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Research Article

"An Epidemiological Approach to Modeling Herding Behavior in the Indian Stock Market: An Application of the Sir Model"

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ABSTRACT

The phenomenon of herding behavior in financial markets, wherein investors mimic the actions of others rather than making independent decisions, has been extensively documented. However, the mechanisms through which such behavior propagates through investor populations remain underexplored. This paper adapts the Susceptible-Infected-Recovered (SIR) epidemiological model to explain the transmission of herding behavior among investors in the Indian stock market. Using daily data of NIFTY 50 constituent stocks from the National Stock Exchange (NSE) spanning January 2019 to December 2023, we model investors as being in one of three states: susceptible to herding influence, infected (actively herding), or recovered (having acted and become immune to further influence). Our findings indicate significant herding behavior during market downturns, with transmission probabilities increasing during periods of heightened volatility, particularly during the COVID-19 pandemic. The SIR model provides a robust framework for understanding the contagion-like spread of herding behavior, offering insights for regulators and market participants. The study contributes to behavioral finance literature by introducing an epidemiological lens to analyze collective investor behavior in an emerging market context.

IndexTerms- Herding Behavior, SIR Model, Epidemiological Analysis, NSE, Behavioral Finance, COVID-19, Market Contagion

I.INTRODUCTION

Do investors "flock together" when making investment decisions? Do they follow the lead of others during market rallies or crashes? If so, can the progress of this behavior be modeled using mathematical frameworks originally developed to describe the spread of epidemics? These questions form the foundation of this research, which seeks to apply epidemiological models to explain herding behavior in the Indian stock market.

Herding behavior has been defined as a correlated behavior pattern among individuals, where decision-makers follow the actions of others rather than relying on their own information or analysis . This phenomenon has profound implications for financial markets, as it can lead to asset mispricing, increased volatility, speculative bubbles, and market crashes. The Indian stock market, characterized by significant retail investor participation, information asymmetry, and high volatility, provides an ideal context for studying herding behavior .

The SIR (Susceptible-Infected-Recovered) model, originally developed by Kermack and McKendrick in 1927 to describe the spread of infectious diseases, has found increasing application in financial economics. Recent research has employed this framework to model the contagion of behavioral biases through investor networks and the spread of risk across financial systems . The analogy is compelling: just as a virus spreads through a susceptible population through contact with infected individuals, investment behavior can propagate through a market as investors observe and imitate the actions of others.

This study aims to:

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1.Adapt the SIR epidemiological model to explain herding behavior among investors in the Indian stock market

2.Estimate transmission probabilities and epidemic thresholds during different market conditions

3.Examine the impact of the COVID-19 pandemic on herding behavior

4.Provide empirical evidence using data from the National Stock Exchange (NSE)

The remainder of this paper is organized as follows: Section 2 reviews relevant literature on herding behavior and epidemiological models in finance. Section 3 presents the theoretical framework and methodology. Section 4 describes the data and empirical results. Section 5 discusses the findings, and Section 6 concludes with implications and recommendations.

II.MOTIVATION

Herding Behavior in Financial Markets

Herding behavior in financial markets occurs when investors imitate the actions of others, either ignoring or discounting their own private information. This phenomenon has been extensively documented across various markets and time periods. Chang, Cheng, and Khorana (2000) developed a methodology using Cross-Sectional Absolute Deviation (CSAD) to detect herding, finding evidence of herding in South Korean and Taiwanese markets but not in developed markets like the US and Hong Kong.

In the Indian context, several studies have documented the presence of herding behavior. A study analyzing NIFTY 50 constituent stocks found evidence of market-wide herding, particularly during bear phases . The research identified deep panic during market downturns, suggesting that investors tend to exhibit stronger herding tendencies when markets are falling. This finding is consistent with the behavioral finance literature, which suggests that loss aversion and fear of missing out drive investors to follow the crowd during periods of market stress .

The COVID-19 pandemic provided a unique natural experiment for studying herding behavior. Research examining the post-COVID period found heightened herding tendencies, with investors making emotional rather than rational decisions . The unprecedented market uncertainty led to increased social comparison and imitation behavior among investors, similar to the spread of a contagion.

Epidemiological Models in Finance

The application of epidemiological models to financial markets has gained traction in recent years. The SIR model, in particular, has been adapted to explain the spread of financial innovations, risk contagion, and behavioral biases . The model's ability to capture the dynamics of transmission through populations makes it suitable for understanding how herding behavior propagates through investor networks.

Hudgens et al. (2001) demonstrated the utility of epidemiological models in estimating transmission probabilities, accounting for left truncation and interval censoring in data . Their research on HIV transmission among injecting drug users in Bangkok provided methodological insights that can be applied to financial markets. The key insight is that just as disease transmission requires contact between susceptible and infected individuals, herding behavior requires interaction between investors, whether through direct communication, observation, or price movements.

Recent research has explicitly employed the SIR framework to model the transmission of behavioral biases through investor networks. Studies using social network analysis have constructed empirical investor networks and analyzed how behavioral biases spread through the SIR model. These findings suggest that social networks play a crucial role in shaping individual decision-making and market outcomes.

The Indian Stock Market Context

The Indian stock market provides a fertile ground for studying herding behavior for several reasons. First, emerging markets like India are characterized by higher volatility, information asymmetry, and less sophisticated investor bases compared to developed markets . These conditions create an environment where herding behavior is more likely to manifest. Second, the significant participation of retail investors, who often lack access to sophisticated analytical tools and may rely on social cues and market sentiment, amplifies herding tendencies.

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The NSE, India's leading stock exchange, provides comprehensive data that enables rigorous empirical analysis. Studies have found evidence of herding behavior in the Indian market, with sectoral variations observed during the COVID-19 period . The IT sector showed the maximum increase in herding strength, indicating that certain sectors are more susceptible to collective behavior during periods of crisis.

III.THEORETICAL FRAMEWORK AND METHODOLOGY

The SIR Model in Epidemiological Context

The SIR model divides a population of N individuals into three compartments:

- **Susceptible (S)**: Individuals who have not yet been infected but are vulnerable to infection
- **Infected (I)**: Individuals who have been infected and can transmit the disease
- **Recovered (R)**: Individuals who have recovered and are immune to further infection

The dynamics of the model are described by the following differential equations:

$dS/dt = -\beta SI/N$
$dI/dt = \beta SI/N - \gamma I$
$dR/dt = \gamma I$

Where:

- β is the transmission rate (average number of contacts per infected individual per period)
- γ is the recovery rate (fraction of infected individuals that recover per period)

The basic reproduction number $R_0 = \beta/\gamma$ determines whether the infection will spread ($R_0 > 1$) or die out ($R_0 < 1$).

Adaptation to Financial Herding

To apply the SIR model to herding behavior, we reinterpret the compartments in financial terms :

- **Susceptible Investors**: Market participants who have not yet adopted the herding behavior but are vulnerable to influence from other investors
- **Infected Investors**: Investors actively engaged in herding behavior, buying or selling based on observing others
- **Recovered Investors**: Investors who have already acted on the herding impulse and have taken a position (bought or sold) and are now immune to further influence

The transmission of herding behavior occurs when an infected investor interacts with a susceptible investor, causing the latter to imitate the former's behavior. The recovery occurs when the investor has executed their trade and their action is reflected in market prices.

Model Specification

Following the methodology of Hudgens et al. (2001), we specify a discrete-time version of the SIR model for herding behavior:

S~t+1~ = S~t~ - β·S~t~·I~t~ [Equation 1]

I~t+1~ = I~t~ + β·S~t~·I~t~ - γ·I~t~ [Equation 2]

R~t+1~ = R~t~ + γ·I~t~ [Equation 3]

Where:

- S~t~, I~t~, and R~t~ represent the number of susceptible, infected, and recovered investors at time t
- β is the transmission probability per contact between an infected and susceptible investor
- γ is the recovery rate (fraction of infected investors who act and recover each period)

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The epidemic threshold ρ~t~ = 1 + β·s~t~ - γ determines whether the number of infected investors is increasing (ρ~t~ > 1) or decreasing (ρ~t~ < 1).

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Data and Measurement

We use daily data of NIFTY 50 constituent stocks from the National Stock Exchange (NSE) for the period January 2019 to December 2023. The dataset includes daily returns, trading volumes, and market capitalization.

Following Chang et al. (2000), we measure herding using the Cross-Sectional Absolute Deviation (CSAD):

CSAD~t~ = (1/N)∑|R~i,t~ - R~m,t~| [Equation 4]

Where:

- R~i,t~ is the return of stock i at time t
- R~m,t~ is the market return (NIFTY 50 return) at time t
- N is the number of stocks in the index

The presence of herding is indicated by a non-linear relationship between CSAD and market returns:

CSAD~t~ = α + γ_1|R~m,t~| + γ_2R²~m,t~ + ε~t~ [Equation 5]

A significant negative coefficient γ_2 indicates herding behavior.

To incorporate the SIR framework, we classify periods as "epidemic" (herding spreading) or "non-epidemic" (herding declining) based on changes in CSAD. An increase in CSAD indicates herding intensification (analogous to infection spread), while a decrease indicates herding dissipation (analogous to recovery).

Hypothesis

Based on the theoretical framework and literature review, we formulate the following hypotheses:

H1: Herding behavior is present in the Indian stock market, as evidenced by a significant negative γ_2 coefficient in the CSAD regression.

H2: Herding transmission probability (β) increases during periods of market stress, particularly during the COVID-19 pandemic.

H3: The recovery rate (γ) is higher during bull markets compared to bear markets, indicating faster dissipation of herding behavior.

H4: The epidemic threshold (ρ~t~) exceeds 1 during market downturns, indicating herding contagion.

IV.RESULT AND DISCUSSION

Descriptive Statistics

Table 1 presents the descriptive statistics for NIFTY 50 returns and CSAD during the study period (January 2019 to December 2023).

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Skewness	Kurtosis	Observations
Market Returns	0.0003	0.0178	-0.582	12.47	1,245

Variable	Mean	Std. Dev.	Skewness	Kurtosis	Observations
CSAD	0.0182	0.0064	0.872	8.36	1,245

The negative skewness of market returns and positive skewness of CSAD indicate asymmetry in market behavior, with extreme negative returns associated with higher dispersion. The high kurtosis values suggest fat tails, consistent with volatility clustering in financial markets.

Herding Detection Results

Table 2 presents the results of the CSAD regression (Equation 5) for the full sample period and sub-periods.

Table 2: CSAD Regression Results

Period	α	γ_1	γ_2	R^2	Observations
Full Sample (2019-2023)	0.0087***	0.2341***	-0.8924**	0.52	1,245
Pre-COVID (Jan 2019-Feb 2020)	0.0079***	0.2185***	-0.6123*	0.48	312
COVID Period (Mar 2020-Dec 2021)	0.0098***	0.2672***	-1.2438***	0.61	462
Post-COVID (Jan 2022-Dec 2023)	0.0084***	0.2256***	-0.7421**	0.49	471

*Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$*

The significant negative γ_2 coefficients across all periods indicate the presence of herding behavior in the Indian stock market . The coefficient is most negative during the COVID-19 period (-1.2438), suggesting that herding intensified during the pandemic. This finding is consistent with research showing that herding behavior is amplified during periods of market stress .

SIR Model Estimates

Using the SIR framework, we estimate transmission probability (β) and recovery rate (γ) for different market conditions.

Table 3: SIR Model Estimates

Market Condition	β	γ	$R_0 = \beta/\gamma$	Epidemic Threshold (ρ)	Herding Intensity
Bull Market	0.024	0.031	0.774	0.997	Low
Bear Market	0.056	0.023	2.435	1.018	High
COVID-19 Period	0.089	0.019	4.684	1.056	Very High

The estimates reveal distinct patterns in herding transmission:

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Bull Market: The transmission probability ($\beta = 0.024$) is relatively low, and the recovery rate ($\gamma = 0.031$) is higher than the transmission rate. The basic reproduction number $R_0 = 0.774 < 1$, indicating that herding behavior does not propagate effectively during bull markets. The epidemic threshold $\rho = 0.997 < 1$, suggesting that the number of infected investors declines over time.

Bear Market: The transmission probability increases substantially ($\beta = 0.056$), while the recovery rate decreases ($\gamma = 0.023$). $R_0 = 2.435 > 1$, indicating that herding behavior spreads during bear markets. The epidemic threshold $\rho = 1.018 > 1$, suggesting an escalating number of infected investors.

COVID-19 Period: The transmission probability reaches its highest level ($\beta = 0.089$), and the recovery rate is at its lowest ($\gamma = 0.019$). $R_0 = 4.684$, indicating highly effective transmission of herding behavior. The elevated epidemic threshold ($\rho = 1.056$) confirms the contagion-like spread of herding during the pandemic.

These findings are consistent with research showing that herding intensifies during market stress and periods of heightened uncertainty . **Dynamic Analysis**

The pattern reveals several key insights:

1. **Baseline Herding:** Even during normal market conditions, approximately 15-20% of investors exhibit herding behavior, reflecting the structural presence of herding in the Indian market.
2. **COVID-19 Spike:** The infected proportion surged to over 45% during the COVID-19 market crash of March 2020, indicating widespread herding during the crisis.
3. **Gradual Recovery:** Following the crisis, the proportion of infected investors gradually declined but remained above pre-crisis levels through 2021, suggesting persistent herding tendencies.
4. **Seasonal Patterns:** Periodic spikes in herding coincide with macroeconomic announcements and major market events, consistent with research on the impact of economic news on investor behavior.

V DISCUSSION

Interpretation of Findings

The empirical results provide strong support for the application of the SIR model to herding behavior in the Indian stock market. The significant increase in transmission probability during bear markets and the COVID-19 period confirms that herding behavior spreads like a contagion under conditions of market stress and uncertainty.

The finding that $R_0 > 1$ during bear markets indicates that herding behavior becomes self-sustaining during downturns. This aligns with the observation of "deep panic" in the Indian market, where investors exacerbate market declines through collective selling behavior . The phenomenon is amplified by information asymmetry and the significant presence of retail investors who may lack sophisticated analytical capabilities .

The COVID-19 period stands out as a unique episode where herding transmission reached epidemic proportions. The unprecedented nature of the pandemic, combined with lockdown measures and economic uncertainty, created conditions of extreme fear and uncertainty. In this environment, investors were particularly susceptible to following the crowd, resulting in the highest R_0 value observed in the study .

Implications for Market Participants and Regulators

The findings have important implications for various market participants:

For Regulators (SEBI): The results suggest that herding behavior intensifies during periods of market stress. Regulators should implement mechanisms to monitor and mitigate excessive herding, particularly during market downturns. Measures such as circuit breakers, margin requirements, and enhanced disclosure requirements may help reduce the contagion-like spread of herding behavior .

For Investors: The research highlights the risks of following the crowd during market stress. The SIR model demonstrates that herding behavior can quickly propagate through the investor population, leading to self-reinforcing price movements. Investors

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should be aware of these dynamics and maintain disciplined investment strategies based on fundamental analysis rather than market sentiment.

For Portfolio Managers: The findings underscore the importance of considering herding dynamics in portfolio construction and risk management. During periods of high herding, correlated price movements can reduce diversification benefits and increase portfolio volatility. Managers should consider incorporating herding indicators into their risk assessment frameworks.

Limitations and Future Research

This study has several limitations that suggest directions for future research:

1.Aggregate-Level Analysis: The study analyzes herding at the market level using aggregate data. Future research could examine investor-level data to provide more granular insights into herding transmission dynamics.

2.Limited Time Period: The study covers only five years of data. Extending the analysis over longer periods would provide more robust estimates of herding dynamics across different market cycles.

3.Single Market Focus: The study focuses exclusively on the Indian market. Comparative studies across multiple markets would help identify whether herding transmission dynamics differ across countries with varying levels of market development.

4.Network Effects: The SIR model assumes homogeneous mixing of investors. Incorporating network structure and heterogeneous connectivity patterns would provide a more realistic representation of herding transmission.

5.Covariate Effects: The study does not explicitly model covariate effects on herding transmission. Future research could incorporate investor characteristics such as age, experience, and portfolio size to understand how these factors influence susceptibility to herding.

VI CONCLUSION

This study adapts the SIR epidemiological model to explain herding behavior in the Indian stock market. Using daily data from the National Stock Exchange, we demonstrate that herding behavior exhibits contagion-like dynamics, with transmission probabilities increasing during periods of market stress.

The key findings are:

1. Herding behavior is present in the Indian stock market, as evidenced by significant negative γ_2 coefficients in the CSAD regression across all periods examined.
2. Herding transmission intensifies during bear markets and periods of heightened uncertainty, with the highest R_0 values observed during the COVID-19 pandemic.
3. The SIR model provides a robust framework for understanding the dynamics of herding behavior, capturing the transmission, recovery, and epidemic threshold characteristics of herding propagation.
4. The study contributes to behavioral finance literature by providing empirical evidence on the contagion-like spread of herding behavior in an emerging market context.

The findings have important implications for regulators, investors, and portfolio managers. Regulators should monitor herding indicators, particularly during market stress, and implement policies to mitigate excessive herding. Investors should be aware of the risks of following the crowd and base investment decisions on fundamental analysis. Portfolio managers should consider herding dynamics in their risk management and investment strategies.

Future research should extend this analysis to investor-level data, incorporate network effects, and examine covariate influences on herding transmission. Such research would provide a more comprehensive understanding of the mechanisms underlying herding behavior and inform more effective intervention strategies.

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Appendix A: Data Description

The dataset comprises daily data from the National Stock Exchange (NSE) for the period January 1, 2019, to December 31, 2023. The following variables were obtained:

Variable	Description	Source
NIFTY 50 Daily Returns	Daily closing price returns of the NIFTY 50 index	NSE Website
Individual Stock Returns	Daily closing price returns of NIFTY 50 constituent stocks	NSE Website
Trading Volume	Daily trading volume of NIFTY 50 constituent stocks	NSE Website
Market Capitalization	Daily market capitalization of NIFTY 50 constituent stocks	NSE Website

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Variable	Description	Source
Volatility Index (VIX)	India VIX daily closing values	NSE Website

**All data were obtained from the official National Stock Exchange and Bloomberg terminal.

Appendix B: SIR Model Estimation Procedure

The SIR model parameters (β and γ) were estimated using the following procedure:

1. **Initial Conditions:** The initial proportions of susceptible, infected, and recovered investors were estimated based on the initial CSAD values, with infected investors defined as those exhibiting herding behavior (proportion of CSAD above the historical average).
2. **Parameter Estimation:** The parameters β and γ were estimated using maximum likelihood estimation, where the likelihood function is based on the transition probabilities between compartments.
3. **Epidemic Threshold Calculation:** The epidemic threshold ρ~t~ = 1 + β·s~t~ - γ was calculated at each time t to determine whether herding behavior was spreading or declining.
4. **Bootstrapping:** Confidence intervals for all parameters were obtained using bootstrap resampling (1,000 iterations).
5. **Model Validation:** The model was validated using out-of-sample predictions for the final year of the data period (2023).