Article

Deconstructing the Enron Bubble: The Context of Natural Ponzi Schemes and the Financial Saturation Hypothesis

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Abstract

This study examines the Enron collapse through an integrated theoretical framework combining the financial saturation paradox with the dynamics of a naturally occurring Ponzi process. The central objective is to evaluate whether endogenous market mechanisms—beyond managerial misconduct—played a decisive role in the emergence and breakdown of the Enron stock bubble. A logistic-growth-based saturation model is formulated, incorporating positive feedback effects and bifurcation thresholds, and applied to Enron's stock price data from 1996 to 2001. The computations were performed using LogletLab 4 (version 4.1, 2017) and Microsoft® Excel® 2016 MSO (version 2507). The model estimates market saturation ratios (P/Pp) and logistic growth rate (r), treating market potential, initial price, and time as constants. The results indicate that Enron's share price approached a saturation level of approximately 0.9, signaling a hyper-accelerated, unsustainable growth phase consistent with systemic overheating. This finding supports the hypothesis that a naturally occurring Ponzi dynamic was underway before the firm's collapse. The analysis further suggests a progression from market-driven expansion to intentional manipulation as the bubble matured, linking theoretical saturation stages with observed price behavior. By integrating behavioral–financial insights with saturation theory and Natural Ponzi dynamics, this work offers an alternative interpretation of the Enron case and provides a conceptual basis for future empirical validation and comparative market studies.

Keywords: natural Ponzi; financial saturation; behavioral finance; Enron scandal; positive feedback loops; financial bubbles

1. Introduction

At the end of the Great Depression, some prominent economists of the time argued that the crisis was a short-term phenomenon, and that if people let themselves be carried by the wave caused by the industrial revolution, then after a century, the economy would no longer pose a significant problem to humankind. The century is now nearing its end, and although the wave of industrial progress continues unabated and technological predictions have largely materialized, economic disruptions persist. Throughout the centuries-long history of financial markets, scandalous cases of fraud have reappeared regularly. Opportunists seeking easy profits have devised ever more complex or brazen financial schemes. One of the most infamous and mysterious cases of recent decades surfaced in the United States in 2008, with the exposure of Bernard Lawrence Madoff's massive Ponzi fraud

(Smith, 2010). Before that, the Enron scandal had already shaken markets, ostensibly delivering a clear warning. Guilt was established, perpetrators were convicted, and new legal safeguards—such as the Sarbanes-Oxley Act—were introduced to prevent repetition. Yet only seven years later, a strikingly similar pattern re-emerged, this time on a broader and more destructive scale. Naturally, one might ask, when will the next iteration strike, and what form will it take? The recurrence of such crises, along with delayed recognition and inadequate prevention, suggests a troubling possibility—that events like Enron outpace not only regulation but also our interpretive frameworks. Perhaps the prevailing explanations remain incomplete, or even fundamentally flawed.

For some time now, the liberal worldview has been experiencing serious tests: the failures of politicians, financial crises, growing exclusion, ecological and social catastrophes, and, finally, Brexit and the rise of Trump are attributed to the failures of liberal politics and, above all, the ideology of the free market. A lot of criticism has appeared—speeches, articles, studies, and books. Nobel Prize winner in economics Joseph Stiglitz (Stiglitz, 2010, 2017) emphasizes the potential transformations that occur in pursuit of profit. On the other hand, in an article in the Financial Times from 2010, the same economist admits that economic theory is flawed and that some decisions made based on economic models are wrong.

Ponzi schemes, named after Charles Ponzi, have captivated financial markets and societies since the early 20th century. Their deceptive simplicity and initial allure often mask their intricate and insidious nature. The promise of extraordinary returns and the assurance of security can blind even the most discerning investors. This exploration of notable Ponzi schemes, both historical and recent, serves as a lens through which to examine their common characteristics, societal impact, and essential lessons for a more resilient financial future (Cross, 2024; Deason et al., 2021).

The context of increasing financial depth—driven by growing societal wealth, rising financial saturation risks, and the proliferation of new financial technologies—creates an environment conducive to the emergence of new Ponzi-like and fraudulent schemes. Therefore, only by reanalyzing the old cases of deception, scandal, and fraud in the context of the current progress in economic science can we find clearer answers and explanations as to why they happened. Having received these answers, it becomes possible to take a fresh look at current financial market processes and reduce the risks that such cases, on such scales, will be repeated in the near future or in the distant future. Therefore, research aimed at analyzing the Enron scandal as a financial bubble and the Ponzi phenomenon occurring under natural conditions is relevant.

The structure of this paper is as follows. Section 2 presents the conceptual and historical background, beginning with a review of the classical interpretations of the Enron collapse (Section 2.1), followed by an overview of Ponzi scheme theory and the concept of naturally occurring Ponzi dynamics (Section 2.2). Section 3 consolidates the relocated theoretical material and introduces the Financial Saturation Theory with its saturation paradox, clarifying its role in interpreting market behavior and instabilities. It then develops a formal dynamic model that integrates market saturation and feedback effects. Section 4 applies this model directly to the Enron case, with results focused exclusively on empirical findings. Section 5 interprets these findings in light of relevant studies, showing how Natural Ponzi dynamics may evolve under feedback conditions in the Enron case. The concluding section reflects on the broader implications for financial diagnostics, policy, and avenues for future research.

2. Literature Review and Research Problem

2.1. The Enron Case: Classical Interpretations and Corporate Misconduct

Lessons from historical financial bubbles reveal how speculative dynamics affect emerging industries and serve as cautionary tales. The Enron scandal in the early 2000s is a case in point. It demonstrated how market manipulation and overly optimistic projections can distort investor expectations (Brunet & Shafe, 2006). Enron, once a dominant player in energy markets, inflated reported earnings and manipulated power prices to maintain the illusion of steady growth and sustain high stock prices. When the company's actual financial condition was revealed, its collapse resulted in massive losses and widespread erosion of trust in the energy sector (Nix et al., 2021; Salter, 2008).

Several authors interpret the Enron case through the lens of classical fraud theory, attributing the collapse to ethical failure and executive-level misconduct (Stewart, 2006; Thomas, 2002). Palmer (2012) offers a more nuanced organizational framework, examining the interplay between formal authority and informal power to reveal how systemic wrongdoing evolved internally. Likewise, Tebogo (2011) emphasizes that Enron's reputation had a blinding effect on analysts and investors, who neglected early warning signs. Post-collapse analyses using tools such as the Beneish M-Score, the Modified Altman Z-Score, the Chanos Algorithm, and Grove–Cook ratios all suggested the company's trajectory was predictably unsustainable. These findings reinforce the importance of qualitative scrutiny, which ultimately helped expose dubious accounting practices.

Other scholars point to broader structural factors. Gerding (2005) argues that asset bubbles are frequently accompanied by a rise in securities fraud, not because of unique criminal actors but because of regulatory dilution and cyclical feedback between investor confidence, economic growth, and deregulation. As bubbles inflate, oversight weakens precisely when it is most needed; when they collapse, reregulation often comes too late to prevent damage. Giroux (2008) situates Enron's failure within a web of incentives: executive greed, flawed governance, political lobbying, and complicit gatekeepers—including auditors and regulators—all combined to erode accountability at multiple levels.

Another author (Coffee, 2003) provides a deeper context and tendencies in the sector during the period of the Enron scandal. Between January 1997 and June 2002, approximately 10% of all listed companies in the United States announced at least one financial statement restatement. The stock prices of restating companies declined 10% on average after the announcement of these restatements, with restating firms losing over USD 100 billion in market capitalization over a short three-day trading window surrounding these restatements. Such generalized financial irregularity required a more generic causal explanation than could be found in the facts of Enron, WorldCom, or other specific case histories. Several different explanations are plausible, each focusing on a different actor (but none giving primary attention to the board of directors):

1. The Gatekeeper Story looks to the professional "reputational intermediaries" on whom investors rely for verification and certification and views the surge in financial restatements as the product of reduced legal exposure for gatekeepers and the increased potential for consulting income or other benefits from their clients.

2. The Misaligned Incentives Story instead focuses on managers and a dramatic change in executive compensation during the 1990s, as firms shifted from cash to equity-based compensation. Stock options (and legal changes that enabled management to exercise the option and sell the security without any delay) arguably gave management a strong incentive to inflate reported earnings and create short-term price spikes that were unsustainable, but which they alone could exploit.

3. The Herding Story attributes fund managers' behavior to relative performance incentives, suggesting they are predominantly concerned with short-term, quarter-over-

quarter returns compared to their competitors, which encourages conformity even in the face of market risks. As a result, they have an incentive to "ride the bubble", even when they sense danger, because they fear more the mistake of being prematurely prophetic.

As revealed by an analysis of court decisions, the indictments allege that at various times between 1999 and 2001, Lay, Skilling, Causey, and other Enron executives carried out a scheme to defraud investors, the US Securities and Exchange Commission, and others (Department of Justice, 2004). The alleged scheme was designed to make it appear that Enron's growth in value was natural, in line with analysts' published expectations, that Enron consisted of a number of successful business units, and that the company always had adequate cash flow.

A number of key figures in the company (Ken Lay, Jeff Skiling, Andrew Fastow, Richard Causey) were prosecuted, and 22 individuals were convicted for their actions in connection with the fraud that took place in the company (Enron, 2006). The chronology of the verdicts handed down during the trials of a number of key figures in the Enron fraud case is provided in Table 1.

Table 1. Sentences handed down in the Enron fraud case. Source: Authors' own work based on the Department of Justice (2006a, 2006b, 2006c).

Information on Court Proceedings	Substance of the Judgement
26 September 2006. US District Judge Kenneth Hoyt. Houston District Court.	Andrew Fastow, former Chief Financial Officer of Enron, was sentenced to 6 years in prison for conspiracy to commit securities and money fraud.
23 October 2006. US District Judge Sim Lake. Houston District Court.	Former Enron CEO Jeffrey Skilling was sentenced to 24 years and 4 months in prison for conspiracy, securities fraud, and other charges.
15 November 2006. US District Judge Sim Lake. Houston District Court.	Richard Causey, former Chief Accounting Officer of Enron, was sentenced to 5 years and 6 months in prison for securities fraud related to the company's activities.

In the aftermath of the scandal, the United States created a law (Sarbanes-Oxley Act, 2002) aimed at making corporate activities more transparent, protecting investors, improving disclosure of these activities, and making institutional decisions regarding the implementation of transparency.

Many authors take a classical approach to analyzing Enron's business processes and the extent of the resulting consequences. The classical approach explains the situation in terms of the fact that the root causes of the company's collapse are the prevalence of basic outright fraud at the highest levels of management and a lack of ethics. During the Enron scandal and in subsequent court judgments and academic articles, this phenomenon was interpreted in terms of deception, fraud, and criminal activity. The literature review and court decisions did not interpret the Enron case as the result of a financial bubble or a Natural Ponzi. A review of the literature on the Enron bubble revealed that the Enron scandal was explained by the market laws known at the time, the perpetrators were punished, and the fraud was proven. The literature review revealed that the causes of Enron's collapse have so far been extensively and comprehensively analyzed from the classical point of view of criminal and unethical corporate governance. So far, the Enron case has been treated as a crime, a fraud, and a deception.

2.2. Ponzi Scheme: Naturally Occurring Dynamics

Building on these earlier insights into classic Ponzi behavior, we now shift toward the emerging literature on "Natural" Ponzi dynamics, which emphasizes market-driven feedback and expectation-based acceleration.

The classic Ponzi scheme is defined by the promise of abnormally high returns that attract early investors, who are then repaid using the capital of subsequent investors rather than genuine profits. This mechanism, as outlined by Frankel (2012) and Jacobs and Schain (2011), leads to rapid expansion as new waves of investors are drawn in, ultimately culminating in collapse once the underlying deception becomes unsustainable.

More recently, scholars have begun to explore the concept of a naturally occurring Ponzi scheme, or "Natural Ponzi", which differs from the classic fraud-based model in that it emerges from systemic market behavior rather than intentional deception. Authors such as Basu (2014a) and Weaver (2018) highlight how investor expectations and feedback loops can fuel asset bubbles that mimic Ponzi dynamics without any single architect of fraud. Shiller (2015) offers a particularly compelling account, framing Natural Ponzi schemes as the product of mass investor psychology: rising prices generate expectations of continued growth, which, in turn, attracts more investment, reinforcing the cycle. These conditions sustain a bubble even in the absence of malicious intent.

This behavioral–financial view aligns with earlier theoretical work, particularly Minsky's (1986) Financial Instability Hypothesis, which explains how speculative lending and investor euphoria can lead to unstable financial structures. Although Minsky does not explicitly use the term "Natural Ponzi", his analysis describes endogenous processes that mirror its dynamics. Similarly, Kindleberger (Burton, 2017) identifies how financial manias and speculative surges often exhibit Ponzi-like features, particularly in their feedback-driven momentum.

Nobel laureates Krugman (2009) and Shiller (2015) both analyze how financial instability and irrational exuberance contribute to self-reinforcing market cycles. Krugman's work emphasizes the systemic nature of economic crises, while Shiller demonstrates how market psychology can sustain bubbles with Ponzi-like patterns. Empirical studies, such as those by Gjerstad and Smith (2014), reinforce this view, particularly in housing markets where prices rise based on expectations rather than fundamentals—one of the clearest real-world manifestations of Natural Ponzi conditions.

Complementing the theoretical literature, researchers such as Bartoletti et al. (2020) and Deason et al. (2015) empirically dissect Ponzi mechanisms across both traditional and digital platforms. These studies confirm that such schemes grow through repeated capital injections from new participants, often underpinned by psychological momentum rather than financial substance. Building on this, Basu (2014b, 2018) offers a broader theory in which Ponzi-like behavior can arise organically in economic systems. He describes how the diffusion of psychological states—such as the belief in rapid wealth accumulation—fuels speculative surges, regardless of whether the investor is retail or institutional. These dynamics can perpetuate over time until saturation is reached and the illusion collapses.

Recently, however, the phenomenon of Natural Ponzi schemes and financial saturation has been analyzed in the literature, which offers additional possibilities to explain the Enron collapse. The time difference between the phenomena discovered and the event analysis suggests that it is appropriate to investigate the formation and bursting of the Enron bubble in the context of financial saturation and a Ponzi scheme. Exploring and explaining an old occurrence with new methods and economic theory will lead to a better understanding of the causes of the situation and thus help to better understand and prevent the recurrence of such occurrences in the future. The authors, scientists, and lawyers of the time did not recognize the formation of the bubble in the Enron case and considered its scheme,

rise, and collapse to be simply a fraud, a deception, and a criminal act. The literature review raises the question of whether the Enron scandal can be considered a case of a financial bubble and a natural manifestation of Ponzi dynamics in the natural environment of economic activity.

2.3. The Aim and Objectives of This Study

The research aim of this study has two parts: theoretical and practical. In Section 3, the theoretical part focuses on the research model, which directly follows the formulation of the unsolved problem: how are financial saturation paradoxes related to Natural Ponzi schemes, and did these phenomena boost the Enron bubble and burst? Based on this, the research problem is formulated as follows: was the Enron case affected by financial saturation and the phenomenon of Ponzi dynamics that arose in the natural economic environment?

The aim of this research is to analyze the Natural Ponzi scheme in the context of a financial saturation paradox, to develop a model for bubble formation analysis based on the Natural Ponzi scheme and saturation paradox, and to apply the developed model for Enron bubble deconstruction.

To achieve the aim, the following objectives were set:

- Analyze the financial saturation and Natural Ponzi scheme relationship in the context of positive feedback;
- Develop a model for bubble analysis based on saturation and the Natural Ponzi scheme;
- Apply the model for Enron bubble deconstruction.

Section 3 achieves the first and second objectives: an analysis of the financial saturation and Natural Ponzi scheme relationship in the context of positive feedback is performed, and a model for bubble analysis based on saturation and the Natural Ponzi scheme is adopted. In Section 4, research is performed by applying the model for Enron bubble deconstruction.

3. Materials and Methods

The formulation of the research method begins with a broader context, outlining the basis on which the method was developed and the resulting assumptions. The research model is constructed by combining elements of the saturation paradox from the theory of financial saturation with the concept of the Natural Ponzi scheme. The phenomenon connecting these elements is positive feedback. The discussion first presents the essence of the Natural Ponzi scheme and the saturation paradox in the context of the model, followed by the formulation of the model and its application to the empirical part of this study.

3.1. Financial Saturation, Natural Ponzi, and Positive Feedback

The theory of financial saturation is based on the logistic growth model developed by Verhulst (1838), which was initially applied to biological and demographic systems. In 2002, a saturation percentage system was created based on this model, allowing for a new economic interpretation of systemic limits, market fluctuations, bubble formation, hidden overproduction, hyper-intensity of financial flows, debt imbalances, etc.

The theory of financial saturation allows us to look at traditional economic logic from a different angle. It does not replace the neoclassical paradigm but complements it where traditional models fail: in the maturity and saturation phases. The theory explains why bubbles can form even under seemingly normal conditions.

This theory becomes a tool for assessing systemic imbalances that arise not from inappropriate investment policies but from ignoring structural constraints. The theory reveals the particular features of bubble formation (risk asymmetry, etc.) that arise follow-

ing intense financial saturation. It reveals the reasons for the recurrence of crisis cycles, especially when growth is based on financial rather than productivity logic.

The theory is relevant in practical terms where large and intense financial flows are possible, i.e., when investments exceed the absorption capacity of infrastructure. There are several key findings of the theory: the phenomenon of increasing returns and the debt trap effect. The debt trap effect occurs when investments of borrowed capital (leveraged investments) are made in a saturated market. Then, in the saturation phase, borrowed capital begins to grow significantly faster than equity capital. This phenomenon is not considered in the research model, which relies on the second phenomenon—the phenomenon of increasing returns or the saturation paradox. When discounting cash flows by the saturation percentage, a hyperbolically intensifying growth in returns is observed, which occurs not in conditions of a shortage of financial resources but in conditions of their surplus. As the system approaches its capacity limit, the intensity of investment returns increases dangerously, causing unexpected growth rates. This continues until the system reaches a critical point and becomes destabilized.

Such dynamics, through a renewed equilibrium model and a new supply function, allow us to examine pricing differently. The supply function, showing the relationship between price and quantity, increases the supply price hyperbolically as saturation increases and quantity approaches the limit of supply possibilities. The equilibrium model, with its hyperbolically changing supply function, becomes a demand tool that defines price and can cause market fluctuations, economic bubbles, demand inflation, business cycles, etc. This structure also creates conditions for the Natural Ponzi phenomenon due to the positive feedback loop (Girdzijauskas, 2008, 2011, 2024; Gryshova et al., 2019).

Based on the literature review and following Kaushik Basu (Basu, 2014b), we formulate a definition of a Natural Ponzi scheme: it is a market mechanism where financial saturation and strong positive feedback loops lead to an increase in market profitability, and the excess capital of investors creates a bubble, based on expectations and the involvement of new entrants, rather than on fundamental economic rationale. As the bubble expands, its contraction or bursting may be temporarily masked by financial interventions, but once the saturation point is reached and the flow of new investors is reduced, the system inevitably collapses. It is important to note that a financial bubble forms without the intervention of a deliberate manipulator; it arises from natural market forces. However, deliberate manipulation can occur later to prevent or postpone a market crash. In the case of a Natural Ponzi scheme, manipulation is also possible in the earlier stages, but its manifestation and effect require the appropriate market conditions: bifurcation and financial saturation, the saturation paradox, and a strong positive feedback loop. These definitions provide the basis for integrating the concepts of financial saturation and positive feedback into a unified model of naturally occurring Ponzi schemes.

It is important to stress that the goal of business activity is not the Natural Ponzi scheme itself but the higher returns (profitability or growth rate) it promotes. The problem is that better business performance relies on the formation of a bubble, which can lead to a complete Natural Ponzi scheme and bubble burst. Often, this transformation goes unnoticed by entrepreneurs/managers or is identified too late, when the bubble has become unmanageable. In some cases, the process is successful in returning to business as usual, but if it is not possible to turn the nascent bubble into a real business, the bubble overheats and bursts. It is also possible that the process is visible to the entrepreneurs themselves, but not yet visible (betrayed) to outside observers (market participants). In some cases, as could be predicted, the Natural Ponzi scheme can turn into a deliberate fraud with classic Ponzi characteristics. An increasing proportion of the funds raised (capital) is then used not

to rescue or develop real business but to maintain the bubble by redistributing the funds as a sop to the previous investors.

The most important element of a Natural Ponzi scheme is the expectation that future prices will increase, i.e., a positive feedback loop. Only in the presence of significant positive feedback can the scheme manifest itself and produce tangible results. The occurrence of a Natural Ponzi scheme is based on positive feedback, the strength of which depends on the level of financial saturation. The level of financial saturation (bifurcation, stages) is determined using the theory of financial saturation based on logistic growth.

Positive feedback loops (Karasa & Girdzijauskas, 2024) arise when economic (or other) growth becomes restricted, i.e., when there is disproportionate investment in resource-constrained markets of limited size. Positive feedback at a sufficient frequency intensifies and resonates with the cyclical investment process, with the saturation phenomenon affecting positive expectations, and the market heating up. In other words, intensively rising prices increase demand and hence, profitability expectations, which are shaped by the phenomenon of rising profitability (saturation). The feedback loop further stimulates price increases, thereby accelerating investment.

Based on financial saturation theory (Girdzijauskas, 2002, 2024), the saturation paradox can be defined as follows: if capital is invested in a closed (deficit) market and the financial saturation of that market increases, the profitability of the investment rises unrestrictedly.

Table 2 summarizes the types of schemes and their fundamental reasons, connecting Natural Ponzi and providing schemes in the context of saturation and positive feedback as a result.

Table 2. Classical and Natural Ponzi schemes in the context of financial saturation. Source: Authors' own work.

Type of Scheme	Fundamental Reasons
Naturally occurring Ponzi (Natural Ponzi)	Investors' expectations, mass investment, strong positive feedback, implicit intent, transformation to real business or collapse
Ponzi scheme in the context of financial saturation	Demand > supply, bifurcation, strong positive feedback and resonance, market saturation, saturation paradox, hyperbolic growth, financial bubble, bubble transformation to real business or collapse

The Natural Ponzi scheme and financial saturation relationship in the context of positive feedback is illustrated in Figure 1.
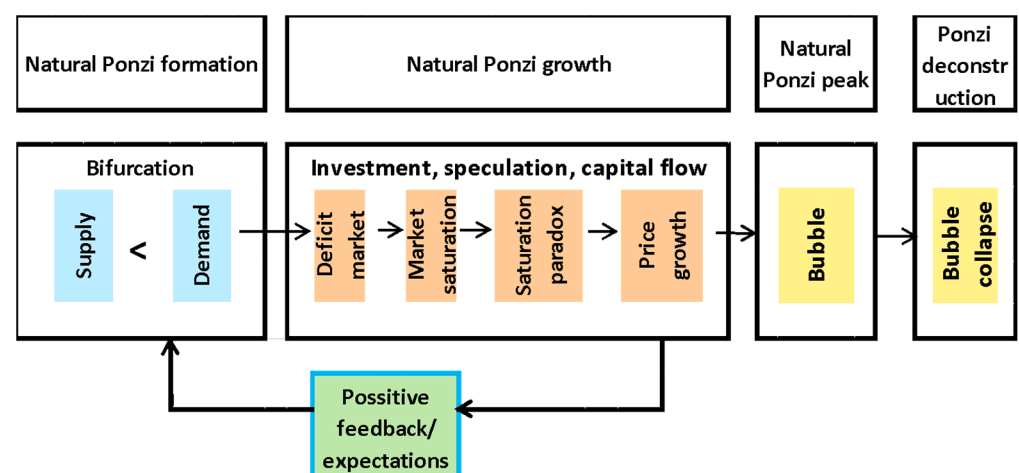

Figure 1. Ponzi scheme and financial saturation relationship. Source: Authors' own work.

The diagram above combines the Natural Ponzi scheme with the financial saturation process. Having established this direct link between Natural Ponzi schemes and the saturation paradox, the theory of financial saturation and its derivatives are then used to apply the bubble and Natural Ponzi scheme model to the Enron case.

3.2. Model Specification

Bubble analysis, based on financial saturation and the Natural Ponzi scheme, is carried out by testing the saturation level of the market with capital. The assumption is made that once a certain level of saturation is reached, the likelihood of market overheating increases and the growth rate becomes extremely high, which affects market prices and output. The model seeks to identify the level of market saturation reached during the period of significant growth. Research also assesses how saturation and growth rate are related to naturally occurring Ponzi schemes. The model identifies critical thresholds of market saturation, particularly at 70% (bifurcation) and 90% (overheating), where speculative dynamics dominate (Mikalauskas & Karaša, 2025). Based on these thresholds, Figure 2 illustrates the three stages of market saturation and Ponzi scheme stages.
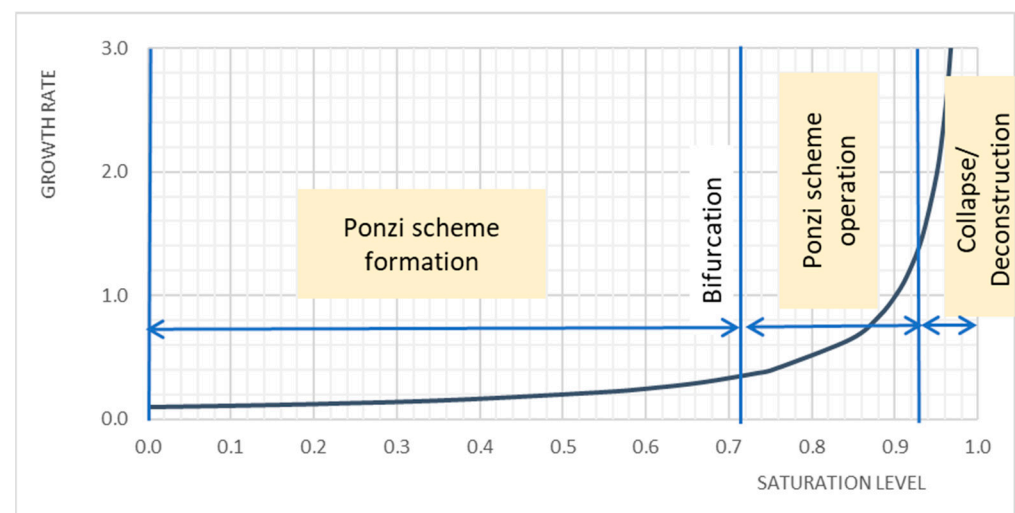

Figure 2. Saturation and Ponzi scheme stages. Source: Authors' own work.

The model is based on saturation (general) percentages (interest). It is based on Formula (1) of the general compound interest model from partial growth interest (Girdzijauskas, 2002; Gryshova et al., 2019):

$$K_a = \frac{K_p \cdot K_0 (1+i)^t}{K_p - K_0 + K_0 (1+i)^t},$$

(1)

where K_p is the market capacity or potential (maximum) value of the invested capital in the market; K_0 is the initial value of the investment; K_a is the accumulated investment (the amount of the capital in terms of its value) over periods; i is growth (interest rate) norm expressed in percentages for one time t unit; and t is the duration of the investment or the number of periods of the investment (measured in the same units of time as time in the interest rate).

Given that 1 + i = r, in this model, the functions are solved concerning the dependent variable (the variable on the left-hand side of the equation (r)). Thus, r could be named the logistic growth rate expressed in an absolute number. This gives a basic equation with an independent variable r and a dependent variable K, representing the units of product quantity in value terms. It is assumed then that the share price is directly correlated with

the accumulated capital in each market, i.e., the value of accumulated capital in the market is directly reflected in the share price. Therefore, in Equation (1), the quantity parameter K is substituted by the price parameter P, and the price "supply" saturation Equation (2) is obtained:

$$r = \sqrt[t]{\frac{P_p - P_0}{P_0} \cdot \frac{P}{P_p - P}},$$ (2)

where r is logistic growth rate of the value of the product (stock) or the price logistic growth rate, expressed as an absolute number; P is the size of the product (stock) in terms of value in period t, i.e., the price of the stock in a given period; P_0 is the initial value of the product (stock), i.e., the initial price; and P_p is the depth (capacity) of the market in terms of value or the potential (maximum) value of the stock price.

The stock price is directly correlated to the accumulated capital in a given market, i.e., the value of the accumulated capital in the market is directly reflected in the stock price, while the time lag is not evaluated in this model. P_0 is the first historical value of the equity at the beginning of the significant growth period in the analysis. The value is taken from the end of the quarter. P_p is calculated using the Loglet model for a given period of significant growth in quarters. t (time) is taken to be of a medium period, i.e., t = 1.

Based on the transformed model, the main research hypothesis is formulated as follows: Enron's rise, growth, and collapse were a financial bubble due to market bifurcation, the amplification of positive feedback loops (accelerated by non-transparent practices), and the manifestation of the then unknown saturation paradox. This led to the formation and bursting of the financial bubble that ruined the company because of the full manifestation of a Natural Ponzi scheme. The full manifestation of the Natural Ponzi scheme occurred in what the model defines as Stage III (collapse/deconstruction). Here, the system becomes highly unstable, and without a strategic pivot toward real business activity, collapse becomes likely. This is the critical point where the Natural Ponzi scheme may transition into deliberate fraud, as actors seek to preserve illusory success. In contrast, when the cycle is moderated before overheating—i.e., if the bubble is deflated or normalized early—then the Ponzi remains partial or goes unnoticed.

After establishing this direct link between the Natural Ponzi scheme and the saturation paradox, the theory of financial saturation and its corollaries are then used to apply the bubble–Ponzi scheme detection model to the Enron case. Based on the logistic growth formula, the model provides calculations to determine the level of saturation. The level of saturation and growth rate are compared to the stages. The stage reached indicates if there is moderate growth, heating, or overheating. According to research results and the developed theoretical model, the Natural Ponzi stage is assumed. The research model is based on saturation theory, and all limitations and assumptions follow from the application of this theory.

Key assumptions include the following:

- The occurrence of a Natural Ponzi scheme is based on positive feedback, the strength of which depends on the level of financial saturation. The level of financial saturation (bifurcation, stages) is determined based on the theory of financial saturation based on logistic growth.
- The model relies on functional relationships, with price as the independent variable and growth rate as the dependent variable. Other variables are treated as constants. To simplify the model, the value of P_p is assumed to be constant, and market saturation varies only with P. Correspondingly, the model assumes that P_p, P_0, and t are constant and fixed volumes.
- The reliability and accuracy of fixed variables are not assessed.

This research adopts a phenomenological approach, linking the theoretical and empirical levels. This method is used to analyze the formation of economic/financial bubbles based on the theory of financial saturation. In the empirical part, logistic growth analysis is used based on the Loglet Lab 4 software package. MS Excel is used for data analysis, distribution, and visualization.

The price, growth, percentages, and capital saturation are presented using a moderately simplified version of the interpretation—a descriptive, textual format. For material presented in a textual format, only simplified arithmetic operations are used. For the purposes of this study, the focus is on one Enron asset price: ENRNQ US Equity price history in the period between 30 September 1980 and 17 November 2004. Data for the analysis of the equity is taken in quarters from the start of the Bloomberg terminal (Bloomberg, 2024).

4. Results

Bloomberg (Bloomberg, 2024) provides Enron asset histories (ENRNQ US Equity) starting from 1980 Q3. The ENRNQ US Equity history finishes in November 2004 (Figure 3). During this more than 20-year period, we found only one important phenomenon in the stock market—the Enron bubble and its burst.
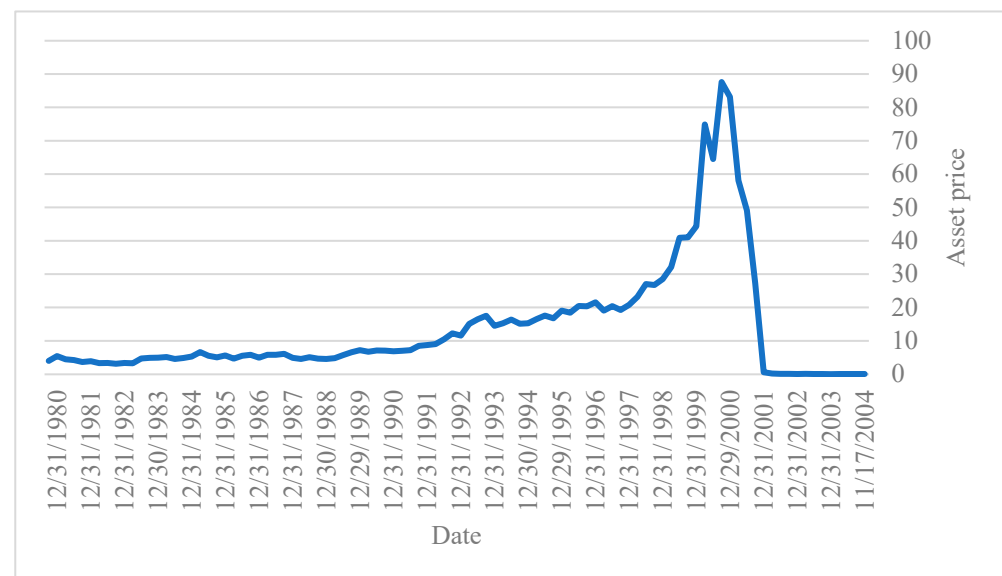

Figure 3. Enron asset price history by quarters. Source: Authors' own work based on (Bloomberg, 2024).

The significant Enron bubble growth and burst period for analysis is considered to occur from 1996 Q1 to 2002 Q2. We assume that this period is crucial for analysis. The dynamics of this period are visualized in Figure 4. We conducted research regarding Ponzi schemes and the financial saturation phenomenon for this period only.

In the beginning (for eight quarters or 2 years), the stock price fluctuated around USD 20. Later (for the next 2 years), the price doubled from USD 20 to USD 44. For the last four periods (quarters) of growth, the price doubled from USD 44 to USD 87 per stock. In 3 years, the price increase reached four times (from the beginning of 1998 to the end of 2000 Q3).

The stock price changes identified a bubble period when price growth was particularly intense. The period between Q1 1996 (period 1 in Loglet) and Q1 2001 (period 21 in Loglet) was chosen for Loglet analysis as a critical growth period. During this period, the value of the stock recorded the highest gains and revealed a bubble formation (Figure 5).
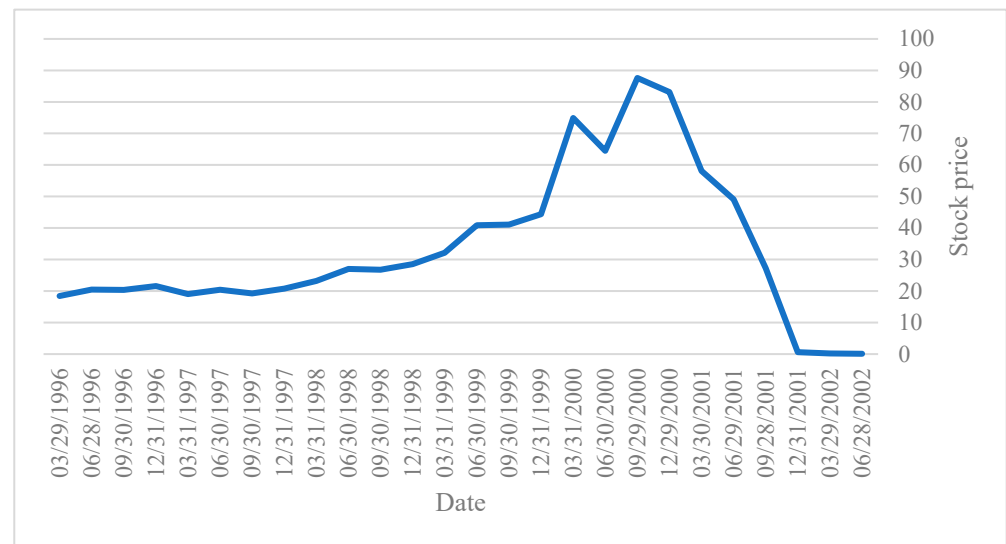
Figure 4. Enron stock price history in the bubble period by quarters. Source: Authors' own work based on (Bloomberg, 2024).
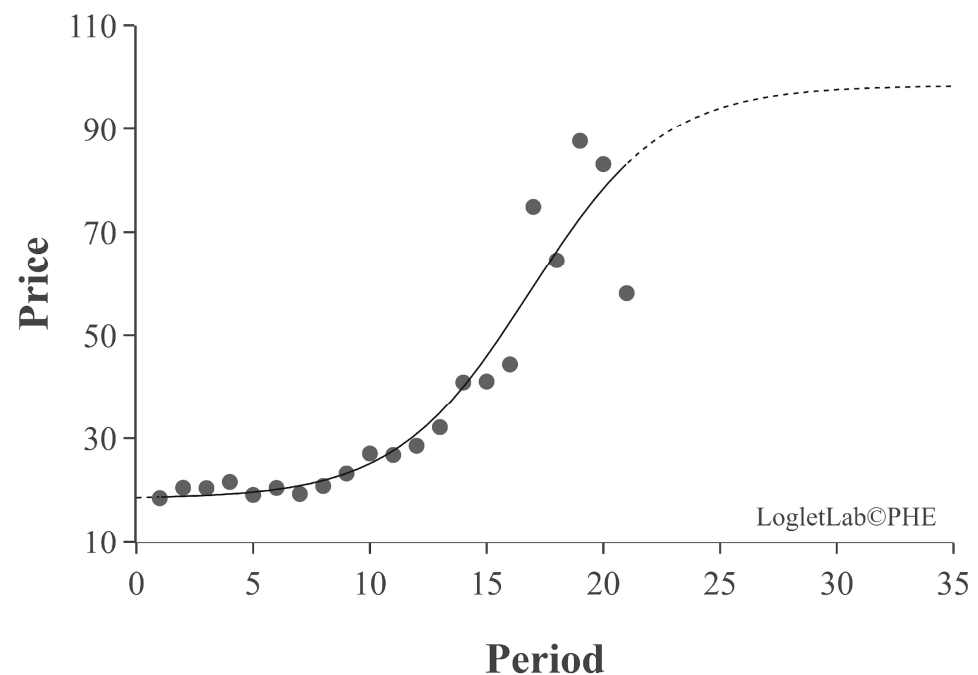

Figure 5. Loglet analysis of the Enron stock price. Source: Authors' own work.

In Figure 5, solid line represents the fitted logistic growth curve based on the observed data. It models how the price evolves over time (Period) and follows the characteristic S-shaped trajectory. Dashed line—indicates the extrapolated portion of the logistic curve beyond the available observations, showing the predicted asymptotic behavior of the price as it approaches saturation. Circles (●)—depict the actual observed data points of Price versus Period, which the solid line attempts to fit. The Loglet analysis showed that logistic growth (S-curve) occurred in this period. This analysis revealed that overheating of the stock price occurred in some periods. Points above S-Curve (periods 17 (2000 Q1), 19 (2000 Q3), and 20 (2000 Q4)) reflect price overheating. The Loglet Lab platform predicted the potential market size (Pp) at the volume of USD 98,5 per stock. The market price capacity (Pp) was used for further analysis of the price saturation level (P/Pp) and the price logistic growth rate (r). The calculations were performed using Formula (2) and the mentioned

assumptions in Section 3. The dynamics of the saturation level and logistic growth rate values over the periods and over the Natural Ponzi stages are shown in Figure 6.
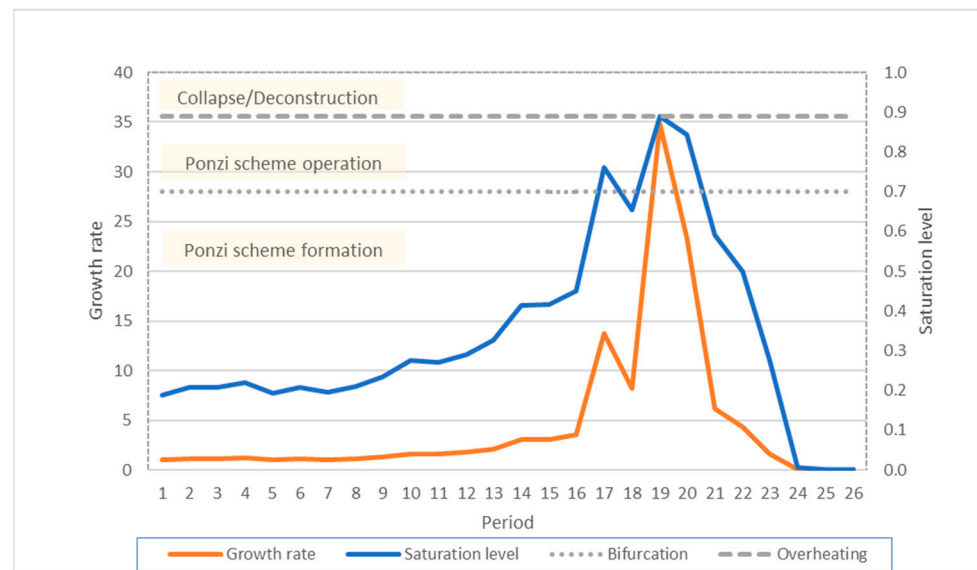

Figure 6. Enron growth rate and saturation level dynamics by period. Source: Authors' own work.

In the price-peak periods (17–20), the price logistic growth rate varied from 13.7 to 34.84, meanwhile price saturation level reached 0.76–0.89 volume. The dynamics of the growth rate and saturation level are directly reflected in the price volatility.

The curve of the price logistic growth rate according to the ranked saturation level (P/P_p) is visualized in Figure 7. The Natural Ponzi stages are shown in the figure. This curve does not reflect the time factor and has a hyperbolic growth form.
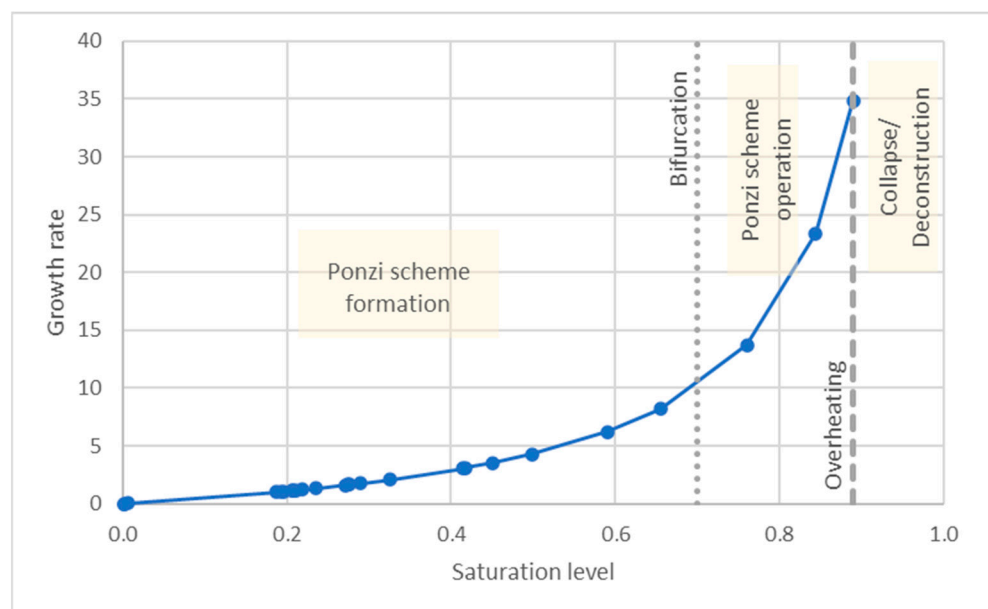

Figure 7. Variation in the growth/yield rate r with the level of saturation. Source: Authors' own work.

The hyperbolic growth curve (Figure 7) shows the distribution of the financial saturation level and the price logistic growth rate r for each quarter of the analysis period. The data are ranked in ascending order of saturation level. Related to model specification and Figure 2, Natural Ponzi stages are added to visualize the relationship of saturation based on the Enron price and Ponzi scheme.

5. Discussion

The structure of the Discussion Section is based on the research aim and objectives. The analysis of the financial saturation and Natural Ponzi scheme relationship in the context of positive feedback was the first objective. A key connection between the Natural Ponzi scheme and the financial saturation theory was found. The analysis results offer a foundation for interpreting how naturally occurring Ponzi dynamics can emerge under conditions of high saturation levels and as the market overheating phase is reached. Together, a naturally occurring Ponzi scheme can be a catalyst for a stronger feedback loop.

Based on these findings, a model for bubble analysis based on saturation and the Natural Ponzi scheme was created (Objective 2). By using the model for bubble analysis based on financial saturation, a Natural Ponzi scheme, as the level of the feedback loop, was included. According to the model, the turning point occurs with market bifurcation, which arises spontaneously through systemic resonance. This bifurcation may go unnoticed by management, yet it marks the transition to a deficit market and sets in motion rising saturation levels. As market saturation increases, the saturation paradox becomes more prominent, leading to price acceleration. These rising prices fuel investor expectations, generating a feedback loop of positive sentiment that further increases demand. In this feedback-driven environment, the Natural Ponzi effect takes hold, amplifying investment inflows based on momentum rather than fundamentals. This cycle of expectation, demand, and capital inflow inflates the bubble until it either self-corrects or collapses under its own instability.

The model for Enron bubble deconstruction revealed that saturation reached a high level (0.76–0.89) during periods of peak growth, causing the price logistic growth to increase to unprecedented levels (r = 13.7–34.84). This saturation level and the overheating stage of Enron's share price revealed a stock price bubble. According to the model, saturation levels exceeding 0.7 signal market bifurcation, and values approaching 0.9 reflect overheating—both of which were observed in Enron's case. These thresholds align with the theoretical preconditions for the emergence of a naturally occurring Ponzi dynamic and its second and third stages.

In a broader, clearer context, the financial saturation, combined with the signs of a Natural Ponzi scheme, pushed Enron's shares to a level of growth in an unstable system that could no longer be sustained by a Natural Ponzi scheme. At this point, the saturation paradox and the Natural Ponzi scheme became fully manifest. The high share price built up by the saturation paradox formed a bubble and allowed the Natural Ponzi scheme to take full effect, exposing the fraud and the company's operational flaws. This resulted in a loss of investor confidence, a decline in capital flow, and the bursting of the bubble, thus destroying the company's entire business and value model. Proven fraud and deception were secondary causes of the case.

Contrary to what has been assumed so far, Enron's initial successful performance is linked to the formation of a financial bubble. The bubble was the result of financial saturation related to the phenomenon of increasing returns and the Natural Ponzi. At a certain saturation level and price logistic growth rate, a naturally occurring Ponzi was triggered, which only reinforced the positive feedback and the price increase. Natural Ponzi manifestations occurred before bifurcation and bubble formation, as the classical approach showed in the literature review, but they did not negatively affect the company before bifurcation. At this stage, it is incorrect to consider management's actions as directly deliberate, as the company's results were good (as confirmed by the Arthur-Andersen audit). The main problem for management (and for the audit firm as well) was that they did not understand the phenomenon of saturation and Natural Ponzi schemes.

This study has some limitations. The identified discrepancies in the dynamics of the index price and accumulated capital in the market over time need to be examined in more detail. This requires additional research on the time lag between the growth rate of capital (internal rate of return) and the index value. The question is whether the observed time lag between the rate of change in capital and the price index allows for a direct, simple transformation of the growth rate into a price, as the theory of financial saturation suggests.

The analysis model consists of five variables, three of which are considered constant sizes. The aim is to simplify the calculations and to clarify the causal relationship between the dependent variable (r) and the independent variable (P). However, this leads to a limitation in the application of the model. It is likely that the potential capacity of the market is not stable and varies over time. This leads to different saturations in different periods and affects the size of the dependent variable r.

The analysis shows that the increase is evident as we approach P_p. However, the determination of P_p is more likely to be based on historical data than on accurate forecasting. The price logistic growth rate (r) can be used to predict that the market is approaching a growth opportunity frontier (potential level), followed by a correction/crash or market capacity change.

The model developed and the saturation, growth rate, and stages calculated using it, which define the manifestation of a Natural Ponzi scheme, confirm the research hypothesis. However, the incorporation of a timeline of fraudulent actions taken by Enron executives would assist in identifying how the Natural Ponzi scheme interacts with a classic Ponzi scheme in this case. In this way, the hypothesis could be tested against the actual historical actions of Enron's management. Further research could analyze if, as a result of high saturation, the full scale of a Natural Ponzi scheme occurred; then, the actions and decisions of the company's management could evolve from a naturally occurring Ponzi into a classic Ponzi, i.e., deliberate subterfuge and then fraud and deception, to maintain the success that had been achieved through the financial saturation that had previously occurred. Further research is needed to evaluate whether the Natural Ponzi scheme transformed into a Classical Ponzi scheme and how the attracted capital was redistributed in the context of fraud and deception. The theoretical and empirical research results allow us to make proposals for further research related to Ponzi scheme conversions and stages based on the strength of positive feedback and financial saturation. A deeper legal context of the Enron case is needed to compare the new approach and law decisions.

The literature review and theoretical part of this study revealed an interesting discovery that is worth mentioning. There is a high probability that, as Kaushik Basu (Basu, 2014b) states, the whole economy is rife with Ponzi schemes. A Natural Ponzi scheme is like the tip of an iceberg that we see above the water, but we do not see the whole iceberg that is under the water. Therefore, in future studies, we suggest developing and applying methods to check how many unmanifested or emerging, or perhaps unnoticed, Natural Ponzi schemes are around us. Research should include what the iceberg is like under the water and the probability that it will rise to the surface. Perhaps cases similar to the Enron case will occur in the near future.

6. Conclusions

Financial saturation and Natural Ponzi schemes are linked through positive feedback (expectations). Financial saturation is necessary for the manifestation of a Natural Ponzi scheme, which strengthens feedback. The more the market is saturated, the more Natural Ponzi schemes occur. A full-scale (peak) Natural Ponzi scheme emerges in the bubble stage. A Natural Ponzi scheme at the bubble could transform to natural (real) business value or to a classical Ponzi scheme (fraud) and bankruptcy. If bubbles do not burst, the Natural

Ponzi scheme could be unnoticed. The evolution of the Ponzi scheme interpretation and the paradox of financial saturation provide a new perspective on past bubbles and their causes.

A bubble analysis model was developed based on financial saturation theory. Using an adapted logistic growth formula, the model evaluates the saturation level and price logistic growth rate, which indicate the growth stage and Natural Ponzi occurrence level.

The analysis based on the Enron stock saturation growth model revealed that the saturation level reached a high stage (III) (0.76–0.89) during periods of peak growth, causing the price logistic growth rate to increase to unprecedented levels (r = 13.7–34.84). The reached saturation level and overheating stage of Enron's share price revealed a stock price bubble. According to the developed model, Enron's asset price was in a financial bubble, and a Natural Ponzi scheme occurred fully. The Natural Ponzi scheme reached operational and final collapse/deconstruction stages.

Enron's initial successful performance is linked to the formation of a financial bubble. The bubble was the result of financial saturation related to the phenomenon of increasing returns with a Natural Ponzi scheme. From a certain saturation level and price logistic growth rate, a naturally occurring Ponzi scheme was triggered, which only reinforced the positive feedback and the price increase. This process stopped in the collapse stage. The business model itself had some unfair schemes, but the main problem for management (and for the audit firm as well) was that they did not understand the phenomenon of saturation and the Natural Ponzi scheme and thus could do little to manage these processes.

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