

Mathematical model for analysis of the relationship between personality traits and psychological biases of individual investors

Anita Kumari *

Ruchi Goyal [†]

Jaipur School of Business

JECRC University

Jaipur

Rajasthan

India

Sunil Kumar [§]

Faculty of Commerce & Management

SGT University

Gurugram

Haryana

India

Abstract

The study is focused on certain personality traits that are significantly associated with investors' biases. The study attempts to develop a more comprehensive mathematical model that covers a wider range of behavioral aspects related to individual investors. The proposed Mathematical model can be used to better understand the major behavioral dimensions that need to be considered for investment decisions in the stock market. In this study, a Partial Least Square Structural Equation Modelling (PLS-SEM) is used to quantify the association between major personality traits i.e. Agreeableness (AG), Conscientiousness (CO), Extroversion (EX), Neuroticism (NE), and Openness (OP) and major psychological biases such as Herding (HE), Overconfidence (OC), Representativeness (RP), and Anchoring (AN) in the stock market. The model is based on a survey of 467 individual investors, who provided information on their personality traits and psychological biases. The regression analysis was done to examine the

* E-mail: anita.tripathi15@gmail.com (Corresponding Author)

[†] E-mail: ruchi.goyal@jecrcu.edu.in

[§] E-mail: skvermamc@gmail.com

relationship between personality traits, and psychological biases. Further, the explanatory power and predictive relevance of the model are tested using R^2 , Q^2 , and RMSE.

Subject Classification: (2020) 82-10, 62H20, 93B45, 62P15.

Keywords: Mathematical model, Quantifying association, Stock market, Training and testing model, Predictive accuracy, Personality traits, Psychological biases, Partial least square structural equation modelling (PLS-SEM).

1. Introduction

On the basis of a few researches that have examined, the relationship between personality traits and psychological biases among investors in the stock market [2]; [12]; [1]. The study has formulated a mathematical model that can quantify the personality traits and biases of individual investors in the stock market. The Big-Five i.e. Extraversion (EX), neuroticism (NE), agreeableness (AG), conscientiousness (CO), and openness to experience (OP), are commonly used to study personality traits [16]. These traits have been found to significantly impact behavioral biases and investment decision-making [2]; [12]; [1].

Traditional financial theories like the efficient market hypothesis (EMH), expected utility theory (EUT), and modern portfolio theory (MPT) emphasize an idealistic approach, for instance, the assumption of EMH is that people can process all relevant information and act logically [20]. On the contrary, researchers like [11]; [23]; [19]; [21]; [22]; and [25]. questioned the presumptions of classical finance theories concerning the rationality of investors and market efficiency. The emerging field of behavioral finance gives an accurate depiction of investors' perspectives on stock market investments [13].

Previous research has not explored the empirical relationship between the Big Five Personality Traits and many of the well-known behavioral biases, such as OC, RP, AN, and HE, that affect individual investors' investment decisions in the stock market. This research gap provides an opportunity to develop a more comprehensive mathematical model that covers a wider range of behavioral aspects related to individual investors.

2. Literature Review

Relationship between big five personality traits & psychological biases

Individual investors may act irrationally due to biases stemming from past experiences or psychological heuristics [24]. Recent researches

have focused on how investors' personality traits affect their investment decision-making and cognitive biases [5]; [6]; [15]; [26].

Agreeableness: Investors with this trait rely on market information and are prone to HE behavior. In addition, they frequently lend a hand, exhibit affection and sympathy, and seek to exhibit a good identity due to their OC bias. As a result, the characteristic of AG influences the manifestation of OC, HE behavior, and disposition effect [6].

Conscientiousness: Conscientiousness is a personality attribute that is associated with being deliberate, structured, purposeful, and self-disciplined as well as participating actively in decision-making. [18]. It has been linked with behavioral biases, such as OC and the disposition effect [15]. CO is positively associated with OC, RP, and AN [3]; [6].

Neuroticism: Investors who exhibit the NE attribute frequently experience anxiety and emotional instability [15]. They exhibit a disposition effect, holding onto losing stocks for a longer period while seeking early profits and often following the advice of advisors and friends, leading to HE behavior [6]. They believe that past performance is a key element in future success, which results in RP and AN bias [2].

Extroversion: The possible impact of EX on behavioral biases and financial choices has been emphasized in numerous researches [7]; [12]; [1]. And linked to herding and overconfidence bias, [15]; [14].

Openness: Investors with OC trait usually update their financial portfolios on a regular basis and abide by the recommendations of their friends, advisors, and peers. However, such investors may display HE and OC bias [15]. They are overly optimistic and rely on prior performance, which causes RP and AN bias [2].

3. Methodology for data analysis

This mathematical research model examines how the big five personality traits influence individual investors' behavioral biases in the stock market by training 90% of the sample size i.e. 467 and testing the model's accuracy on the 10% out-of-sample data. A questionnaire was circulated to 700 individual investors to gather the data, and 467 responses were received after removing missing and outlier responses. The questionnaire was split into four parts: the first part obtained a demographic profile, part two evaluated behavioral biases, the third part assessed the respondents' big five personality traits, and the fourth part evaluated the stock market investment behavior of individual investors.

Table 1 and Figure 1 explains the quality criteria of the questionnaire are tested and validated by reliability and validity analysis i.e. Cronbach's alpha, Composite reliability, AVE. A validated questionnaire was distributed by using the convenience sampling method.

To measure the internal consistency reliability of the responses in the questionnaire Cronbach's Alfa is calculated for each construct.

$$\text{Cronbach's Alfa}(\alpha) = \frac{N * \bar{r}}{1(N-1) * \bar{r}} \quad (1)$$

Where, N = number of items and $\bar{r}$ = average correlation between the items.

Composite Reliability (CR) in the study indicated average correlation between the items of the constructs.

$$\text{Composite Reliability (CR)} = \frac{(\Sigma\lambda)^2}{[(\Sigma\lambda)^2 + \Sigma(1-\lambda^2)]} \quad (2)$$

where the factor loadings (λ) represent the strength of the relationship between each indicator and the latent variable, and $(1-\lambda^2)$ represent the amount of variance in each indicator that is not accounted for by the latent variable.

Average Variance Extracted (AVE) is used to measure the extent to which the indicators of a latent construct are related to each other.

$$\text{Average Variance Extracted (AVE)} = \frac{\Sigma\lambda^2}{[\Sigma\lambda^2 + \Sigma(1-\lambda^2)]} \quad (3)$$

Table 1
Reliability and Validity Analysis

(Con-structs)	(Cron-bach's alpha)	(Compos-ite reli-ability)	(AVE)
AG	0.800	0.811	0.558
CO	0.832	0.853	0.612
EX	0.891	0.895	0.700
NE	0.912	0.914	0.739
OP	0.929	0.931	0.778
OC	0.847	0.848	0.623
RP	0.882	0.883	0.679
AN	0.837	0.842	0.607
HE	0.885	0.894	0.688

Source: The Authors

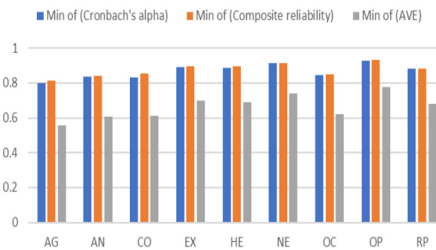


Figure 1
Reliability and Validity Analysis

Where, (λ) represents factor loadings and $(1-\lambda^2)$ represents the amount of variance in each indicator.

Table 1 of the study indicates a high level of internal consistency reliability because Cronbach's Alpha and CR values are > 0.7 [17]; [8]. The average correlation between items is measured by Composite Reliability (CR). For each constructs', Convergent Validity has been calculated by Average Variance Extracted (AVE) and It has been seen above the threshold limit of 0.5 [9]. As a result, it was decided that the constructs were reliable and valid for further research.

4. Analysis of Data

Table 3 and Figure 3 shows the predictive power and accuracy of the model. The models' explanatory power was measured by using path coefficients and R^2 and predictive accuracy was tested using Q^2 and RMSE. Further, model fit is tested through SRMR.

Path line expression indicated the relationships between some specific psychological biases (HE), (OC), (RP), (AN)) and the big five personality traits (NE, EX, OP, AG, CO).

$$OC = \beta_{11}NE + \beta_{12}EX + \beta_{13}OP + \beta_{14}AG + \beta_{15}CO + \varepsilon \quad (i)$$

$$RP = \beta_{21}NE + \beta_{22}EX + \beta_{23}OP + \beta_{24}AG + \beta_{25}CO + \varepsilon \quad (ii)$$

$$AN = \beta_{31}NE + \beta_{32}EX + \beta_{33}OP + \beta_{34}AG + \beta_{35}CO + \varepsilon \quad (iii)$$

$$HE = \beta_{41}NE + \beta_{42}EX + \beta_{43}OP + \beta_{44}AG + \beta_{45}CO + \varepsilon \quad (iv)$$

Coefficient of Determination (R^2) measures explanatory power of the model. The value of R^2 is showing the amount of variance in the endogenous constructs (OC, RP, AN, HE) explained by all of the exogeneous construct (AG, CO, EX, NE, OP).

$$R^2 = 1 - \frac{SS_{regression}}{SS_{total}} \quad (4)$$

Where, $SS_{regression}$: Sum Squared Regression, SS_{total} : Total sum of squares

Cross Validated Redundancy (Q^2). The value of Q^2 is calculated to measure the predictive power of the model.

$$Q^2 = 1 - \frac{\sum SS_d}{\sum SS_{Od}}, \quad (5)$$

Where, D = Omission Distance, SSE = Sum of square of errors, SSO = Sum of squares total.

Root Mean Squared Error of Prediction (RMSE). This study calculated the RMSE value to measure the predictive accuracy of the model.

$$RMSE = \sqrt{\frac{\sum (E - \bar{E})^2}{n}} \quad (6)$$

Where, E=predicted value, $\bar{E}$ = actual value

5. Results and Findings

Subsequent to ensuring the questionnaire's reliability and validity, the explanatory and predictive abilities of the model are evaluated. This is accomplished through the PLS predict technique by the calculation of path coefficients and R^2 . The validity of the model is further assessed by calculating Q^2 and RMSE values.

Figure 2 demonstrates the structural representation of the model. Table 2 depicted the path analysis of structural model in the study. AG has a positive and significant impact on OC, AN, and HE biases except RP bias with (β - value = 0.181, P -value = 0.024, β - value = 0.158, P -value = 0.021, β - value = 0.272, P -value = 0.000 and β - value = 0.122, P -value = 0.092) respectively. Further, the CO has no significant relation with investors' biases because t values and p values are greater than 1.96 and 0.05 respectively. Moreover, NE has also a positive and significant impact on investors' OC, AN, and HE except RP with (β - value = 0.266, P -value = 0.000, β - value = 0.244, P -value = 0.000, β - value = 0.410, P -value = 0.000 and β - value = 0.085, P -value = 0.094) respectively. Further, the result confirms that the EX has a positive and significant impact only on HE of investors with (β - value = 0.259, P -value = 0.001) Further, there is a positive and significant influence of OP on investors' AN and RP with (β -value = 0.275, P-value = 0.000 and β -value = 0.367, P-value = 0.000) respectively. Thus, the result confirms the relationship between all big five personality traits and investors' OC, AN, RP, and HE biases for their investment decision-making.

For explanatory power of the model, R-square values of AN, HE, OC, and RP are 0.606, 0.546, 0.431, and 0.449 respectively that shows the 60%, 54%, 43%, and 44% variation in the investors' biases is impacted by Agreeableness, Neuroticism, Extroversion, and Openness personality traits.

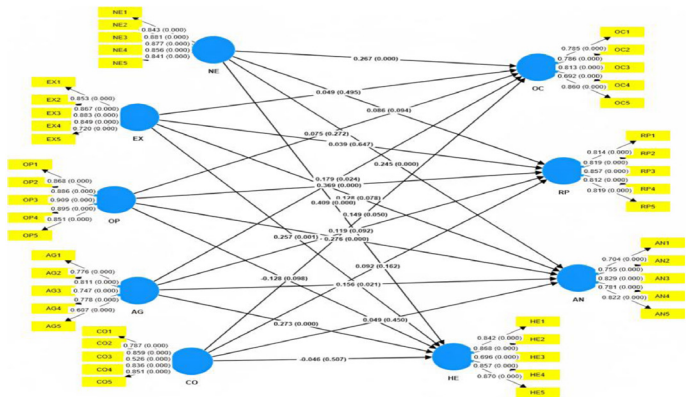


Figure 2
Simulation Structural Model

Table 2
Path coefficients Analysis

Path coefficients	β values	T statistics	P values
AG -> AN	0.158	2.302	0.021**
AG -> HE	0.272	3.883	0.000**
AG -> OC	0.181	2.259	0.024**
AG -> RP	0.122	1.686	0.092
CO -> AN	0.051	0.755	0.450
CO -> HE	-0.049	0.663	0.507
CO -> OC	0.150	1.960	0.050
CO -> RP	0.092	1.399	0.162
EX -> AN	0.127	1.763	0.078
EX -> HE	0.259	3.254	0.001**
EX -> OC	0.049	0.682	0.495
EX -> RP	0.039	0.457	0.647
NE -> AN	0.244	4.659	0.000**
NE -> HE	0.410	9.108	0.000**
NE -> OC	0.266	5.535	0.000**
NE -> RP	0.085	1.676	0.094
OP -> AN	0.275	4.113	0.000**
OP -> HE	-0.129	1.654	0.098
OP -> OC	0.073	1.098	0.272
OP -> RP	0.367	5.213	0.000**

Source: The Authors

Table 3
Predictive Measures

Constructs	R ²	Q ²	RMSE
AN	0.606	0.457	0.74
HE	0.546	0.403	0.776
OC	0.431	0.307	0.836
RP	0.449	0.336	0.819

Source: The Authors

For models' validation, Q² values exceeding 35% are considered to have 'high' predictive relevance [4]. To assess the model's predictive relevance in the study, PLS predict technique with k-fold cross validation (where k=10 equal sized subset of total sample) is used. Q² prediction values for AN, HE, OC, and RP are 46%, 40%, 31%, and 34% respectively. So, these values indicate moderately strong or strong predictive power of the model. Root mean square error (RMSE) value indicated the difference between predicted and actual observations which represents models' performance.

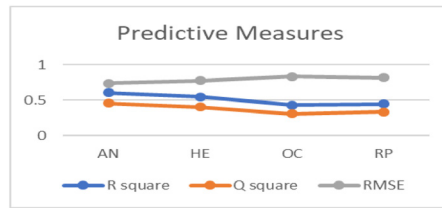


Figure 3
Predictive Measure

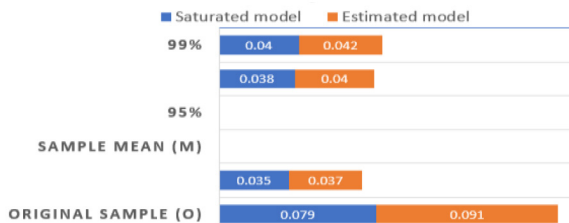


Figure 4
SRMR Values

Figure 4 and Table 4 show the model fitness of the study and it is also evaluated by calculating the SRMR prediction value which should be Less

Table 4
Standardized Root Mean Square Residual (SRMR)

	Original sample (O)	Sample mean (M)	95%	99%
Saturated model	0.079	0.035	0.038	0.04
Estimated model	0.091	0.037	0.04	0.042

Source: The Authors

than 0.08. The model's standardized root mean square residual (SRMR) value is 0.035 indicating a good model fit [10].

5. Conclusion & Implications

Mathematical analysis of the study indicates that, out of the major personality characteristics (AG, NE) have a significant and positive influence on investors' biases (AN, HE, OC), except for the RP for their investment decision-making. R square values indicated that 60%, 54%, 43%, and 44% variation in the investors' biases such as AN, HE, OC, and RP respectively are due to AG, NE, EX, and OP personality traits. Q^2 values for AN, HE, OC, and RP are 46%, 40%, 31%, and 34% respectively, indicated moderately strong or strong predictive power of the model.

Identifying individuals' personality traits and understanding their behavioral biases which reflect investment behavior in the stock market is a must for financial advisors to increase the investment efficiency of individuals as well as the financial market as a whole.

References

- [1] Ahmad, F., Personality traits as predictor of cognitive biases: moderating role of risk-attitude. *Qualitative Research in Financial Markets*, 12(4), 465-484 (2020).
- [2] Baker, H. K., Kumar, S., & Goyal, N., Personality traits and investor sentiment. *Review of Behavioral Finance*, 13(4), 354-369 (2021).
- [3] Bashir, T., Azam, N., Butt, A. A., Javed, A., & Tanvir, A., Are behavioral biases influenced by demographic characteristics & personality traits? Evidence from Pakistan. *European Scientific Journal*, 9(29) (2013).
- [4] Cohen, J., Statistical power analysis. *Current Directions in Psychological Science*, 1(3), 98-101 (1992).
- [5] Durand, R. B., Newby, R., & Sanghani, J., An intimate portrait of the individual investor. *The Journal of Behavioral Finance*, 9(4), 193-208 (2008).
- [6] Durand, R., Newby, R., Tant, K., & Trepongkaruna, S., Overconfidence, overreaction and personality. *Review of Behavioral Finance*, 5(2), 104-133 (2013).

- [7] Gambetti, E., & Giusberti, F., Personality, decision-making styles and investments. *Journal of Behavioral and Experimental Economics*, 80, 14-24 (2019).
- [8] Gefen, D., Straub, D., & Boudreau, M. C., Structural equation modeling and regression: Guidelines for research practice. *Communications of the Association for Information Systems*, 4(1), 7 (2000).
- [9] Hair Jr, J. F., Sarstedt, M., Hopkins, L., & G. Kuppelwieser, V., Partial least squares structural equation modeling (PLS-SEM) An emerging tool in business research. *European business review*, 26(2), 106-121 (2014).
- [10] Hair Jr, J. F., Matthews, L. M., Matthews, R. L., & Sarstedt, M., PLS-SEM or CB-SEM: updated guidelines on which method to use. *International Journal of Multivariate Data Analysis*, 1(2), 107-123 (2017).
- [11] Tversky, A., & Kahneman, D., Judgment under Uncertainty: Heuristics and Biases: Biases in judgments reveal some heuristics of thinking under uncertainty. *Science*, 185(4157), 1124-1131 (1974).
- [12] Kumar, V., & Dudani, R., The big five personality traits and psychological biases: an exploratory study. *Current Psychology*, 1-11 (2021).
- [13] Kumari, A., Goyal, R., & Kumar, S., Review on Behavioral Factors and Individual Investors Psychology Towards Investment Decision Making. *ECS Transactions*, 107(1), 8009 (2022).
- [14] Lai, C. P., Personality traits and stock investment of individuals. *Sustainability*, 11(19), 5474 (2019).
- [15] Lin, H. W., Elucidating the influence of demographics and psychological traits on investment biases. *International Journal of Economics and Management Engineering*, 5(5), 424-429 (2011).
- [16] Mayfield, C., Perdue, G., & Wooten, K., Investment management and personality type. *Financial services review*, 17(3), 219-236 (2008).
- [17] Nunnally, J. C., An overview of psychological measurement. *Clinical diagnosis of mental disorders: A handbook*, 97-146 (1978).
- [18] Picone, P. M., De Massis, A., Tang, Y., & Piccolo, R. F., The psychological foundations of management in family firms: Values, biases, and heuristics. *Family Business Review*, 34(1), 12-32 (2021).

- [19] Shefrin, H., & Statman, M., The disposition to sell winners too early and ride losers too long: Theory and evidence. *The Journal of Finance*, 40(3), 777-790 (1985).
- [20] Shiller, R. J., Human behavior and the efficiency of the financial system. *Handbook of macroeconomics*, 1, 1305-1340 (1999).
- [21] Shiller, R. J., From efficient markets theory to behavioral finance. *Journal of Economic Perspectives*, 17(1), 83-104 (2003).
- [22] Statman, M., Behavioral finance versus standard finance. In *AIMR conference Proceedings*, Vol. 7, pp. 14-22 (1995, December).
- [23] Thaler, R., Mental accounting and consumer choice. *Marketing science*, 4(3), 199-214 (1985).
- [24] Thambireddy, H., Motiramani, J., Dharahasa, S., Anand, N., & Narahari, S., How psychological biases influence investors decisions–Evidence from Indian stock market. *The Kiams-Phronimos*, 1(2), 1-14 (2021).
- [25] Wasan, P., Conceptual framework for online stock trading phenomenon in India. *Journal of Statistics and Management Systems*, 15(1), 93-106 (2012).
- [26] Zhou, Y., The effects of confirmatory bias in two-sender models. *Journal of Information and Optimization Sciences*, 42(2), 467-491 (2021).

