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Research Article

Cryptocurrency Adoption among Saudi Arabian Public University Students: Dual Structural Equation Modelling and Artificial Neural Network Approach

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Cryptocurrency is receiving widespread acceptance in the international market. Unfortunately, little attention is focused on the full identification of the cryptocurrency adoption factors, especially when it comes to emerging nations like Saudi Arabia. The current investigation is aimed at investigating whether the use of dual structural equation modelling and artificial neural network (SEM-ANN) would permit a better comprehension of the determinants of cryptocurrency adoption than the single-step PLS-SEM technique and explore the predictors of cryptocurrency adoption. An extended unified theory of acceptance and use of technology (UTAUT) model was used. A sample of 344 responses from Saudi Arabian students at public universities was used to verify the model. Unlike the majority of existing studies that were based on a single-step PLS-SEM approach, this investigation employed a superior statistical approach, the dual SEM-ANN approach, considered a unique methodological approach that can recognise variables' connections that are both linear and nonlinear and predict relationships with higher accuracy. Moreover, the dual SEM-ANN analysis revealed security as the most important factor influencing whether users would accept cryptocurrency, followed by effort expectancy and awareness. The application of the dual SEM-ANN technique and the extension of the UTAUT model with security and awareness constructs have enhanced the existing technology adoption literature. Additionally, methodological, theoretical, and practical contributions were offered by this study.

1. Introduction

The world has witnessed numerous technological advancements in the last decade, like the Internet of Things, electronic commerce, and digital payment systems. These changes are reflected in the way individuals interact including how they exchange money [1, 2]. As a result of the continuous change in the means of financial exchange from paper to virtual currency, cryptocurrency has emerged [3, 4]. Cryptocurrency is a digital currency based on a blockchain which is an advanced encryption technique used for financial exchanges. Cryptocurrency transactions are secured, transparent, and anonymous [5, 6]. Moreover, cryptocurrency transactions are not under the control of any financial institutions [7]. Hence, cryptocurrency users enjoy faster transaction time and lower transaction costs.

Furthermore, the recent boom of cryptocurrency has led to a considerable expansion of the cryptocurrency market size [8–10]. The adoption of cryptocurrency by multinational companies such as Expedia, Wikipedia, Dell and Microsoft, and AliExpress [11, 12] is a sign of a bright future for the technology [13]. The cryptocurrency adoption rate is higher in developed economies than that in developing economies like Saudi Arabia, and regulatory policies for cryptocurrency adoption are in the infancy stage [14, 15].

Widespread usage of cryptocurrency was forecasted to help in transforming the national economies, especially in developing nations [12]. Moreover, the potential of cryptocurrency in boosting the e-commerce market has been acknowledged [16]. However, the maximum benefits of cryptocurrency could only be achieved if the technology is

widely adopted among individuals [17]. Extensive adoption of cryptocurrency among Saudi Arabians could help the country in achieving its vision 2030 of shifting from an economy based on oil to one based on knowledge [18]. Unfortunately, the adoption of cryptocurrency among individuals in Saudi Arabia is low [14, 19]. Hence, it is crucial to have a thorough understanding of the determinants of cryptocurrency adoption that could stimulate the adoption of the technology among Saudi Arabian users. Previous researchers have called for a deep investigation of the factors of cryptocurrency adoption [20].

The majority of existing studies on cryptocurrency adoption are from the context of developed nations whose cultures and challenges differ from those of Saudi Arabia [11, 20]. The majority of existing studies overlooked Saudi Arabian users' perspectives on cryptocurrency adoption factors [15]. Understanding users' behavioural intention towards cryptocurrency adoption and being able to predict the cryptocurrency adoption factors from the view of Saudi Arabian users may be necessary for the widespread use of cryptocurrency in the country to support the achievement of Saudi Arabian Vision 2030 [21–23].

Additionally, in contrast to other studies utilizing single-stage PLS-SEM [13, 24] that could only identify linear connections among constructs, this investigation utilized dual SEM-ANN that could detect nonlinear as well as linear connections between constructs to predict determinants of cryptocurrency adoption more accurately, as recommended by prior studies [11, 25–27]. This investigation attempts to bridge the literature gaps and achieves the following objectives:

(a) To investigate whether the use of dual SEM-ANN produces more extensive research outcomes in comparison to the single PLS-SEM approach

(b) To investigate the factors that impact users' decision to utilize cryptocurrency

Therefore, as recommendations by Wang et al. [27] and Lee et al. [26], this investigation employed a dual SEM-ANN approach to achieve more accurate results. Accordingly, the proposed model of the current investigation can assist cryptocurrency developers with insight for enhancing the features of the technology for its wider adoption among users in emerging economies. This investigation is based on the unified theory of acceptance and use of technology model expanded with the insertion of awareness and security.

2. Literature Review

2.1. Unified Theory of Acceptance and Use of Technology as a Suitable Model. Some studies examine cryptocurrency adoption through the viewpoint of the technology adoption model [28]; however, TAM ignores the influence of social relations and hence is not deemed suitable for this research [2]. The UTAUT model was acknowledged as a suitable model for the prediction of technology adoption among individuals owing to its high predictive power compared to other theories. UTAUT was developed by Venkatesh et al. [29], through the synthesis of eight different theories, namely, TAM, theory of planned behaviour, theory of reasoned action, model of PC utilization (MPCU), motivational model, combined TAM-theory of planned behaviour, innovation and diffusion theory (IDT), and social cognitive theory. UTAUT model proposes variables as determining factors of behavioural intent to adopt technology, namely, effort expectancy, facilitating conditions, performance expectancy, and social influence as shown in Figure 1.

Prior investigations have documented the high reliability of the UTAUT model. However, some scholars have extended the UTAUT model with the inclusion of more variables to extend its predictive power. Similarly, we included the constructs of awareness and technology to the existing UTAUT constructs for better prediction of cryptocurrency adoption factors from the Saudi Arabian perspective.

2.2. Conceptual Framework of the Study. The present study extends the original UTAUT model by adding security and awareness constructs. The rest of the constructs including performance expectancy and effort expectancy are drawn from the original UTAUT. The performance expectancy and effort expectancy have both been used extensively in research and are regarded as the most common antecedents of behavioural intent [12]. Additionally, variables such as social influence and facilitating conditions have been rarely studied [12]. Likewise, variables like awareness [30] and security [31] are rarely investigated in the existing literature [12]. Hence, the proposed model of this investigation is on the basis of the UTAUT model extended with awareness and security. These additional constructs are considered crucial in the Saudi Arabian context. Cryptocurrency is an emerging technology. Hence, it is crucial to explore the effect of Saudi Arabians' awareness of cryptocurrency and their perception of security concerning the adoption of technology as a means of financial exchange. As evident in Figure 2, performance expectancy, effort expectancy, social influence, facilitating conditions, awareness, and security are proposed as determining factors of users' behavioural intent to use cryptocurrency in Saudi Arabia. A detailed discussion of hypothesis development is presented in the next section.

2.3. Hypothesis Development and Conceptual Framework

2.3.1. Performance Expectancy (PE). Performance expectancy may be thought of as the degree to which individuals obtain advantages and values from the adoption of a certain technology like convenience and ease of use [29]. Performance expectation has been the main indication for influencing users' behavioural intent to use technology in the existing technology adoption literature [32, 33]. It has been demonstrated that before utilizing an innovation, an individual evaluates options using a cost-benefit analysis [34]. Therefore, users' perception of additional benefits of utilizing an innovation would boost their perception of the value of such innovation [29].

Likewise, Rogers et al. [35] hint that an innovation has to provide an additional advantage compared to the existing option for it to be accepted by an individual. The above-mentioned benefits are in line with the performance

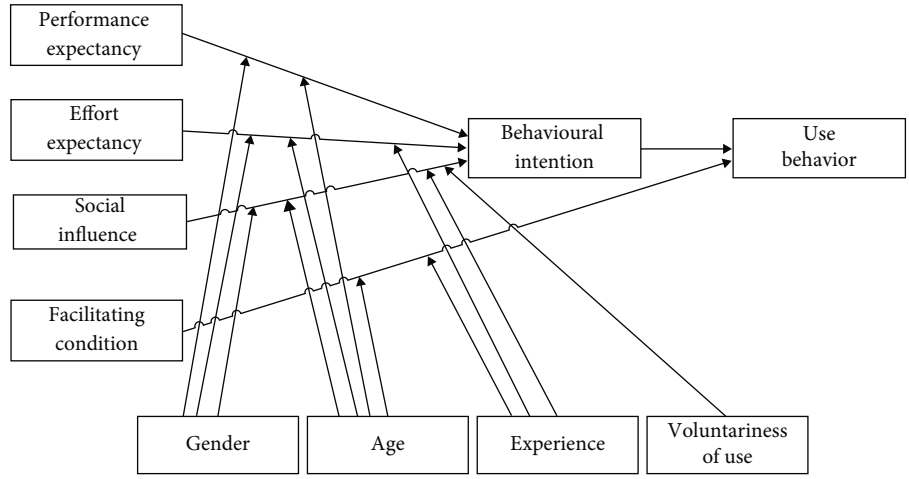

Figure 1: The unified theory of acceptance and use of technology [29].

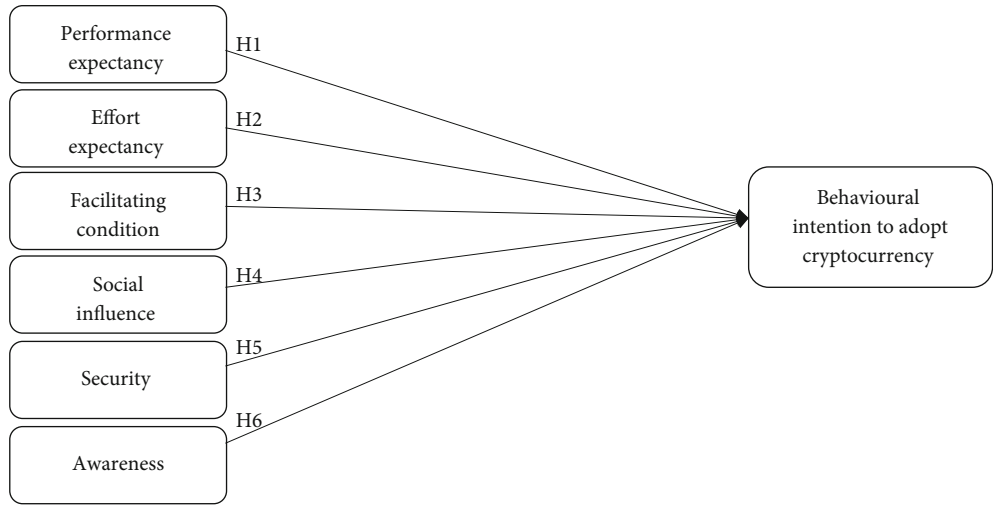

Figure 2: Conceptual model of the study.

expectancy. Ho and Ko [36] also reported that users' perception of utility was acknowledged to have a motivating influence on cryptocurrency adoption. As a result, the study anticipates that performance expectancy would enhance the adoption of cryptocurrency among Saudi Arabian users. Consequently, considering the aforementioned arguments, we articulate the hypothesis below:

Hypothesis 1. Performance expectancy has a positive effect on the intention to adopt cryptocurrency.

2.3.2. Effort Expectancy (EE). Effort expectancy is described as the simplicity with which individuals utilize an innovation [34] that consequently impacted the individuals' intention towards the innovation [37]. Studies have revealed the relevance of effort expectancy on the intention of an individual to adopt a technology [32, 33].

Ter Ji-Xi et al. [38] claimed that, apart from the benefits users get from the adoption of technology, individuals also consider the time and effort required to utilize technology in their decision for adopting the technology. Due to the absence of central control institution, cryptocurrency transactions are fast and easier than other online payment systems such as PayPal. So, it is hoped that effort expectancy would have a positive impact on Saudi Arabian students of public universities to use cryptocurrency. Effort expectancy was acknowledged to be a vital criterion for determining the intention of Saudi Arabians to use cryptocurrency. Many studies have also claimed a critical influence of effort expectancy on users' adoption of cryptocurrency [39]. Therefore, it is anticipated that Saudi Arabian students at public universities would be more inclined to utilize cryptocurrency if it requires less effort to perform financial transactions. Thus, this investigation formulates the hypothesis below:

Hypothesis 2. Effort expectancy has a positive effect on the intention to adopt cryptocurrency.

2.3.3. Facilitating Conditions (FC). The facilitating condition denotes a person's view that new technology may be used

with ease since the necessary technical infrastructure is available [34]. Existing literature revealed empirical evidence implying that an intention of an individual to embrace cryptocurrency is mainly impacted by facilitating conditions [40, 41]. In this research, facilitating conditions reflects the perception of the availability of the necessary resources like internet connectivity; the flexibility of utilizing cryptocurrency on different IT devices, like smartphone, laptop, and tablet; and essential knowledge required to conduct a financial transaction using cryptocurrency. Extant literature has revealed the positive influence of facilitating conditions on motivating individuals to accept cryptocurrency as a means of financial transactions [7, 20, 42]. Therefore, considering the aforementioned justifications, this investigation proposes the following:

Hypothesis 3. Facilitating conditions have a positive effect on the intention to adopt cryptocurrency.

2.3.4. Social Influence (SI). Social influence refers to individuals' perception of the level to which their friends and family are influencing them to adopt innovation [34]. Social influence has been positively linked to the adoption of several emerging technologies, including mobile banking [37], wearable technologies [43], and mobile wallets [12]. Social influence may be quite important, particularly when there is little knowledge about technology [44]. Cryptocurrency adoption is deemed to be a solitary action. Hence, the positive recommendations on the cryptocurrency benefits from friends and family members could positively influence the students of Saudi Arabian public institutions to use cryptocurrency. The Nseke [45] research, which examined the adoption of cryptocurrency among Africans, confirmed this view by offering empirical evidence that showed the stimulating influence of social influence on the cryptocurrency adoption intention. Many studies reported social influence as an important factor of individuals' intent to adopt cryptocurrency [7, 20, 37, 42]. So, the researchers hypothesized the following:

Hypothesis 4. Social influence has a positive effect on the intention to adopt cryptocurrency.

2.3.5. Security. Security refers to users' assessment of the level of protection against threats associated with utilizing online technology. People are hesitant to adopt technology when they feel unsecured about using the technology [2]. Cryptocurrency transactions take place virtually. Individuals may be afraid of the possibility of financial loss as a result of cybercrime [46]. The security of cryptocurrency would increase the morale of individuals utilizing the technology, allowing cryptocurrency to gain widespread adoption as a replacement for physical currency [47]. Students at Saudi Arabia's public institutions are more inclined to utilize cryptocurrency if they perceive it to be a secure means of payment [48]. Recent studies have shown that security is a driving force for the adoption of digital currency [31, 39, 49]. In Malaysia, a lack of security was a significant inhibitor of behavioural intentions to use cryptocurrency [46]. Thus, Saudi Arabian public university students are more probable to utilize cryptocurrencies if they believe it to be a safe technology. The researchers, therefore, postulate the following:

Hypothesis 5. Security has a positive effect on behavioural intention to adopt cryptocurrency.

2.3.6. Awareness. Awareness was explained as a person's level of familiarity with innovation and its advantages [50]. We defined awareness as the amount of knowledge Saudi Arabian public university students have concerning cryptocurrency and its advantages. Innovation diffusion theory was the first to suggest the significance of awareness to technological adoption [51]. Cryptocurrency is a new technology. As a result, people lack knowledge of the advantages of cryptocurrency, particularly in emerging nations like the KSA. It has been shown that the level of awareness of an innovation affects the perception of its benefits, and consequently, the behavioural intent to adopt the innovation [51]. There are pieces of evidence indicating that the intention of an individual to utilize cryptocurrencies is positively impacted by awareness [50, 52, 53]. However, a lack of user understanding of cryptocurrency might potentially prevent the adoption of cryptocurrency [30]. Thus, there is further research on the impact of awareness of Saudi Arabian public university students' cryptocurrency adoption behavioural intention. Consequently, we formulated the following:

Hypothesis 6. Awareness has a positive effect on behavioural intention to adopt cryptocurrency.

3. Research Methodology

3.1. The Population of the Study. All students at the five largest public universities, specifically, King Fahd University; King Saud University; University of Hail; Petroleum, Minerals, King Abdulaziz University; and King Khalid University. The five geographical provinces of north, south, east, west, and middle are where the universities are located. The decision to focus on these universities was motivated by a number of factors. First, these institutions represent a large and diverse student body, offering a broad cross-section of the Saudi Arabian student population. They span various geographic and socioeconomic backgrounds, thus providing us with a heterogenous sample to study. Furthermore, these universities have been pioneers in digital infrastructure, technology usage, and fintech adoption within the education sector in Saudi Arabia. Therefore, we hypothesized that the students from these universities would be more likely to engage with cryptocurrencies. Private universities were excluded from this study due to limited budget and time constraints.

3.2. Data Collection. To fulfil the study's purpose, to gather data, the researchers used online surveys. Bhattacherjee [54] asserts that online surveys have some advantages, i.e., cost-effectiveness, time-saving, and access to a larger audience. Since the study is aimed at investigating the behaviour of students, which were studying particularly at the five public universities, a nonprobability purposive sampling

approach was used for data collection. This approach is considered most effective when there is a need to study a certain domain [55].

Google survey form was used to create the survey link. The survey link was forwarded to the deans of Student Affairs, King Fahd University of Petroleum and Minerals, King Abdulaziz University, King Saud University, University of Hail, and King Khalid University. The students were then provided with the survey link by the deans via their institutions' mailing lists. Data collection took place between August 2022 to October 2022. G*Power was utilized to estimate the minimum sample size, and the results showed that 189 represented the minimum sample size with 0.95 statistical power. 344 valid responses, however, were gathered. All of the variables were measured via a five-point Likert scale. The validity of the survey was pretested by academic experts in the field of technology adoption. The survey was pilot-tested on a small sample. The reliability of all the constructs was revealed to be more than 0.70, which showed a good pilot test result.

3.3. Data Analysis. In contrast to earlier empirical investigations that used a single-step PLS-SEM analysis technique by Sohaib et al. [56], the current research has applied a cutting-edge dual SEM–ANN technique to analyse the relationships hypothesized in the conceptual model [26]. There are two phases in this approach. PLS-SEM was first employed to find significant factors of behavioural intent to adopt cryptocurrency. To rank the significant predictors through sensitivity analysis in the next phase, an artificial neural network was applied to the significant determinants acquired from the PLS-SEM analysis of the initial stage.

3.4. PLS-SEM. The proposed theoretical model was evaluated via the PLS-SEM analysis. PLS-SEM was preferred over covariance-based SEM (CB-SEM) because it can evaluate complicated models [57], manage small samples, and work with nonnormal data [58]. Additionally, it was proposed that PLS-SEM is more effective than CB-SEM [59]. The two components of analysis utilizing PLS-SEM are the measurement model and structural model assessment [60]. While the outer model analyses validity and reliability, the inner model examines the strength of correlations between variables [58].

3.5. Artificial Neural Network (ANN). When PLS-SEM was successfully analysed, an artificial neural network (ANN) is applied to strengthen and verify the PLS-SEM results. Henseler et al. [61] assert that the usage of ANN is crucial in predictive studies. ANN is capable of identifying linear and nonlinear connections to predict causal relationships with higher accuracy. This study used a multilayer perceptron (MLP) neural network based on feedforward ANN analysis, which has three layers, namely, input, hidden, and output layers. The hidden layer connects the input layer to the output layer. Hidden nodes are represented by weights [62]. The input layer contains the significant factors of the PLS-SEM analysis as its inputs and transmits them in the form of synaptic weights to the hidden layer. The sigmoid function is used for the activation of the hidden layer and output layer [56].

4. Results

4.1. Descriptive Results. Table 1 shows the characteristics of this study's respondents. Generally, 360 responses were gathered from which 344 were deemed valid for further analysis. Data on demographics were analysed using SPSS 25. Males are the bulk of the respondents (61.3%). By age group, most responders are in the age range of 18 and 24 (54.4%). The majority of responders hold bachelor's degrees (63.1%). Likewise, King Saud University students make up the majority of the respondents (33.7%).

4.2. Common Method Bias (CMB). To account for common method bias, we utilized a combination of statistical and procedural remedies as proposed by Podsakoff et al. [63]. Harman's single factor test was employed. Results show that a single factor's contribution to the overall variance was 34%, which was less than 50% [63]. The researchers also utilized a correlation matrix to further assess common method bias as suggested by Lowry and Gaskin [64]. From the correlation matrix result, none of the components had a value of more than 0.90, depicting that CMB was not seen to be a big threat.

4.3. Assessment of the Outer Model. The measurement model was examined by evaluating the reliability of the constructs through the examination of Cronbach's α, rho_A, and composite reliability (CR). We also examined convergent validity via factor loadings and average variance extracted (AVE) and discriminant validity [59]. Results in Table 2 showed that all the factor loadings are more than 0.7 [65], AVE values are higher than 0.5 [66], and Cronbach's α, rho_A, and CR values are all greater than 0.7 [67]. Moreover, discriminant validity was assessed by using the heterotrait monotrait ratio (HTMT). As disclosed in Table 3, all HTMT ratios are less than 0.85 as proposed by Henseler et al. [57]. Hence, no significant issues concerning discriminant validity were discovered.

4.4. Assessment of Multicollinearity. This study also examined multicollinearity based on Kock and Lynn [68]. Multicollinearity could result in an erroneous study. We assess multicollinearity in this study through the evaluation of variance inflation factor (VIF) values. As depicted in Table 4, all VIF values were found to be below 3.3 [39].

4.5. Assessment of the Inner Model. When the measurement model was successfully evaluated, the structural model was then assessed. A bootstrapping technique with 5000 iterations was employed to test the proposed hypotheses, as recommended by Hair et al. [59]. The findings of the hypotheses are shown in Table 4. As shown in Figure 3, the combined effect of the proposed determinants accounted for 64.9% of the variance towards behavioural intention to adopt cryptocurrency [70]. The effect size (f^2) of the study constructs and the coefficient of determination (R^2) value are also displayed in Table 4. The blindfolding procedure

Table 1: Demographic profiles of respondents.

Demographic variable	Frequency	Percentage (%)
Gender		
Female	133	38.7
Male	211	61.3
Age group		
18-24	187	54.4
25-35	104	30.2
36-45	53	15.4
Current educational level		
Bachelor's	217	63.1
Master's	92	26.7
PhD	35	10.2
University		
King Fahd University of Petroleum and Minerals	21	6.1
King Saud University	116	33.7
King Abdulaziz University	109	31.7
King Khalid University	68	19.8
University of Hail	30	8.7

Source: self-created.

was also run to determine the predictive relevance (Q^2) of the study model. The Q^2 value was found to be 0.432 as displayed in Table 4. The variance inflation factor (VIF) values were calculated to assess multicollinearity among predictor variables. As shown in Table 4, all the VIF values were below 5, indicating no significant multicollinearity. The regression analysis results are reliable, allowing meaningful conclusions about variable relationships. Hence, our path model has a medium predictive accuracy [59].

Table 4 illustrates that the studied constructs, AW − >BI (Hypothesis 1: $\beta = 0.119$, $t = 2.316$, $p = 0.010$),

EE − >BI (Hypothesis 2: $\beta = 0.308$, $t = 5.521$, $p = 0.001$), PE − >BI (Hypothesis 4: $\beta = 0.099$, $t = 1.73$, $p = 0.042$), SE − >BI (Hypothesis 5: $\beta = 0.290$, $t = 4.640$, $p = 0.001$), and SI − >BI (Hypothesis 6: $\beta = 0.133$, $t = 2.333$, $p = 0.010$), were discovered to have a significant positive influence on users' adoption of cryptocurrency. So, Hypothesis 1, Hypothesis 2, Hypothesis 4, Hypothesis 5, and Hypothesis 6 were supported. However, FC − >BI (Hypothesis 3: $\beta = 0.026$, $t = 0.787$, $p = 0.216$) did not have a significant effect. Thus, Hypothesis 3 was not supported.

4.6. Artificial Neural Network Analysis. Artificial neural network analysis was performed through the use of SPSS 25 software, with significant factors of the PLS-SEM analysis (i.e., awareness, security, performance expectancy, effort expectancy, and social influence) as its input (see Figure 4).

In this work, both hidden and output neurons are activated using the sigmoid function. To boost the performance of the present model, the range for input and output neurons is also normalized between [0,1] [71]. Additionally, a ten-fold cross-validation approach was used with 10% of the data for testing and 90% for training, to prevent overfitting in ANN models.

To determine the accuracy of our ANN model, the root mean square of errors (RMSE) was utilized. The RMSE values for training and testing were 0.7883 and 0.821, respectively, as shown in Table 5. The ANN model has great accuracy since the RMSE values for the training and testing data are only slightly different.

Furthermore, sensitivity analysis was carried out to determine the normalized importance of the input variables of the ANN model of the current study. To compute the relative normalized importance, each predictor's mean was compared to the highest mean value, represented as a percentage. Details of the normalized importance and the mean importance of each predictor are provided in Table 6. As represented in Table 6, the outcome of the sensitivity analysis disclosed that security is the most important predictor of behavioural intention to adopt cryptocurrency, followed by effort expectancy, and awareness. Moreover, social influence was found to be the least predictor of the behaviour intention of Saudi Arabian public university students to adopt cryptocurrency.

Also, Liébana-Cabanillas et al. [71] proposed the computation of the goodness of fit of an ANN model as part of the validation of its effectiveness. The goodness of fit is synonymous to the R^2 in the PLS-SEM analysis. To determine the ANN model's predictive power, Equation (1) was used to calculate the goodness-of-fit index.

$$R^2 = 1 - \frac{\text{RMSE}}{S_y^2}, \tag{1}$$

where S_y^2 represents the variance of the preferred output as indicated by the mean (SSE) of the testing process. The outcome suggests that the ANN model predicts 94.93% of cryptocurrency adoption.

The R^2 value of cryptocurrency adoption was 64.9% for the PLS-SEM analysis as opposed to that of the ANN analysis which disclosed an R^2 value of 94.93%, hence, disclosing a higher predictive power of the ANN model over the PLS-SEM model. Moreover, as implied in Table 7, the results of the PLS-SEM and ANN analysis showed some nominal differences that are due to the more accurate prediction of the ANN analysis and its ability to detect nonlinear relationships among the constructs.

5. Discussion

This study is aimed at exploring the determinants of cryptocurrency adoption among students of public universities in Saudi Arabia via the UTAUT model extended with security and awareness. Results of our investigation, all proposed relationships except facilitating condition (Hypothesis 3), awareness, performance expectancy, effort expectancy, security, and social influence (Hypothesis 1, Hypothesis 2, Hypothesis 4, Hypothesis 5, and Hypothesis 6), were found statistically significant predictors of cryptocurrency. The study's findings indicate that users' behavioural intention to use cryptocurrency was positively influenced by awareness (Hypothesis 1: $\beta = 0.119$). This shows that students at

Table 2: Measurement model evaluation [69].

Construct	Items	Loadings	Cronbach's α	rho_A	CR	AVE
Awareness	AW1	0.824	0.835	0.841	0.902	0.755
	AW2	0.829				
	AW3	0.947				
Behavioural intention	BI1	0.808	0.776	0.777	0.87	0.690
	BI2	0.831				
	BI3	0.853				
Effort expectancy	EE1	0.790	0.803	0.824	0.871	0.630
	EE2	0.782				
	EE3	0.716				
	EE4	0.878				
Facilitating condition	FC1	0.777	0.793	0.839	0.876	0.703
	FC2	0.896				
	FC3	0.838				
Performance expectancy	PE1	0.859	0.852	0.867	0.9	0.693
	PE2	0.760				
	PE3	0.846				
	PE4	0.861				
Security	SEC1	0.894	0.779	0.798	0.872	0.696
	SEC2	0.862				
	SEC3	0.738				
Social influence	SI1	0.877	0.831	0.835	0.899	0.747
	SI2	0.864				
	SI3	0.852				

Saudi Arabian public universities are expected to have a higher inclination to adopt cryptocurrency when they become familiar with cryptocurrency and knowledgeable about its advantages. Additionally, the outcome of this investigation has firmly established a connection between performance expectancy and cryptocurrency adoption (Hypothesis 4: $\beta = 0.099$). In other words, Saudi Arabian public university students will be more inclined to the adoption of cryptocurrency when they see it as a helpful technology that offers several advantages including time-saving, convenience, and cost-effectiveness. The outcomes of this investigation are in line with prior research [32, 40]. As anticipated, effort expectancy has demonstrated a positive and significant effect on the behavioural intention of users (Hypothesis 2: $\beta = 0.308$). This finding concurs with those of Beh et al. [40]. This hints that making cryptocurrency use simple and convenient is essential to motivating the intention to use cryptocurrency among Saudi Arabian public university students.

The finding from this investigation disclosed that facilitating condition was insignificant to the behavioural intention to adopt cryptocurrency (Hypothesis 3: $\beta = 0.026$). This result is in agreement with those of Shaw and Sergueeva [33] and Merhi et al. [37]. The possible reason for this outcome could be that, in the context of this study, it is easy to get the prerequisites for using cryptocurrency; all that is needed are a smartphone, tablet, or laptop with internet access to perform cryptocurrency transactions. All these are available to the students of public universities in Saudi Arabia.

A significant impact was found on the association between social influence and behavioural intention to adopt cryptocurrency among students of Saudi Arabian public universities (Hypothesis 6: $\beta = 0.133$). The finding contradicts some existing studies that claim an insignificant impact of social influence on cryptocurrency adoption [31]. Our findings highlight that the opinions of close and loved ones, including family members and peers, affect the intention of Saudi Arabian students of public universities to adopt cryptocurrency.

Security was acknowledged as a crucial predictor of behavioural intention to adopt cryptocurrency among the students of public universities in the KSA (Hypothesis 5: $\beta = 0.290$). The outcome matched that of Almarashdeh et al. [72]. This result reflects the impression of worry about the security of financial transactions related to the use of cryptocurrency among students of Saudi Arabian public universities. Security was the most important predictor of behavioural intention to adopt cryptocurrency in this study as revealed by the ANN analysis. Due to the virtual nature of cryptocurrency transactions, security is crucial to the adoption of the technology [48]. This shows that proper safety measures are required to be put in the design of cryptocurrency to prevent

Table 3: HTMT ratio.

Construct	AW	BI	EE	FC	PE	SE	SI
AW	-						
BI	0.758	-					
EE	0.766	0.889	-				
FC	0.127	0.172	0.173	-			
PE	0.716	0.815	0.823	0.168	-		
SE	0.688	0.882	0.761	0.157	0.854	-	
SI	0.679	0.780	0.738	0.090	0.783	0.770	-

Note: AW: awareness; BI: behavioural intention; EE: effort expectancy; FC: facilitating condition; PE: performance expectancy; SE: security; SI: social influence.

Table 4: Hypothesis testing.

Hypothesis	Relation	β-value	t-value	p-value	Decision	f^2	R^2	Q^2	VIF
H1	AW – >BI	0.119	2.316*	0.010	Supported	0.021	0.649	0.432	1.936
H2	EE – >BI	0.308	5.521**	0.001	Supported	0.114			2.360
H3	FC – >BI	0.026	0.787	0.216	Not supported	0.002			1.027
H4	PE – >BI	0.099	1.731*	0.042	Supported	0.010			2.800
H5	SE – >BI	0.290	4.640**	0.001	Supported	0.108			2.211
H6	SI – >BI	0.133	2.333**	0.010	Supported	0.024			2.114

Significance level: *$t > 1.645$; $p < 0.05$; **$t > 2.33$; $p < 0.01$.

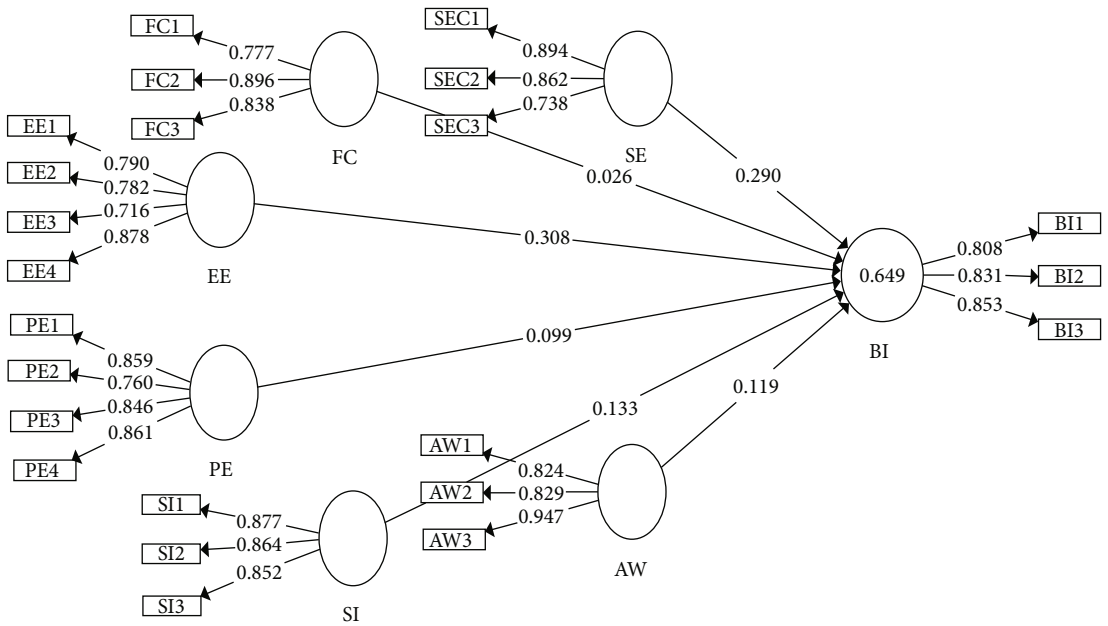

Figure 3: PLS path model of the study.

any possible risk and hazard associated with cryptocurrency adoption that might deter cryptocurrency usage.

5.1. Contribution to the Theory. The results of the current investigation have advanced the existing information system literature in general and cryptocurrency in particular by broadening the understanding of the researchers, cryptocurrency developers, Saudi Arabian government, and students at public universities in Saudi Arabia regarding the important factors of cryptocurrency adoption. UTAUT was selected as the ideal model since it is recommended to explain the adoption process of emerging innovation [34]. The current study is among the few that have improved the validity to look into and explain the factors that could affect the behavioural intent of students at Saudi Arabian public universities to adopt cryptocurrency as a developing

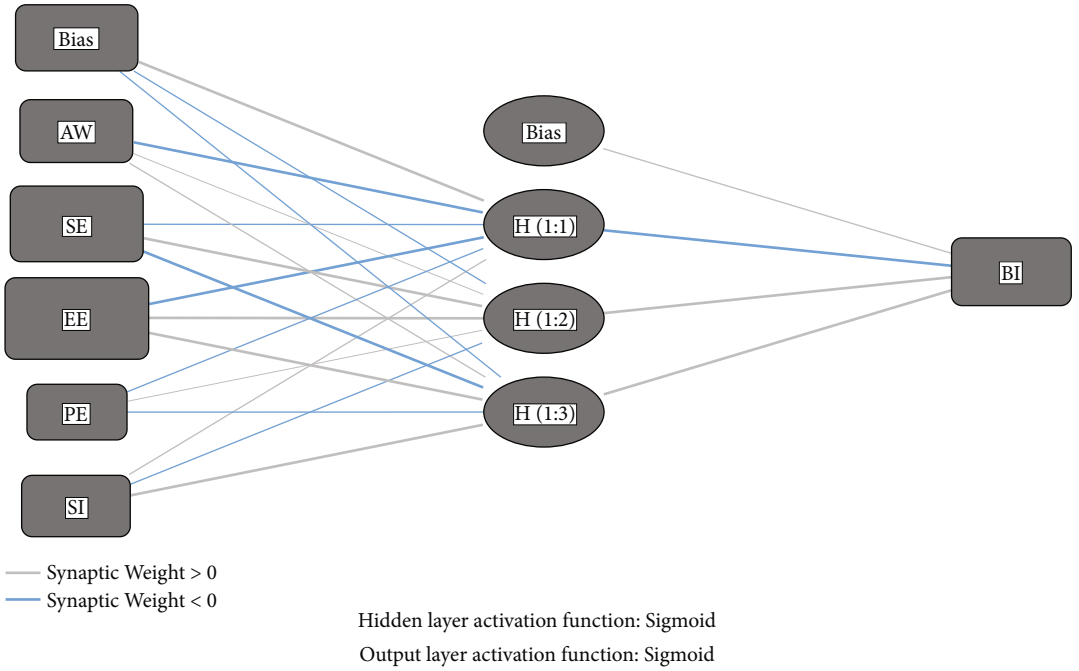

Figure 4: Artificial neural network model of the study.

Table 5: RMSE values.

Neural network	Input neurons: SE, AW, EE, PE, and SI Output neuron: FAD						Total
	Training			Testing			
	N	SSE	RMSE	N	SSE	RMSE	
1	306	135.135	0.814	38	16.568	0.789	344
2	311	130.207	0.733	33	14.169	0.697	344
3	311	132.283	0.72	33	14.563	0.818	344
4	306	133.354	0.801	38	16.709	0.895	344
5	301	132.636	0.834	43	19.633	0.93	344
6	313	131.18	0.712	31	13.887	0.742	344
7	304	134.666	0.829	38	16.585	0.763	344
8	310	135.521	0.774	34	15.183	0.971	344
9	304	134.129	0.832	40	18.162	0-925	344
10	307	133.992	0.834	37	16.577	0.784	344
Mean		133.31	0.7883		16.2036	0.821	
SD		1.72788	0.04979		1.81073	0.27363	

Notes: SE = security; AW = awareness; EE = effort expectancy; PE = performance expectancy; SI = social influence.

nation. Although the UTAUT model already provides a satisfactory perspective on innovation adoption, it is necessary to incorporate new to propose a model that is capable of interpreting individuals' intentions towards sensitive technologies such as cryptocurrency [34].

Hence, the current investigation extends the original UTAUT model by incorporating awareness and security constructs. Accordingly, the study findings showed that awareness, performance expectancy, effort expectancy, security, and social influence positively impact the behavioural intention to adopt cryptocurrency, from the view of Saudi Arabian users. The findings of the study enable researchers, cryptocurrency developers, and the Saudi Arabian government to have a thorough grasp of the factors of cryptocurrency in the Saudi Arabian context.

Furthermore, it is in contrast to previous studies that employed a single-stage approach using PLS-SEM [33, 37, 56] to forecast the intricacies linked with the decision to adopt cryptocurrency. This study employs a dual SEM-ANN methodology to determine not only the linear and compensatory links among the research variables but also the nonlinear and noncompensatory correlations among

Table 6: Sensitivity analysis with normalized importance for cryptocurrency adoption.

Neural network	Relative importance				
	AW	SE	EE	PE	SI
1	0.167	0.304	0.186	0.158	0.185
2	0.175	0.171	0.258	0.239	0.157
3	0.172	0.189	0.249	0.237	0.153
4	0.163	0.218	0.286	0.171	0.162
5	0.228	0.276	0.184	0.170	0.142
6	0.173	0.198	0.275	0.215	0.139
7	0.210	0.281	0.231	0.119	0.159
8	0.155	0.197	0.275	0.172	0.202
9	0.128	0.240	0.275	0.211	0.146
10	0.169	0.255	0.279	0.112	0.184
Mean relative importance	0.188	0.359	0.264	0.167	0.021
Normalized importance	52.3%	100.0%	73.4%	46.6%	6.0%

Note: AW = awareness; SE = security; EE = effort expectancy; PE = performance expectancy; SI = social influence.

Table 7: Comparison between PLS-SEM and ANN results.

Predictors	PLS-SEM		Neural network	
	Path coefficients	Ranking	Relative importance	Ranking
AW	0.188	3	0.119	4
SE	0.359	1	0.308	1
EE	0.264	2	0.099	5
PE	0.167	4	0.290	2
SI	0.021	5	0.133	3

Notes: AW = awareness; SE = security; EE = effort expectancy; PE = performance expectancy; SI = social influence.

the study variables for more accurate prediction results [73]. The dual SEM-ANN approach is a novel and robust method that is rarely applied in existing cryptocurrency adoption studies [56].

The dual SEM-ANN approach is important since an individual's behaviour intention to adopt cryptocurrency linear relationship of the SEM analysis could not offer a complete explanation of the complex human decision process regarding the adoption of cryptocurrency [74]. Hence, this investigation was able to achieve a better prediction outcome than existing studies due to the application of the dual SEM-ANN approach.

5.2. Practical Implications. The empirical results from this investigation also have important practical implications. The findings of this study will help service providers develop strategies that can promote the adoption of cryptocurrency among individuals in developing economies like Saudi Arabia by emphasising ways to make the process of using cryptocurrency more beneficial, simple, and safe for the users. For instance, a significant portion of Saudi Arabia's population consists of expatriates who regularly send money to their home countries. Using cryptocurrencies for these transactions could be more cost-effective and faster than traditional remittance channels, while also bypassing issues of currency conversion. Service providers could design targeted marketing campaigns to raise awareness about this advantage among the expatriate population. This study found a positive impact of security on the adoption of blockchain technology; therefore, service providers must ensure that robust security measures are in place in their products to protect user data and assets. Compliance with these regulations could also be used as a selling point to increase user trust in the security of cryptocurrencies. Considering the importance of awareness in the adoption of cryptocurrency, service providers should invest in user-friendly platforms that can cater to users with varying levels of digital literacy. They should design interfaces in Arabic and incorporate features that align with local customs and user habits.

Additionally, financial institutions and the Saudi Arabian government may also raise awareness of the benefits of using cryptocurrencies to increase the adoption rate. Furthermore, the current investigation helps in identifying the important factors affecting cryptocurrency adoption, thus, providing insight for the Saudi Arabian government and cryptocurrency developers to design effective strategies for enhancing the level of cryptocurrency adoption. The outcomes of the investigation have shown that if users find the technology secure, simple to use, and able to help them complete the task, the likelihood of its adoption increases. In addition, Saudi Arabian policymakers must be aware of the significance of the widespread adoption of cryptocurrency to the economic growth of developing

nations like Saudi Arabia [10]. Cryptocurrency provides a convenient, low-cost, and fast option for conducting financial transactions [7].

5.3. Limitations and Future Suggestions. Despite its numerous contributions, this research has some limitations. Data collection was performed cross-sectionally, but human behaviour changes over time. Therefore, future researchers might consider a longitudinal approach to data collection to better comprehend the influence of progressive changes on the adoption of cryptocurrency among Saudi Arabian users. Secondly, the results of this investigation reflect the perception of Saudi Arabian users and cannot be generalized to other developing countries due to contextual differences. Hence, a similar study is needed in other developing countries to further validate the research model of this study. Thirdly, future investigations might explore the postadoption behaviour of cryptocurrency users to identify the variables that motivate continuous usage of cryptocurrency among Saudi Arabian users. Lastly, future researchers should evaluate the results of ANNs with more than one layer.

6. Conclusion

The emergence of a new financial payment system by way of cryptocurrency has certainly changed the nature of the global market. This research is aimed at exploring the factors of cryptocurrency adoption through an innovative SEM-ANN methodology via the UTAUT model extended with awareness and security constructs. Results showed that awareness, performance expectancy, effort expectancy, security, and social influence are positive factors of cryptocurrency adoption. The outcome enhances the body of knowledge, both theoretically and practically, enabling cryptocurrency developers and policymakers to identify the key factors that could encourage individuals to use cryptocurrency for financial transaction purposes.

Data Availability

Data is available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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