

## ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

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## A SECTORAL PERSPECTIVE ON FRONTRUNNERS AND INFORMATION CASCADES: CENTRAL AND ISOLATED CLEARING ANALYSIS USING ISOLATION FOREST<sup>1</sup>

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### ÖZ

Bu çalışma, 3 Eylül 2021 ile 9 Nisan 2024 tarihleri arasında Borsa İstanbul'da işlem gören 448 şirketin hisse fiyatları ve takas verilerini kullanarak bilgi asimetrisi, stratejik alım-satım davranışları ve spekülasyon hareketlerinin piyasalardaki etkilerini incelemektedir. Araştırma, bilgi kaskadı ve öncüller kavramları çerçevesinde merkezi ve izole brokerların rollerini, sektörel etkilerini ve yatırım getirilerine katkılarını değerlendirmektedir. Çalışmanın amacı, izole brokerların spekülasyon işlemleri ve merkezi brokerların uzun vadeli yatırımlarının piyasa dinamikleri üzerindeki etkilerini anlamaktır. Anomali tespiti, Isolation Forest algoritmasıyla gerçekleştirilmiş ve tespit edilen anomalilerin piyasa fiyatlarına etkisi analiz edilmiştir. Aracı kurumlar arasındaki ilişkiler, piyasalardaki bilgi akışını değerlendirmek amacıyla ağ teorisi kullanılarak incelenmiştir. Bulgular, her iki broker tipinin de teknoloji ve enerji gibi yüksek getirili sektörleri hedeflediğini, ancak merkezi brokerların daha istikrarlı sektörlerde düşük riskli stratejileri tercih ettiğini göstermektedir. K-Means kümeleme analizi ile sektörel getiriler gruplanmış, Restaurant ve Otel gibi bazı sektörlerde izole brokerların önemli kazançlar sağladığı, diğer sektörlerde ise merkezi brokerların daha baskın olduğu tespit edilmiştir. Bu sonuçlar, spekülasyon işlemleri ve bilgi asimetrisinin finansal piyasalardaki dinamikler üzerindeki etkilerine dair değerli içgörüler sunmaktadır.

**Anahtar Kelimeler:** Isolation Forest, Anomali Tespiti, Bilgi Çağlayanı, Öncüller, Yatırımcı Davranışları

### SEKTÖREL PERSPEKTİFTEN ÖNCÜLER VE BİLGİ KASKADLARI: İZOLASYON ORMANI İLE MERKEZİ VE YALITILMIŞ TAKAS ANALİZİ

#### ABSTRACT

This study investigates the effects of information asymmetry, strategic trading behaviors, and speculative movements in markets, using stock prices and clearing data from 448 companies listed on Borsa Istanbul between September 3, 2021, and April 9, 2024. It examines the roles of central and isolated brokers within the frameworks of information cascade and frontrunning, assessing their sectoral impacts and contributions to investment returns. The research aims to explore the influence of speculative trading by isolated brokers and long-term investments by central brokers on market dynamics. Anomaly detection was conducted through the Isolation Forest algorithm, analyzing the effects of detected anomalies on market prices. Relationships between brokerage firms were studied using network theory to evaluate information flow in the market. Findings show that both broker types pursue high-return sectors like technology and energy, with central brokers favoring lower-risk strategies in stable sectors. K-Means clustering analysis grouped sectoral returns, highlighting that isolated brokers achieved significant gains in sectors such as Restaurant and Hotels, while central brokers were more dominant in others. These results provide valuable insights into the dynamics of speculative trading and the impact of information asymmetry on financial markets.

**Keywords:** Isolation Forest, Anomaly Detection, Information Cascade, Frontrunner, Investor Behavior

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## INTRODUCTION

This study provides a sectoral analysis aimed at understanding information asymmetry and strategic trading behaviors in stock markets by incorporating the metaphors of information cascade and frontrunner. The term "information cascade" refers to situations where participants with limited information make decisions based on the observed actions of others in the market. In such cases, frontrunners, defined as informed traders, play a pivotal role as the initial triggers that can cause significant fluctuations in market prices. Essentially, the concepts of information cascade and frontrunner can essentially be viewed as subsets of herding behavior, where groups of participants attempt to capture the main trend by forming their own foundations regarding the accuracy or validity of the incoming information. This study examines the sectoral effects of this information dissemination and frontrunning phenomenon in the market structure.

The primary objective of this study is to examine, on a sectoral basis, the presence of information cascade and frontrunner effects, as well as how these phenomena create return differentials in stock prices, using daily clearing and price data from 448 companies listed on Borsa Istanbul between September 3, 2021, and April 9, 2024. Specifically, by analyzing the differences between central brokers/nodes and isolated brokers/nodes, the study aims to evaluate the comparative impacts of these market participants. Furthermore, it investigates whether these effects vary across sectors and how such variations are reflected in investment returns. The study also examines the advantages of identifying and tracking isolated nodes, providing insights into E. Fama's efficient market hypothesis, which posits that markets are fully informed. While markets respond to new information as efficiently as possible, pre-positioning strategies and the risk-reward trade-offs associated with the influence of information on the market are critical considerations.

The study explores whether the ability of the Isolation Forest (iForest) algorithm to detect isolated nodes or brokers provides an advantage in identifying anomalies that may signify violations of the efficient market hypothesis in financial markets. These anomalies, such as information cascades and frontrunners, represent rare and extreme deviations in trading behavior. The analysis examines whether tracking institutions exhibiting such deviations offers a distinct advantage over monitoring central nodes, which typically reflect normal trading activity (Fama, 1970).

### 1. Literature Review

Financial markets are dynamic ecosystems where information asymmetry and strategic trading behaviors significantly influence price formation and market efficiency. The phenomenon of information cascades, as explored by Bikhchandani et al. (1992) and Hirshleifer and Teoh (2003), highlights how investors often make decisions based on observed actions rather than their private information, leading to herding behaviors. Similarly, frontrunner effects, identified in studies such as Scharfstein and Stein (1990), emphasize the role of informed traders who act ahead of others, shaping market trends and amplifying price volatility.

The advent of machine learning techniques has introduced innovative tools for analyzing these behaviors. Algorithms such as Isolation Forest (iForest) and clustering methods like K-Means have been employed to detect anomalies and uncover patterns in trading activities (Liu et al., 2008). These approaches complement traditional methods by providing scalable, efficient solutions for identifying irregularities in large, complex datasets. Furthermore, studies on sectoral dynamics reveal that the impact of information asymmetry and speculative behaviors varies across industries, driven by differences in volatility, growth potential, and market structure (Raafat et al., 2009).

This study builds on this body of literature by applying advanced machine learning algorithms to examine the roles of Cent and Iso Brokers in İstanbul Stock Exchange. By integrating insights from information asymmetry theories and computational anomaly detection, the research contributes

to understanding the nuanced interplay of institutional and speculative trading across diverse sectors.

### **1.1. Theoretical Framework: Information Cascade, Frontrunner, and Herding Behavior**

Financial markets are dynamic and complex systems in which investors continuously observe one another and make decisions based on the information derived from these observations. Within this context, the concepts of information cascade, frontrunner, and herding behavior play a pivotal role in understanding market dynamics. These interrelated concepts offer valuable insights into the effects of information flow on market prices and investor behavior. Considered collectively, they provide a comprehensive framework for analyzing the psychological and social factors driving market movements.

The concepts of information cascade and frontrunner can be regarded as subcategories of herding behavior. Both illustrate the tendency of market participants to emulate the actions of others in their investment decisions rather than relying exclusively on their own analysis. Herding behavior arises when individuals disregard their independent analysis and information, instead placing trust in the decisions of others who are perceived to possess superior information. Within this process, information cascade occurs as investors with limited information observe the actions of frontrunners and adjust their decisions accordingly.

Frontrunners play a pivotal role within herding behavior, as they are typically the first to act and initiate market movements. Armed with an informational advantage, these participants take early positions in the market, often triggering a domino effect. This can result in the misdirection of information flow or cause market fluctuations driven by trades that are not entirely based on accurate information. In this context, the concepts of information cascade and frontrunner, in relation to herding behavior, illustrate investors' tendency to follow market trends rather than conducting independent analyses to verify the accuracy or validity of such movements. This phenomenon, in particular, encourages investors to attempt to capitalize by closely tracking market participants with faster access to information (Froot et al., 1992; Huberman & Regev, 2001; Fiore & Monore, 2008).

### **1.2. Information Cascade: The Spread of Information Flow**

An information cascade occurs when the actions of a few well-informed individuals in the market are observed and subsequently imitated by other participants. When an investor begins to make decisions based not on their own private information but on the observed actions of others, it prompts similar behavior among other investors. This chain reaction creates an information cascade, where the actions of one investor lead others to follow, and the process intensifies over time. Bikhchandani et al. (1992) define this phenomenon as a situation where individuals, even if equipped with independent information, base their actions on the observed behaviors of others.

### **1.3. Frontrunner: The First to Act Based on Information**

A frontrunner refers to an individual or institution that acts first in the market based on privileged or not yet widely known information. Frontrunners take positions by leveraging information that has not yet been perceived or disseminated across the market, thereby attracting the attention of other investors. These participants are often the first to anticipate or initiate significant price movements in the market. Scharfstein and Stein (1990) observe that frontrunners can trigger herding behavior, as other market participants tend to imitate these early movers by making similar trades. By accelerating the dissemination of information within the market, frontrunners contribute to the formation of broader information cascades.

### **1.4. Herding Behavior: Collective Decision-Making and Imitation**

Herding behavior, as outlined by Bikhchandani et al. (1992), arises from four fundamental mechanisms underpinning uniform social behavior: sanctions on deviations, positive payoff

externalities, confirmatory preferences, and communication. Driven by the pursuit of higher returns with lower risk, individuals exhibit a sequence of behaviors—herding, information cascade, and frontrunning—facilitated by communication. Herding reflects the tendency of individuals to disregard their private information and follow the majority's actions. In financial markets, herding occurs when investors abandon their independent analyses and evaluations to mimic the behavior of other market participants. This behavior is rooted in the belief that others may possess superior information or signals. Banerjee (1992) argues that herding can arise from individuals rationally trusting the actions of others and is particularly prevalent in markets characterized by information asymmetry.

### **1.5. The Relationship Between Information Cascade, Frontrunners, and Herding Behavior**

The concepts of information cascade and frontrunner are closely intertwined with herding behavior, and when analyzed collectively, they offer valuable insights into the dynamics of financial markets. A frontrunner initiates the first move in the market based on privileged information, and when this action is observed and replicated by other investors, it triggers an information cascade. Herding behavior further amplifies this cascade, as investors choose to follow the frontrunner's actions, believing they are guided by superior information (Kumar & Lee, 2006; Cipriani & Guarino, 2014; Doherty, 2018; Tiniç, 2020; Johnston & Lachance, 2022).

This process can lead to market fluctuations and increased volatility. In particular, in less liquid and smaller-volume markets, the actions of frontrunners can significantly influence market movements, and when coupled with herding behavior, these fluctuations become even more pronounced. Consequently, the effects of information cascades and frontrunners emerge as powerful drivers of investors' decision-making processes. The interplay of these factors offers a crucial framework for understanding price dynamics and associated risks in the market.

In this study, this theoretical framework has been utilized to analyze the roles of central and isolated brokers within information cascades and their impact on returns at both the stock and sectoral levels. Specifically, the study aimed to deepen our understanding of market dynamics by examining how the flow of leading information propagates between dominant and peripheral brokers during trading and how this propagation creates a phenomenon akin to information radiation.

The process can be conceptualized in stages, illustrating how investors' tendencies toward herding behavior, the aspiration to act as frontrunners, awareness of information cascades, and the appetite for acquiring privileged information and taking risks converge. This framework provides a cohesive explanation of the interconnectedness of these concepts and their collective impact on market dynamics.

**Information Gathering and Analysis:** Investors gather and analyze market information from various sources, including general market data, economic indicators, company-specific news, and technical analyses.

**Decision Point:** The investor evaluates whether the information collected is adequate to make an informed decision.

**Search for Insider Information:** Investors who perceive a lack of sufficient information often seek deeper, more specialized knowledge. This pursuit may involve conducting detailed analyses of financial reports, building close relationships with company management, or accessing undisclosed industry insights.

**Decision Point:** The investor evaluates whether the information obtained qualifies as insider information.

**Desire to Become a Frontrunner:** Investors who believe they possess crucial information capable of impacting the market often exhibit a strong desire to act as frontrunners. This involves aiming to be the first to initiate or significantly influence market movements.

**Decision Point:** The investor decides whether to act preemptively based on this information and position themselves as a frontrunner.

**Risk-Taking and Investment Decision:** Becoming a frontrunner typically entails taking significant risks. Investors carefully assess these risks, seeking high returns by acting on early information.

**Decision Point:** The investor evaluates the magnitude of the risk and determines whether to proceed with such a strategy.

**Tendency Toward Herding Behavior:** Investors may exhibit herding behavior by observing and mimicking the actions of others. This tendency is particularly prevalent among those who follow market leaders or frontrunners.

**Decision Point:** The investor reevaluates their investment decision in light of the movements observed in other market participants.

**Awareness of Information Cascade and Market Response:**

Investors develop an awareness of the information cascade, evaluating their roles within the process and the potential returns it may yield. This awareness can prompt them to modify their behaviors and strategies accordingly.

**Decision Point:** The investor determines whether to actively participate in the information cascade.

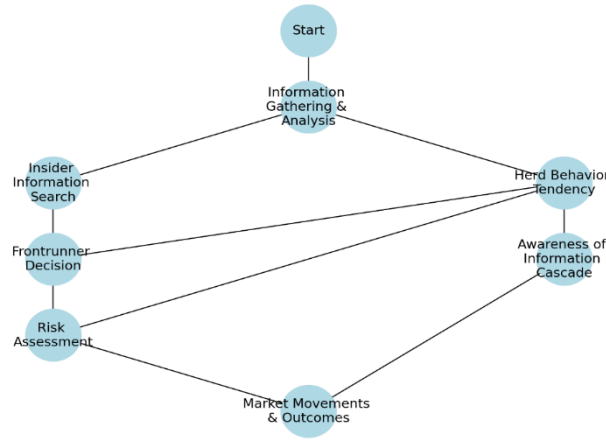
**Market Movements and Outcomes:**

The collective actions of investors in this process significantly influence market prices and volatility. The dynamics of information cascades and frontrunners play a pivotal role in shaping market movements and determining the returns realized by investors.

Graph 1 begins with the Information Gathering and Analysis phase, where investors initially collect and analyze available market information. This is followed by the Search for Insider Information phase. If investors successfully acquire insider information, they transition to the Desire to Become a Frontrunner phase. Upon deciding to act as a frontrunner, they move to the Risk-Taking and Investment Decision phase. Conversely, if insider information cannot be obtained, investors default to Herding Behavior.

In the Desire to Become a Frontrunner phase, if the investor chooses to proceed as a frontrunner, they continue to the Risk-Taking and Investment Decision phase. If not, they revert to herding behavior. During the Risk-Taking and Investment Decision phase, if the risks are accepted, the investor advances to the Market Movements and Outcomes phase. If the risks are deemed unacceptable, the process loops back to herding behavior.

At the Herding Behavior phase, investors align their actions with those of others, transitioning to the Information Cascade Awareness and Market Response phase. If investors choose not to follow the herd, the process either restarts from the beginning or leads to a renewed search for information. In the final phase, Market Movements and Outcomes, the cumulative impact of all these steps is assessed, reflecting the results of investors' decisions and overall market dynamics.



**Graph 1:** Investor Behavior Flow Diagram: Herding Tendency, Desire to Become a Frontrunner, and Information Cascade Awareness

## 2. Data and Methods

This study analyzes the price and clearing data of 520 stocks from companies listed on Borsa Istanbul, covering the period from September 3, 2021, to April 9, 2024. The Isolation Forest (iForest) algorithm and network interaction analyses were employed to detect central and isolated nodes. Additionally, the K-Means clustering algorithm was applied to group central and isolated nodes across various sectors based on their rankings and returns. Initially, the iForest machine learning algorithm was used to identify anomalies in brokerage transactions and prices, pinpointing days with abnormal market movements. Subsequently, clearing data from these anomaly days were analyzed to determine whether these movements indicated potential information leaks or frontrunner trading behaviors.

Using network analysis techniques, the relationships between brokerage firms were examined, shedding light on how these connections facilitated the flow of information in the market. Across 41 sectors and 448 stocks, node ranking analyses for central and isolated nodes provided insights into the presence and behavior of these nodes at a sectoral level. Information cascade and frontrunner tendencies were identified within these sectors. Each central and isolated node was characterized by its average return, maximum return, minimum return, and standard deviations, with risk-return trade-offs visualized through Sankey diagrams. This approach enabled a comprehensive risk-return analysis of stocks influenced by information cascades and frontrunner effects, evaluating the relative advantages and risks of central versus isolated positioning.

Finally, K-Means clustering analysis was used to examine sectoral returns and the distribution of central and isolated nodes. In this context, the study distinguishes itself as one of the first to analyze information cascade and frontrunner effects specifically within the Turkish market. By integrating machine learning and network theory, the study presents an innovative methodology for examining the flow of information in financial markets and its impact on investment returns.

The iForest algorithm is an effective unsupervised learning method for anomaly detection. The term "isolation" aptly reflects the algorithm's working principle, as it operates by isolating data points from the rest of the dataset. It is specifically designed to identify rare or unusual data points, commonly referred to as anomalies.

The iForest algorithm constructs trees by randomly selecting features and assigning random threshold values to these features. Each tree aims to isolate data points within the dataset. The core intuition behind the algorithm is that anomalous data points require fewer splits (or isolations) to separate compared to normal data points. In other words, isolating a rare and distinct point is inherently easier than isolating a more common one (Liu et al., 2008).

Steps in the Algorithm:

1. **Random Tree Construction (Isolation Tree):** The algorithm begins by randomly selecting a feature from the dataset and assigning a random threshold value to that feature. Based on this threshold, the dataset is split into subsets. This process is repeated iteratively until each data point is uniquely isolated.
2. **Path Length Calculation:** For each data point, the length of the path required to isolate it within the tree is calculated. Anomalous data points typically exhibit shorter path lengths, as their distinct characteristics make them easier to isolate from the rest of the dataset, requiring fewer splits.
3. **Anomaly Score Calculation:** The anomaly score for each data point is derived from its path length, with the score being inversely proportional to the length of the path. Shorter paths correspond to higher anomaly scores, indicating that these points are easier to isolate. Conversely, normal data points, characterized by longer path lengths, receive lower anomaly scores.

Isolation Forest calculates the anomaly score of a data point as follows:

$$s(x, n) = 2^{-\frac{E(h(x))}{c(n)}}$$

$S(x,n)$  represents the anomaly score.

$E(h(x))$ , is the expected path length for the data point  $x$

$C(n)$ , is the expected path length for a dataset of size  $n$ , calculated using the formula:

$$c(n) = 2H(n - 1) - \frac{2(n-1)}{n}$$

where  $H(i)$  represents the  $i$ -th harmonic number.

Anomaly scores range between 0 and 1. Points with scores close to 1 indicate higher anomalous behavior, while points with scores closer to 0 are considered normal.

### 2.1. Comparison of the iForest Algorithm with Other Anomaly Detection Algorithms

As an unsupervised machine learning algorithm, the iForest offers low computational cost when applied to large datasets, such as extensive stock transactions and time series data. Utilizing tree structures to isolate anomalies, iForest can process data with remarkable speed. Its linear time complexity ( $O(n \log n)$ ) makes it highly efficient when working with large datasets, particularly when analyzing vast amounts of data across multiple sectors and stocks. makes it particularly efficient for analyzing large datasets, especially those spanning multiple sectors and stocks.

The identification of frontrunners often involves detecting rare and concealed transactions within stock market data. iForest excels in this context by rapidly identifying deviations from normal transaction volumes and price movements, classifying them as anomalies characterized by short path lengths. In contrast, traditional methods, such as Local Outlier Factor (LOF), typically incur higher computational costs, making iForest a more practical choice for large-scale financial data analysis.

iForest algorithm employs sub-sampling, enabling it to perform effectively even with high-dimensional datasets. This feature allows the construction of robust models using small sample sizes, without the need to process the entire dataset, making it highly efficient for detecting phenomena such as information cascades and frontrunners. The isolation-based approach, particularly when applied to data that has been cleaned of irrelevant elements, excels in anomaly detection by mitigating issues like masking and swamping. Given that frontrunners typically engage in rare and inconspicuous transactions in the stock market, isolating subgroups within the data enhances the detection of these anomalies.

By design, the iForest algorithm identifies isolated nodes through shorter path lengths, facilitating the separation of rare and extreme deviations, such as information cascades and frontrunner behaviors, from central (normal) nodes in stock market transactions. This capability provides a significant advantage in uncovering anomalies that may indicate potential violations of the efficient market hypothesis in financial markets (Vijayakumar et al., 2021; Yang et al., 2023; Delafuente et al., 2024).

Frontrunners are market participants who gain rapid access to privileged information and operate outside the normal flow of trading. These transactions can be identified as isolated nodes using the iForest algorithm, which effectively distinguishes them from central nodes. Unlike traditional anomaly detection methods, such as the LOF or distance-based approaches, which rely on calculating distance or density to define anomalies, iForest operates without these measures. This makes it particularly effective for detecting anomalies in complex, multidimensional financial data where traditional methods often struggle with performance issues.

In a dataset containing 448 stocks, density-based methods would encounter significant computational challenges, as they require calculating distances for every transaction. The iForest algorithm, leveraging its isolation principle, significantly reduces this computational burden. By employing sub-sampling, it mitigates issues such as "masking" and "swamping," where anomaly clusters are overshadowed by normal data clusters. This capability is critical for identifying the behaviors of frontrunners in the stock market, as these transactions are often hidden within the vast volume of trading activity (Ounacer et al., 2018; Söderström & Knudsen, 2022; Tang et al., 2023).

The ability to quickly isolate anomalies without relying on resource-intensive calculations gives iForest a substantial advantage in identifying rare and significant deviations, such as frontrunner activities, which can otherwise go unnoticed in the noise of large datasets.

However, when compared with other anomaly detection algorithms, the iForest algorithm has both advantages and disadvantages:

**Local Outlier Factor (LOF):** The LOF algorithm detects anomalies by considering the local density of each data point, making it effective in cases where local density variations are important. However, LOF can be computationally expensive in high-dimensional and large datasets (Breunig et al., 2000).

**One-Class SVM (Support Vector Machine):** One-Class SVM provides a powerful non-linear classification method for anomaly detection, particularly suitable for well-separated classes. However, in high-dimensional and large datasets, training time can be significantly long, and hyperparameter tuning can be sensitive and challenging (Schölkopf et al., 2001).

**DBSCAN (Density-Based Spatial Clustering of Applications with Noise):** DBSCAN is a density-based clustering method that can detect anomalies by identifying differences in density between clusters. The algorithm is highly sensitive to its two hyperparameters (epsilon and minPoints), and correct tuning of these parameters is crucial for effective performance (Ester et al., 1996).

iForest algorithm serves as a robust anomaly detection tool, particularly in datasets characterized by heterogeneity and varying densities. However, conducting comparative analyses with alternative methods is essential to select the most appropriate algorithm based on the specific characteristics of the data. Understanding the strengths and limitations of different algorithms is critical for choosing the optimal model for anomaly detection.

### 3. Results and Discussion

In this study, a machine learning-based approach was applied to detect anomalies in stock market transactions and analyze their impact on stock returns. Specifically, the iForest algorithm was employed to identify unusual trading patterns among brokerage firms. Such anomalies arise when certain institutions exhibit trading behaviors that deviate significantly from the norm. Early



detection of these behaviors is crucial, as they may signal market manipulations such as "information dissemination" or "frontrunning," which pose serious risks to market integrity.

In the initial phase, the iForest algorithm was employed to detect anomalies, leveraging its effectiveness in identifying outliers in high-dimensional data. By analyzing the trading behavior of each brokerage firm, the algorithm aimed to identify transactions that deviated significantly from the norm. Unusual trading volumes on specific days were flagged as anomalies, potentially indicating the actions of brokerage firms with informational advantages who diverge from typical market behavior.

Following the detection of anomalies, price movements on the flagged days were analyzed. The changes in stock prices on these anomaly days were evaluated to explore the relationship between price fluctuations and the trading behaviors of the brokerage firms. This phase is critical for understanding how trading anomalies impact market prices, shedding light on the influence of irregular trading activities on overall market dynamics.

In the next phase, periodic returns were calculated using stock prices from the days immediately preceding and following the anomaly detection. The return was defined as the difference between the starting price before the anomaly and the ending price in the subsequent days. These returns were then correlated with the detected anomalies to evaluate their potential impact on the market. The primary objective of this stage was to elucidate the role of unusual trading activities in stock pricing.

The trading relationships and rankings between brokerage firms were visualized within a network structure, represented by nodes (brokerage firms) and edges (transaction connections between firms). Using Python programming tools such as NetworkX and Plotly, various network metrics were computed, including node centralities, clustering coefficients, and connectivity. Metrics such as Clustering Coefficient, Degree Centrality, Closeness Centrality, and Betweenness Centrality were calculated to assess the roles and significance of nodes within the network. These metrics provided a robust framework for understanding the dominance of central players in the market and the influence of isolated nodes on market dynamics.

Subsequently, a comparative analysis was performed to examine the impact of central and isolated brokerage firms on the market, focusing on their risk-return relationships. Risk-return dynamics were visually represented using Sankey diagrams, which illustrated how capital flows differ between central and isolated nodes.

Additionally, the average returns, medians, and distributions of central and isolated nodes were compared. The K-Means clustering algorithm was employed to uncover fundamental differences between the two groups, revealing critical distinctions in the performance and behavior of central versus isolated brokerage firms within the network.

In Figure 1, an analysis of the data from 448 stocks since 2021, using the iForest algorithm, reveals that an average of 25 brokerage firms operate as central nodes (cent brokers) within the network. By contrast, the number of isolated nodes (iso brokers) is significantly lower, averaging approximately 2. Central nodes maintain a much broader trading network, while isolated nodes are typically connected to a limited number of brokerage firms. This suggests that central nodes exert a more widespread influence on the market, whereas isolated nodes engage in more restricted trading activities.

Interestingly, isolated nodes tend to rank higher than central nodes, indicating that while their trading activities achieve higher rankings, their overall market impact remains limited. This reflects the tendency of central nodes to interact with the most active brokerage firms in the market, whereas isolated nodes are more likely to collaborate with smaller, less active firms, despite occasionally achieving higher rankings in specific contexts. The standard deviations between Cent and Iso values further highlight notable differences. The variance between Iso Broker Max (15.9) and Cent Broker Avg (3.18) is particularly striking. Isolated nodes exhibit

greater variability across a broader range, whereas central nodes demonstrate a more stable and consistent structure.

In conclusion, central nodes exert a broader influence on the market, interacting with a larger number of brokerage firms and contributing to higher market participation and trade volume. In contrast, isolated nodes, operating at the market's periphery, participate in trading structures that are less impactful but may occasionally produce unexpected outcomes.

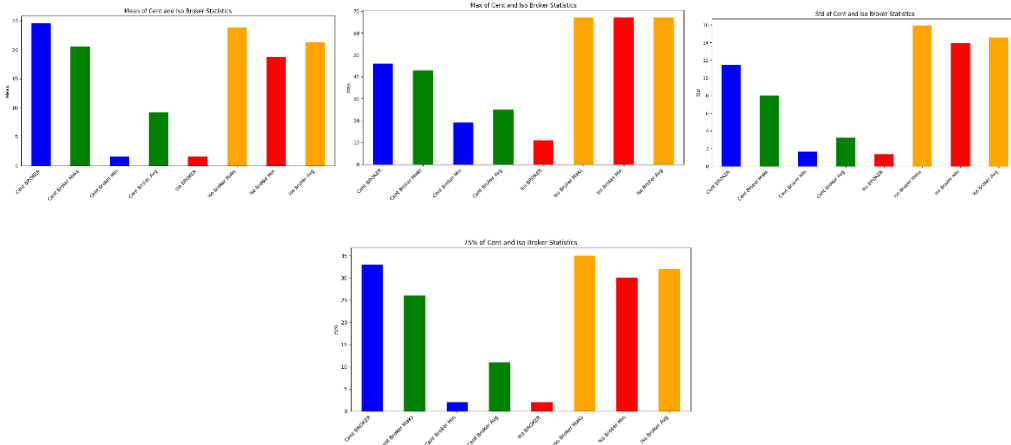


Figure 1. Descriptive Statistics for Cent and Iso Brokers/Nodes

The analysis of Cent and Iso nodes, based on their rankings and numerical significance as determined by the iForest algorithm, is further explored in subsequent sections, with a focus on comparisons in terms of risk and return. Utilizing Sankey diagrams and K-Means clustering analysis, the interactions within Cent nodes, within Iso nodes, and between these two groups will be examined. This analysis will specifically evaluate their trading activity, even in cases where differences in lot sizes are negligible at the sectoral level. The primary objective is to understand how these nodes interact internally and with one another across various sectors, offering deeper insights into their influence on market dynamics and trading behaviors.

### 3.1. Cent Broker Average v.s. Iso Broker Average in Sectoral Ranking

The descriptive statistics for the rankings of central (Cent) and isolated (Iso) nodes, including their average, maximum, and minimum values across sectors, offer valuable insights into the brokerage firms and sectors analyzed.

A high average Cent Broker value within a sector suggests that these brokers are consistently engaged in long-term, stable trading activities. This trend is typically observed in sectors dominated by well-established firms, which provide stable returns and are less susceptible to speculative trades. Conversely, a lower Cent Avg may indicate fewer brokers consistently participating in these stocks, potentially signaling higher volatility, reduced institutional interest, or smaller market capitalization within the sector.

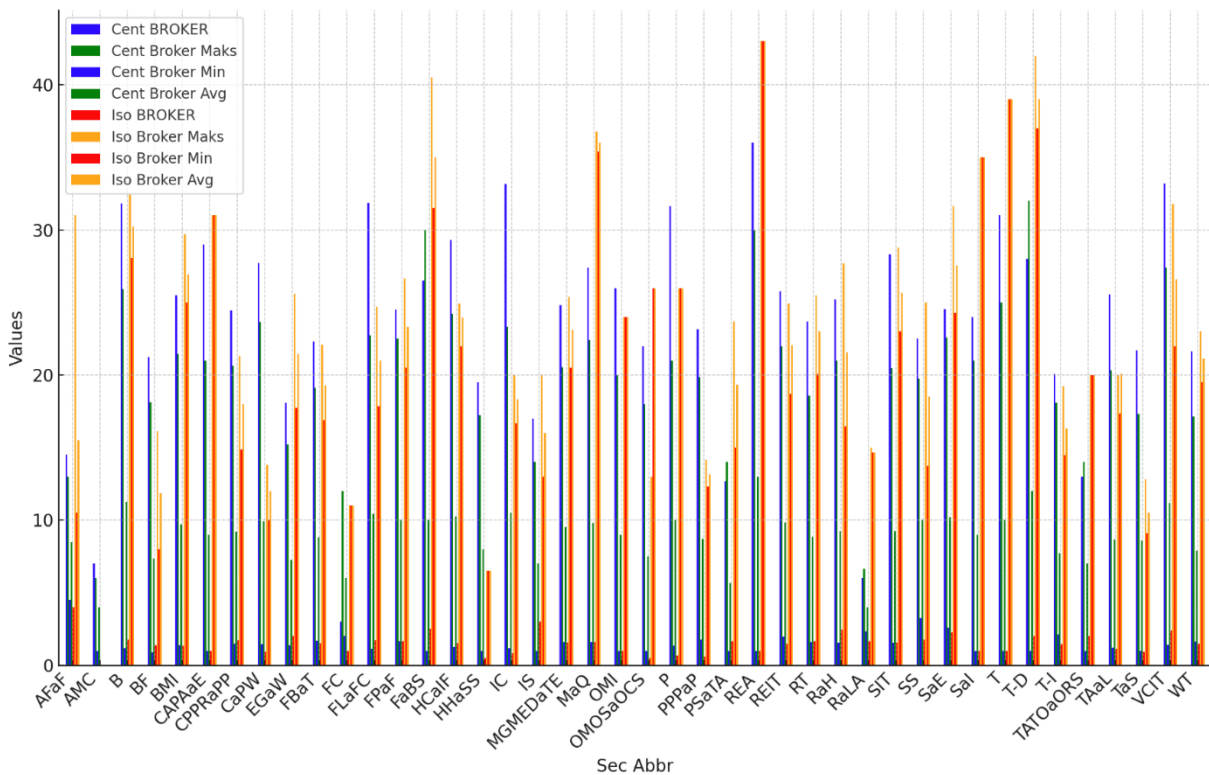
A high Iso Avg implies significant involvement of brokers in isolated, potentially short-term or speculative trading activities. Sectors with a high Iso Avg are often influenced by transient events, speculative trades, or insider information. In contrast, a low Iso Avg indicates fewer isolated brokers, suggesting greater market stability and reduced speculative activity within the sector.

A high Cent Broker Max value in a sector reflects periods where a significant number of brokers were active, often coinciding with major market events, news, or the involvement of large institutional players. Examples include financial disclosures, sector-specific regulations, or geopolitical developments. In contrast, a low Cent Broker Max indicates that even during peak activity periods, only a limited number of brokers were engaged with those stocks. This suggests niche markets or sectors with restricted liquidity.

Sectors with a high Iso Broker Max value often experience sharp fluctuations driven by speculative trading or short-term positioning. Such sectors are typically more susceptible to market rumors, major news events, or regulatory changes. Conversely, a low Iso Max suggests fewer spikes in isolated activities, indicating a more stable and less reactive market environment.

A high minimum Cent Broker value within a sector indicates that even during the calmest periods, a core group of institutional brokers remains consistently active. This pattern is common in sectors characterized by steady and regular trading, such as finance or energy. Conversely, a low minimum Cent Broker value suggests that at certain times, very few or no central brokers are active, pointing to high volatility or limited interest in sectors dominated by smaller or emerging companies.

A high minimum Iso Broker value indicates that speculative or isolated trading activities persist even during quieter periods. This is typical of sectors that consistently offer short-term opportunities or are influenced by news-driven trades. On the other hand, low Iso Min values reflect periods where speculative or isolated activities drop to nearly zero, indicating sectors that are generally more stable and less volatile.



**Figure 2.** Sector-wise Comparison of Cent ve Iso Nodes Descriptive Statistics

Figure 2 examines the ranking of sectors based on Cent and Iso broker data. The visual analysis presented in the figure aligns with the model's hypotheses and the anticipated findings of the study's advanced analysis. It demonstrates that institutional and speculative interest varies significantly across sectors, influenced by the sector's inherent characteristics, external market dynamics, and sector-specific events. This variation underscores how diverse factors drive broker participation in specific sectors, reflecting both long-term institutional involvement (Cent brokers) and more volatile, speculative activities (Iso brokers).

*AFaF Sector:* The relatively high average value of Cent Brokers indicates strong, stable, and long-term institutional interest in this sector. Agricultural and food-related businesses are typically resilient to market downturns due to the essential nature of their products. The moderate Iso values suggest the presence of speculative activities, likely driven by factors such as agricultural price fluctuations, commodity volatility, or regulatory changes. The consistent Iso Min value (1.0) indicates that speculative brokers are almost always active in this sector, likely responding to seasonal or commodity-driven market fluctuations.

*AMC Sector:* The identical minimum, maximum, and average values of Cent Brokers (7) reflect a highly stable trading environment with consistent institutional participation. This indicates limited volatility and minimal speculative interest in the sector. The absence of Iso Brokers suggests that speculative or isolated activities are rare. The automotive and manufacturing components sector typically emphasizes long-term investments and strategic partnerships over short-term speculation, which explains the low Iso participation.

*B Sector:* The high Cent Avg (31.83) and Max (44) values demonstrate strong institutional interest in this sector. As a cornerstone of the economy, the banking and finance sector attracts many institutional brokers due to its appeal to long-term investors. The high Min value (19) indicates that even during calm periods, a significant number of brokers remain active in this sector. The relatively low Iso Avg (1.75) and a minimum of 0 suggest that speculative or short-term trading is less common, while the Max Iso value (7) indicates that isolated activities may increase around significant events such as earnings reports or regulatory changes.

*BF Sector:* The high Cent Avg (31.83) and Max (44) values highlight strong institutional interest in this sector. As a cornerstone of the economy, the banking and finance sector attracts a significant number of institutional brokers due to its appeal to long-term investors. The high Min value (19) further indicates that even during calm periods, a substantial number of brokers remain active. In contrast, the relatively low Iso Avg (1.75) and a minimum of 0 suggest that speculative or short-term trading is infrequent. However, the Max Iso value (7) implies that isolated activities may temporarily increase around significant events such as earnings reports or regulatory changes.

*BMI Sector:* Although the Cent Avg for brokers is relatively high (21.25), the Min value of 0 reveals that institutional interest occasionally drops to zero. This fluctuation likely reflects the cyclical nature of the sector, with high levels of interest during economic expansion and declines during downturns. The Max Iso value (5) indicates occasional speculative activity, driven by factors such as commodity price volatility or geopolitical events affecting material and fuel supply chains.

*CAPAAE Sector:* The identical values for all Cent metrics (Avg, Min, Max) highlight exceptionally stable institutional participation in this sector. The aerospace and capital goods industries, characterized by their reliance on long-term investments and strategic partnerships, consistently attract institutional brokers. The low and uniform Iso values (all 1.0) further indicate minimal speculative trading activity. This stability is likely driven by the sector's focus on long-term contracts, government agreements, and capital-intensive projects, which naturally discourage short-term speculative trades and result in low volatility.

*CPPRaPP Sector:* The relatively high Cent Avg reflects strong institutional interest, likely attributed to the sector's fundamental role in manufacturing and raw materials. However, the Min value of 0 indicates that institutional participation is cyclical and influenced by commodity price fluctuations or variations in industrial demand. The Max Iso value (6) suggests an increase in speculative activity during significant events, such as commodity price changes, regulatory announcements, or environmental policies impacting chemical production.

*CaPW Sector:* The high Cent Max value (38) highlights strong institutional interest in this sector, particularly during periods of infrastructure development or regulatory changes. The continuous demand for essential utilities such as water and energy makes this sector appealing to long-term investors. The low Iso Avg (0.91) and Max (3.0) values indicate limited speculative trading. As a stable sector with predictable, long-term revenue streams, utilities naturally attract fewer short-term speculators.

*EGaW Sector:* The wide range between Cent Min (0) and Cent Max (40) indicates fluctuating institutional interest, likely driven by the cyclical nature of energy prices. Institutional brokers tend to become more active during periods of elevated energy prices or significant infrastructure investments, while their involvement declines during downturns. The relatively high Iso Avg (2.0)

and Max (5.0) suggest a notable presence of speculative trading in this sector, influenced by energy price volatility and geopolitical factors affecting energy supply.

*FBaT Sector:* The relatively high Cent Avg (22.3) reflects stable institutional participation in the food and beverage sector. As this sector is less sensitive to economic cycles, it tends to attract consistent interest from institutional investors. The Iso Min (0) and Max (4) values indicate moderate speculative activity. While generally stable, the sector may experience speculative trades driven by factors such as specific product launches, regulatory changes, or price fluctuations in key commodities like sugar or grain.

High Cent Avg values are commonly observed in sectors such as B and BMI, reflecting stable and long-term institutional interest. These well-established sectors benefit from a continuous flow of institutional participation. In contrast, sectors like AMC, characterized by low Iso Avg values, exhibit minimal short-term speculative activity, attributed to their focus on stable, long-term growth rather than short-term events.

High Iso Min values in sectors such as AFaF indicate persistent speculative activity, even during quieter periods, likely driven by commodity price fluctuations and seasonal variations. Conversely, sectors like BF and BMI, which show zero Iso Min values, suggest that isolated brokers completely withdraw during certain periods, reflecting the cyclical or event-driven nature of these sectors.

Sectors like CAPAaE and CaPW demonstrate stable institutional participation and minimal speculative trading, largely due to their capital-intensive and long-term investment structures. These sectors primarily attract long-term institutional interest rather than short-term speculative trades.

In sectors such as EGaW and FBaT, medium to high Iso Max values indicate active speculative trading during significant events, such as fluctuations in commodity or energy prices. These sectors are more susceptible to external shocks, leading to short-term speculative activities. Finally, sectors like CPPRaPP and EGaW exhibit a large gap between Cent Min and Cent Max values, reflecting significant fluctuations in institutional interest. This volatility is often driven by commodity cycles, regulatory changes, or environmental factors impacting demand and profitability.

Overall, the tendencies of sectors to have Cent and Iso nodes, as reflected in the above findings, can be summarized based on the following attributes:

#### *Market Cyclicality and Speculation:*

Sectors like Basic Materials and Fuel (BF) are affected by cyclical demands tied to broader economic trends. During low-demand periods, the number of Cent brokers can drop significantly (e.g., Min value 0), while at peak demand, the Max value can rise sharply. Sectors influenced by commodity price cycles, such as Chemicals (CPPRaPP) and Energy (EGaW), tend to show fluctuating institutional participation (e.g., Cent Min value 0), while speculative brokers respond to short-term price changes or geopolitical events. The Food and Beverage (FBaT) sector, although generally stable, attracts some speculation due to the cyclical nature of raw material prices and seasonal consumer demand.

#### *Sector Stability and Long-Term Investments:*

Sectors such as B exhibit high institutional participation (Cent Avg: 31.83), underscoring their importance and stability within the economy. Even during downturns, this sector maintains a relatively high Min value (19), reflecting consistent institutional engagement. Similarly, sectors like CAPAaE and CaPW, EGaW are characterized by stable, long-term institutional participation, as indicated by their high Cent Avg values. These sectors are particularly attractive to institutional investors due to their essential nature, dependable income streams, and revenue derived from government contracts or regulatory frameworks.

*Event-Driven Activity/Speculation:*

Sectors with high Iso Broker Max values, such as AFaF and BF, often experience spikes in speculative activity triggered by external events like commodity price fluctuations or seasonal factors. In contrast, sectors like AMC, with zero Iso activity, are less susceptible to event-driven trading and instead focus on long-term fundamentals.

Sectors such as EGaW and CPPRaPP frequently exhibit sudden increases in Iso Broker activity, driven by factors such as commodity price volatility, environmental regulations, or geopolitical tensions that fuel short-term speculation. Meanwhile, FBaT sector demonstrates moderate speculative activity, influenced by seasonal demand fluctuations or the introduction of new products.

*Innovation Cycles:*

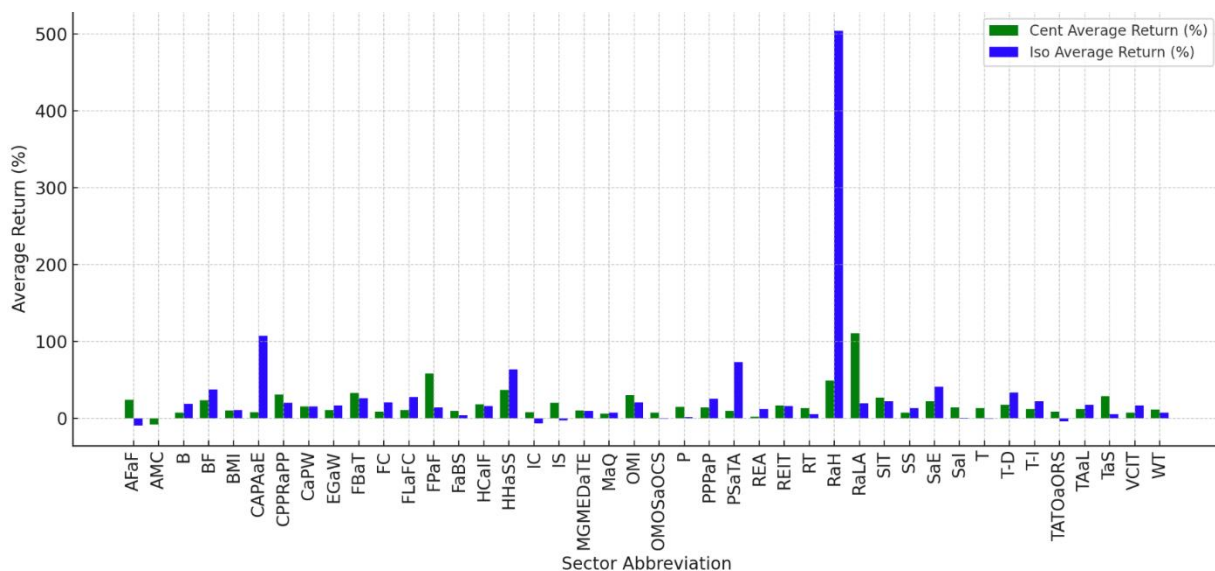
In sectors such as BMI, the relatively high Cent Avg (25.48) and Max (41) values underscore significant institutional interest, reflecting the long-term investments required to support innovation cycles, such as the development of new medical technologies.

*Market Stability and Volatility:*

Sectors such as CaPW, EGaW and CAPAaE exhibit high institutional participation and low speculative interest, reflecting their inherent market stability, long-term income streams, and capital-intensive structures. In contrast, sectors that are more dependent on commodity prices, such as CPPRaPP and EGaW, experience greater volatility in both institutional and speculative activities.

**2.2 Sectoral Risk-Return Comparison of Cent and Iso Nodes**

Building on the insights developed above regarding the rankings of Cent and Iso nodes derived from the iForest algorithm, a risk-return comparison for these nodes would offer valuable perspectives. Such an analysis could elucidate the relationship between the risks assumed and the returns achieved, based on the positioning of Cent or Iso nodes across various sectors. This sectoral comparison would provide deeper insights into how the positioning of these nodes influences their performance in terms of risk and return.



**Figure 3.** Central and Isolated Nodes Sector-wise Average Return Comparison

Figure 3 illustrates the returns of Cent and Iso nodes across various sectors, revealing notable differences both between sectors and within the Cent and Iso nodes themselves. These variations highlight the distinct dynamics of institutional (Cent) and speculative (Iso) activities across

sectors. While some sectors exhibit higher returns for Cent nodes, others demonstrate more prominent returns for Iso nodes. The observed differences, both within and between these groups, underscore the unique market behaviors and influences associated with each node type in different sectors.



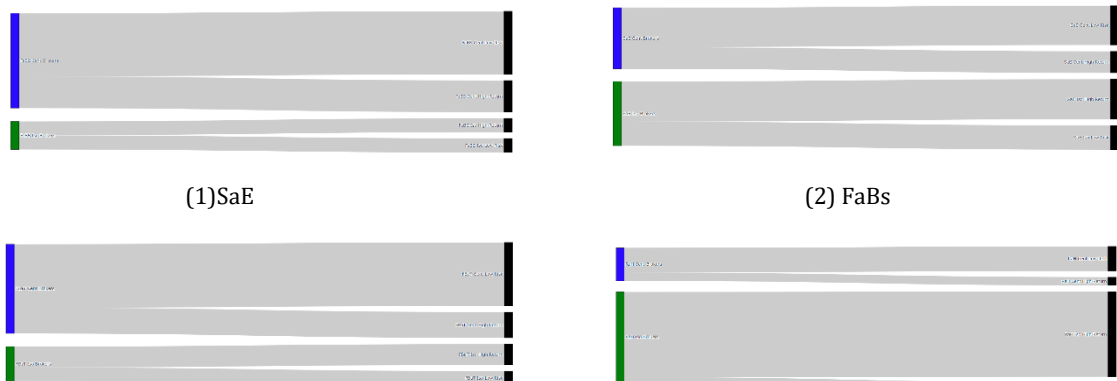
**Figure 4.** Comparison of Sankey Diagram for Central and Isolated Nodes (All Sectors)

Figures 3 and 4 illustrate the behavior of Cent and Iso brokers in terms of risk-return trade-offs during their pursuit of returns. Cent Brokers, typically institutional investors with a focus on long-term and stable returns, prioritize controlled risks. Their investment strategies generally fall into two primary categories: high returns and low risks. The high-return strategy indicates that these brokers often position themselves in sectors and trades offering substantial gains, while the low-risk strategy reflects their preference for relatively safer investments. This underscores that Cent Brokers, while managing large portfolios, place significant emphasis on risk minimization and typically concentrate on sectors with stable growth. Institutional investors, as a result, adopt a more conservative approach, prioritizing risk-adjusted returns.

Iso Brokers, by contrast, exhibit a more speculative and opportunistic approach, frequently targeting transactions with high return potential. However, their occasional pursuit of lower-risk opportunities demonstrates that Iso Brokers are not solely focused on high profits. Instead, they aim to capitalize on temporary price movements, adapting flexibly to changing market conditions. Iso Brokers often position themselves in sectors sensitive to news or events, seizing high-return opportunities while occasionally engaging in low-risk trades.

Both groups implement distinct risk management strategies. Cent Brokers generally adhere to a consistent approach, emphasizing risk-adjusted returns, while Iso Brokers adopt a more dynamic, opportunity-driven strategy without completely disregarding excessive risk.

Following the risk-return analysis of both Cent and Iso brokers using Sankey diagrams, it becomes crucial to examine sectoral differences. Understanding how these strategies operate across various sectors provides valuable insights into the application of Cent and Iso brokers' investment approaches under different market conditions.



(3) FbaT



(4) RaH



(5) CPRaPP



(6) MGEDTaTE



(7) FPaF



(8) CaPW



(9) T-I



(10) TaS



(11) WT



(12) HcaIF



(13) PPPaP



(14) REIT



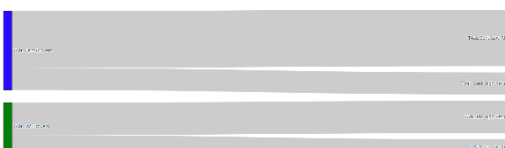
(15) AFaF



(16) B



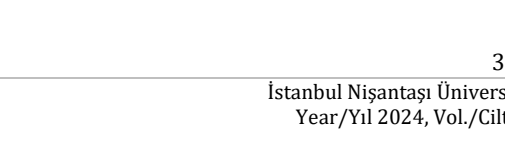
(17) BMI



(18) P



(19) TAaL



(20) RT







(21) FLaFC



(22) OMI



(23) SaI



(24) MaQ



(25) SS



(26) IC



(27) RaLA



(28) OMOSaOCS



(29) CAPAaE



(30) HHaSS



(31) TAT0aORS



(32) AMC



(33) BF



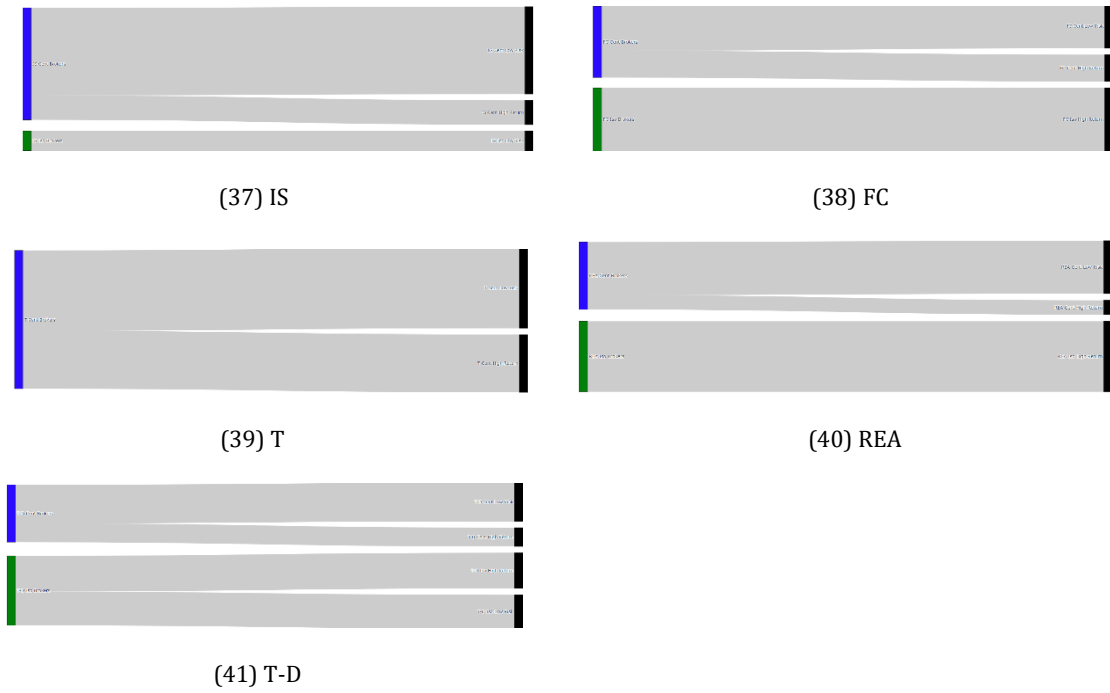
(34) EgaW



(35) VCIT



(36) PSaTA



**Figure 5.** Sector-wise Comparison of Sankey Diagram for Central and Isolated Nodes<sup>2</sup>

*SaE Sector:* Cent Brokers' emphasis on low risk suggests that this sector offers safe and stable investment opportunities, making it attractive to long-term institutional investors. Iso Brokers, meanwhile, pursue both high returns and low risk, indicating that speculative investors see opportunities for both significant short-term gains and safety in event-driven market fluctuations.

*FaBs Sector:* Cent Brokers' focus on low risk, coupled with moderate attention to high returns, reflects the perception of this sector as stable with moderate growth potential. In contrast, Iso Brokers' strong emphasis on high returns implies that this sector experiences greater volatility or short-term profit potential.

*FbaT Sector:* Cent Brokers balance high returns with low risk, suggesting that this sector provides both growth and stability, making it suitable for diversified institutional strategies. Iso Brokers' focus on high returns highlights speculative activities, driven by short-term opportunities within the sector.

*RaH Sector:* Cent Brokers primarily concentrate on low-risk strategies, positioning this sector as a safe haven for institutional investors with minimal emphasis on aggressive growth. Interestingly, Iso Brokers also focus on low risk, which may seem unexpected for speculative investors. This indicates that even speculative activities in this sector are driven by predictable and stable market conditions.

*CPRaPP Sector:* Cent Brokers prioritize low risk with moderate attention to high returns, portraying this sector as low-risk and stable for institutional investors. Conversely, Iso Brokers' strong focus on high returns suggests that speculative opportunities in this sector are driven by market volatility or short-term developments.

*MGMEDTaTE Sector:* Cent Brokers' focus on low risk reflects the perception of this sector as reliable, though with limited high-growth potential. On the other hand, Iso Brokers' focus on high

<sup>2</sup> Stone and Earth-Based (SaE); Food and Beverage Services (FaBS); Food, Beverage, and Tobacco (FbaT); Restaurants and Hotels (RaH); Chemicals, Pharmaceuticals, Petroleum, Rubber, and Plastic Products (CPRaPP); Metal Goods, Machinery, Electrical Devices, and Transportation Equipment (MGMEDaTE); Forestry Products and Furniture (FPaF); Construction and Public Works (CaPW); Technology - Informatics (T-I); Transportation and Storage (TaS); Wholesale Trade (WT); Holding Companies and Investment Firms (HCaIF); Paper, Paper Products, and Printing (PPPaP); Real Estate Investment Trusts (REIT); Agriculture, Forestry, and Fishing (AFaF); Banks (B); Basic Metal Industry (BMI); Publishing (P); Textiles, Apparel, and Leather (TAaL); Retail Trade (RT); Financial Leasing and Factoring Companies (FLaFC); Other Manufacturing Industries (OMI); Security and Investigation (SaI); Mining and Quarrying (MaQ); Sports Services (SS); Insurance Companies (IC); Securities Investment Trusts (SIT); Rental and Leasing Activities (RaLA); Office Management, Office Support, and Other Company Support (OMOSaOCS); Creative Arts, Performing Arts, and Entertainment (CAPAaE); Human Health and Social Services (HHaSS); Travel Agencies, Tour Operators, and Other Reservation Services (TAT0aORS); Asset Management Companies (AMC); Brokerage Firms (BF); Electricity, Gas, and Water (EGaW); Venture Capital Investment Trusts (VCIT); Professional, Scientific, and Technical Activities (PSaTA); Information Services (IS); Financing Companies (FC); Telecommunications (T); Real Estate Activities (REA); Technology - Defense (T-D)

returns underscores their interest in short-term speculative opportunities arising from sector volatility or event-driven activities.

*FPaF Sector:* Cent Brokers' emphasis on low risk reflects a conservative approach by institutional investors, highlighting the stability of this sector. Iso Brokers balance high returns with low risk, suggesting that both speculative and conservative transactions are viable in this sector.

*CaPW Sector:* Cent Brokers' focus on low risk underscores this sector as a defensive option for institutional investors. In contrast, Iso Brokers' focus on high returns indicates that this sector also attracts volatile and speculative high-gain strategies.

*T-I Sector:* Cent Brokers' strong focus on low risk, combined with minimal attention to high returns, suggests that this sector is stable but characterized by slow growth. Meanwhile, Iso Brokers' focus on high returns points to speculative interest driven by market volatility within this sector.

*TaS Sector:* Cent Brokers prioritize low risk, indicating that institutional investors view this sector as stable and low-risk. Iso Brokers' strong focus on high returns reveals that speculators identify short-term high-profit opportunities in this sector.

*WT Sector:* Cent Brokers' emphasis on low risk demonstrates that institutional investors prioritize safety and stable returns, signaling that this sector is unsuitable for aggressive growth strategies. Iso Brokers' focus on high returns highlights speculative interest in short-term opportunities, with the absence of a low-risk focus reflecting the sector's volatility.

*HcaIF Sector:* Cent Brokers focus on low risk while also considering moderate high returns, suggesting that this sector offers stability with some growth potential for long-term investors. Iso Brokers' strong focus on high returns indicates the presence of speculative opportunities, targeting short-term market gains.

*PPPaP Sector:* Cent Brokers' emphasis on low risk reflects that institutional investors perceive this sector as stable and predictable, albeit with limited high-growth potential. Iso Brokers' focus on high returns suggests that speculative investors are drawn to the sector's volatility, seeking short-term gains.

*REIT Sector:* Most Cent Brokers prioritize low risk, positioning this sector as a safe haven for institutional investors. The limited emphasis on high returns indicates modest growth potential, with safety being the primary focus. Iso Brokers, targeting high returns, acknowledge the sector's speculative potential and its comparatively volatile nature.

*AFaF Sector:* Cent Brokers' focus on low risk reflects a conservative approach by institutional investors aiming for stable returns. Iso Brokers' balanced focus on both high returns and low risk indicates that this sector accommodates both speculative and conservative strategies.

*B Sector:* Cent Brokers' low-risk focus highlights this sector as a secure and stable investment option. However, some flow toward high returns suggests limited growth potential. Iso Brokers, targeting high returns, leverage speculative opportunities to benefit from short-term market fluctuations.

*BMI Sector:* Cent Brokers prioritize low risk, emphasizing stability and aversion to volatility. The limited focus on high returns suggests moderate growth opportunities, but safety remains the primary objective. Iso Brokers, focusing on high returns, actively pursue short-term profit opportunities driven by sector volatility.

*P Sector:* Cent Brokers' strong emphasis on low risk underscores this sector's stability and appeal for defensive investments by institutional investors. Iso Brokers, targeting high returns, aim to capitalize on short-term profit opportunities, suggesting that the sector offers limited yet attractive short-term potential.

*TAAI Sector:* Cent Brokers' strong focus on low risk highlights stability and safety as the key priorities in this sector. Iso Brokers, with a focus on high returns, demonstrate speculative interest, exploring short-term profit opportunities within the sector.

*RT Sector:* Cent Brokers' primary focus on low risk positions this sector as a stable and secure investment area for institutional investors. Iso Brokers, targeting high returns, reflect speculative interest in short-term, high-reward opportunities within this sector.

*FLaFC Sector:* Cent Brokers emphasize low risk, signaling that this sector offers stability and minimal risk for institutional investors. The lack of attention to high returns suggests limited growth potential. Iso Brokers, focusing on high returns, pursue short-term profit opportunities despite the sector's overall stability.

*OMI Sector:* Cent Brokers' focus on low risk indicates that institutional investors perceive this sector as safe and predictable. A modest flow towards high returns suggests some, albeit limited, growth potential. Iso Brokers, targeting high returns, aim to capitalize on speculative opportunities driven by volatility or event-related fluctuations.

*Sal Sector:* Cent Brokers' emphasis on low risk highlights this sector as stable and secure for institutional investors. A minor flow towards high returns indicates limited growth potential. Iso Brokers, focusing on high returns, exploit speculative opportunities fueled by market volatility or short-term events.

*MaQ Sector:* Cent Brokers' strong focus on low risk underscores the preference of institutional investors for safe and low-risk investments in this sector. Iso Brokers, targeting high returns, pursue short-term profit opportunities, reflecting the sector's high speculative potential.

*SS Sector:* Cent Brokers primarily focus on low risk, indicating that institutional investors seek secure investments to minimize risk in this sector. While the emphasis on high returns is minimal, some growth opportunities are evident. Iso Brokers, targeting high returns, attract speculative investors seeking high-risk, high-reward opportunities.

*IC Sector:* Cent Brokers' focus on low risk demonstrates that institutional investors view this sector as stable and secure. Iso Brokers, targeting high returns, signal speculative interest in short-term opportunities driven by market volatility or event-specific gains.

*RaLA Sector:* Cent Brokers' emphasis on low risk highlights this sector's stability and security for institutional investors. Minimal flow towards high returns suggests limited growth potential. Iso Brokers, focusing on high returns, aim to capitalize on short-term fluctuations within the sector.

*OMOSaOCS Sector:* Cent Brokers' focus on low risk indicates that institutional investors prioritize stability and security in this sector. Iso Brokers, targeting high returns, attract speculative investors seeking short-term market gains, despite the sector's overall stability.

*CAPAAE Sector:* Cent Brokers primarily emphasize low risk, reflecting the sector's appeal as a stable and secure investment for institutional investors. The limited focus on high returns suggests minimal growth opportunities. Iso Brokers, targeting high returns, attract speculative investors pursuing short-term profit opportunities.

*HHaSS Sector:* Cent Brokers' focus on low risk highlights the prioritization of safety and stability by institutional investors. The limited flow toward high returns suggests few growth opportunities. Iso Brokers, focusing on high returns, signal speculative interest in short-term profit opportunities within this sector.

*TATOaORS Sector:* Cent Brokers primarily focus on low risk, indicating that institutional investors view this sector as stable and secure. Minimal flow toward high returns suggests limited growth potential. The absence of Iso Broker activity indicates a lack of speculative interest, likely due to low volatility or short-term profit potential.

*AMC Sector:* Cent Brokers' emphasis on low risk reflects their perception of this sector as safe and predictable. The absence of high-return flow suggests little growth expectation, while the lack of Iso Brokers indicates the sector does not attract speculative opportunities.

*BF Sector:* Cent Brokers demonstrate a balanced focus between low risk and high returns, indicating the sector offers both stability and growth potential. Iso Brokers' strong focus on high returns suggests that speculative investors target this sector for short-term gains. The presence

of some low-risk flow indicates Iso Brokers also identify secure opportunities during periods of low volatility.

*EGaW Sector:* Cent Brokers primarily focus on low risk, reflecting institutional investors' risk-averse strategies in this sector. A moderate flow toward high returns suggests some growth opportunities. Iso Brokers, targeting high returns, seek speculative opportunities but also exhibit a focus on low risk, indicating a more balanced approach.

*VCIT Sector:* Cent Brokers' heavy focus on low risk signals limited growth expectations in this sector. Iso Brokers target high returns, aiming to capitalize on short-term price fluctuations.

*PSaTA Sector:* Cent Brokers prioritize low risk, indicating institutional investors view this sector as stable and secure. A limited flow toward high returns suggests moderate growth potential. Iso Brokers, targeting high returns, aim to leverage short-term volatility or event-driven gains.

*IS Sector:* Cent Brokers' strong emphasis on low risk underscores their risk-averse stance in this sector. Minimal flow toward high returns indicates limited growth potential. Iso Brokers' focus on high returns reflects abundant speculative opportunities. The absence of low-risk flow for Iso Brokers suggests that speculative investors prioritize volatility and short-term profit potential over risk avoidance.

The utilities sector stands out as a preferred area for Cent Brokers, characterized by their low-risk approach and focus on safe, predictable returns. This sector serves as an attractive defensive mechanism for institutional investors, particularly during periods of market uncertainty. Essential services such as electricity, water, and gas act as safe havens. Iso Brokers, while targeting high-return opportunities, engage in fewer speculative transactions due to the sector's lower volatility. Speculative activities are typically driven by short-term energy price fluctuations or regulatory changes.

In the technology sector, Cent Brokers predominantly adopt a low-risk approach but also exhibit interest in high returns, reflecting the sector's rapid growth potential. Despite the inherent volatility of technology stocks, institutional investors prioritize risk management. Conversely, Iso Brokers focus on high returns, leveraging opportunities arising from innovations, unexpected earnings announcements, and shifts in market sentiment, which underscore the sector's abundance of short-term profit opportunities.

The healthcare and pharmaceuticals sector offers low-risk, stable returns for Cent Brokers, with additional interest in high returns due to growth prospects in biotechnology and pharmaceutical companies. Iso Brokers balance low-risk and high-return transactions, capitalizing on drug approvals, clinical trial outcomes, and mergers or acquisitions, presenting a blend of speculative and conservative opportunities.

The consumer products sector is primarily a low-risk investment area for Cent Brokers, particularly during economic downturns, as it provides stable and predictable returns. However, Iso Brokers show limited interest due to the sector's lower volatility. Nevertheless, short-term opportunities may arise from earnings announcements or changes in consumer confidence.

In the financial services sector, Cent Brokers view this area as a stable and secure investment, particularly in established firms like banks and insurance companies offering low-risk opportunities. In contrast, Iso Brokers pursue high-return opportunities driven by changes in interest rates, regulatory developments, and macroeconomic fluctuations, making this sector attractive to speculative investors.

The energy sector appeals to Cent Brokers for low-risk investments in large, established energy companies while also attracting interest in high returns in growth areas such as renewable energy. Iso Brokers focus on short-term, high-reward transactions influenced by energy price fluctuations, geopolitical tensions, and changes in energy policies.

The industrial sector is predominantly viewed as a low-risk investment by Cent Brokers, particularly as large industrial companies often experience stable demand. On the other hand, Iso Brokers identify speculative opportunities tied to business cycles, infrastructure projects, and geopolitical developments.

In the real estate sector, Cent Brokers favor low-risk, long-term income opportunities, particularly in rental income and commercial properties. Conversely, Iso Brokers target speculative opportunities arising from interest rate changes and potential real estate market bubbles.

The telecommunications sector is considered low-risk by Cent Brokers due to stable cash flows derived from long-term contracts. Iso Brokers, however, focus on high-return opportunities related to technological advancements and mergers or acquisitions.

Finally, the consumer discretionary sector offers a balanced investment landscape for Cent Brokers, with both low-risk and high-return opportunities, particularly in large retail firms that thrive during economic expansions. Meanwhile, Iso Brokers concentrate on high returns, targeting short-term profit opportunities in industries such as luxury goods, automotive, and entertainment.

In summary, sectors can be broadly categorized into defensive sectors (utilities, consumer staples, real estate), growth and volatile sectors (technology, energy, financial services), and sectors with mixed opportunities (healthcare, industrials, consumer discretionary).

Defensive sectors are favored by Cent Brokers for their low-risk profiles, offering stability and predictability. These sectors attract institutional investors, particularly during periods of market uncertainty. Utilities, consumer staples, and real estate provide reliable returns with minimal volatility. Iso Brokers, however, exhibit limited speculative interest in these sectors, preferring those with higher volatility.

Growth and volatile sectors, such as technology, energy, and financial services, attract Cent Brokers with a cautious approach, balancing risk management with the pursuit of high returns due to their significant growth potential. Iso Brokers are drawn to these sectors by high-return opportunities driven by volatility stemming from market fluctuations, technological innovations, or macroeconomic events.

Sectors with mixed opportunities, including healthcare, industrials, and consumer discretionary, offer a blend of stability and growth. For Cent Brokers, these sectors provide a balanced flow between low-risk investments and high-return potential. Iso Brokers focus on high returns, capitalizing on short-term volatility driven by innovations, economic cycles, or shifts in consumer demand.

Key findings reveal that the technology and energy sectors attract both Cent Brokers and Iso Brokers, reflecting their growth potential and associated volatility risk. The healthcare sector combines stability in basic services with volatility in biotechnology and pharmaceutical developments, appealing to both defensive and speculative strategies. Meanwhile, the financial services sector garners significant speculative interest due to frequent short-term price fluctuations influenced by macroeconomic changes.

### 2.3 K-Means Sector-Based CENT AND Iso Broker Clustering Analysis

In Figure 6 and Table 1, the clusters to which sectors belong, based on the returns of their Cent and Iso nodes, have been analyzed using the K-Means clustering method. Three clusters were identified based on the sectoral returns of Cent and Iso brokers.

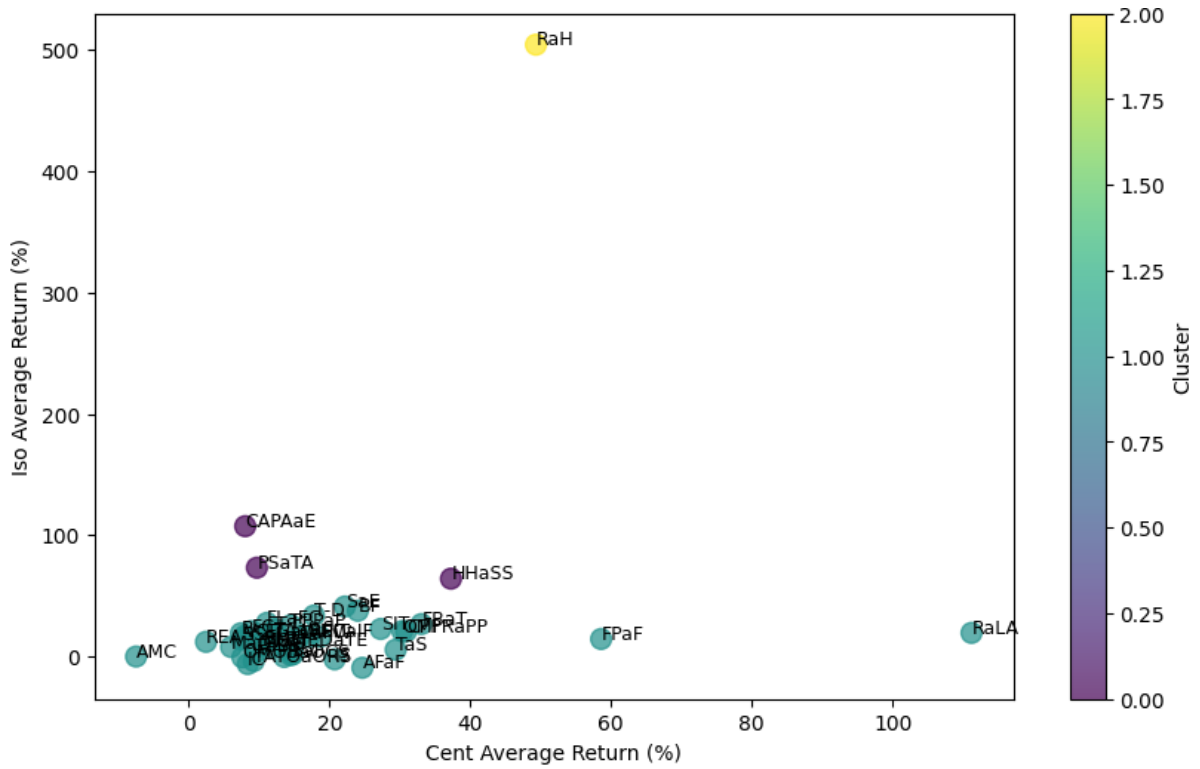


Figure 6. Sector Clusters Based on Cent and Iso Broker Average Return (%) (Averaged by Sector)

The different clusters in Figure 6 are grouped based on the return structures of the sectors. In Table 1, the return statistics of Cent and Iso brokers for each sector are provided along with their corresponding cluster labels. This allows for a clear comparison of how sectors align within the clusters based on the performance of their Cent and Iso brokers, offering insights into sector-specific return dynamics.

Table 1. K-Means Sectoral Cluster Analysis

Sec Abbr	Cent Average Return (%)	Iso Average Return (%)	Cluster
AFaF	24.680457	-9.269755	1
AMC	-7.464972	0.000000	1
B	7.432334	19.216868	1
BF	24.042523	37.733193	1
BMI	10.641746	10.744300	1
CAPaE	8.037838	107.428571	0
CPPRaPP	30.890230	20.724021	1
CaPW	15.668802	16.037434	1
EGaW	10.915768	16.968535	1
FBaT	33.073028	26.765204	1
FC	8.921218	20.935894	1
FLaFC	11.131969	27.778415	1
FPaF	58.606759	14.461594	1
FaBS	9.712543	4.252392	1
HCaIF	18.678730	16.264757	1
HHaSS	37.272971	64.179954	0
IC	8.403395	-6.179812	1
IS	20.749894	-2.317890	1
MGMEDaTE	10.482103	9.661472	1
MaQ	6.032987	7.864161	1
OMI	30.358327	20.994475	1
OMOSaOCS	7.637249	-0.638298	1
P	14.831384	1.880832	1
PPPaP	14.540861	25.880805	1

PSaTA	9.697399	73.191734	0
REA	2.470824	12.121212	1
REIT	17.106252	16.238313	1
RT	13.981107	5.656287	1
RaH	49.350355	504.236000	2
RaLA	111.228899	19.497778	1
SIT	27.286426	22.743325	1
SS	7.588074	14.028942	1
SaE	22.203403	41.233809	1
Sal	14.498064	1.169591	1
T	13.594617	-0.346021	1
T-D	17.805897	33.809445	1
T-I	12.316337	22.502171	1
TAT0aORS	9.261267	-3.703704	1
TAAI	12.141882	17.841397	1
TaS	29.414323	5.636805	1
VCIT	7.960938	17.090213	1
WT	11.692324	7.674937	1

According to Figure 6 and Table 1, the sectors grouped in Cluster 0 and Cluster 1 generally exhibit low returns for both Cent and Iso Brokers, mostly ranging between 0% and 50%. This pattern suggests that in these sectors, both Cent and Iso brokers deliver similar and relatively less effective returns.

- Cluster 2 comprises sectors with high Iso Returns, where independent players dominate (e.g., RaH).
- Cluster 1 is characterized by moderate Iso Returns and high Cent Returns, reflecting the dominance of more centralized players.
- Cluster 0 includes sectors where both Cent and Iso Returns are low.

The RaH sector stands out with an exceptionally high Iso Average Return (exceeding 500%) and a relatively low Cent Average Return. This highlights that small and isolated players have achieved significantly higher returns in this sector, whereas centralized players have seen comparatively lower performance.

In contrast, sectors like RaLA and FPaf display notably high Cent Average Returns (approximately 100%), while their Iso Average Returns remain relatively low (around 0-50%). This indicates that these sectors are more heavily influenced by centralized players, and the returns are primarily driven by these dominant participants.

Sectors such as CAPAaE, PSaTA, and HHaSS exhibit high Iso Average Returns (above 100%) and relatively lower Cent Average Returns, indicating that Iso Brokers have achieved significant gains in these sectors, whereas centralized players have generated comparatively lower returns.

Overall, the cluster analysis highlights distinct dynamics across sectors. For instance, in sectors like RaH, independent players achieve exceptionally high returns, underscoring their dominance in these areas. Conversely, sectors such as RaLA and FPaf are characterized by the dominance of centralized players, where Cent Brokers drive market returns. These findings clearly demonstrate the varying impacts of large and small players across different sectors, providing valuable insights into sector-specific market dynamics.

## CONCLUSION

This study provides valuable insights into the dynamics of information asymmetry and frontrunner effects within Borsa İstanbul, highlighting the varying roles of Cent and Iso Brokers across different sectors. By applying advanced machine learning algorithms such as iForest and K-Means, the research successfully identified anomalies and patterns that influence market dynamics. The findings emphasize that sectors like technology, energy, and healthcare are



particularly susceptible to information cascades and frontrunner behaviors, where independent players often capitalize on early actions to gain significant advantages. Conversely, sectors dominated by Cent Brokers, such as finance and utilities, exhibit greater stability and are primarily driven by long-term investments.

The results underscore the need for robust regulatory frameworks to mitigate the effects of frontrunner activities and reduce information asymmetry. By employing anomaly detection algorithms, regulatory authorities can enhance market transparency and efficiency. The study also highlights the importance of investors understanding the dynamics of information cascades, enabling them to better navigate short-term profit opportunities and anticipate market movements.

Furthermore, the cluster analysis reveals a clear distinction between sectors dominated by independent players and those controlled by centralized entities. For instance, sectors such as RaH, where Iso Brokers achieve exceptionally high returns, contrast sharply with sectors like RaLA and FPaF, where Cent Brokers drive market performance. These differences illustrate the nuanced interplay between market participants and the varying levels of volatility and growth potential across sectors.

Looking ahead, future research could expand upon these findings by examining longer time periods and incorporating additional dimensions, such as geographic and market capitalization classifications. Comparative studies utilizing alternative anomaly detection algorithms could also provide deeper insights into the robustness and versatility of these methods.

Ultimately, this study highlights the critical role of advanced analytical tools in understanding and managing complex market behaviors, offering practical implications for both policymakers and market participants. By addressing information asymmetry and fostering market stability, stakeholders can contribute to the development of more transparent, equitable, and efficient financial markets.

## **POLICY RECOMMENDATION**

This study provides critical insights into the dynamics of information asymmetry and frontrunner effects within Borsa İstanbul, leveraging advanced analytical tools such as the iForest and K-Means algorithms. These methods have proven effective in detecting anomalous trading activities and identifying patterns that influence market dynamics. The findings reveal that sectors such as technology, energy, and healthcare, where information cascades are prevalent, are particularly vulnerable to frontrunners. These actors gain a competitive advantage by acting early and steering the flow of information, often exacerbating market volatility. Conversely, sectors dominated by Cent Brokers, such as finance and utilities, exhibit greater market stability due to the focus on long-term, low-risk investments.

Regulatory authorities should develop robust policies aimed at reducing information asymmetry and mitigating the impact of frontrunners. This is especially critical in the digital age, where rapid information dissemination and social interactions among market participants amplify the effects of information cascades. Enhanced oversight mechanisms should be introduced to monitor and manage these dynamics, ensuring fair and transparent market operations.

Algorithms such as iForest should be systematically employed by regulatory bodies for real-time anomaly detection. By identifying irregular trading patterns early, regulators can act swiftly to address frontrunner activities and safeguard market efficiency. Expanding the use of such algorithms across different market segments can provide a proactive approach to stabilizing markets prone to volatility.

Investors, both institutional and individual, must pay closer attention to information cascades to understand the dynamics of short-term profit opportunities. Institutional investors, in particular, should strengthen their capabilities to analyze the influence of frontrunners on market movements. This includes adopting tools and strategies to mitigate the risks posed by frontrunner activities and aligning investment strategies with long-term market stability.

Future studies should explore broader time periods and expand the scope to include diverse classifications beyond sectoral divisions, such as market capitalization or geographic focus. Comparative research involving alternative anomaly detection algorithms (e.g., LOF, One-Class SVM) could provide additional insights into the strengths and limitations of various methodologies. These efforts will deepen the understanding of how information asymmetry and frontrunner effects evolve over time and across different markets.

The findings of this study underscore the significant role of Cent and Iso Brokers in shaping market dynamics, particularly in sectors with varying levels of volatility and growth potential. By adopting targeted regulatory measures, promoting investor education, and enhancing technological monitoring tools, policymakers and market participants can better navigate the challenges posed by information asymmetry and frontrunner effects. Ultimately, these actions will contribute to a more transparent, equitable, and efficient financial market ecosystem.

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**EXTENDED ABSTRACT***GENİŞLETİLMİŞ ÖZET*

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**A SECTORAL PERSPECTIVE ON FRONTRUNNERS AND INFORMATION  
CASCADES: CENTRAL AND ISOLATED CLEARING ANALYSIS USING  
ISOLATION FOREST**

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This study explores the dynamics of information asymmetry, strategic trading behaviors, and speculative movements in financial markets, focusing on 448 companies listed on Borsa İstanbul between September 3, 2021, and April 9, 2024. It addresses the critical question of how central (Cent) and isolated (Iso) brokers influence market dynamics, investment returns, and sectoral volatility through the frameworks of information cascade and frontrunner behavior.

Information cascades emerge when investors base their decisions on observed actions rather than their own analysis, while frontrunners—defined as informed traders—capitalize on their informational advantage to initiate market trends. The study is necessary to understand the dual role of Cent and Iso brokers in shaping market behavior and to evaluate the risks and opportunities these dynamics present to investors.

The study builds on the foundational concepts of information cascades and herding behavior (Bikhchandani, Hirshleifer, and Welch, 1992; Scharfstein and Stein, 1990). Previous research emphasizes how informed traders influence market trends, but there is limited exploration of how these effects vary sectorally and temporally.

Using machine learning algorithms like Isolation Forest and K-Means clustering, this research addresses the gap in identifying anomalies in trading behaviors and quantifying their impact on sectoral returns. Unlike earlier studies, which predominantly focus on developed markets, this paper contextualizes these phenomena within an emerging market, providing novel insights into the Turkish stock exchange.

This study employs the Isolation Forest algorithm for anomaly detection and the K-Means clustering method for grouping sectoral returns. Price and clearing data of 448 stocks from 41 sectors were analyzed to identify trading anomalies. The Isolation Forest algorithm identified days with abnormal trading behaviors, potentially indicating frontrunner activities or information cascades. Relationships between brokerage firms were mapped using network theory to analyze the flow of information in the market. K-Means clustering grouped sectors based on Cent and Iso broker returns, highlighting patterns of institutional and speculative interest.

The study underscores the critical role of advanced machine learning algorithms in detecting anomalies and understanding the dynamics of information cascades and frontrunner effects. It contributes to the literature by demonstrating how these phenomena influence market efficiency and sectoral returns.

Regulatory authorities should adopt anomaly detection algorithms like Isolation Forest for real-time monitoring of trading behaviors. Enhanced transparency and stricter regulations can mitigate the risks posed by frontrunner activities, particularly in volatile sectors.

Institutional investors should leverage advanced analytical tools to anticipate the impact of information cascades and align their strategies accordingly. Individual investors must be cautious of speculative activities in Iso-dominated sectors, balancing high returns with associated risks.

The study focuses on a three-year period and the Turkish market, limiting its generalizability. Future research could expand the timeframe, explore global markets, and incorporate alternative algorithms to validate findings.

By addressing the nuances of Cent and Iso broker behaviors, this study provides actionable insights for policymakers, investors, and academics, fostering more transparent and efficient financial markets.

**KATKI ORANI BEYANI VE ÇIKAR ÇATIŞMASI BİLDİRİMİ**

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