulatory environment.

Vanderpal (2015) investigates the relationship between R&D spending and corporate value, focusing on a sample of 103 companies with significant R&D expenditures from 1979 to 2013. The study reveals a positive impact of R&D on corporate value, indicating that increased R&D spending correlates with enhanced financial performance. However, the author notes that the benefits of R&D investments may not be immediately apparent and can vary depending on industry characteristics and market conditions. In addition, as per Issa and Gevorkyan (2022), the pharmaceutical industry is the most vulnerable among the financial, technology, auto, energy and airline industries in their sample.

This study highlights that, unlike the financial sector, the pharmaceutical industry maintained low debt levels until 2006. However, debt levels have been steadily rising since then, with a noticeable increase after 2014. Major companies like Merck and Pfizer faced vulnerabilities during the 2008 financial crisis due to their financial structures and still appear to carry excess debt. To address these issues empirically, the study introduces a new methodology for measuring overleveraging. Excess leveraging occurs when borrowing surpasses a firm's debt capacity, which is defined as sustainable or optimal debt. Overleveraging is calculated as the gap between actual debt and optimal debt. The analysis builds on the prior literature, including work by Stein (2012a), Schleer and Semmler (2016), Issa (2020), and Issa and Gevorkyan (2022), employing a dynamic version of the Stein model. This approach uses time-series data to calculate the excess debt levels of twenty pharmaceutical companies.

Overleveraging often aligns with lending booms, which are usually known antecedents to economic instability due to increased risk-taking. Such conditions can lead to financial turmoil when adverse shocks occur, as seen during the 2008 crisis or even the COVID-19 pandemic. Since 2012, pharmaceutical companies have continued to excessively leverage, raising concerns about another potential crisis affecting the sector. Numerous studies explore how asset price channels contribute to systemic financial instability, including works by Brunnermeier and Sannikov (2014), Mittnik and Semmler (2012, 2013), Stein (2012a, 2012b), Gross et al. (2017), and Issa and Gevorkyan (2022).

This paper examines if and how excess debt, as defined by Stein (2006), can be considered an early warning signal for pharmaceutical companies, and takes an additional dimension by comparing it to the excess leverage before and during the recent global financial crisis. In addition, it develops two key metrics to assess the financial health and performance of firms within the pharmaceutical industry. First, we calculated the leverage score by multiplying the excess debt of each firm by the sum of five critical financial ratios, an approach that allowed us to create a comprehensive metric that captures the various dimensions of leverage. Second, we determined the performance score by aggregating three vital profitability indicators, which offered a holistic evaluation of the firm's financial performance. Our main hypothesis is that excessive debt in the pharmaceutical industry, measured as the deviation between actual and optimal debt levels, negatively impacts financial stability and firm performance, with specific vulnerability observed before and during periods of macroeconomic instability such as the 2008 financial crisis.

The results indicated that all companies experienced vulnerability during the 2007–2009 financial crisis, with credit build-up, or overleveraging, beginning as early as 2005. However, most companies in our sample demonstrated better performance and lower leverage levels during the crisis, which moderated their impact and enhanced their resilience. Despite this, some companies continued to rely on leveraging and faced second-round effects around 2012–2013 and beyond, as evidenced by higher levels of excess debt during this period.

This study contributes to the growing body of literature on corporate overleveraging, balance-sheet dynamics, and the impact of macroeconomic instability shocks.

This paper is organized as follows: Following the introduction and rationale of this study in Section 1, Section 2 gives the literature review about the corporate structure of the pharmaceutical industry as well as the literature related to the theoretical model. Section 3 provides the theoretical model. Section 4 presents empirical and graphical analysis of the results. The policy implications are presented in Section 5, Section 6 concludes the paper, and Section 7 presents the limitations. The appendices provide the technical background of the economic model and the calculations of excess debt.

2. Literature Review

The stability of the pharmaceutical sector warrants critical examination, particularly concerning debt sustainability at both the corporate and macroeconomic levels. This study explores how existing analytical frameworks can assess the future outlook of debt sustainability for individual corporations, the industry as a whole, and its broader macroeconomic implications. However, before examining these issues, it is important to review foundational work on the topic, especially given the amount of the existing literature on corporate debt dynamics.

In traditional financial theory, the Modigliani–Miller theorem posits that firms in frictionless markets can finance all profitable projects regardless of financing type or level (Modigliani and Miller 1958). However, financing frictions, such as factors that prevent firms from accessing capital seamlessly, substantially affect corporate financing behavior in real markets. The presence of these frictions is especially impactful in capital-intensive industries like pharmaceuticals, where long R&D cycles, high costs, and strict regulatory requirements influence capital structure decisions uniquely.

Pharmaceutical companies face persistent financing frictions that limit their flexibility in quickly raising capital, particularly through debt issuance. Unlike manufacturing- or production-based industries, where revenue generation is more immediate, the extended periods before pharmaceutical firms can commercialize new products increase the risk associated with debt financing. High default risks in the industry, primarily due to potential R&D project failures, make it challenging for these firms to adhere strictly to target capital structures. Indeed, research indicates that most firms aspire to target debt ratios (Graham and Harvey 2001), but deviations from these targets can restrict further debt issuance (Leary and Roberts 2005). For pharmaceutical firms, such deviations from target or optimal leverage ratios are often necessary to sustain prolonged investment in innovative projects, despite the associated limitations on accessing additional debt.

Moreover, industry-specific capital constraints impact the firms' capacity to achieve optimal leverage levels, with many firms prioritizing flexibility to navigate regulatory hurdles and long development cycles over rigid adherence to target capital structures. The pharmaceutical industry's high R&D requirements create a situation where firms must strategically deviate from their optimal debt ratios, often opting for underleveraging as a safeguard against unpredictable cash flows and regulatory delays. This aligns with the findings of Hovakimian et al. (2001) and Fama and French (2002), who demonstrate that deviations from target leverage can indeed restrict further debt acquisition, an effect that is intensified in high-risk, high-cost sectors like pharmaceuticals. Through the lens of financing frictions, the pharmaceutical industry offers a compelling case study in how firms balance leverage with the operational flexibility needed to sustain innovation. Unlike sectors with more stable and immediate revenue cycles, pharmaceutical firms frequently adapt their leverage targets to accommodate long-term project timelines and potential regulatory shifts, even at the expense of increasing financing costs or experiencing limited access to additional capital during adverse conditions.

Jokipii and Monnin (2013) conceptualize banking sector instability as the probability of insolvency occurring within the upcoming quarter. They posit that if the aggregate market value of assets held by all banks in a country is insufficient to cover total debt by the end of a certain quarter, the entire banking sector is deemed insolvent. The "distance-to-default" is thus defined as the gap between the current state of the banking sector and its default threshold. Given the strong interconnections among banks, this study argues that vulnerabilities can emerge through this distance-to-default metric, influenced by country-specific, time-varying covariance matrices. Such interconnectedness can precipitate a contagion effect, rendering the entire banking sector insolvent. There exist numerous studies that have explored issues pertaining to the asset price channel as a trigger for banking system instability.

Focusing specifically on the banking sector, Brunnermeier and Sannikov (2014) examine how shocks to asset prices can cause a vicious cycle that can impact banks' balance sheets. They introduce the concept of a "volatility paradox", wherein heightened volatility leads to increased risk-taking and excessive borrowing, ultimately disrupting the real sector. For instance, a decline in asset prices erodes banks' equity values and net worth, prompting higher margin loan requirements. To maintain liquidity, financial intermediaries may resort to haircuts and deleveraging, leading to fire sales that further depress asset prices. This downward spiral triggers an endogenous surge in volatility, consequently elevating systemic risk.

Similarly, Mittnik and Semmler (2012, 2013) identify the primary cause of banking sector instability as the unchecked expansion of capital assets through excessive borrowing, facilitated by inadequate financial regulation. They highlight how substantial payouts without sufficient "skin in the game" potentially influence banks' risk-taking behavior by promoting further equity development and increased leveraging. As elevated payouts lead to higher leverage, they can increase aggregate risk and risk premia across the entire financial system. Consequently, the onset of defaults amplifies risk spreads and risk premia, which in turn exposes banks to vulnerabilities and financial stress induced by securities' price fluctuations.

Stein (2008, 2012a) posits that destabilizing mechanisms stem from the interplay between asset prices and borrowing patterns. Overleveraging begins when banks' assets become overvalued, resulting in above-average returns due to rising housing prices that boost owners' equity. This scenario stimulates banks' demand for mortgages and funds, allowing them to reap capital gains beyond normal returns. Under these circumstances, banks transition from optimal to excessive leverage. Stein's analysis rests on the "no free lunch" constraint, which assumes that the mean interest rate exceeds long-term capital gains. For overleveraging to occur, a breach of the "no free lunch" constraint is necessary, as observed during the global financial crisis (GFC). When capital gains surpass financing costs, banks achieve excess returns on capital and elevated net worth. In contrast, a decrease in capital gains increases credit spreads, causing actual leverage to diverge significantly from optimal levels. This divergence leads to rapid deterioration of banks' balance sheets and triggers amplified downward effects. Stein suggests utilizing trends in capital gains and interest rates to more accurately measure optimal debt, defining "excess debt" as the disparity between actual and optimal debt.

Extending beyond the U.S. banking sector's overleveraged exposure to the real estate market during the GFC, Schleer and Semmler (2016) investigate the spillover effects of leveraging on the broader non-financial sector. They begin with the theoretical premise that an overleveraged banking sector leads to credit supply constraints and delays in economic recovery. Their findings indicate that in the years preceding the GFC, actual debt levels deviated from optimal debt, resulting in overleveraging within the banking sector.

In the pharmaceutical industry, research highlights complex inter-relationships between R&D investments, debt financing, corporate governance, and firm performance. Toçi et al. (2021) find that R&D investments have lagged effects on firm growth, becoming significant in the second year and increasing thereafter. Debt management plays a pivotal role in influencing corporate value and capital structure, with Wu et al. (2021) identifying a positive correlation between debt levels and earnings per share. Corporate governance mechanisms—such as board characteristics and ownership concentration—are positively associated with R&D investment, whereas debt financing shows a negative association (Muhammad et al. 2022). Additionally, debt financing moderates and partially mediates the relationship between corporate governance and R&D investment. Realdi and Siregar (2022) demonstrate that ownership and debt policy significantly affect firm value, though the impact of cash flow remains ambiguous. These studies underscore the close relationship between financial governance, R&D investments, and firm performance in the pharmaceutical sector.

Singh and Faircloth (2005) examine the influence of corporate debt on long-term investment and firm performance among large U.S. manufacturing firms. By analyzing the effect of leverage on R&D expenditure and considering corporate performance drivers as intermediary variables, they uncover a strong negative correlation between financial leverage and R&D spending. This suggests that higher leverage leads to reduced R&D expenditure, thereby limiting future growth opportunities.

In a different context, Nyambuu and Bernard (2015) utilize Stein's (2006) model to calculate optimal debt for developing countries. Their paper applies the framework at a macroeconomic level, in comparison to the emphasis of our paper on the micro-level. Both studies employ the optimal debt ratios to define the distance-from-default indicator: corporate default in our case, and sovereign default in theirs. The models solve a stochastic dynamic decision problem that maximizes the expected present value of consumption utility to determine optimal debt. While both calculate optimal debt, the methodologies diverge in metrics used; we incorporate data on capital gains/losses, market interest rates, and capital productivity, whereas Nyambuu and Bernard (2015) use GDP ratios, current account balances, and historical data. Nyambuu and Bernard (2015) demonstrate that rising external debt ratios heighten a country's vulnerability to shocks and increase default risk. Analogously, our findings indicate that an increase in a corporation's excess debt elevates its default risk. In both models, a sudden consumption drop leads to a reduction in the optimal or sustainable debt level. This aligns with Stein's (2006) assertion that a debt crisis can ensue "if the attempt to service the debt requires a drastic decline in consumption".

3. Empirical Approach and Definition of Variables

3.1. Background

Stein (2012a) argues that the 2008 financial crisis in the United States was primarily caused by private households accumulating excessive mortgage obligations—a bubble in the mortgage market characterized by unsustainable debt-to-income ratios. This differs from the financial turmoil of the 1980s, which was associated with the business sector. According to Stein (2012a, 2012b), whether debt issues originated in the public or private sectors across different countries, the common outcome was a decline in asset values. The processes involved led to a contagion effect that spread either from the U.S. to Europe or among European nations, depending on the specific relationships between debtors and creditors being examined. Importantly, Stein emphasizes that in all cases, the core problem was not the mere existence of debt but the presence of excessive debt within the entities under analysis.

By formulating an optimal debt ratio, Stein (2006) developed an early warning signal (EWS) for a debt crisis, defined by the excess debt of households, that is, when the actual debt ratio exceeds the optimal level. As this excess debt increases, so does the likelihood of a debt crisis. Evidence indicates that rising house prices since the late 1990s led to above-average capital gains for households, which, in turn, increased homeowner equity. This surge prompted a greater supply of mortgages and resulted in financial obligations consuming a larger percentage of disposable income for private households. Simultaneously, loan quality deteriorated due to the rise in subprime mortgages. This unsustainable trajectory meant that when capital gains fell below interest rates, debtors could no longer service their debts. The subsequent foreclosures triggered a collapse in the value of financial derivatives.

3.2. Theoretical Model

To define overleveraging, we adopted a model of optimal leverage that is a low-dimensional stochastic variant inspired by the banking leverage models of Stein (2006, 2008, 2012b), Brunnermeier and Sannikov (2014), and Issa (2020). In these frameworks, leveraging and payouts are treated as decision variables, while net worth functions as a stochastic state variable. Although Brunnermeier and Sannikov (2014) concentrated on the financial sector, our study focuses on the pharmaceutical industry, providing a more general setting than their paper. The model includes households that save and financial experts acting as intermediaries who invest in capital assets owned by both households and financial intermediaries, each with different discount rates. Our analysis was specifically centered on the behavior of the highly financialized pharmaceutical sector.

In constructing our model, we incorporated preferences into the objective function and utilized Brownian Motions as state variables, similar to the approaches in the referenced studies. Stein (2012b) and Issa (2020), under certain conditions, employ logarithmic utility, allowing for the exact calculation of excess leveraging. Like in our model, the return on capital is stochastic due to capital gains, and the interest rate is also stochastic. This contrasts with Brunnermeier and Sannikov (2014), where only the capital return is stochastic, and the interest rate remains constant. While both Brunnermeier and Sannikov (2014) and Stein (2012a) used continuous-time models, our problem was formulated in discrete time, featuring a discounted instantaneous payout and an optimal leveraging function.

Moreover, Brunnermeier and Sannikov (2014), Stein (2012a), and Issa (2020) all suggest that shocks to asset prices can initiate a vicious cycle affecting companies' balance sheets. Specifically, risk-taking and excessive borrowing tend to occur when asset prices are volatile. They describe the "volatility paradox" as the phenomenon where shocks to asset prices adversely impact companies' balance sheets, leading to disruptions in the real economy. When asset prices fall, companies' equity values and net worth decrease, which in turn leads to increased margin loan requirements. To maintain liquidity, financial intermediaries take haircuts and reduce leverage, triggering a fire sale of assets. This further depresses asset prices and net worth, causing an endogenous spike in volatility and risk for all parties, ultimately creating a downward spiral. These observations align with the findings in our paper.

To determine the optimal debt ratio, Stein applied stochastic optimal control (SOC). In this approach, a hypothetical investor selects an optimal debt ratio, $f(t)$, to maximize the expected value of a concave function of net worth, $X(t)$, over a given time horizon. The model assumes that the optimal debt-to-net-worth ratio is heavily influenced by the stochastic behavior of the capital gain variable. The net worth grows at its maximum rate when the debt ratio is at the optimal level. The full mathematics of the Stein model (Stein 2006) are provided in Appendix A.

Stein's formula for the optimal debt ratio is as follows:

$$f^*(t) = [(r-i) + \beta - \alpha y(t) - \frac{\left(\frac{1}{2}\right)\left(\sigma_p^2 - \sigma_i \sigma_p \rho\right)}{\sigma^2}] \quad (1)$$

subject to the following:

$$Risk = \sigma^2 = \sigma_i + \sigma_p - \left(2\rho_{ip}\sigma_i\sigma_p\right) \quad (2)$$

where

- r is the capital gain or loss of the company;
- i is the cost of credit;
- β is the productivity of capital;
- $y(t)$ is the deviation of capital gain from its trend;
- σ^2 is the variance;
- ρ is the negative correlation between interest rate and capital gain.

This model enabled Stein to identify excess debt levels and provide early warnings of potential financial crises. It highlights the link between excessive leverage, volatile pricing of complex securities, and the erosion of net worth across households, firms, and institutions.

In this paper, we developed an original theoretical model of corporate capital structure inspired by Stein's and Issa's framework but extended it in new directions. Unlike Stein's model, which assumes constant productivity of capital, we calculated this variable dynamically for individual companies over the years 2000–2018. Using time-series data, we estimated the optimal debt ratios and compared them to actual debt levels to assess overleveraging.

3.3. Data and Methodology

To calculate the optimal debt ratios from 2000 to 2018, we collected data on companies' capital gains or losses, market interest rates, and productivity of capital. This analysis focused on a sample of 20 pharmaceutical companies, with data sourced from Bloomberg, FactSet, and annual reports. The selection of the 20 companies was driven by the study's objective to focus on the largest and most influential players in the pharmaceutical industry. These companies represent the highest market capitalization within the sector, ensuring that our analysis captures the financial behaviors and leverage dynamics of industry leaders. Given their substantial share in the market, their financial decisions and trends are pivotal in shaping the overall financial health and stability of the pharmaceutical industry.

Calculations were summarized in 20 detailed tables, with key variables outlined as follows:

- Capital gain/loss (Column 1): Representing annual returns from capital appreciation or depreciation, calculated as the percentage change in market capitalization. Market caps were smoothed using the Hodrick–Prescott (HP) filter to remove short-term fluctuations.
- Market interest rate (Column 2): Measured by the 10-year Treasury yield.
- Productivity of capital (Column 3): Calculated as gross revenue divided by total capital, which includes shareholder equity and half of both short- and long-term debt.
- Risk components (Columns 4–9): Variance and deviations of beta, interest rate, and capital gain; correlation between interest rate and capital gain; and risk terms derived from these factors.
- Risk metrics (Columns 10–13): Standard deviations of interest rate and capital gains, combined to calculate the total risk borne by equity investors.
- Normalized optimal debt ratios (Column 14–15): Normalized optimal debt ratios using Column 14, the mean and standard deviation of the optimal debt values.
- Actual debt ratios (Column 16–17): Normalized actual debt ratios.
- Excess debt (Column 18): Deviation between the actual and the optimal debt.

This ratio is positive only when the net return exceeds the risk premium. The normalized debt ratios were adjusted to remove seasonal effects, and negative values indicate periods with lower optimal debt ratios. Actual debt ratios were normalized similarly. Excess debt was calculated as the difference between actual and optimal debt ratios. The Table A1 in Appendix B is presented list of companies and the full calculations of a sample of ten companies are presented in Tables A2–A10 in Appendix C.

Building upon the concepts of optimal and excess debt previously discussed, we developed a leverage score to evaluate the stability of these companies in relation to their debt levels and strategies.

3.4. Leverage and Performance Scores

Building on the analysis of optimal and excess debt, we introduced two additional metrics, namely the leverage score and the performance score. The leverage score multiplies the excess debt previously calculated by a weighted combination of five financial ratios—debt-to-asset, debt-to-equity, debt-to-capital, debt-to-cash, and debt-to-EBITDA—in order to assess a company's financial stability. The performance score aggregates three profitability indicators, namely the Return on Assets (ROA), Return on Equity (ROE), and Net Income Margin, in order to provide a holistic view of a company's financial performance. These calculations and analyses are presented through tables and graphs, providing insights into optimal debt strategies and the implications of overleveraging. This approach builds on Stein's foundational work while offering new dimensions for assessing corporate financial health. Using different scores has been popular in the recent literature. For instance, Shahrour et al. (2025) investigated the issue of the impact of climate change on credit risk by examining a company's emission category score. The authors conducted a comprehensive sectoral analysis to understand the industry-specific effects of climate risk better. The findings emphasized the importance of incorporating climate risk into companies' risk management strategies.

4. Empirical Analysis

4.1. Graphical Results and Analysis: Actual vs. Optimal Debt

Next, applying the methodology presented in the previous section, optimal leverage was calculated for a sample of 20 companies in the pharmaceutical industry. For the companies under study, this analysis was performed using the companies' total long-term debts and total assets. As noted, total long-term debt represents a company's total debt with a maturity date of more than one year from the balance-sheet date. Total assets represent the value of a company's total assets.[1] The vertical axes of the graphs in Figure 1 represent the debt ratios, while horizontal axes represent the years. First, Figure 1 shows the aggregated optimal debt against actual debt ratios for the whole industry. The debt ratios for the industry are weighted averages of the companies in our sample.

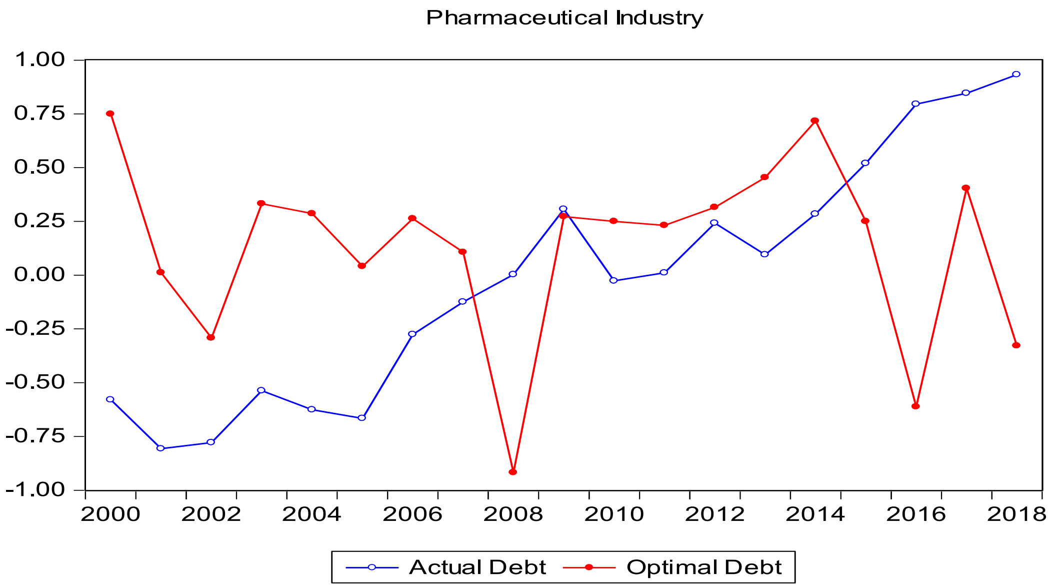


Figure 1. Actual vs. optimal debt industry estimation. Source: authors' calculations based on data from Bloomberg.

Figure 1 illustrates the actual against the optimal debt plotted over the period from 2000 to 2018. The x-axis represents the time intervals, and the y-axis indicates the debt values. Examining the actual debt depicted by the blue line, we observe a notable initial decline, followed by a series of fluctuations. After reaching a low point, the debt values begin a gradual upward trajectory with intermittent dips and rises. This indicates variability in the actual debt over the analyzed periods, possibly reflecting external economic factors or internal policy changes impacting debt management. However, we do observe an overall trend of increasing actual debt during the whole period and a stronger increase starting 2013.

The optimal debt ratios, represented by the red line, start at a relatively high value and experience a sharp decrease early on. This is followed by a series of peaks and troughs, illustrating significant volatility. Unlike the actual debt, the optimal debt does not follow a consistent trend but rather oscillates frequently, suggesting that the optimal debt targets or benchmarks are subject to frequent adjustments and are highly affected by crisis times. During bust periods, lending becomes scarce, and the cost of debt becomes high.

Generally speaking, periods where actual debt aligns closely with optimal debt indicate successful debt management by meeting target levels. However, there are also periods where the actual debt deviates significantly from the optimal values, highlighting discrepancies between planned and actual debt levels as well as excessive risk-taking and short-term planning.

As mentioned above, the pharmaceutical industry has notably increased its leverage, especially after 2013, driven by a confluence of strategic, financial, and market-driven factors. One of the primary drivers has been the pursuit of mergers and acquisitions (M&As). Pharmaceutical companies have increasingly turned to M&A to fuel growth, acquiring new products, technologies, and expanding their market share. Leveraging debt has provided these companies with the necessary capital to finance such acquisitions. This trend has been particularly pronounced as many companies faced patent cliffs, where the expiration of patents on blockbuster drugs threatened significant revenue declines.

Another significant factor contributing to the increase in leverage is the favorable borrowing conditions resulting from historically low interest rates, especially in the years following the 2008 financial crisis. These low rates made borrowing more attractive, enabling pharmaceutical companies to finance expansions and acquisitions at a lower cost. Additionally, the low-interest environment presented opportunities for refinancing existing debt under more favorable terms, further incentivizing the use of leverage.

Furthermore, the competitive nature of the pharmaceutical industry has driven companies to invest heavily in research and development (R&D). Leveraging debt has provided the financial resources necessary for substantial R&D investments, enabling companies to innovate and stay ahead in the competitive market. The pressure to develop new drugs and therapies, coupled with the high costs associated with R&D, has made borrowing an attractive option for maintaining a robust pipeline of new products.

The graphs in Figure 2 show the optimal against the actual debt ratio for the sample of twenty companies under study. The list of companies is found in Appendix B. The optimal debt ratios for most of the companies exhibited similar trends. For a number of years preceding the 2007–2009 financial crisis, these companies had high optimal debt ratios. For most of the companies, about a year or two prior to 2007, optimal debt ratios began to drop, and the decrease was severe in most cases right before the crisis. Another interesting observation is that optimal debt for some companies was more stable during the years immediately following the crisis. Moreover, the trend of actual debt exceeding optimal debt clearly reversed post-crisis for most companies in the sample, especially after 2013. In the next paragraphs, each company is separately discussed.

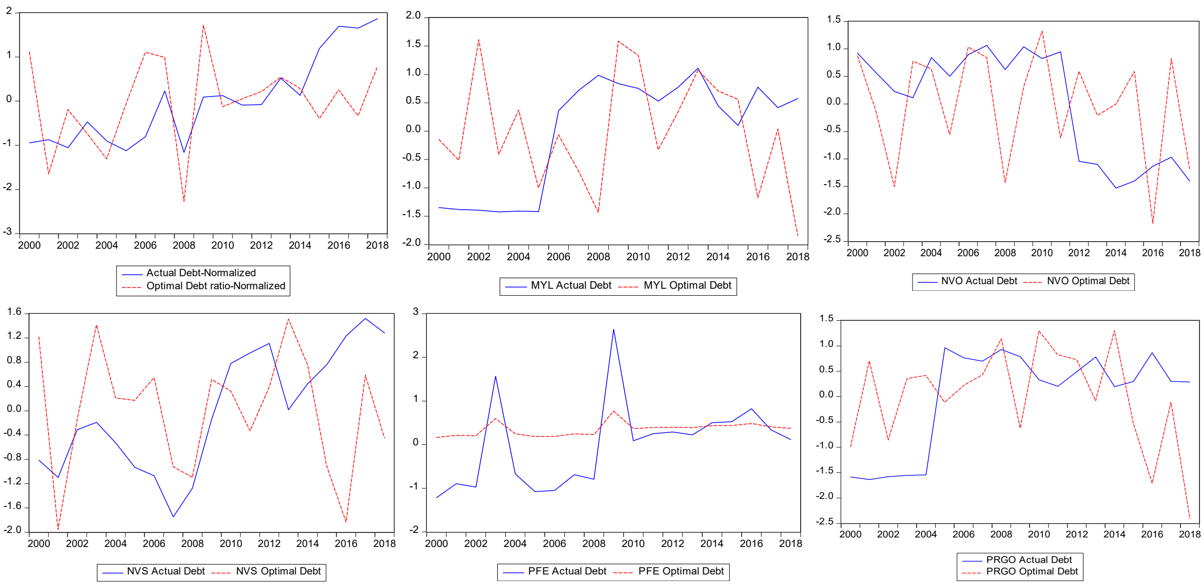


Figure 2. *Cont.*

Figure 2. Companies optimal versus actual debt ratio. Source: Authors' calculations based on data from Bloomberg.

For Eli Lilly and Company (LLY), AmerisourceBergen Corporation (ABC), Allergan (AGN), GlaxoSmithKline (GSK), Mylan N.V. (MYL), Novartis (NVS), and Sanofi (SNY) the optimal debt shows significant fluctuations from 2000 to 2018, while the actual debt mostly remains low, indicating better debt management. Consequently, excess debt varies over the years, except for AGN where we occasionally see actual debt exceeds optimal levels. Pfizer Inc. (PFE) also exhibits significant optimal debt ratio fluctuations over the years, but excess debt varies, with notable peaks indicating periods of higher-than-optimal debt levels. Pfizer should monitor high leverage periods closely to maintain stability.

On the other hand, for Abbott Laboratories (ABT), Akorn, Inc. (AKRX), Merck & Co., Inc. (MRK), and Novo Nordisk (NVO), optimal debt exhibits moderate fluctuations while a consistent approach is maintained to keeping actual debt within or below optimal levels. We also see that for Adobe Inc. (ADBE), optimal debt shows a steady increase over the years with a lower actual level and well-controlled excess debt. ADBE does have prudent financial strategies. Cardinal Health (CAH), Endo Pharmaceuticals (ENDP), Johnson & Johnson (JNJ), McKesson Corporation (MCK), Perrigo Company plc (PRGO), Dr. Reddy's Laboratories (RDY), and Zoetis Inc. (ZTS) follow the same trend where optimal debt displays moderate variability and actual debt is maintained at low levels, with some years showing overleveraging. Overall, these companies effectively manage their debt but need to ensure it does not exceed optimal levels frequently.

4.2. Graphical Results and Analysis: Excess Debt

For further analysis, the deviation of the companies' actual debt ratios from the mean over the period from 2000 to 2018 was calculated as an alternative proxy for excess debt ratio. Excess debt ratios were calculated for the 20 abovementioned companies. For this calculation, each company's total assets and long-term debts were used to calculate debt ratios, as previously noted. Total assets represent the company's total balance-sheet assets at the end of the period. Long-term debts are the balance of each company's debts that are due for more than one year at the end of each period. On the basis of the presented calculation method, the excess debts of the respective companies were calculated,[2] and graphs of the excess debt ratios are exhibited in Figure 3.

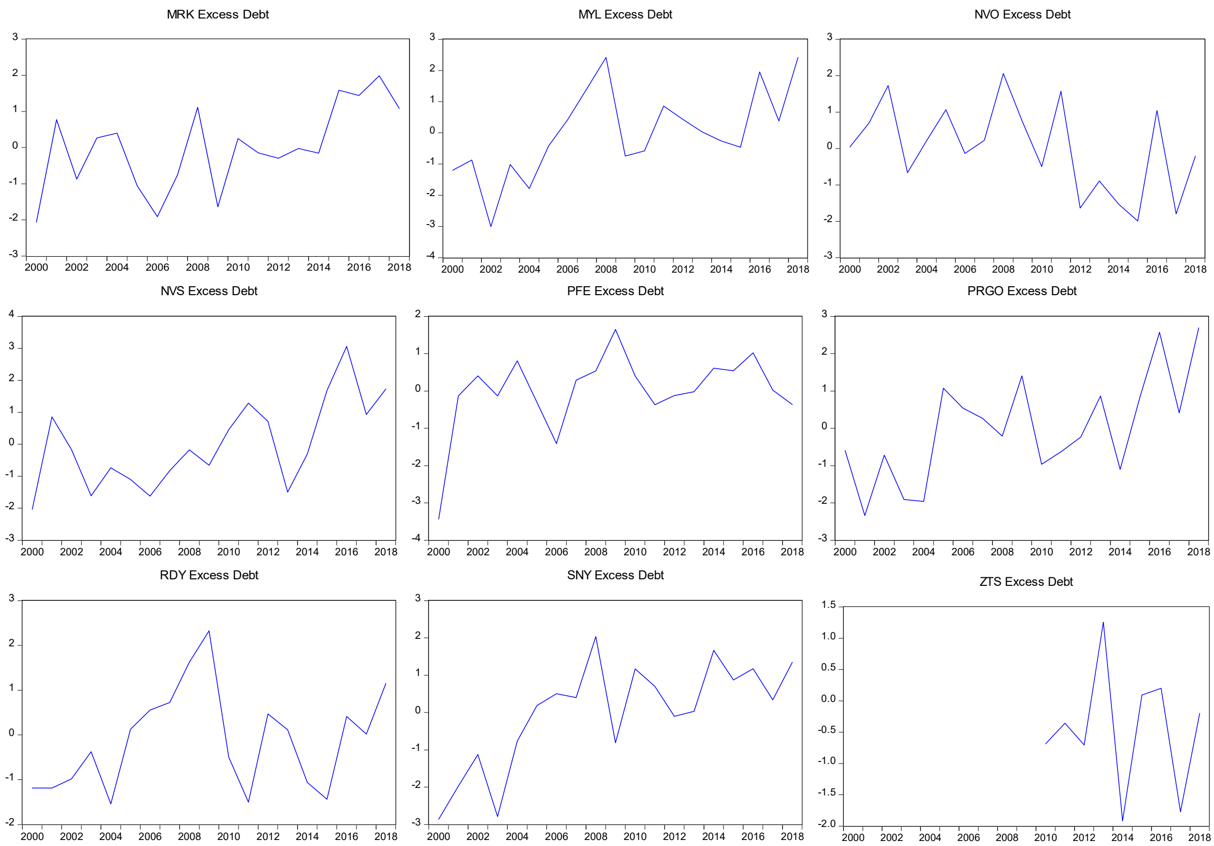


Figure 3. *Cont.*

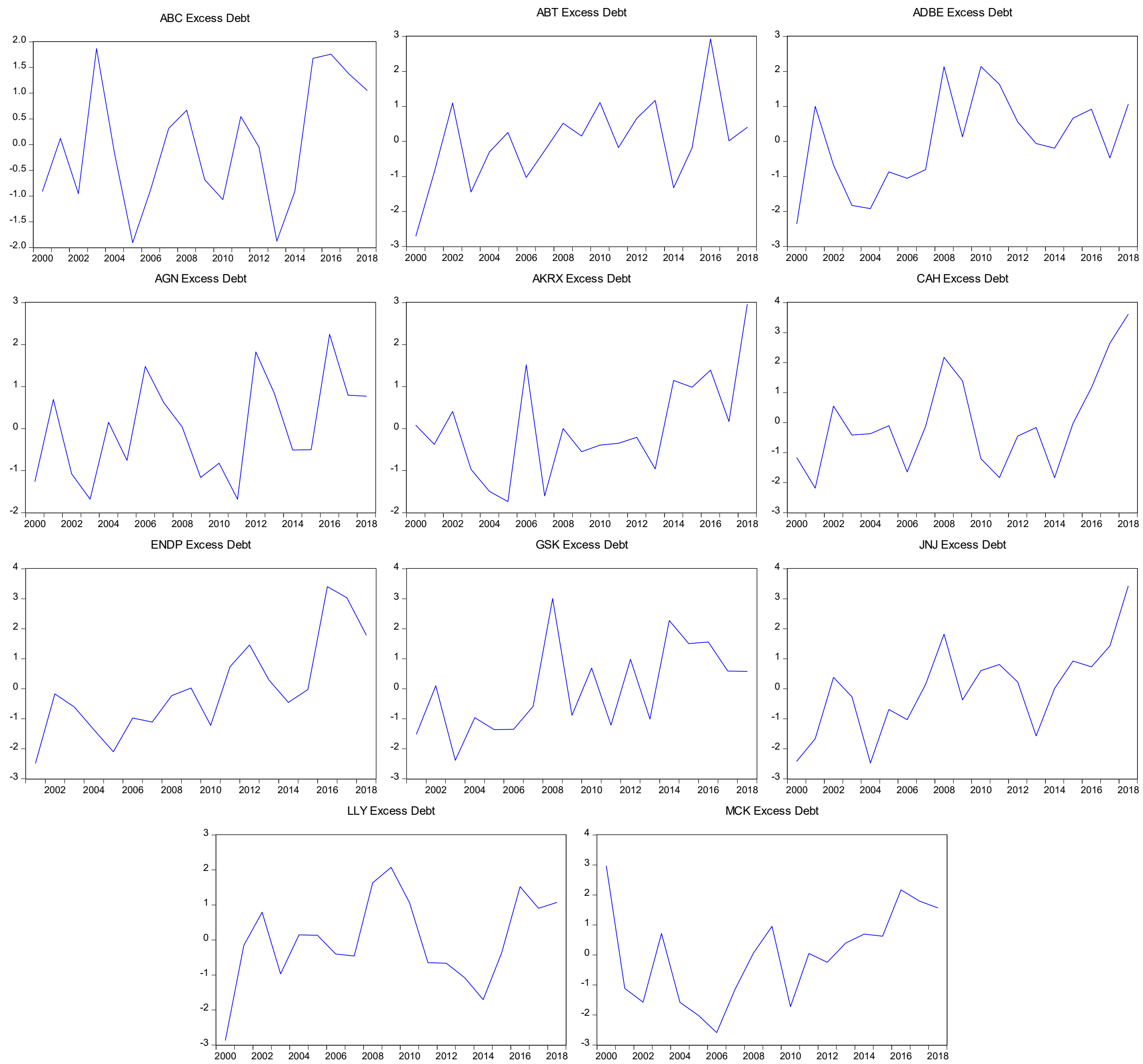


Figure 3. Companies' excess debt. Source: Authors' calculations based on data from Bloomberg.

In the graphs in Figure 3, vertical axes are the deviation of debt ratios, namely, excess debt ratio, while horizontal axes represent years. Graphs show that all companies in this study exhibited a similar movement in debt ratio for most of the period with excess debt between 2007 and 2009 during the financial crisis. All companies had excess debt in the years preceding and during the financial crisis, with excess debt higher for some companies after the crisis. However, the most notable inference is that after 2013, almost all companies have high excess debt.

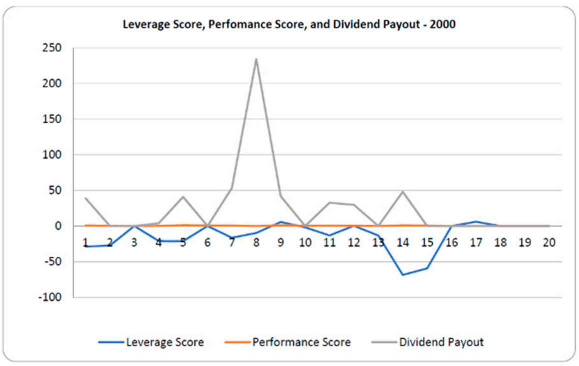
As mentioned in the previous section, the top performers were Abbott Laboratories (ABT), Adobe Inc. (ADBE), Johnson & Johnson (JNJ), Zoetis Inc. (ZTS), Merck & Co. (MRK), and Novo Nordisk (NVO), which consistently manage to keep their actual debt lower than or close to the optimal levels. The moderate performers were Eli Lilly (LLY), GlaxoSmithKline (GSK), like Pfizer Inc. (PFE) and Dr. Reddy's Laboratories (RDY), which also manage their debt effectively but show periods of higher-than-optimal debt levels. Finally, the underperformers were Endo Pharmaceuticals (ENDP) and Allergan (AGN), McKesson Corporation (MCK) and Perrigo Company plc (PRGO), which exhibit higher variability in excess debt, indicating challenges in maintaining optimal debt levels consistently.

4.3. Graphical Results and Analysis: Leverage, Performance Score and Dividend Payout

As mentioned above, the leverage and performance scores were calculated to give a further in-depth analysis to the debt assessment of these companies. The calculation involved multiplying the excess debt by a combined set of five financial ratios. This comprehensive indicator offers a detailed view of the firm's leverage by considering different facets of debt in relation to various financial benchmarks. On the other hand, the performance score was derived by summing three primary profitability metrics, to reflect the firm's overall financial performance and profitability, providing a holistic perspective on its economic efficiency and ability to generate profit relative to its debt, assets, equity, and revenue.

Figure 4 below depicts the leverage score against the performance score and the dividend payout for the twenty firms in our sample. Each graph corresponds to a year, and the companies below are labeled from 1 to 20 as follows:

Abbott Laboratories (ABT)
Allergan, Inc. (AGN)
AmerisourceBergen Corp (ABC)
Adobe Powers Digital Healthcare Innovation (ADBE)
Cardinal Health, Inc. (CAH)
Eli Lilly and Company (LLY)
GlaxoSmithKline Plc. (GSK)
Johnson & Johnson (JNJ)
McKesson Corporation (MCK)
Merck & Company, Inc. (MRK)
Mylan Inc. (MYL)
Novartis AG (NVS)
Novo Nordisk (NVO)
Perrigo Company (PRGO)
Pfizer, Inc. (PFE)
Sanofi (SNY)
Zoetis Inc. (ZTS)
Akorn, Inc. (AKRX)
Dr. Reddy's Laboratories Ltd. (RDY)
Endo International Plc. (ENDP)



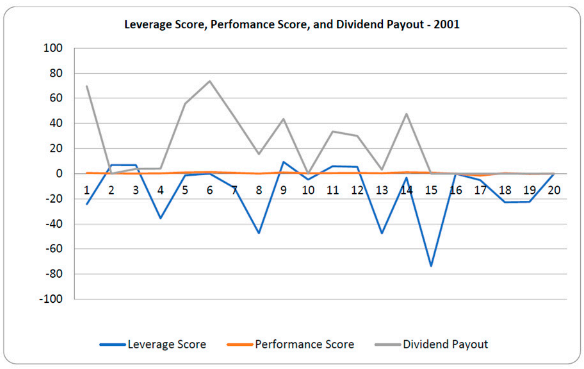


Figure 4. *Cont.*

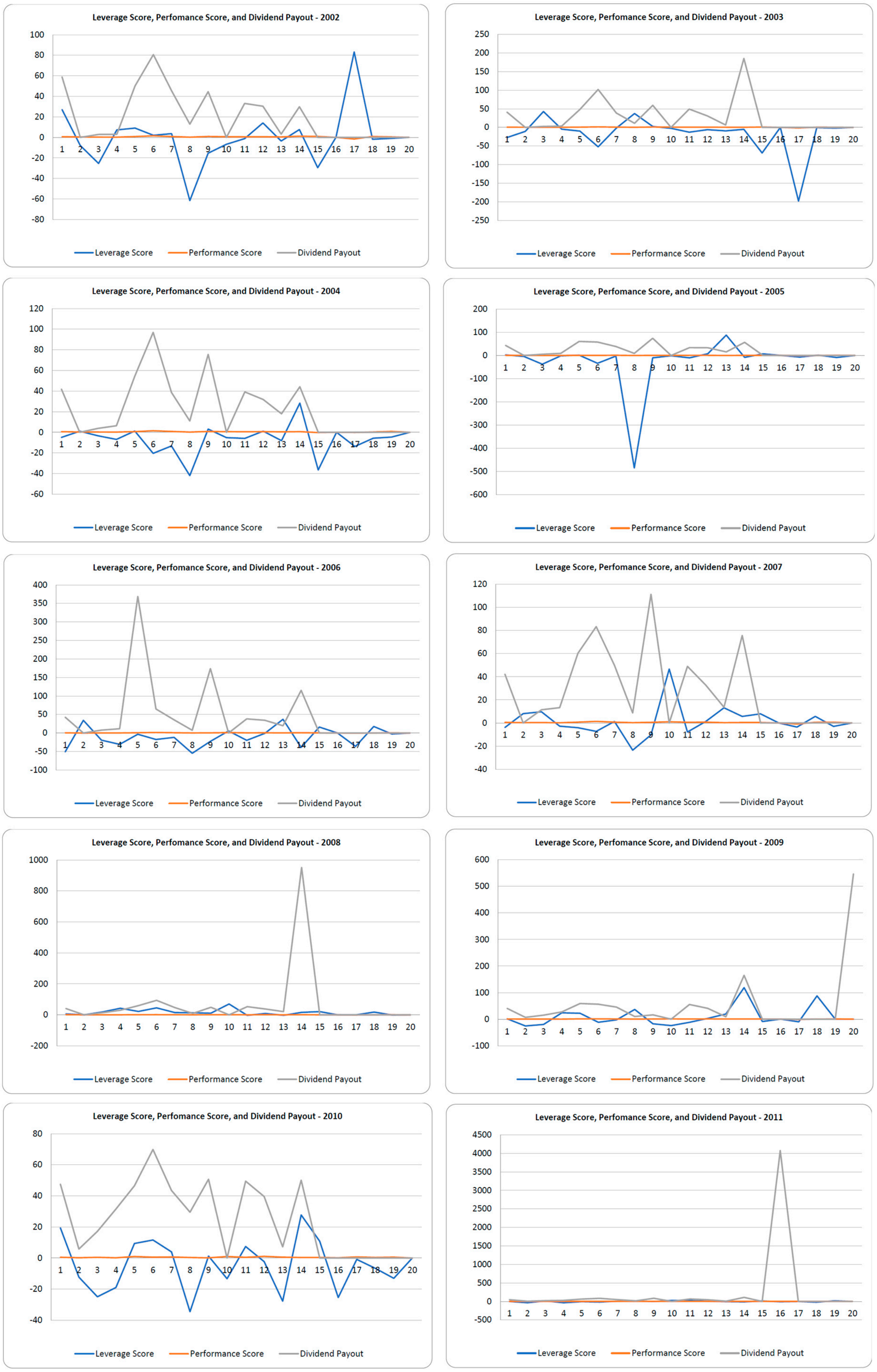


Figure 4. *Cont.*

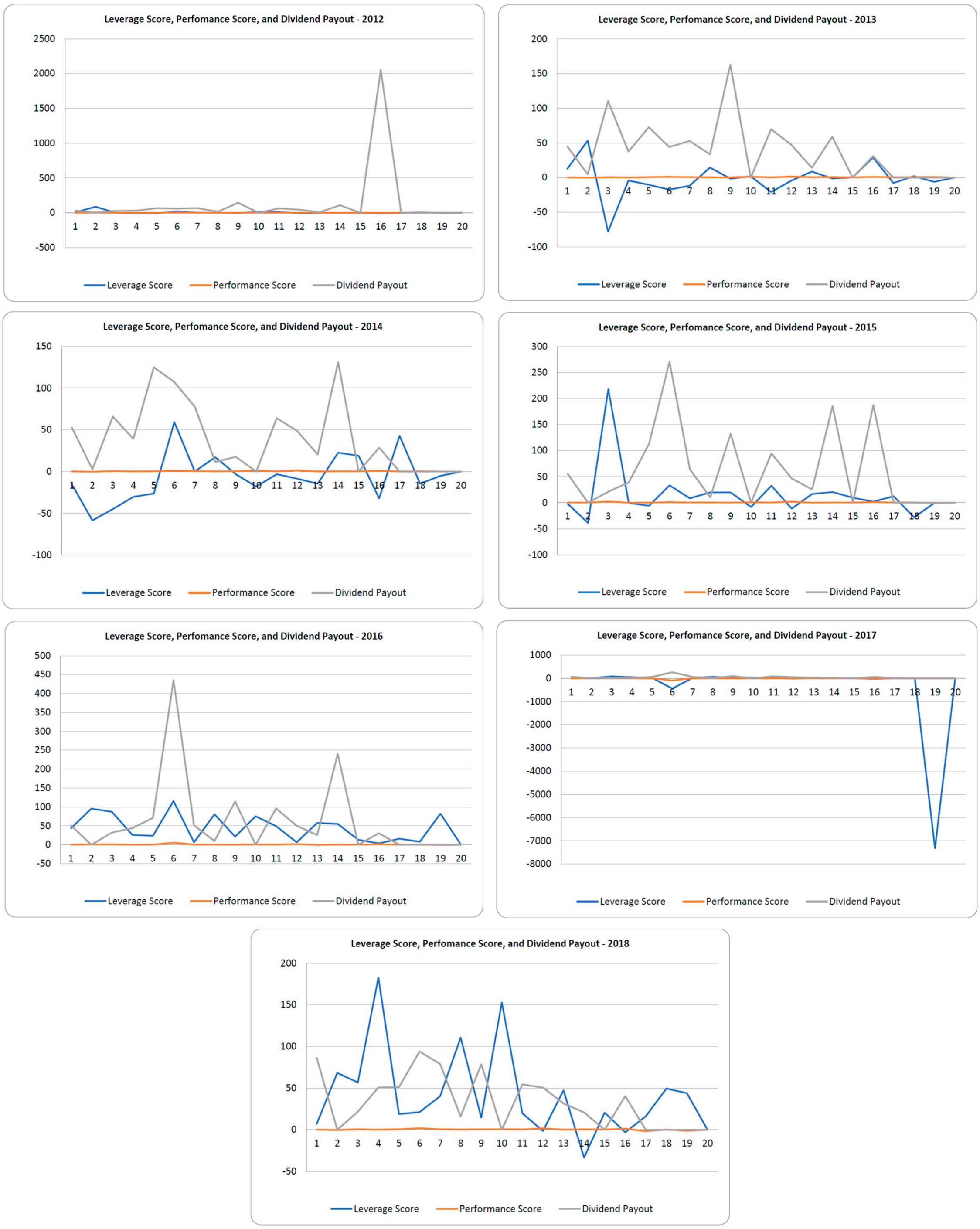


Figure 4. Companies' leverage score, performance score, and dividend payout. Source: Authors' calculations based on data from Bloomberg.

The graphs above depicting the leverage versus performance score and dividend payout for the twenty pharmaceutical companies, providing significant insights into the financial strategies and performance within the whole pharmaceutical industry over the years. As we can see from these graphs, we find that higher leverage does not consistently translate into lower performance, nor does lower leverage consistently result in higher performance. This suggests that the effective management of excess debt, rather than the absolute level of leverage, is crucial to maintaining high performance. We also see that there is noticeable volatility in leverage scores across the industry, particularly in the years surrounding economic recessions and major market shifts (e.g., the 2008 financial crisis) which aligns with the previous findings on excess debt. Companies with higher leverage often saw substantial swings in their leverage scores, indicating the sensitivity of these companies to macroeconomic conditions.

In addition, we see that despite fluctuations in leverage and performance scores, dividend payouts remained relatively stable for many companies. This indicates a commitment to returning value to shareholders, even during periods of financial strain, and an attempt to retain them and keep the stock price stable. However, in years of extreme financial stress such as the GFC, some companies reduced or suspended dividend payouts. The pharmaceutical industry, given its essential nature, tends to maintain performance even during economic downturns, though leverage scores may increase due to higher borrowing. Companies in this sector often leverage debt strategically to invest in R&D, mergers, and acquisitions, which are crucial for maintaining long-term competitiveness.

To further explore the specifics of some of the companies, we will discuss the ones that showed some interesting insights. To start with, Johnson & Johnson consistently maintained a relatively stable leverage score, coupled with strong performance metrics. Their dividend payout remained steady, reflecting their strong cash flow generation. On the other hand, Pfizer showed more variability in its leverage score, particularly during the mid-2000s. Despite this, the company managed to maintain a strong performance score, and its dividend payouts were among the most consistent, reflecting confidence in its long-term financial health. Mylan displayed one of the more volatile leverage scores, especially during the 2008 crisis. The company's performance score, however, did not drop as significantly, indicating that Mylan may have used debt to navigate through challenging periods, although at a cost of higher financial risk. Dividend payouts for Mylan were lower compared to industry leaders, likely due to the need to reinvest earnings to stabilize the balance sheet. Eli Lilly exhibited a relatively low leverage score throughout the period; their performance score remained strong, and dividend payouts were also stable. Finally, Sanofi's leverage score was higher compared to many peers, particularly in the early 2010s. However, their performance scores were also robust, and the company maintained a consistent dividend payout.

The analysis of these pharmaceutical companies highlights the diverse approaches within the industry regarding leverage and performance management. While higher leverage can pose risks, companies that manage debt effectively can still maintain strong performance and stable dividend payouts. The industry's ability to sustain dividend payouts, even during financial downturns, reflects its resilience and the importance of strategic debt management. Individual company strategies vary widely, but those that balance leverage with strong operational performance tend to deliver better long-term results.

5. Policy Implication

After our thorough analysis, the question is how should policymakers think about the pharmaceutical industry? A better understanding of these policy questions requires specific knowledge about the riskiness of the companies and the leverage level undertaken by pharmaceutical companies, as well as the profitability of these companies.

The findings of this paper suggest several policy recommendations aimed at enhancing the performance of both the pharmaceutical sector and the broader corporate sector. The main policy implication is to minimize overall risky debt and establish an optimal debt structure to prevent financial instability and potential defaults. A key challenge in formulating such a policy pertains to regulations, as it involves setting an optimal debt ratio based on a corporation's net worth. Given that higher risk often correlates with higher returns, reducing risk by securing loans, such as those provided to certain companies, presents a significant challenge.

This paper distinguishes between the optimal and actual leverage of financial institutions. Another policy challenge is to introduce and reinforce risk-weighted capital buffers and the use of collateral that can be rapidly converted into liquidity. Despite the costs associated with repossession, collateral remains a potent tool for ensuring stability. Policymakers should mandate higher collateral for riskier borrowers and financial institutions vulnerable to shocks, such as fluctuations in oil prices or crises like the GFC and COVID-19 pandemic.

Furthermore, when companies recognize that they are burdened by excessive debt, the focus should shift from maximizing profits to ensuring stability. Companies can take corrective actions by maintaining cash flow, increasing capital reserves, and limiting lending to high-risk borrowers. Balancing actual and optimal debt levels is critical for maintaining financial stability and reducing the risk of financial distress. Investors tend to favor companies with robust debt management practices, as these reflect sound financial strategies and long-term sustainability.

The analysis of the 20 pharmaceutical companies in this study shows that most manage their debt levels effectively, keeping actual debt within or below optimal levels. However, continuous monitoring and adjustment of debt strategies are necessary to ensure financial health and maintain investor confidence. Strategic debt management, aligned with operational cash flows and profitability, is crucial for sustaining growth and stability in the competitive pharmaceutical industry.

It should be noted that the pharmaceutical sector operates within a complex ecosystem where interactions with adjacent industries, notably healthcare and technology, play a significant role in shaping financial decisions, including capital structure and leverage. (Hunter and Stephens 2010). As pharmaceutical firms seek to innovate and commercialize products, they often depend on partnerships across these sectors, which can significantly impact their leverage decisions. Partnerships between pharmaceutical companies and technology firms have become increasingly important, especially in recent years with the rise of digital health, AI, and big data. For example, collaborations such as the one between GlaxoSmithKline (GSK) and Google's life sciences subsidiary, Verily, aim to leverage data analytics for drug discovery and development.

The interdependencies between pharmaceutical companies and other sectors influence their financial stability and risk management approaches. For example, reliance on healthcare sector policies can introduce regulatory risks, while partnerships with tech firms may expose companies to cybersecurity and data privacy risks. Consequently, companies may adjust their debt levels to ensure sufficient cash reserves for managing these sector-specific risks.

6. Conclusions

This study presented a model that helps identify the early warning signs of a financial crisis in the pharmaceutical industry based on the presence of excess debt or what is called overleveraging. We presented a measure of overleveraging defined as the difference between actual and sustainable debt. Furthermore, we conducted an empirical study on overleveraging for 20 companies and studied the vulnerabilities of the companies.

As results showed, the actual debt levels in the pharmaceutical industry have shown significant fluctuations over time, with an overall increasing trend, particularly after 2013. These fluctuations likely result from various external economic factors and internal policy changes impacting debt management. In contrast, the optimal debt ratios exhibited some volatility, frequently oscillating without a consistent trend. This suggests that optimal debt targets are subject to frequent adjustments, especially during economic downturns when lending becomes scarce, and the cost of debt rises.

The increasing leverage in the pharmaceutical industry post-2013 has been primarily driven by M&A, as companies sought growth through acquiring new products, technologies, and expanding market share. Favorable borrowing conditions, particularly the low interest rates following the 2008 financial crisis, further incentivized this trend, enabling companies to finance expansions and refinance existing debt at a lower cost. Additionally, the competitive nature of the industry has pushed companies to invest heavily in R&D, with leveraging debt providing the necessary financial resources for innovation and maintaining a robust pipeline of new products.

Therefore, pharmaceutical companies should revisit their strategies to provide higher returns while maintaining financial stability.

While the paper focuses on the pharmaceutical sector, it seeks to contribute more broadly to the literature by highlighting how industry-specific risks, particularly those arising from R&D intensity and regulatory pressures, uniquely impact leverage dynamics.

7. Limitations

Although the study provides a robust analysis of the leverage and associated potential risks of bankruptcies in the pharmaceutical sector, several limitations merit consideration. Firstly, the study's sample size of 20 firms may be insufficient to capture the diversity and complexity of the entire industry. A more extensive and varied sample would enhance the external validity of the study; however, it is essential to note that this concentration on top-tier companies allows for a detailed, high-quality analysis that provides actionable insights. Including smaller firms with less comprehensive data or significantly different financial characteristics could dilute the study's focus and reduce its applicability to major policy and investment decisions. Furthermore, the extensive data requirements for our dynamic calculation of optimal debt ratios were time-consuming and necessitated the use of high-quality, reliable data, which are more readily available for the largest pharmaceutical firms. This ensures the robustness and accuracy of our findings.

Secondly, the study's reliance on historical fiscal data from 2000 to 2018 introduces a temporal limitation. Economic conditions, regulatory landscapes, and market dynamics can evolve over time; however, addressing these factors in depth falls outside the scope of our paper. Our study's primary objective is to analyze trends in overleveraging within the pharmaceutical sector by employing a dynamic model to calculate optimal debt ratios. While the model incorporates key variables such as capital productivity, market interest rates, and capital gains to provide robust insights into debt behavior, it does not explicitly aim to forecast future trends or control for exogenous changes in regulatory or economic environments.

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Appendix A

Mathematical Derivation of Stein's (2012a) Optimal Debt.

Here, Stein shows how the optimal debt ratio is derived in the logarithm case.

The stochastic differential Equation is (A1)

$$dX(t) = X(t)\left[(1 + f(t))\left(\frac{dP(t)}{P(t)} + \beta(t)dt\right) - i(t)f(t) - cdt\right] \tag{A1}$$

where the debt ratio is $f(t) = \frac{L(t)}{X(t)} = \frac{Debt}{Net\ Worth}$; capital gain or loss is $\frac{dP(t)}{P(t)}$; productivity of capital is $\beta(t) = \frac{Income}{Assets}$; interest rate is $i(t)$; $(1 + f(t)) = \frac{Assets}{Net\ Worth}$; ratio of consumption is $c = \frac{(Consumption\ or\ Dividends)}{Net\ Worth}$ and is taken as given.

Let the price evolve as follows:

$$dP(t) = P(t)\big(\alpha(t)dt + o_p dw_p(t)\big) \tag{A2}$$

where $\alpha(t)$ represents the asset's drift component, and the interest rate is represented by the sum of i and a Brownian Motion term as follows:

$$i(t) = idt + o_i dw_i(t) \tag{A3}$$

Substituting (A2) and (A3) in (A1) and deriving (A4),

$$\begin{gathered} dX(t) = X(t)\big[(1 + f(t))\big(\big(\alpha(t)dt + o_p dw_p(t)\big) + \beta(t)dt\big) - i(t)f(t)dt - cdt\big] \\ dX(t) = X(t)(Mf(t))dt + X(t)\beta f(t) \end{gathered} \tag{A4}$$

$$\begin{gathered} Mf(t) = [(1 + f(t))((\alpha(t)dt) + \beta(t)dt) - i(t)f(t)dt - cdt] \\ \beta(t) = \big[(1 + f(t))o_p dw_p - o_i f(t)dw_i(t)\big] \\ \beta^2 f(t) = \left[\left(1 + f(t)^2\right)o^2{}_p\, dt + f(t)^2 o^2{}_i\, dt - 2f(t)(1 + f(t))o_i o_p dw_p dw_i\right] \\ \text{Risk} = Rf(t) = \left(\tfrac{1}{2}\right)\left[\left(1 + f(t)^2\right)o^2{}_p\, dt + f(t)^2 o^2{}_i\, dt - 2f(t)(1 + f(t))o_i o_p\right] \end{gathered}$$

$Mf(t)$ contains the deterministic terms, and $\beta(t)$ contains the stochastic terms. To solve for $X(t)$, consider the change in $ln\ X(t)$ in (A5). This is based upon the Ito equation of stochastic calculus. A great virtue of using the logarithm criterion is that one does not need to use dynamic programming. The expectation of $dlnX(t)$ is (A6).

$$dlnX(t) = \left(\frac{1}{X(t)}\right)dXt - (\frac{1}{2}X(t)^2)(dx(t)^2) \tag{A5}$$

$$E[d(lnX(t))] = [Mf(t)] - R[f(t)]dt \tag{A6}$$

The correlation $\rho dt = E\big(dw_p dw_i\big)$ is negative, which increases risk. $(dt)^2 = 0$, $dwdt = 0$.

The optimal debt ratio f^* maximizes the difference between the mean and risk.

$$\begin{gathered} f^* = argmax_f[M(f(t)) - R(f(t))] = [\alpha(t) + \beta(t) - i] - [\left(\frac{(\sigma_p^2 - \rho\sigma_i\sigma_{p)}}{\sigma^2}\right)] \\ f^* = argmax_f[M(f(t)) - R(f(t))] = f^*(t) = \{(r - i) + \beta - \alpha y(t) - (\frac{1/2(\sigma_p^2 - \rho_{ip}\sigma_i\sigma_{p)}}{\sigma^2})\} \end{gathered} \tag{A7}$$

s.t.

$$Risk = \sigma^2 = \sigma_i{}^2 + \sigma_p{}^2 - \big(2\rho_{ip}\sigma_i\sigma_p\big)$$

Model I:

Model I assumes that the price $P(t)$ has a trend rt and a deviation $Y(t)$ from it (A8). The deviation $Y(t)$ follows an Ornstein–Uhlenbeck ergodic mean reverting process (A9). Coefficient α is positive and finite. The interest rate is the same as in model II.

$$P(t) = Pexp(rt + y(t)) \tag{A8}$$

The deviation from the trend is demonstrated through the following:

$$y(t) = ln\ P(t) - ln\ P - rt$$

The mean reversion aspect characterized by a convergence of α is defined as follows:

$$dy(t) = -\alpha(t)dt + o_p dw_p(t) \tag{A9}$$

In this model, Stein defines E(dw) = 0; $E(dw)^2 = dt$

$$limy(t) \sim N\left(0, \frac{o^2}{2\alpha}\right)$$

Stein constrains the solution such that r $\leq i$ and calls this the "No free lunch constraint". Therefore, using the stochastic calculus in model I as the first term in (A10),

$$\begin{aligned} dP(t) &= P(t)\big(\alpha(t)dt + o_p dw_p(t)\big) \\ dP(t)/P(t) &= \left(r - \alpha y(t) + \tfrac{1}{2}{o_p}^2\right)dt + o_p dw_p \end{aligned} \tag{A10}$$

where $\alpha(t)$ represents the asset's drift component, and the interest rate is represented by the sum of i and a Brownian Motion term as follows:

$$i(t) = idt + o_i dw_i(t)$$

Substituting (A10) in (A7) and deriving (A11), the optimal debt ratio in model I is as follows:

$$f^*(t) = [(r - i) + \beta - \alpha y(t) - \frac{\left(\frac{1}{2}\right)\left(o_p^2 - o_i o_p \rho\right)}{o^2}] \tag{A11}$$

Consider $\beta(t)$ as deterministic.

Model II:

In model II, the price equation is (A12). The drift is $\alpha(t)dt = \pi dt$, and the diffusion is $o_p dw_p$.

$$dP(t)/P(t) = \pi dt + o_p dw_p \tag{A12}$$

The optimal debt ratio $f^*(t)$ is (A13). Consider $\beta(t)$ as deterministic.

$$f^*(t) = [(\pi + \beta(t) - i) - \frac{\left(o_p^2 - o_i o_p \rho\right)}{o^2}] \tag{A13}$$

s.t.

$$\sigma^2 = {\sigma_i}^2 + {\sigma_p}^2 - \left(2\rho_{ip}\sigma_i\sigma_p\right)$$

In terms of a maximization portfolio decision, we have the following:

$$[\alpha_t \ (E(R_{t+1}) - R_{F,\ t+1}) - \frac{k}{2}\alpha_t^2\sigma_t^2] \quad \text{(A14)}$$

Appendix B

Table A1. List of companies.

Company Name
1. Abbott Laboratories (ABT)
2. Adobe Powers Digital Healthcare Innovation (ADBE)
3. Akorn, Inc. (AKRX)
4. Allergan, Inc. (AGN)
5. AmerisourceBergen Corp (ABC)
6. Cardinal Health, Inc. (CAH)
7. Dr. Reddy's Laboratories Ltd. (RDY)
8. Eli Lilly and Company (LLY)
9. Endo International Plc. (ENDP)
10. GlaxoSmithKline Plc. (GSK)
11. Johnson & Johnson (JNJ)
12. McKesson Corporation (MCK)
13. Merck & Company, Inc. (MRK)
14. Mylan Inc. (MYL)
15. Novartis AG (NVS)
16. Novo Nordisk (NVO)
17. Perrigo Company (PRGO)
18. Pfizer, Inc. (PFE)
19. Sanofi (SNY)
20. Zoetis Inc. (ZTS)

Source: Bloomberg. Note: The industry sub-sample includes the top twenty publicly traded companies (depending on data availability) based on their market capitalization and total assets compared to others in the respective industry.

Appendix C

Table A2. Calculations of optimal and excess debt: MRK. (* means: f* is optimal debt while f is just debt.)

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance (αy(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, $f^{*}(t)$	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
MRK	2000	0.380637	0.0258	1.457089	0.651	0.072	0.06	(0.0098)	0.326002	(0.0002)	0.0133	0.2999	(0.0004)	0.314	3.47	1.11	0.259266	(0.95)	(2.06)
	2001	−0.38145	0.0243	1.596219	0.791	0.073	0.06	(0.0113)	0.063625	(0.0000)	0.0133	0.2999	(0.0001)	0.313	1.04	(1.65)	0.263026	(0.87)	0.77
	2002	−0.049	0.0209	1.517071	0.711	0.001	0.06	(0.0147)	1.220455	(0.0011)	0.0133	0.2999	(0.0021)	0.315	2.33	(0.19)	0.253509	(1.06)	(0.87)
	2003	−0.19233	0.0188	0.757817	(0.048)	0.018	0.06	(0.0168)	−0.17977	0.0002	0.0133	0.2999	0.0004	0.313	1.84	(0.74)	0.283986	(0.47)	0.27
	2004	−0.30844	0.0286	0.741791	(0.064)	0.048	0.06	(0.0070)	−0.02925	0.0000	0.0133	0.2999	0.0000	0.313	1.34	(1.31)	0.261519	(0.90)	0.40
	2005	−0.02224	0.0191	0.680445	(0.125)	0.000	0.06	(0.0165)	0.289487	(0.0003)	0.0133	0.2999	(0.0006)	0.314	2.43	(0.06)	0.250157	(1.12)	(1.06)
	2006	0.361757	0.0197	0.706944	(0.099)	0.065	0.06	(0.0159)	−0.23071	0.0002	0.0133	0.2999	0.0004	0.313	3.46	1.11	0.266577	(0.81)	(1.91)
	2007	0.335699	0.0339	0.708388	(0.097)	0.056	0.06	(0.0017)	−0.61418	0.0001	0.0133	0.2999	0.0001	0.313	3.36	0.99	0.320597	0.23	(0.76)
	2008	−0.49246	0.0373	0.704118	(0.102)	0.121	0.06	0.0017	0.844034	0.0001	0.0133	0.2999	0.0002	0.313	0.49	(2.28)	0.248114	(1.16)	1.11
	2009	0.772557	0.0252	0.343243	(0.462)	0.298	0.06	(0.0104)	0.032726	(0.0000)	0.0133	0.2999	(0.0000)	0.313	4.01	1.73	0.3133	0.09	(1.64)
	2010	−0.02197	0.0374	0.615651	(0.190)	0.000	0.06	0.0018	−0.56458	(0.0001)	0.0133	0.2999	(0.0001)	0.313	2.38	(0.13)	0.315132	0.13	0.25
	2011	0.032054	0.0476	0.649622	(0.156)	0.001	0.06	0.0120	1.136156	0.0008	0.0133	0.2999	0.0016	0.312	2.54	0.05	0.30382	(0.09)	(0.14)
	2012	0.080869	0.0442	0.639647	(0.166)	0.003	0.06	0.0086	0.317886	0.0002	0.0133	0.2999	0.0003	0.313	2.68	0.22	0.304536	(0.08)	(0.30)
	2013	0.182489	0.0422	0.608262	(0.197)	0.017	0.06	0.0066	0.14084	0.0001	0.0133	0.2999	0.0001	0.313	2.97	0.54	0.335567	0.52	(0.03)
	2014	0.10002	0.0415	0.643107	(0.163)	0.005	0.06	0.0059	−0.07144	(0.0000)	0.0133	0.2999	(0.0001)	0.313	2.74	0.29	0.315574	0.13	(0.15)
	2015	−0.08859	0.0405	0.608293	(0.197)	0.004	0.06	0.0049	0.271684	0.0001	0.0133	0.2999	0.0002	0.313	2.15	(0.39)	0.370871	1.20	1.59
	2018	0.101557	0.0504	0.668161	(0.138)	0.005	0.06	0.0148	−0.15986	(0.0001)	0.0133	0.2999	(0.0003)	0.313	2.72	0.26	0.397003	1.70	1.44
	2017	−0.06229	0.0516	0.749622	(0.056)	0.002	0.06	0.0160	−0.15986	(0.0002)	0.0133	0.2999	(0.0003)	0.313	2.20	(0.33)	0.394767	1.65	1.99
	2018	0.30552	0.0666	0.912492	0.107	0.047	0.06	0.0310	−0.15986	(0.0003)	0.0133	0.2999	(0.0006)	0.314	3.18	0.78	0.40598	1.87	1.09

Table A3. Calculations of optimal and excess debt: MYL.

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance (αγ(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, $f^*(t)$	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
MYL	2000	0.004639	0.0258	0.625369	(0.087)	0.000	(0.24)	(0.0098)	0.326002	0.0008	0.0133	0.3512	0.0015	0.363	1.91	(0.15)	0.037084	(1.35)	(1.20)
	2001	−0.09216	0.0243	0.663316	(0.049)	0.004	(0.24)	(0.0113)	0.063625	0.0002	0.0133	0.3512	0.0003	0.364	1.62	(0.51)	0.028755	(1.38)	(0.87)
	2002	0.729036	0.0209	0.739587	0.027	0.266	(0.24)	(0.0147)	1.220455	0.0043	0.0133	0.3512	0.0087	0.356	3.26	1.61	0.026295	(1.39)	(3.00)
	2003	−0.06738	0.0188	0.812143	0.100	0.002	(0.24)	(0.0168)	−0.17977	(0.0007)	0.0133	0.3512	(0.0015)	0.366	1.70	(0.41)	0.018978	(1.42)	(1.01)
	2004	0.171347	0.0286	0.786745	0.075	0.015	(0.24)	(0.0070)	−0.02925	(0.0000)	0.0133	0.3512	(0.0001)	0.365	2.30	0.37	0.022255	(1.41)	(1.78)
	2005	−0.21785	0.0191	0.64218	(0.070)	0.024	(0.24)	(0.0165)	0.289487	0.0012	0.0133	0.3512	0.0023	0.362	1.25	(1.00)	0.02071	(1.42)	(0.42)
	2006	0.030615	0.0197	0.974048	0.262	0.000	(0.24)	(0.0159)	−0.23071	(0.0009)	0.0133	0.3512	(0.0018)	0.366	1.97	(0.06)	0.43711	0.36	0.42
	2007	−0.12986	0.0339	0.308016	(0.404)	0.008	(0.24)	(0.0017)	−0.61418	(0.0002)	0.0133	0.3512	(0.0005)	0.365	1.48	(0.70)	0.52083	0.72	1.42
	2008	−0.29576	0.0373	0.814779	0.103	0.044	(0.24)	0.0017	0.844034	(0.0004)	0.0133	0.3512	(0.0007)	0.365	0.92	(1.43)	0.583905	0.98	2.42
	2009	0.874213	0.0252	0.762418	0.050	0.382	(0.24)	(0.0104)	0.032726	0.0001	0.0133	0.3512	0.0002	0.364	3.24	1.59	0.549763	0.84	(0.75)
	2010	0.631405	0.0374	0.748061	0.036	0.199	(0.24)	0.0018	−0.56458	0.0003	0.0133	0.3512	0.0005	0.364	3.04	1.33	0.529765	0.75	(0.58)
	2011	−0.00635	0.0476	0.853926	0.142	0.000	(0.24)	0.0120	1.136156	(0.0033)	0.0133	0.3512	(0.0066)	0.371	1.76	(0.33)	0.476818	0.53	0.86
	2012	0.184771	0.0442	0.938942	0.227	0.017	(0.24)	0.0086	0.317886	(0.0007)	0.0133	0.3512	(0.0013)	0.366	2.28	0.34	0.534916	0.78	0.43
	2013	0.486638	0.0422	0.806563	0.094	0.118	(0.24)	0.0066	0.14084	(0.0002)	0.0133	0.3512	(0.0005)	0.365	2.84	1.07	0.612685	1.11	0.03
	2014	0.311498	0.0415	0.859337	0.147	0.049	(0.24)	0.0059	−0.07144	0.0001	0.0133	0.3512	0.0002	0.364	2.56	0.71	0.457666	0.45	(0.26)
	2015	0.254183	0.0405	0.612165	(0.100)	0.032	(0.24)	0.0049	0.271684	(0.0003)	0.0133	0.3512	(0.0006)	0.365	2.45	0.56	0.376316	0.10	(0.46)
	2018	−0.23013	0.0504	0.499443	(0.213)	0.026	(0.24)	0.0148	−0.15986	0.0006	0.0133	0.3512	0.0011	0.363	1.12	(1.17)	0.534694	0.77	1.95
	2017	0.086004	0.0516	0.533797	(0.178)	0.004	(0.24)	0.0160	−0.15986	0.0006	0.0133	0.3512	0.0012	0.363	2.05	0.04	0.450016	0.41	0.38
	2018	−0.36279	0.0666	0.549851	(0.162)	0.066	(0.24)	0.0310	−0.15986	0.0012	0.0133	0.3512	0.0024	0.362	0.60	(1.84)	0.488164	0.58	2.42

Table A4. Calculations of optimal and excess debt: NVO.

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance ($\alpha\gamma$(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, f^*(t)	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
NVO	2000	0.434895	0.0258	1.041069	(0.267)	0.095	(0.23)	(0.0098)	0.326002	0.0007	0.0133	0.3197	0.0014	0.332	4.90	0.88	0.099337	0.92	0.04
	2001	0.072557	0.0243	0.992329	(0.315)	0.003	(0.23)	(0.0113)	0.063625	0.0002	0.0133	0.3197	0.0003	0.333	4.07	(0.13)	0.090849	0.57	0.70
	2002	−0.29329	0.0209	0.846677	(0.461)	0.043	(0.23)	(0.0147)	1.220455	0.0040	0.0133	0.3197	0.0081	0.325	2.94	(1.50)	0.082518	0.23	1.73
	2003	0.401592	0.0188	0.811105	(0.497)	0.081	(0.23)	(0.0168)	−0.17977	(0.0007)	0.0133	0.3197	(0.0014)	0.334	4.81	0.78	0.079736	0.11	(0.66)
	2004	0.344758	0.0286	0.847303	(0.460)	0.059	(0.23)	(0.0070)	−0.02925	(0.0000)	0.0133	0.3197	(0.0001)	0.333	4.70	0.64	0.097481	0.84	0.21
	2005	−0.05849	0.0191	1.043968	(0.264)	0.002	(0.23)	(0.0165)	0.289487	0.0011	0.0133	0.3197	0.0022	0.331	3.72	(0.56)	0.089252	0.50	1.06
	2006	0.540929	0.0197	1.009346	(0.298)	0.146	(0.23)	(0.0159)	−0.23071	(0.0008)	0.0133	0.3197	(0.0017)	0.335	5.03	1.03	0.098743	0.90	(0.14)
	2007	0.451363	0.0339	1.009326	(0.298)	0.102	(0.23)	(0.0017)	−0.61418	(0.0002)	0.0133	0.3197	(0.0005)	0.333	4.87	0.84	0.102826	1.07	0.22
	2008	−0.24084	0.0373	1.17937	(0.128)	0.029	(0.23)	0.0017	0.844034	(0.0003)	0.0133	0.3197	(0.0007)	0.334	3.00	(1.43)	0.092208	0.63	2.06
	2009	0.216628	0.0252	1.189375	(0.118)	0.023	(0.23)	(0.0104)	0.032726	0.0001	0.0133	0.3197	0.0002	0.333	4.43	0.32	0.10217	1.04	0.72
	2010	0.800299	0.0374	1.35221	0.045	0.320	(0.23)	0.0018	−0.56458	0.0002	0.0133	0.3197	0.0005	0.333	5.26	1.33	0.097082	0.83	(0.50)
	2011	−0.01383	0.0476	1.485853	0.178	0.000	(0.23)	0.0120	1.136156	(0.0031)	0.0133	0.3197	(0.0062)	0.339	3.67	(0.62)	0.100019	0.95	1.57
	2012	0.360295	0.0442	1.57443	0.267	0.065	(0.23)	0.0086	0.317886	(0.0006)	0.0133	0.3197	(0.0012)	0.334	4.66	0.59	0.05176	(1.04)	(1.64)
	2013	0.071428	0.0422	1.589864	0.282	0.003	(0.23)	0.0066	0.14084	(0.0002)	0.0133	0.3197	(0.0004)	0.333	4.00	(0.21)	0.050372	(1.10)	(0.89)
	2014	0.130707	0.0415	1.873632	0.566	0.009	(0.23)	0.0059	−0.07144	0.0001	0.0133	0.3197	0.0002	0.333	4.17	(0.00)	0.039955	(1.53)	(1.53)
	2015	0.348756	0.0405	1.778744	0.471	0.061	(0.23)	0.0049	0.271684	(0.0003)	0.0133	0.3197	(0.0006)	0.334	4.66	0.59	0.043105	(1.40)	(1.99)
	2018	−0.39006	0.0504	1.942669	0.635	0.076	(0.23)	0.0148	−0.15986	0.0005	0.0133	0.3197	0.0011	0.332	2.39	(2.17)	0.04956	(1.13)	1.04
	2017	0.459136	0.0516	1.618614	0.311	0.105	(0.23)	0.0160	−0.15986	0.0006	0.0133	0.3197	0.0012	0.332	4.85	0.83	0.053578	(0.97)	(1.79)
	2018	−0.17146	0.0666	1.660556	0.353	0.015	(0.23)	0.0310	−0.15986	0.0011	0.0133	0.3197	0.0022	0.331	3.19	(1.19)	0.043026	(1.40)	(0.21)

Table A5. Calculations of optimal and excess debt: NVS.

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance (αγ(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, f*(t)	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
NVS	2000	0.198219	0.0258	1.102178	0.295	0.020	(0.11)	(0.0098)	0.326002	0.0003	0.0133	0.1303	0.0007	0.143	6.72	1.22	0.165235	(0.81)	(2.03)
	2001	−0.20326	0.0243	0.872528	0.065	0.021	(0.11)	(0.0113)	0.063625	0.0001	0.0133	0.1303	0.0002	0.143	3.90	(1.96)	0.152889	(1.10)	0.86
	2002	−0.01895	0.0209	0.843186	0.036	0.000	(0.11)	(0.0147)	1.220455	0.0020	0.0133	0.1303	0.0039	0.140	5.51	(0.15)	0.186956	(0.31)	(0.17)
	2003	0.23437	0.0188	0.909313	0.102	0.027	(0.11)	(0.0168)	−0.17977	(0.0003)	0.0133	0.1303	(0.0007)	0.144	6.90	1.42	0.192185	(0.19)	(1.61)
	2004	0.059866	0.0286	0.918617	0.111	0.002	(0.11)	(0.0070)	−0.02925	(0.0000)	0.0133	0.1303	(0.0000)	0.144	5.83	0.21	0.177641	(0.53)	(0.74)
	2005	0.037326	0.0191	0.864335	0.057	0.001	(0.11)	(0.0165)	0.289487	0.0005	0.0133	0.1303	0.0010	0.142	5.79	0.17	0.16005	(0.93)	(1.10)
	2006	0.10255	0.0197	0.88579	0.079	0.005	(0.11)	(0.0159)	−0.23071	(0.0004)	0.0133	0.1303	(0.0008)	0.144	6.13	0.55	0.1541	(1.07)	(1.62)
	2007	−0.07745	0.0339	1.013227	0.206	0.003	(0.11)	(0.0017)	−0.61418	(0.0001)	0.0133	0.1303	(0.0002)	0.144	4.82	(0.92)	0.124781	(1.75)	(0.82)
	2008	−0.09442	0.0373	1.034006	0.227	0.004	(0.11)	0.0017	0.844034	(0.0002)	0.0133	0.1303	(0.0003)	0.144	4.66	(1.10)	0.145276	(1.27)	(0.18)
	2009	0.097587	0.0252	0.832402	0.025	0.005	(0.11)	(0.0104)	0.032726	0.0000	0.0133	0.1303	0.0001	0.143	6.10	0.52	0.194471	(0.14)	(0.65)
	2010	0.082993	0.0374	0.668976	(0.138)	0.003	(0.11)	0.0018	−0.56458	0.0001	0.0133	0.1303	0.0002	0.143	5.93	0.32	0.23428	0.78	0.46
	2011	0.02533	0.0476	0.804093	(0.003)	0.000	(0.11)	0.0120	1.136156	(0.0015)	0.0133	0.1303	(0.0030)	0.147	5.34	(0.33)	0.241778	0.95	1.29
	2012	0.106312	0.0442	0.731984	(0.075)	0.006	(0.11)	0.0086	0.317886	(0.0003)	0.0133	0.1303	(0.0006)	0.144	5.99	0.39	0.248625	1.11	0.72
	2013	0.277826	0.0422	0.7185	(0.089)	0.039	(0.11)	0.0066	0.14084	(0.0001)	0.0133	0.1303	(0.0002)	0.144	6.99	1.51	0.201293	0.02	(1.49)
	2014	0.150646	0.0415	0.687025	(0.120)	0.011	(0.11)	0.0059	−0.07144	0.0000	0.0133	0.1303	0.0001	0.143	6.31	0.75	0.219879	0.45	(0.31)
	2015	−0.07063	0.0405	0.645972	(0.161)	0.002	(0.11)	0.0049	0.271684	(0.0001)	0.0133	0.1303	(0.0003)	0.144	4.82	(0.92)	0.233558	0.76	1.68
	2018	−0.16908	0.0504	0.620338	(0.187)	0.014	(0.11)	0.0148	−0.15986	0.0003	0.0133	0.1303	0.0005	0.143	4.01	(1.83)	0.253789	1.23	3.06
	2017	0.134109	0.0516	0.613634	(0.194)	0.009	(0.11)	0.0160	−0.15986	0.0003	0.0133	0.1303	0.0006	0.143	6.16	0.59	0.266376	1.52	0.93
	2018	0.005773	0.0666	0.570527	(0.237)	0.000	(0.11)	0.0310	−0.15986	0.0005	0.0133	0.1303	0.0011	0.142	5.24	(0.45)	0.255999	1.28	1.73

Table A6. Calculations of optimal and excess debt: PFE.

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance (αγ(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, f*(t)	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
PFE	2000	1.326306	0.0258	1.226523	0.642	0.880	(0.06)	(0.0098)	0.326002	0.0002	0.0133	0.3510	0.0004	0.364	2.76	2.22	0.162728	(1.21)	(3.43)
	2001	−0.13877	0.0243	1.075381	0.491	0.010	(0.06)	(0.0113)	0.063625	0.0000	0.0133	0.3510	0.0001	0.364	1.13	(0.76)	0.212802	(0.89)	(0.13)
	2002	−0.24693	0.0209	1.07786	0.493	0.030	(0.06)	(0.0147)	1.220455	0.0010	0.0133	0.3510	0.0021	0.362	0.79	(1.38)	0.200521	(0.97)	0.41
	2003	0.43085	0.0188	0.515168	(0.070)	0.093	(0.06)	(0.0168)	−0.17977	(0.0002)	0.0133	0.3510	(0.0003)	0.365	2.48	1.70	0.598434	1.56	(0.13)
	2004	−0.25445	0.0286	0.562993	(0.022)	0.032	(0.06)	(0.0070)	−0.02925	(0.0000)	0.0133	0.3510	(0.0000)	0.364	0.74	(1.48)	0.247896	(0.67)	0.81
	2005	−0.14576	0.0191	0.532288	(0.053)	0.011	(0.06)	(0.0165)	0.289487	0.0003	0.0133	0.3510	0.0005	0.364	1.13	(0.77)	0.184373	(1.08)	(0.30)
	2006	0.074876	0.0197	0.505952	(0.079)	0.003	(0.06)	(0.0159)	−0.23071	(0.0002)	0.0133	0.3510	(0.0004)	0.365	1.75	0.36	0.188211	(1.05)	(1.41)
	2007	−0.16711	0.0339	0.542083	(0.043)	0.014	(0.06)	(0.0017)	−0.61418	(0.0001)	0.0133	0.3510	(0.0001)	0.364	1.01	(0.98)	0.245002	(0.69)	0.29
	2008	−0.22258	0.0373	0.5983	0.013	0.025	(0.06)	0.0017	0.844034	(0.0001)	0.0133	0.3510	(0.0002)	0.364	0.82	(1.33)	0.229023	(0.79)	0.54
	2009	0.228687	0.0252	0.342685	(0.242)	0.026	(0.06)	(0.0104)	0.032726	0.0000	0.0133	0.3510	0.0000	0.364	2.09	0.99	0.767247	2.64	1.65
	2010	−0.0443	0.0374	0.489881	(0.095)	0.001	(0.06)	0.0018	−0.56458	0.0001	0.0133	0.3510	0.0001	0.364	1.38	(0.31)	0.366816	0.09	0.40
	2011	0.168457	0.0476	0.498686	(0.086)	0.014	(0.06)	0.0120	1.136156	(0.0008)	0.0133	0.3510	(0.0016)	0.366	1.89	0.62	0.392136	0.25	(0.37)
	2012	0.113188	0.0442	0.422721	(0.162)	0.006	(0.06)	0.0086	0.317886	(0.0002)	0.0133	0.3510	(0.0003)	0.365	1.78	0.41	0.398581	0.29	(0.12)
	2013	0.074115	0.0422	0.41656	(0.168)	0.003	(0.06)	0.0066	0.14084	(0.0001)	0.0133	0.3510	(0.0001)	0.364	1.69	0.25	0.388137	0.22	(0.02)
	2014	−0.00019	0.0415	0.424702	(0.160)	0.000	(0.06)	0.0059	−0.07144	0.0000	0.0133	0.3510	0.0000	0.364	1.49	(0.11)	0.43206	0.50	0.61
	2015	0.017168	0.0405	0.44967	(0.135)	0.000	(0.06)	0.0049	0.271684	(0.0001)	0.0133	0.3510	(0.0002)	0.364	1.54	(0.02)	0.43556	0.53	0.54
	2018	−0.01091	0.0504	0.47699	(0.108)	0.000	(0.06)	0.0148	−0.15986	0.0001	0.0133	0.3510	0.0003	0.364	1.44	(0.20)	0.481895	0.82	1.02
	2017	0.09843	0.0516	0.447701	(0.137)	0.005	(0.06)	0.0160	−0.15986	0.0001	0.0133	0.3510	0.0003	0.364	1.72	0.32	0.406223	0.34	0.02
	2018	0.152326	0.0666	0.505172	(0.080)	0.012	(0.06)	0.0310	−0.15986	0.0003	0.0133	0.3510	0.0006	0.364	1.81	0.48	0.371403	0.12	(0.36)

Table A7. Calculations of optimal and excess debt: PRGO.

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance (αγ(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, f*(t)	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
PRGO	2000	−0.26088	0.0258	1.919311	0.788	0.034	(0.17)	(0.0098)	0.326002	0.0005	0.0133	0.5645	0.0011	0.577	1.41	(0.99)	0.04004	(1.58)	(0.59)
	2001	1.664935	0.0243	1.717543	0.587	1.386	(0.17)	(0.0113)	0.063625	0.0001	0.0133	0.5645	0.0002	0.577	2.40	0.70	0.031737	(1.64)	(2.34)
	2002	−0.2371	0.0209	1.748667	0.618	0.028	(0.17)	(0.0147)	1.220455	0.0031	0.0133	0.5645	0.0062	0.572	1.48	(0.86)	0.040998	(1.58)	(0.72)
	2003	0.174721	0.0188	1.635157	0.504	0.015	(0.17)	(0.0168)	−0.17977	(0.0005)	0.0133	0.5645	(0.0010)	0.579	2.20	0.36	0.045039	(1.55)	(1.91)
	2004	0.209592	0.0286	1.488981	0.358	0.022	(0.17)	(0.0070)	−0.02925	(0.0000)	0.0133	0.5645	(0.0001)	0.578	2.23	0.42	0.046603	(1.54)	(1.96)
	2005	−0.00572	0.0191	0.951311	(0.180)	0.000	(0.17)	(0.0165)	0.289487	0.0008	0.0133	0.5645	0.0016	0.576	1.92	(0.11)	0.453729	0.96	1.07
	2006	0.122749	0.0197	1.236032	0.105	0.008	(0.17)	(0.0159)	−0.23071	(0.0006)	0.0133	0.5645	(0.0013)	0.579	2.12	0.22	0.42182	0.77	0.54
	2007	0.22234	0.0339	1.150897	0.020	0.025	(0.17)	(0.0017)	−0.61418	(0.0002)	0.0133	0.5645	(0.0004)	0.578	2.24	0.43	0.410797	0.70	0.27
	2008	0.660915	0.0373	1.056053	(0.075)	0.218	(0.17)	0.0017	0.844034	(0.0003)	0.0133	0.5645	(0.0005)	0.578	2.66	1.14	0.448222	0.93	(0.21)
	2009	−0.15632	0.0252	1.370639	0.240	0.012	(0.17)	(0.0104)	0.032726	0.0001	0.0133	0.5645	0.0001	0.578	1.62	(0.62)	0.425147	0.79	1.41
	2010	1.118007	0.0374	1.226116	0.095	0.625	(0.17)	0.0018	−0.56458	0.0002	0.0133	0.5645	0.0004	0.577	2.75	1.30	0.351416	0.33	(0.96)
	2011	0.467732	0.0476	1.331861	0.201	0.109	(0.17)	0.0120	1.136156	(0.0024)	0.0133	0.5645	(0.0047)	0.582	2.47	0.82	0.329924	0.20	(0.62)
	2012	0.384204	0.0442	1.204205	0.073	0.074	(0.17)	0.0086	0.317886	(0.0005)	0.0133	0.5645	(0.0009)	0.579	2.41	0.73	0.377411	0.49	(0.23)
	2013	0.032617	0.0422	1.014153	(0.117)	0.001	(0.17)	0.0066	0.14084	(0.0002)	0.0133	0.5645	(0.0003)	0.578	1.94	(0.08)	0.424003	0.78	0.86
	2014	1.052254	0.0415	0.330254	(0.801)	0.554	(0.17)	0.0059	−0.07144	0.0001	0.0133	0.5645	0.0001	0.578	2.75	1.30	0.329299	0.20	(1.10)
	2015	−0.11386	0.0405	0.317706	(0.813)	0.006	(0.17)	0.0049	0.271684	(0.0002)	0.0133	0.5645	(0.0005)	0.578	1.68	(0.53)	0.345775	0.30	0.83
	2018	−0.4236	0.0504	0.568748	(0.562)	0.090	(0.17)	0.0148	−0.15986	0.0004	0.0133	0.5645	0.0008	0.577	0.98	(1.71)	0.438079	0.87	2.57
	2017	0.028231	0.0516	0.601815	(0.529)	0.000	(0.17)	0.0160	−0.15986	0.0004	0.0133	0.5645	0.0009	0.577	1.92	(0.11)	0.345883	0.30	0.41
	2018	−0.57089	0.0666	0.617978	(0.513)	0.163	(0.17)	0.0310	−0.15986	0.0009	0.0133	0.5645	0.0017	0.576	0.58	(2.40)	0.343965	0.29	2.69

Table A8. Calculations of optimal and excess debt: RDY.

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance (αγ(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, f*(t)	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
RDY	2000		0.0258		(1.049)	0.000	(0.12)	(0.0098)	0.326002	0.0004	0.0133	0.5658	0.0007	0.578	1.77	0.06		(1.13)	(1.19)
	2001		0.0243		(1.049)	0.000	(0.12)	(0.0113)	0.063625	0.0001	0.0133	0.5658	0.0002	0.579	1.77	0.06		(1.13)	(1.19)
	2002		0.0209	1.150896	0.102	0.000	(0.12)	(0.0147)	1.220455	0.0021	0.0133	0.5658	0.0042	0.575	1.79	0.12	0.030731	(0.87)	(0.98)
	2003	−0.14135	0.0188	0.99516	(0.054)	0.010	(0.12)	(0.0168)	−0.17977	(0.0004)	0.0133	0.5658	(0.0007)	0.580	1.52	(0.60)	0.017886	(0.98)	(0.37)
	2004	0.156803	0.0286	0.905594	(0.144)	0.012	(0.12)	(0.0070)	−0.02925	(0.0000)	0.0133	0.5658	(0.0000)	0.579	2.01	0.69	0.032006	(0.86)	(1.54)
	2005	−0.2436	0.0191	0.837457	(0.212)	0.030	(0.12)	(0.0165)	0.289487	0.0006	0.0133	0.5658	0.0011	0.578	1.31	(1.13)	0.014121	(1.01)	0.13
	2006	0.88953	0.0197	0.626553	(0.423)	0.396	(0.12)	(0.0159)	−0.23071	(0.0004)	0.0133	0.5658	(0.0009)	0.580	2.63	2.28	0.469234	2.83	0.56
	2007	0.151386	0.0339	1.151877	0.103	0.011	(0.12)	(0.0017)	−0.61418	(0.0001)	0.0133	0.5658	(0.0002)	0.579	1.99	0.64	0.294861	1.36	0.72
	2008	−0.1187	0.0373	0.876615	(0.173)	0.007	(0.12)	0.0017	0.844034	(0.0002)	0.0133	0.5658	(0.0003)	0.579	1.53	(0.57)	0.258584	1.06	1.62
	2009	−0.34338	0.0252	1.650298	0.601	0.059	(0.12)	(0.0104)	0.032726	0.0000	0.0133	0.5658	0.0001	0.579	1.07	(1.75)	0.201998	0.58	2.33
	2010	1.942169	0.0374	1.185645	0.136	1.886	(0.12)	0.0018	−0.56458	0.0001	0.0133	0.5658	0.0002	0.579	1.85	0.25	0.104482	(0.24)	(0.50)
	2011	0.299158	0.0476	1.176517	0.127	0.045	(0.12)	0.0120	1.136156	(0.0016)	0.0133	0.5658	(0.0032)	0.582	2.15	1.05	0.080631	(0.45)	(1.50)
	2012	−0.05596	0.0442	1.325577	0.276	0.002	(0.12)	0.0086	0.317886	(0.0003)	0.0133	0.5658	(0.0006)	0.580	1.63	(0.29)	0.153989	0.17	0.47
	2013	−0.06252	0.0422	1.149836	0.101	0.002	(0.12)	0.0066	0.14084	(0.0001)	0.0133	0.5658	(0.0002)	0.579	1.63	(0.31)	0.109701	(0.20)	0.11
	2014	0.322499	0.0415	1.051667	0.002	0.052	(0.12)	0.0059	−0.07144	0.0000	0.0133	0.5658	0.0001	0.579	2.21	1.19	0.148975	0.13	(1.06)
	2015	0.310022	0.0405	1.03149	(0.018)	0.048	(0.12)	0.0049	0.271684	(0.0002)	0.0133	0.5658	(0.0003)	0.579	2.19	1.15	0.099942	(0.28)	(1.44)
	2018	−0.1794	0.0504	1.034985	(0.014)	0.016	(0.12)	0.0148	−0.15986	0.0003	0.0133	0.5658	0.0006	0.579	1.39	(0.93)	0.071978	(0.52)	0.41
	2017	−0.14079	0.0516	0.828279	(0.221)	0.010	(0.12)	0.0160	−0.15986	0.0003	0.0133	0.5658	0.0006	0.578	1.46	(0.73)	0.049026	(0.71)	0.02
	2018	−0.21217	0.0666	0.858086	(0.191)	0.023	(0.12)	0.0310	−0.15986	0.0006	0.0133	0.5658	0.0012	0.578	1.30	(1.17)	0.130547	(0.02)	1.15

Table A9. Calculations of optimal and excess debt: SNY.

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance (αγ(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, $f^*(t)$	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
SNY	2000	0.595696	0.0258	9.011576	6.455	0.177	(0.24)	(0.0098)	0.326002	0.0008	0.0133	0.3066	0.0015	0.318	9.26	1.80	0.165805	(1.06)	(2.86)
	2001	0.115517	0.0243	8.074121	5.518	0.007	(0.24)	(0.0113)	0.063625	0.0002	0.0133	0.3066	0.0003	0.320	8.26	0.31	0.123304	(1.66)	(1.97)
	2002	−0.20106	0.0209	5.685717	3.129	0.020	(0.24)	(0.0147)	1.220455	0.0042	0.0133	0.3066	0.0085	0.311	7.45	(0.91)	0.096311	(2.03)	(1.13)
	2003	0.21586	0.0188	5.516577	2.960	0.023	(0.24)	(0.0168)	−0.17977	(0.0007)	0.0133	0.3066	(0.0014)	0.321	8.49	0.66	0.089317	(2.13)	(2.79)
	2004	1.036402	0.0286	1.499665	(1.057)	0.537	(0.24)	(0.0070)	−0.02925	(0.0000)	0.0133	0.3066	(0.0001)	0.320	9.46	2.09	0.336108	1.32	(0.77)
	2005	0.105869	0.0191	1.680915	(0.876)	0.006	(0.24)	(0.0165)	0.289487	0.0011	0.0133	0.3066	0.0023	0.318	8.31	0.38	0.281705	0.56	0.19
	2006	0.059397	0.0197	1.666648	(0.890)	0.002	(0.24)	(0.0159)	−0.23071	(0.0009)	0.0133	0.3066	(0.0017)	0.322	8.06	0.01	0.278603	0.52	0.50
	2007	−0.02092	0.0339	1.546424	(1.010)	0.000	(0.24)	(0.0017)	−0.61418	(0.0002)	0.0133	0.3066	(0.0005)	0.320	7.81	(0.37)	0.243708	0.03	0.40
	2008	−0.31686	0.0373	0.967225	(1.589)	0.050	(0.24)	0.0017	0.844034	(0.0003)	0.0133	0.3066	(0.0007)	0.321	6.71	(2.00)	0.244086	0.04	2.03
	2009	0.239505	0.0252	1.222772	(1.334)	0.029	(0.24)	(0.0104)	0.032726	0.0001	0.0133	0.3066	0.0002	0.320	8.58	0.78	0.239312	(0.03)	(0.81)
	2010	−0.19204	0.0374	0.95508	(1.601)	0.018	(0.24)	0.0018	−0.56458	0.0002	0.0133	0.3066	0.0005	0.319	7.23	(1.23)	0.237111	(0.06)	1.17
	2011	0.166559	0.0476	1.137676	(1.419)	0.014	(0.24)	0.0120	1.136156	(0.0032)	0.0133	0.3066	(0.0065)	0.326	8.14	0.14	0.301423	0.84	0.70
	2012	0.280518	0.0442	1.320978	(1.236)	0.039	(0.24)	0.0086	0.317886	(0.0007)	0.0133	0.3066	(0.0013)	0.321	8.57	0.77	0.289257	0.67	(0.10)
	2013	0.126543	0.0422	1.471526	(1.085)	0.008	(0.24)	0.0066	0.14084	(0.0002)	0.0133	0.3066	(0.0004)	0.320	8.22	0.24	0.261236	0.28	0.03
	2014	−0.14613	0.0415	1.433647	(1.123)	0.011	(0.24)	0.0059	−0.07144	0.0001	0.0133	0.3066	0.0002	0.320	7.38	(1.01)	0.288443	0.66	1.67
	2015	−0.07291	0.0405	1.429669	(1.127)	0.003	(0.24)	0.0049	0.271684	(0.0003)	0.0133	0.3066	(0.0006)	0.321	7.61	(0.66)	0.257064	0.22	0.87
	2018	−0.07209	0.0504	1.371205	(1.185)	0.003	(0.24)	0.0148	−0.15986	0.0006	0.0133	0.3066	0.0011	0.319	7.63	(0.63)	0.280104	0.54	1.17
	2017	0.049826	0.0516	1.235898	(1.321)	0.001	(0.24)	0.0160	−0.15986	0.0006	0.0133	0.3066	0.0012	0.319	8.01	(0.06)	0.261599	0.28	0.34
	2018	−0.00356	0.0666	1.346607	(1.210)	0.000	(0.24)	0.0310	−0.15986	0.0012	0.0133	0.3066	0.0024	0.318	7.83	(0.33)	0.314134	1.02	1.35

Table A10. Calculations of Optimal and Excess Debt: ZTS.

Company	Year	Capital Gains/(Losses), (r)	Interest Rate (i)	Beta (Productivity of Capital, β)	Beta Variance (αγ(t))	Half Square of Capital Gain Variance	Correlation of Interest and Capital Gain Variables	Interest Rate Variance	Capital Gain Variance	Correlation and Variances of Interest and Capital Gain	Std. Deviation of Interest Rate	Std. Deviation of Capital Gain	2 × (Correlation and Variances of Interest and Capital Gain)	Risk	Optimal Debt Ratio, $f^*(t)$	Normalized Optimal Debt Ratio	Actual Debt Ratio	Normalized Actual Debt Ratio	Excess Debt
ZTS	2000		0.0258		(1.114)	0.000	(0.09)	(0.0098)	0.326002	0.0003	0.0133	0.1106	0.0006	0.123	8.83	(0.39)		(2.18)	(1.80)
	2001		0.0243		(1.114)	0.000	(0.09)	(0.0113)	0.063625	0.0001	0.0133	0.1106	0.0001	0.124	8.80	(0.42)		(2.18)	(1.77)
	2002		0.0209		(1.114)	0.000	(0.09)	(0.0147)	1.220455	0.0016	0.0133	0.1106	0.0033	0.121	9.08	(0.03)		(2.18)	(2.16)
	2003		0.0188		(1.114)	0.000	(0.09)	(0.0168)	−0.17977	(0.0003)	0.0133	0.1106	(0.0006)	0.124	8.80	(0.43)		(2.18)	(1.76)
	2004		0.0286		(1.114)	0.000	(0.09)	(0.0070)	−0.02925	(0.0000)	0.0133	0.1106	(0.0000)	0.124	8.76	(0.49)		(2.18)	(1.70)
	2005		0.0191		(1.114)	0.000	(0.09)	(0.0165)	0.289487	0.0004	0.0133	0.1106	0.0009	0.123	8.90	(0.28)		(2.18)	(1.91)
	2006		0.0197		(1.114)	0.000	(0.09)	(0.0159)	−0.23071	(0.0003)	0.0133	0.1106	(0.0007)	0.125	8.78	(0.45)		(2.18)	(1.73)
	2007		0.0339		(1.114)	0.000	(0.09)	(0.0017)	−0.61418	(0.0001)	0.0133	0.1106	(0.0002)	0.124	8.70	(0.56)		(2.18)	(1.62)
	2008		0.0373		(1.114)	0.000	(0.09)	0.0017	0.844034	(0.0001)	0.0133	0.1106	(0.0003)	0.124	8.67	(0.61)		(2.18)	(1.57)
	2009		0.0252		(1.114)	0.000	(0.09)	(0.0104)	0.032726	0.0000	0.0133	0.1106	0.0001	0.124	8.79	(0.44)		(2.18)	(1.75)
	2010		0.0374	0.867943	(0.246)	0.000	(0.09)	0.0018	−0.56458	0.0001	0.0133	0.1106	0.0002	0.124	8.70	(0.56)	0.214232	(1.25)	(0.69)
	2011		0.0476	0.933922	(0.180)	0.000	(0.09)	0.0120	1.136156	(0.0013)	0.0133	0.1106	(0.0025)	0.126	8.42	(0.96)	0.198214	(1.32)	(0.36)
	2012		0.0442	0.888525	(0.225)	0.000	(0.09)	0.0086	0.317886	(0.0003)	0.0133	0.1106	(0.0005)	0.124	8.60	(0.72)	0.175343	(1.42)	(0.70)
	2013		0.0422	1.359666	0.246	0.000	(0.09)	0.0066	0.14084	(0.0001)	0.0133	0.1106	(0.0002)	0.124	8.64	(0.66)	0.637542	0.60	1.26
	2014	0.3198	0.0415	1.396265	0.282	0.051	(0.09)	0.0059	−0.07144	0.0000	0.0133	0.1106	0.0001	0.124	10.83	2.49	0.63221	0.58	(1.92)
	2015	0.1049	0.0405	1.239111	0.125	0.006	(0.09)	0.0049	0.271684	(0.0001)	0.0133	0.1106	(0.0002)	0.124	9.45	0.50	0.637053	0.60	0.09
	2018	0.1069	0.0504	1.2111	0.097	0.006	(0.09)	0.0148	−0.15986	0.0002	0.0133	0.1106	0.0004	0.123	9.44	0.49	0.657995	0.69	0.20
	2017	0.3274	0.0516	1.138597	0.025	0.054	(0.09)	0.0160	−0.15986	0.0002	0.0133	0.1106	0.0005	0.123	10.83	2.49	0.66457	0.72	(1.77)
	2018	0.1714	0.0666	0.988796	(0.125)	0.015	(0.09)	0.0310	−0.15986	0.0005	0.0133	0.1106	0.0009	0.123	9.79	1.00	0.683771	0.80	(0.20)

Notes

[1] Such as cash, accounts receivable, investments in other firms, properties, and intangible assets.

[2] See attached Appendix C for detailed calculations of excess debt of a sample of companies in Tables A2–A10.

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