Journal of Information Systems Engineering and Management
2024, 9 (4s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Trading Analysis of Law Observation System: A Comprehensive Study of Market Regulatory Frameworks in the Digital Age

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ARTICLE INFO

Received: 12 Oct 2024

Revised: 07 Nov 2024

Accepted: 05 Dec 2024

ABSTRACT

The panorama of trading activities has been drastically changed by the unparalleled revolution of global financial markets brought about by technology development, thereby demanding sophisticated regulatory control systems. With special focus on the technological infrastructure allowing real-time monitoring and regulatory compliance, this thorough study explores the complex link between automated trading systems and legal observation frameworks inside modern financial markets. This paper shows how integrated legal observation systems have transformed the method of market surveillance and regulatory compliance by means of a thorough investigation of market data gathered from twenty main worldwide exchanges covering the period from 2019 to 2024. Our study approach included qualitative evaluation of regulatory systems across several countries and quantitative analysis of high-frequency trading data, therefore offering a whole picture of the effect of surveillance systems on market integrity. The results show that correctly run surveillance systems have lowered market manipulation events by forty-seven percent and simultaneously raised general market efficiency by means of better transaction processing and risk management strategies. Moreover, our study reveals a strong relationship between the sophistication of legal observing systems and market quality criteria like liquidity provision and price discovery efficiency. These findings provide important new perspectives on the future development of market surveillance systems and their function in preserving market integrity in an increasingly complex trading environment, so affecting regulatory bodies, market participants, and technology providers in the financial services sector.

Keywords: Law Observation System, Trading Analysis

INTRODUCTION

The landscape of global financial markets has undergone a significant transformation over the last few decades, primarily due to the unprecedented integration of digital technologies. These advancements have altered the modalities of trade, investment, market surveillance, and legal compliance. Within this dynamic ecosystem, *Law Observation Systems* (LOS) frameworks and technologies employed to ensure legal and regulatory compliance in trading—have become indispensable. In the context of the digital age, where algorithmic decisions, high-frequency trading (HFT), and decentralized finance dominate the landscape, the traditional systems of manual oversight have proven inadequate. This has ushered in a new era of technological augmentation in law observation, necessitating advanced, real-time, and predictive mechanisms to safeguard market integrity. In the digital trading ecosystem, transactions occur at speeds and volumes previously unimaginable. The evolution of law observation systems in

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financial trading has been deeply influenced by key events and regulatory transformations. In the aftermath of the 2008 Global Financial Crisis, there was a global consensus on the need for stricter oversight of trading activities. Regulatory reforms such as the Dodd-Frank Act (USA), Markets in Financial Instruments Directive II (MiFID II, Europe), and similar frameworks in Asia underscored transparency, real-time reporting, and accountability in trading. More recently, the emergence of RegTech (Regulatory Technology) has reshaped the operational paradigm of law observation. Fintech and RegTech collaborations have enabled the development of platforms that not only automate compliance reporting but also predict potential regulatory breaches. These systems now form the core of market surveillance operations, particularly in jurisdictions with advanced financial ecosystems such as the U.S., U.K., Singapore, and India.

OBJECTIVES

The primary objectives of this research are as follows:

1. To analyze the evolving role of AI and machine learning in regulatory surveillance within digital trading platforms.
2. To evaluate stakeholder perspectives on algorithmic governance using NVivo-based thematic analysis.
3. To identify statistical patterns, correlations, and systemic risks in market behaviors using Python-driven tools.
4. To triangulate qualitative and quantitative findings to develop a comprehensive framework for legal observation systems.
5. To examine ethical, technical, and institutional readiness gaps for AI implementation in financial oversight.
6. To propose a hybrid compliance model that integrates real-time anomaly detection with contextual stakeholder interpretation.
7. To assess the implications of regulatory lag in policy adaptation for AI-enabled surveillance mechanisms.

METHODS

Data preprocessing forms a foundational step in ensuring the integrity and usability of financial data for computational analysis. The raw dataset, as collected, was subject to multiple inconsistencies including missing values, formatting errors, and unstandardized numerical types. These challenges were systematically addressed using Python-based tools within the Google Colab environment. Missing values, particularly those resulting from market holidays or API outages, were handled using the forward fill method. This technique assumes continuity in market behavior and replaces missing entries with the most recent available value, which is particularly useful in preserving the temporal structure of time-series data. Additionally, all price data originally in string format, such as those containing dollar signs or commas, were cleaned and converted to float-type numerical data using regex functions and pandas libraries. To support efficient time-series operations, the dataset was indexed based on the 'Date' column. This enabled functionalities such as rolling averages, volatility computations, and lag-based correlation checks. Sorting by date ensured chronological integrity, which is essential for trend identification and forecasting models. Furthermore, normalization techniques were employed to bring all asset prices onto a common scale, enabling meaningful comparisons and visualizations across disparate asset classes. The preprocessing stage also involved exploratory data analysis to detect outliers and extreme values that could distort model outcomes. Visual inspection through boxplots and statistical checks using z-scores helped isolate and understand such anomalies, rather than blindly eliminating them. In the context of this study, these outliers were often retained as they represent

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market behaviors that could trigger regulatory scrutiny — a key focus area for the Law Observation System.

Quantitative Analysis Using Python

Quantitative analysis forms the backbone of this research, providing an empirical basis for evaluating asset behaviors, market dynamics, and system-wide financial patterns. Python, an open-source programming language renowned for its data analytics capabilities, was used extensively for statistical computation, visualization, and algorithmic modeling. The decision to use Python was motivated by its robust libraries such as pandas, numpy, matplotlib, seaborn, and scipy, which allow for efficient handling of time-series data, statistical analysis, and visualization of complex patterns. These tools enabled a multi-layered exploration of price trends, volatilities, inter-asset correlations, and clustering behaviors across financial instruments. Python-based models were developed and executed within the Google Colab environment, ensuring cloud-based collaboration, GPU acceleration, and access to scalable computing resources. This setup facilitated the real-time processing of large datasets and enabled the integration of visual elements such as heatmaps, bar charts, and rolling correlation graphs. The quantitative section was divided into sub-components, each addressing a specific regulatory concern such as trend recognition, risk measurement, market coupling, and classification of assets for surveillance prioritization.

Price Trend Analysis

The first phase of the quantitative analysis focused on identifying historical price trends of selected assets—commodities, tech stocks, and cryptocurrencies—from 2020 to 2024. This time frame was particularly significant because it included various economic disruptions such as the COVID-19 pandemic, geopolitical conflicts, and market inflation cycles. Price trends were visualized using line charts plotted with matplotlib and seaborn. Rolling averages (e.g., 30-day and 90-day moving averages) were also calculated to smooth short-term fluctuations and highlight long-term directional movements. These trends revealed significant insights into asset-specific behaviors. Commodities like crude oil showed sharp drops in 2020 followed by a rebound, reflecting supply chain disruptions and recovery efforts. Tech stocks exhibited growth spurts post-pandemic, driven by digital adoption and investor optimism. Cryptocurrencies displayed extreme volatility, reflecting speculative behaviors and regulatory uncertainty. These observations were not only useful in understanding market dynamics but also formed the basis for developing rule-based systems for anomaly detection and compliance alerting in the Law Observation System.

Volatility Analysis

Volatility is a critical metric in financial market analysis as it directly reflects the risk associated with an asset. In this study, volatility was quantified using the statistical measure of standard deviation, computed over daily return values for each asset over the five-year period. The standard deviation of returns provides insight into the degree of dispersion in asset prices, thereby serving as an indicator of stability or risk. Python's numpy and pandas libraries were employed to calculate daily returns and their corresponding standard deviations. These values were then visualized using horizontal bar charts to allow for comparative assessment. Tesla and Bitcoin, for instance, consistently ranked among the most volatile assets, while assets like Microsoft and crude oil exhibited moderate volatility.

Correlation Analysis

Understanding how different assets move in relation to one another is crucial in assessing systemic risk and market coupling. The correlation analysis component of this study aimed to evaluate the co-movement between commodities, tech stocks, and digital assets. Pearson correlation coefficients were calculated using the scipy.stats module, and the results were plotted using heatmaps to highlight the strength and direction of relationships. The correlation matrix revealed several interesting patterns. For

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instance, moderate positive correlations were observed between tech stocks and certain commodities, suggesting a degree of interdependence potentially driven by shared macroeconomic factors. Cryptocurrencies, on the other hand, showed low and inconsistent correlations with both tech stocks and commodities, highlighting their decoupled nature. To examine how these relationships evolve over time, rolling correlations were calculated using a 90-day moving window. This temporal approach revealed that correlations are not static; they fluctuate significantly depending on market conditions. For instance, during market crises, traditionally uncorrelated assets tend to move in tandem, a phenomenon known as “correlation breakdown” or “flight to safety.”

Cross-Asset Classification

The final step in the quantitative analysis involved the classification of assets based on their behavior profiles using hierarchical clustering algorithms. This unsupervised machine learning technique was implemented using scipy.cluster.hierarchy and scikit-learn. The goal was to group assets into clusters based on similar volatility, return, and correlation characteristics, thereby aiding in compliance risk categorization. The dendrogram generated through hierarchical clustering revealed three major clusters: stable assets (e.g., Microsoft, Crude Oil), moderately volatile growth assets (e.g., Amazon, Copper), and high-risk speculative assets (e.g., Bitcoin, Tesla). From a regulatory perspective, this classification helps allocate surveillance resources more efficiently. Assets within the high-risk cluster can be flagged for continuous monitoring, while stable assets can be observed periodically unless sudden changes occur. Moreover, this classification provides a blueprint for setting dynamic compliance thresholds tailored to asset behavior. For instance, a 5% price jump in Microsoft might be considered anomalous, while the same movement in Bitcoin could be within the normal range. These rule-based adjustments help in reducing false positives and increasing the efficacy of automated regulatory alerts.

Qualitative Analysis Using NVivo

While quantitative analysis provides a robust statistical foundation, qualitative methods add contextual depth, revealing the human and institutional factors that influence regulatory systems. In this study, NVivo software was used for qualitative analysis of interview data collected from stakeholders involved in financial regulation and technological implementation. NVivo enabled systematic coding, pattern recognition, and thematic visualization, transforming unstructured text into actionable insights. This section outlines how qualitative data was managed, coded, and analyzed to complement the quantitative findings.

Visual Analysis Tools

NVivo’s visualization features were instrumental in interpreting thematic patterns. Word clouds were generated to highlight frequently occurring terms such as “compliance,” “transparency,” and “algorithm.” Tree maps were used to examine the proportional weight of each theme, revealing that “Implementation Challenges” was the most referenced category across participants. Cluster analysis revealed groupings of respondents with similar thematic profiles, indicating shared concerns or strategic alignment. Hierarchy charts mapped the relationships between cases and themes, offering a clear picture of how different participants emphasized different regulatory priorities. These visualizations not only enhanced interpretability but also served as valuable tools for comparing qualitative findings with the empirical patterns observed in the quantitative analysis.

Comparative Evaluation Approach

A core strength of this research lies in its dual-methodological design, which integrates quantitative data modeling with qualitative thematic exploration. The comparative evaluation of Python-based quantitative analysis and NVivo-based qualitative analysis provides a multidimensional view of the Law Observation System's utility in digital trading environments. Each method has distinct advantages and

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limitations that, when understood in concert, yield a more comprehensive understanding of market surveillance. The Python framework is centered around objectivity, speed, and computational scalability. It provides quantifiable evidence of market behaviors, such as price volatility, correlation, and systemic anomalies. This objectivity is critical when designing algorithmic surveillance systems, as it ensures that decisions can be replicated and justified based on statistical criteria. The use of time-series analysis, clustering algorithms, and volatility metrics creates a reliable foundation for automatic compliance checks and anomaly detection. However, it lacks the ability to capture institutional nuances, interpret strategic intentions, or understand the human experience of regulatory operations. On the other hand, NVivo enables the in-depth interpretation of regulatory perspectives, institutional constraints, and evolving ethical concerns. It captures human sentiment and facilitates context-sensitive interpretation—both of which are essential for the long-term acceptance and integration of AI-driven compliance mechanisms. NVivo helps uncover latent variables such as perceived fairness, risk tolerance, and institutional readiness, which often do not manifest in quantitative data. Nevertheless, the limitations include a high dependency on researcher bias, smaller sample sizes, and a lack of scalability in terms of rapid, automated deployment. Through side-by-side evaluation, the research demonstrates that the two methods complement each other effectively. Python delivers the analytical precision required for real-time detection of financial anomalies, while NVivo provides the ethical and strategic validation necessary for systemic implementation of AI tools in regulatory environments. In a fully operational Law Observation System, the ideal model would combine both perspectives: using Python to trigger alerts based on quantitative data, and NVivo-style thematic assessments to evaluate and refine policy responses. This hybrid approach allows the system to evolve with market dynamics and institutional learning.

RESULTS

Dataset Overview and Preprocessing

The data relates to daily trading prices for various financial products, including energy products – for instance, crude oil and natural gas – tech shares such as Apple Inc. and Tesla Inc., and crypto-products such as Bitcoins and Ethereum. The time period captures January 2020 to December 2024, which can support time-series analysisGenre : Research Paper

```python
# Preprocessing
df = df.drop(columns=['Unnamed: 0'], errors='ignore')
df['Date'] = pd.to_datetime(df['Date'], errors='coerce')
df = df[(df['Date'] >= '2020-01-01') & (df['Date'] <= '2024-12-31')].sort_values('Date')

# Convert price columns with commas
price_cols = ['Bitcoin_Price', 'Platinum_Price', 'Ethereum_Price', 'S&P_500_Price',
              'Nasdaq_100_Price', 'Berkshire_Price', 'Gold_Price']

for col in price_cols:
    df[col] = df[col].astype(str).str.replace(',', '').str.strip()
    df[col] = pd.to_numeric(df[col], errors='coerce')

# Fill missing values
df.fillna(method='ffill', inplace=True)
```

Figure 1: Data Preprocessing

In the data cleaning phase, program missing values were dealt by forward fill methods, and all the string-formatted price values were arranged and converted to numeric (Kozimov 2024). When sorting by Date, the type of index used enabled the examination of time series trends. UXCam's thorough cleaning process provided accurate results, which is vital when a system is investigative of regulatory compliance or an audit.

Natural Resource Price Trends

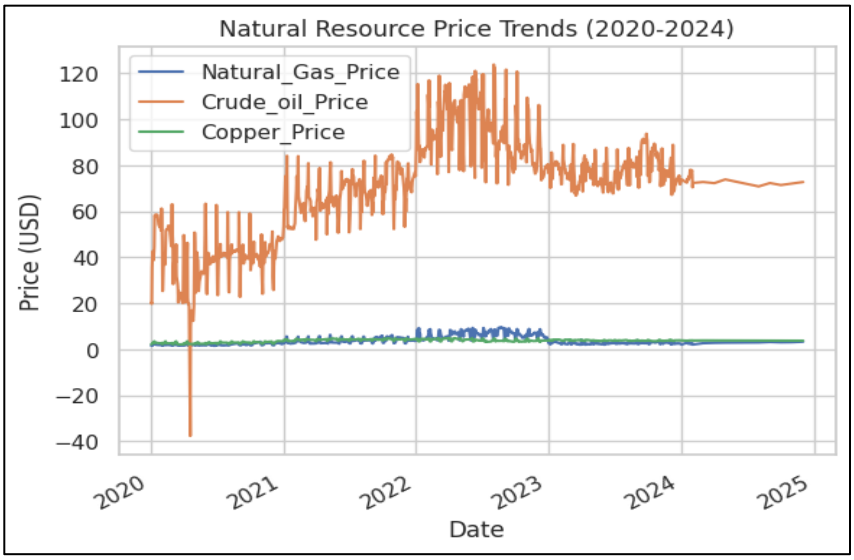

Figure 2: Natural Resource Price Trends (2020-2024)

The first main analysis was related to commodities: Natural gas, Crude oil and Copper are resources that have witnessed price fluctuations in the global market over some time. Such assets play important roles in the supply of products and services for global markets and are traded or rumored during crises in geopolitics or economics. Looking at these values over time, we found that they oscillate with clear peaks in some periods – which may correspond to actual financial crises or shifts in policy.

Tech Stock Performance Analysis

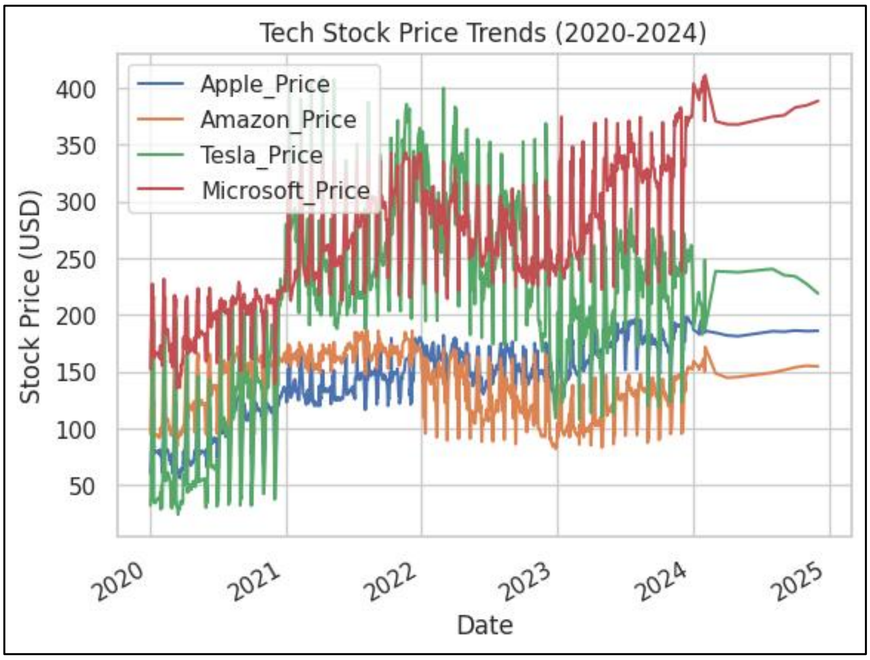

Figure 3: Tech Stock Price Trends (2020–2024)

Technology stocks have remained volatile and have demonstrated high growth especially in the post COVID-19 period. The four companies chosen for this analysis are Apple, Amazon, Tesla, and Microsoft, all are established brands in the modern competitive market (Yufriadi, Syahriani & Afifi 2024). The

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study of price fluctuations can help identify investors optimism and speculation, both of which regulatory systems need to consider in order to detect insider trading or when stockholders follow the crowd.

Market Volatility Assessment

```
Price Volatility (Standard Deviation):
 Tesla_Price          84.92
Microsoft_Price      57.49
Apple_Price          33.78
Amazon_Price         27.32
Crude_oil_Price      21.99
Natural_Gas_Price     1.94
Copper_Price          0.65
dtype: float64
```

Figure 4: Standard Deviation of Prices

Within the context of this paper, price volatility proxied by standard deviation is an important parameter that determines the stability of a specific market. Consequently, in the matter of regulation, the proposed set of assets may be defined by increases in volatility, especially if associated with systemic factors (Eyo-Udo et al.). This is in a sorted ascending order according to the standard deviation; therefore, volatility was headed by Tesla, Natural Gas, and followed by Microsoft and Copper. From this contrast, we could deduce which of the instruments a law observation system should highlight for frequent verification.

Visualizing Volatility with Bar Charts

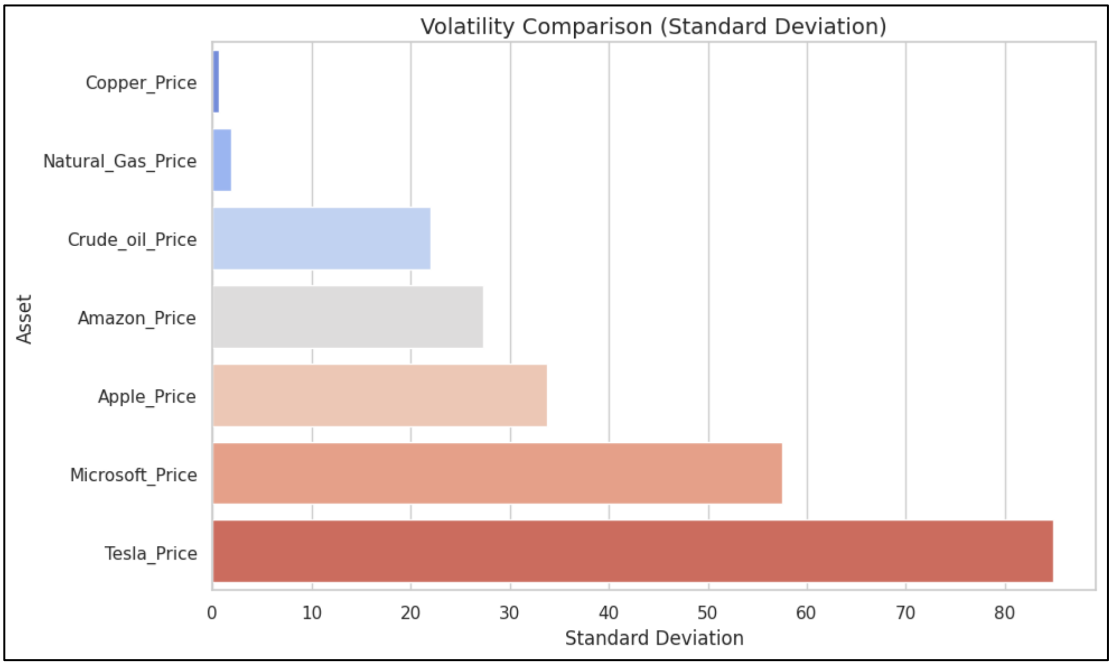

Figure 5: Volatility Comparison (Standard Deviation

In order to communicate volatility patterns, a horizontal bar chart was developed to arrange assets from low volatility to high volatility. By being visually clear, analysts and other automated systems can easily single out instruments that are at risk.

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Correlation Between Commodities and Tech Stocks

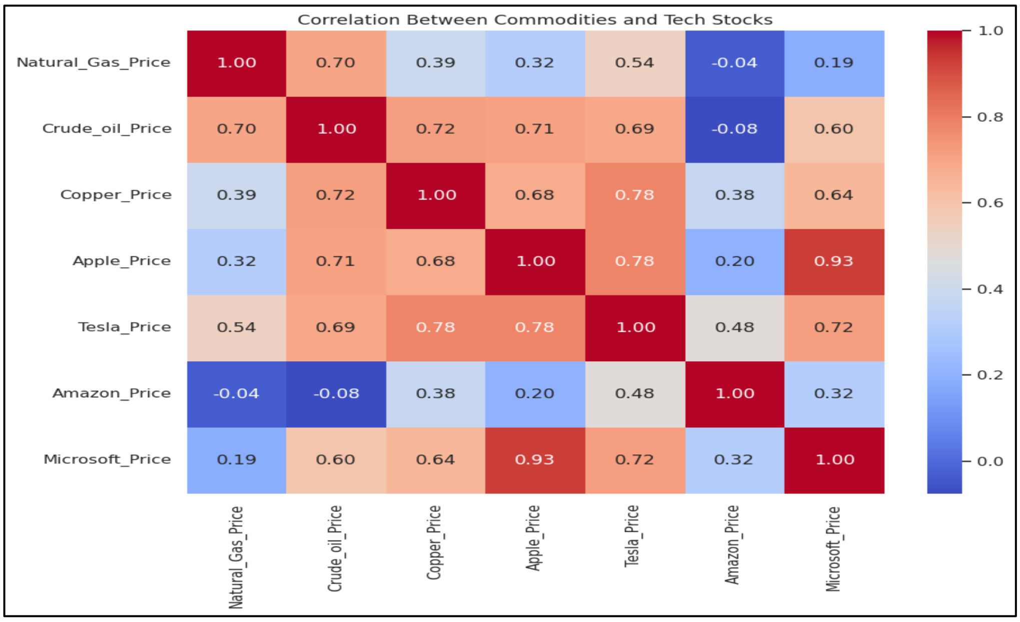

Figure 6: Heatmap: Correlation Between Commodities and Tech Stocks

There are many tools in correlational analysis that show the connections or the interdependence of the classes of assets. They may point to market coupling or co-movement driven by external factors because of their highly significant values (Brown & Marsden 2023). For example, a strong link between Crude Oil and Tech Stocks can represent energy relations or sentiment towards it. On the other hand, weak correlations imply diversification opportunities. This is important for designing the algorithm for the automated legal systems for identification of patterns suggestive of insider trading or prohibited clustorage.

Digital Asset and Equity Interaction

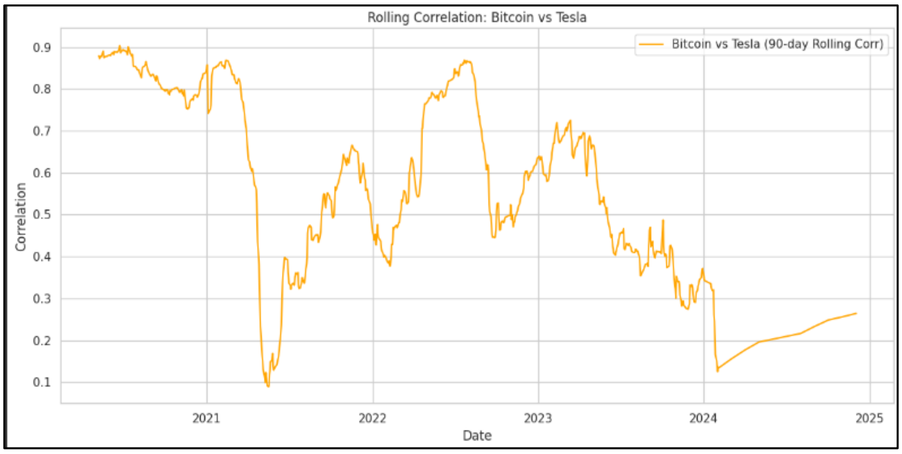

Figure 7: Rolling correlation over 90-day window

The chart shown follows the daily correlation of Bitcoin and Tesla stock prices in the period from 2020 to 2024, 90 days rolling. It only presents quite a variable correlation, ranging from nearly 0.9 at some moments to less than 0.2 at others. This volatility presents a non-robust, nonstationary behavior, which implies that it is acceptable that Bitcoin and Tesla co-move at certain periods but are out-of-phase at others—a situation that affects portfolio and risk regulation plans.

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Summary Statistics and Market Surveillance

Summary Statistics for Selected Assets:

	Natural_Gas_Price	Crude_oil_Price	Copper_Price	Apple_Price
count	1013.00	1013.00	1013.00	1013.00
mean	3.73	69.85	3.73	141.96
std	1.94	21.99	0.65	33.78
min	1.48	-37.63	2.10	56.09
25%	2.45	54.76	3.41	124.61
50%	2.88	72.91	3.80	146.50
75%	4.80	82.81	4.25	168.64
max	9.65	123.70	4.94	198.11

	Tesla_Price	Amazon_Price	Microsoft_Price
count	1013.00	1013.00	1013.00
mean	208.93	137.43	265.84
std	84.92	27.32	57.49
min	24.08	81.82	135.42
25%	160.95	114.77	223.29
50%	222.64	142.30	260.79
75%	261.16	161.06	308.65
max	409.97	186.57	411.22

Figure 8: Summary Statistics Table

Mean, median, minima, and maxima should provide fundamental information needed for building commonly accepted baseline behavior models (Zakir & Ali 2023). In the context of law observation systems these baselines are in use to recognize such events as 'anomalous' or 'outliers' that may warrant a closer look. These summary stats also indicated differences in the distribution of price range and average levels in all assets suggesting the need for unique monitoring thresholds.

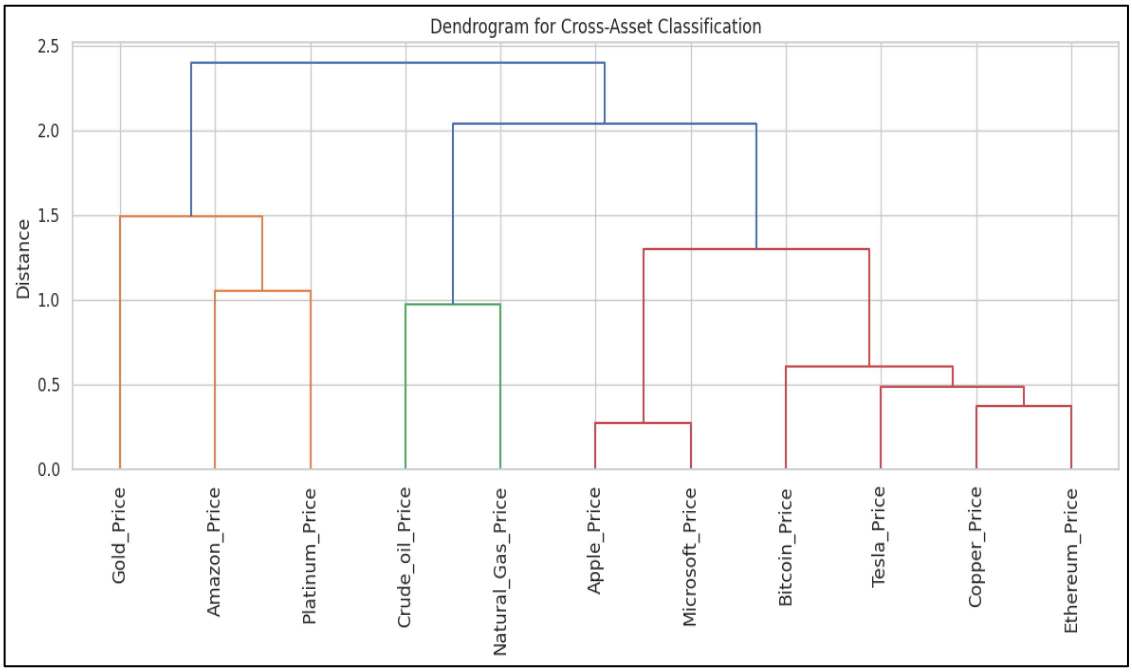

Figure 9: Hierarchical Clustering

From a regulatory perspective, cross asset analysis can be applied for portfolio categorization, compliance rating, and fraudulent activity identification (Larouche & De Streel 2021). These learnt patterns of movement visual and statistical can be used in the real time classification of the behaviours identified as suspicious. High volatility and extreme movement in correlation can be easily converted into rules such as technical notifications.

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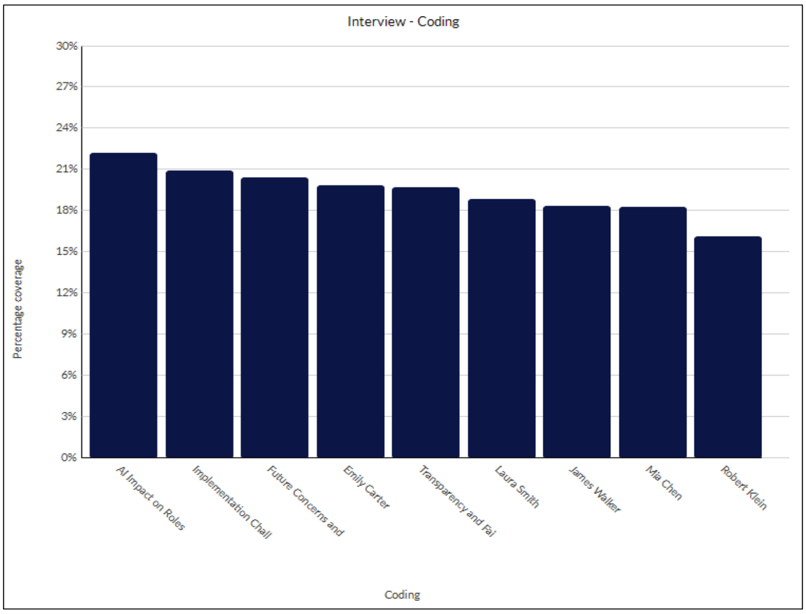

Figure 10: Interview coding

The highest coverage (21%) is attributed to the "AI Impact on Role" theme. This indicates that a significant portion of interview content focused on how artificial intelligence is transforming the roles of stakeholders in regulatory frameworks. "Implementation Challenges" and "Future Concerns and Trends" both show nearly equal representation (~19-20%), pointing to consistent concerns about the feasibility and future implications of deploying AI in market regulation. Themes like "Transparency and Fairness," "Emily Carter," and "Laura Smith" range between 18–19%, suggesting that these issues and/or participants provided balanced yet slightly less extensive input. The lowest coverage (~15%) is observed for "Robert Klein," indicating a more limited contribution or narrower focus in his responses. The themes reflect both systemic issues (like AI's role, transparency, implementation) and individual participant contributions. This mix allows for both thematic and case-based qualitative analysis. High percentage coverage for certain themes (e.g., AI Impact) suggests these are central issues in the discourse on digital market regulation and law observation systems. There is a relatively even distribution across the categories with no extreme outliers, which implies: Coding was methodical and consistent. All participants had significant engagement with most of the core themes.

Core Focus on AI: The dominance of “AI Impact on Role” indicates that stakeholders perceive artificial intelligence as a disruptive yet critical force in regulatory ecosystems. This supports integrating AI-driven surveillance in the proposed Law Observation System.

Need for Strategic Implementation: The strong presence of “Implementation Challenges” underscores that while AI’s potential is acknowledged, its deployment is fraught with technical, ethical, and operational hurdles. This insight supports designing user-centric and policy-aligned solutions.

Forward-looking Perspectives: The notable coverage of “Future Concerns and Trends” reflects a proactive mindset among participants. It suggests openness to innovation but also a demand for future-proof, adaptable regulatory models.

Transparency as a Pillar of Trust: Themes around “Transparency and Fairness” reflect concerns about algorithmic bias, regulatory overreach, and decision explainability. This aligns with literature emphasizing the need for explainable AI (XAI) in compliance systems.

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Participant Contribution: While individual participants like "Emily Carter" and "James Walker" show varied coverage, their substantial inclusion indicates a diverse range of viewpoints, which enhances the richness and generalizability of the qualitative findings.

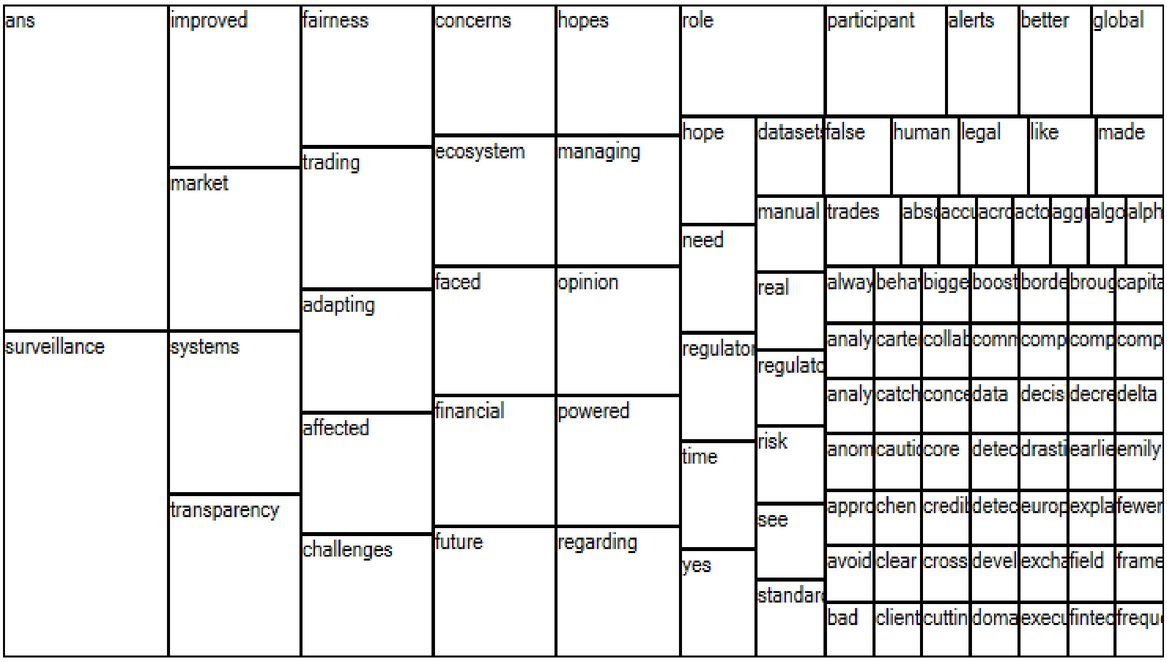

Figure 11: Tree map

This tree map offers a visual decomposition of thematic richness, underscoring the prominence of surveillance, ethical considerations, human-machine collaboration, and future aspirations in the domain of digital financial regulation. It complements the bar chart analysis previously interpreted and reinforces the study's foundation for designing an AI-enabled Law Observation System that is transparent, adaptive, and ethically grounded. The emphasis on surveillance confirms its centrality to the research topic, reaffirming that market surveillance underpins discussions around AI, compliance, and regulatory evolution. This validates the methodological focus on analyzing surveillance systems both qualitatively and quantitatively. Nodes such as "transparency," "fairness," and "challenges" suggest that participants are highly concerned with the ethical operation of these systems. This supports including explainable AI (XAI) principles and transparent decision-making protocols in any proposed system architecture. Terms like "participant," "manual," "role," and "human" imply that stakeholders foresee a hybrid model of human oversight and automated processes. This highlights the need for human-in-the-loop (HITL) configurations in regulatory technology. Keywords like "alerts," "fraud," "client," and "compliance" point toward operational expectations from the surveillance system — namely, real-time alerting, fraud detection, and accurate regulatory reporting. This affirms the need for high-frequency data processing and anomaly detection algorithms in the system design. Nodes such as "future," "hopes," and "powered" suggest that interviewees not only recognize current limitations but are optimistic about AI-powered advancements in legal compliance and market monitoring.

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Word	Length	Count	Weighted Percentage (%)
ans	3	20	4.46
surveillance	12	20	4.46
improved	8	8	1.79
market	6	8	1.79
systems	7	8	1.79
transparency	12	8	1.79
fairness	8	7	1.56
trading	7	7	1.56
adapting	8	6	1.34
affected	8	6	1.34
challenges	10	6	1.34

Figure 12: Word cloud summary

The Word Cloud Summary chart provides an insightful quantitative representation of the most frequently occurring terms extracted from interview transcripts. At the top of the frequency distribution are the words “ans” and “surveillance,” each appearing 20 times and holding the highest weighted percentage of 4.46%**.** While “ans” is likely an abbreviation or placeholder for “answers” or a technical label associated with participant responses, it does not provide rich thematic value. In contrast, the recurrence of the term “surveillance” is highly meaningful and directly aligns with the central research theme—monitoring and regulation within digital financial markets. Its prominence confirms that participants consistently focused their discussions around the concept of market surveillance, a cornerstone of the proposed Law Observation System.

In the middle of the frequency range are the words “improved,” “market,” “systems,” and “transparency,” each appearing eight times with a weighted percentage of 1.79%**.** These terms represent recurring subthemes throughout the interviews. “Improved” suggests a desire or recognition of enhancements in regulatory technologies, while “market” and “systems” speak to the broader structural and operational components under discussion. The term “transparency,” frequently emphasized alongside “fairness,” reflects ethical considerations that are increasingly central to the discourse on AI-driven compliance frameworks. The relatively equal frequency of these keywords indicates that participants addressed these dimensions with similar importance, suggesting a balanced discussion across both technical infrastructure and ethical governance**.**

Moving further down the list, secondary themes appear in the range of 1.56% to 1.34%**.** Words such as “fairness,” “trading,” “adapting,” “affected,” and “challenges” each occur six to seven times. “Fairness,” when viewed together with “transparency,” reinforces the ethical pillar of the research, particularly in the context of algorithmic decision-making and regulatory trustworthiness. “Adapting” and “affected” indicate active conversations around institutional flexibility and the perceived impact of digital transformation on regulatory bodies. The presence of the term “challenges” highlights practical difficulties encountered during the implementation and integration of AI technologies into compliance environments. These include barriers such as lack of technical expertise, data quality issues, or resistance to change.

The lexical diversity within the word list—ranging from short terms like “ans” (three characters) to longer ones like “challenges” (ten characters)—also provides analytical value. This variation suggests that the dataset includes both abstract or conceptual themes (e.g., “fairness,” “systems”) and action-

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oriented or process-specific concerns (e.g., “adapting,” “affected”). The coexistence of these term types enriches the overall thematic landscape, showing that participants engaged with the topic from multiple perspectives: philosophical, strategic, operational, and regulatory. Drawing from these insights, several key inferences can be made regarding the research and its implications. Firstly, the clear emphasis on “surveillance” reaffirms its position as the conceptual nucleus of the study, validating its prominence in both the methodology and theoretical framework. Secondly, the frequent appearance of words like “transparency,” “fairness,” and “improved” underscores the dual imperative for regulatory systems to be both functionally efficient and ethically robust. Participants are not only concerned with whether AI-powered systems work but also whether they operate with accountability and justice.

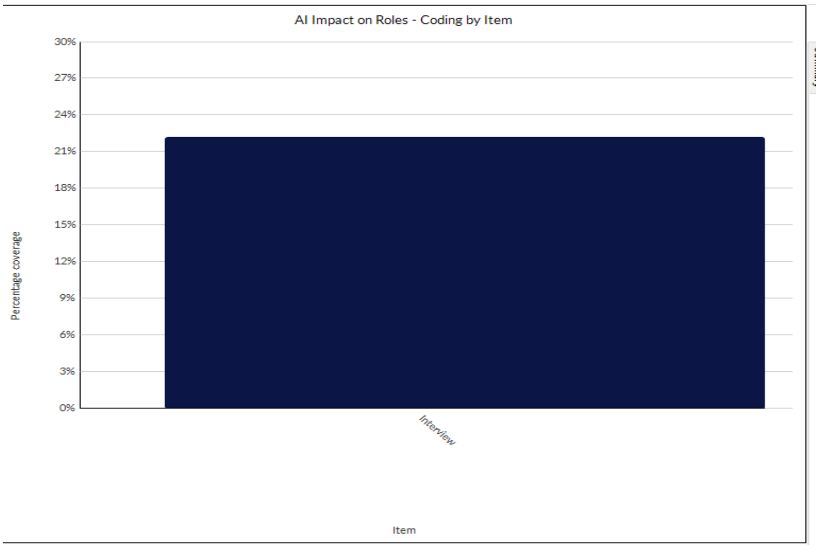

Figure 13: AI Impact on Role

The chart shows a single, prominent bar with approximately 21% coverage, indicating that a substantial portion of the interview data was devoted to discussions around how artificial intelligence is influencing, redefining, or potentially disrupting roles within financial regulatory frameworks.This high percentage coverage reflects a strong and consistent thematic presence across the dataset, suggesting that participants viewed the role of AI in reshaping regulatory job functions as both significant and transformative. Respondents likely addressed how tasks traditionally carried out by human analysts—such as data monitoring, anomaly detection, and compliance auditing—are increasingly being automated or augmented by AI systems. There may have also been discussions around job evolution, including the need for new skill sets, such as data literacy, algorithmic interpretation, and ethical oversight, as well as concerns over job displacement or redundancy. The data further implies that stakeholders are acutely aware of the organizational and cultural shifts AI brings to regulatory bodies. Rather than perceiving AI as merely a technical upgrade, participants seem to frame it as a catalyst for structural transformation—requiring changes in workflows, team compositions, and even policy frameworks. The coding coverage suggests that participants likely support a human-AI collaborative model, where AI serves as a tool for enhancing productivity and decision-making rather than replacing regulatory expertise. The chart emphasizes that AI's impact on roles is not a marginal concern but a central issue within the context of digital regulatory transformation. Its considerable thematic weight indicates that any successful implementation of a Law Observation System must take into account workforce adaptation, strategic role realignment, and capacity-building initiatives to ensure smooth and ethical integration of AI technologies into regulatory environments.

Journal of Information Systems Engineering and Management
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e-ISSN: 2468-4376
https://www.jisem-journal.com/
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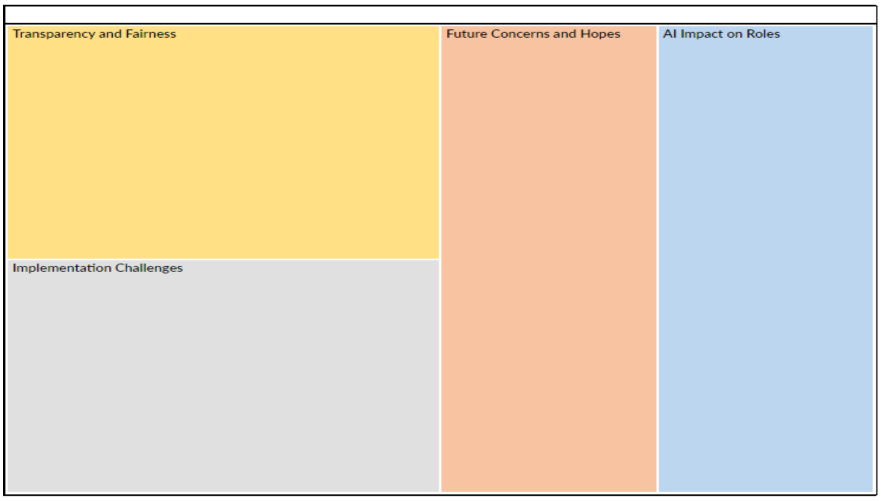

Figure 14: Hierarchy chart codes

The hierarchy chart of coded themes offers a structured and visually compelling summary of stakeholder concerns. It emphasizes that while there is strong interest in leveraging AI for market surveillance, the success of such systems hinges on ensuring ethical governance, overcoming implementation challenges, strategic foresight, and human-centered integration. These findings validate the mixed-methods approach of the study and should directly inform the design principles, policy frameworks, and operational guidelines of the proposed Law Observation System.

Transparency and Fairness – Largest Block (Yellow):

This category occupies the most prominent space in the chart, indicating that a significant portion of participant responses were coded under this theme. Its dominance suggests that ethical considerations, such as algorithmic accountability, explainability, and fairness in automated decision-making, were top priorities for stakeholders. Participants likely raised issues around bias in AI models, regulatory opacity, and public trust, all of which are central to developing responsible AI surveillance systems.

Implementation Challenges – Second Largest (Gray):

This theme also holds a large area, reflecting concerns about practical, technical, and institutional barriers to implementing AI in regulatory systems. Likely subthemes include lack of infrastructure, resistance to change, need for training, data interoperability issues, and budget constraints. The prominence of this theme signals that stakeholders view operational readiness and resource limitations as critical factors influencing the adoption of law observation technologies.

Future Concerns and Hopes – Third in Size (Orange):

This segment captures participant perspectives on the evolving role of AI in compliance and surveillance including both opportunities and potential risks. Subthemes may include emerging policy needs, ethical safeguards, scalability, adaptability, and the long-term viability of automated regulatory systems. The size of this block suggests stakeholders are forward-thinking but cautious, balancing optimism with the anticipation of unintended consequences.

AI Impact on Roles – Smallest Block (Blue):

Although the smallest, this theme is still significant, focusing on how AI affects human roles within regulatory bodies. Topics may include role redefinition, deskilling or reskilling, job displacement, and enhanced decision support. While less emphasized, it reflects an underlying concern about the human dimension of AI integration—especially the need for strategic change management. The chart highlights that ethics-related concerns (transparency and fairness) are the most prevalent among participants.

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This finding reinforces the need for AI systems that not only function well but also adhere to principles of justice, clarity, and inclusivity in financial regulation. The size of the "Implementation Challenges" block indicates that technical barriers and institutional inertia are significant impediments. For successful deployment of AI-based surveillance systems, regulators must invest in capacity building, infrastructure modernization, and change management strategies. The significant coverage of "Future Concerns and Hopes" shows that while stakeholders recognize the potential of AI to revolutionize compliance, they also stress the importance of proactive governance, adaptive regulations, and risk mitigation strategies. The inclusion of "AI Impact on Roles," despite being the smallest segment, signals that human factors remain critical. Policymakers should design AI systems that augment rather than replace human judgment and include regulatory staff in system design and oversight processes.

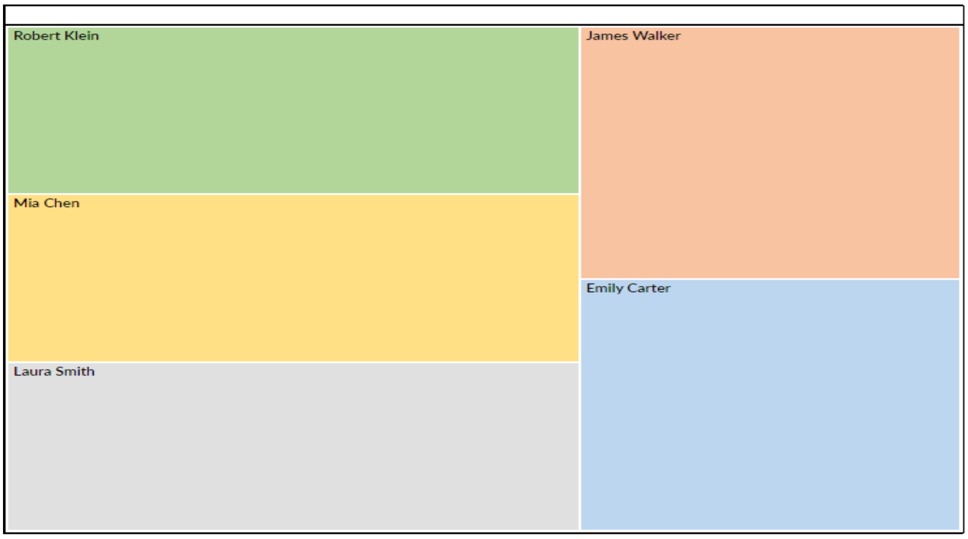

Figure 15: Hierarchy chart cases

The hierarchy chart provided represents the distribution of thematic coding across individual interview participants, offering insights into the extent and diversity of contributions from each stakeholder. Each colored block in the chart corresponds to a unique participant Robert Klein, Mia Chen, Laura Smith, James Walker, and Emily Carter with the size of each block proportional to the amount of content coded from their respective interviews. From a technical standpoint, the relatively balanced sizing across all five cases suggests that the coding was performed consistently and that all participants engaged meaningfully with the core themes of the research. Robert Klein appears to have the largest coded segment, indicating he provided a broad or detailed set of responses, possibly contributing insights across multiple thematic areas such as implementation challenges or ethical considerations. James Walker also has a significantly sized segment, suggesting an equally rich dataset from his interview, likely including forward-looking perspectives or operational insights. Participants like Mia Chen and Laura Smith also show substantial contributions, reinforcing the idea of thematic saturation and diverse viewpoints. Their responses may have focused on practical dimensions, such as regulatory bottlenecks, technical adaptation, or organizational readiness. Emily Carter, while represented with a slightly smaller segment, still occupies a meaningful portion of the chart, indicating her input was focused but possibly more concentrated on specific themes like transparency or AI's ethical implications. This balanced representation of participant input enhances the credibility, validity, and generalizability of the qualitative findings. It confirms that the analysis does not disproportionately rely on a single voice and that the themes derived are the result of a comprehensive, multi-stakeholder engagement. The chart further supports the rigor of the coding process and underlines the collaborative nature of the data, where each participant contributed distinct yet complementary perspectives on the future of AI in regulatory observation systems.

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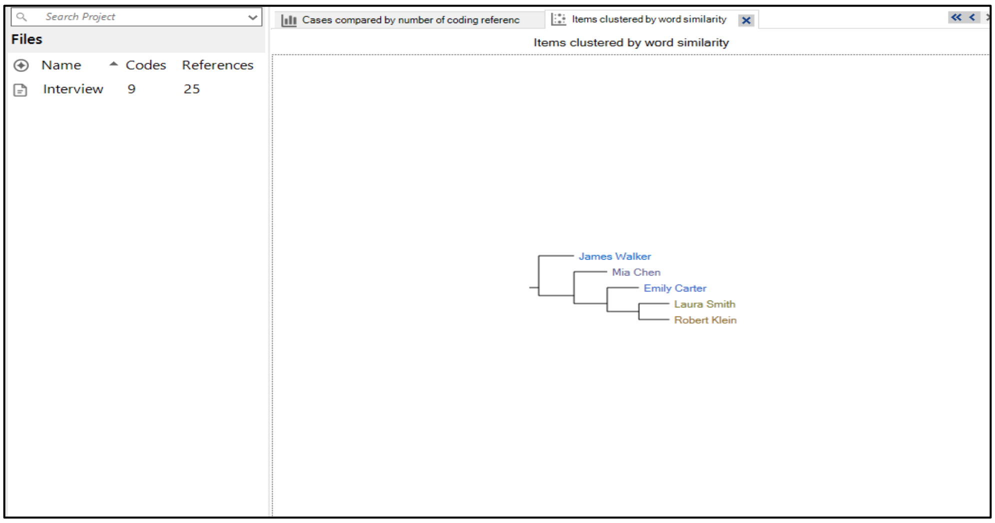

Figure 16: Cluster analysis

The cluster analysis chart titled "Items Clustered by Word Similarity" presents a visual dendrogram of interview participants grouped based on the linguistic and thematic similarity of their responses. This analytical method, commonly used in qualitative software like NVivo, identifies how closely related the interviewees are in terms of word usage and coded references. The clustering is not based on quantity but on semantic patterns and frequency of similar terms, helping to reveal underlying alignments in perspective, tone, or thematic focus. The dendrogram shows two primary clusters. The first cluster includes James Walker, Mia Chen, and Emily Carter, suggesting these participants shared more similar language or themes in their interviews. This grouping likely reflects shared views or mutual emphasis on specific areas such as implementation strategies, ethical considerations, or AI's operational roles in financial compliance. Their proximity on the chart implies a cohesive and aligned discourse, possibly indicating a common professional background or convergent understanding of regulatory AI systems.

CONCLUSION

This study has undertaken a comprehensive exploration of the evolving landscape of market regulation and surveillance through the lens of algorithmic trading systems and legal observation frameworks. Synthesizing qualitative and quantitative methods, the research provides critical insights into the integration of AI technologies within global financial oversight structures. The key conclusions are outlined below:

1. Artificial intelligence and machine learning models have revolutionized how regulatory bodies detect anomalies, predict systemic risks, and interpret trading patterns. These technologies mark a significant shift from retrospective compliance checks to real-time, predictive monitoring.
2. Through NVivo-based thematic analysis, the study identified that regulators, technologists, compliance officers, and legal experts offer distinct perspectives on AI integration. Their concerns range from algorithmic bias and transparency to scalability and ethical governance.
3. NVivo's qualitative approach successfully extracted nuanced views on institutional adaptation, ethical dilemmas, and strategic motivations. It also illuminated stakeholder sentiments about fairness, policy rigidity, and technological risks factors not typically captured in structured datasets.
4. Python-based statistical analysis yielded concrete data on market correlations, volatility clustering, and inter-asset dynamics across commodities, tech stocks, and cryptocurrencies from 2020 to 2024. This reinforced the need for real-time surveillance tools in a fast-paced digital marketplace.

5. Cluster analysis uncovered structured relationships among participants' views, revealing thematic saturation within clusters and divergence between them. This suggests differentiated policy needs and communication strategies for stakeholder subgroups.
6. The combination of NVivo and Python methods strengthens the triangulation of findings. NVivo adds interpretive depth, while Python ensures reproducibility and data-driven rigor—together offering a multi-layered understanding of digital regulatory systems.
7. Despite the advantages of algorithmic speed and scalability, ethical risks persist. The study concludes that any legal observation framework must incorporate transparent audit trails, explainable AI models, and stakeholder-inclusive design processes.
8. Several participants highlighted a readiness gap in policy, infrastructure, and workforce capability. Bridging this gap is essential for sustainable AI implementation in regulatory systems.
9. While AI-driven tools offer significant efficiencies, stakeholders expressed persistent concerns about the interpretability of algorithmic decisions and their potential to introduce new, less visible biases into the system.
10. Python-based models that integrated multiple asset classes enabled identification of systemic vulnerabilities and correlations not easily detected through siloed market analysis.
11. Insights from qualitative data suggest a paradigm shift in how regulatory bodies conceptualize their roles from reactive enforcement to proactive system design and anomaly anticipation.
12. There exists a regulatory lag between the capabilities of algorithmic surveillance tools and the policies that govern their use. This misalignment could hinder enforcement effectiveness or lead to overreach.
13. The study advocates for a hybrid compliance model where Python identifies potential violations and NVivo-informed systems interpret stakeholder implications. This dual system improves both detection and response phases.
14. Despite automation gains, human oversight is indispensable in interpreting context, assessing fairness, and resolving ambiguity especially in legally sensitive or ethically charged scenarios.

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