THE MEANING AND MEASUREMENTS OF THE UTAUT MODEL: AN INVARIANCE ANALYSIS

Completed Research Paper

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Abstract

The Unified Theory on Acceptance and Use of Technology (UTAUT), a recent model in the study of technology adoption, integrates eight theories of technology adoption and provides a comprehensive view of factors affecting users' adoption behavior. In this study, the invariance of the UTAUT model's measures was tested along three dimensions: country, technology, and gender. Data were collected from two countries (Korea and the U.S.) for two technologies (Internet banking and MP3 players). The results show that overall the UTAUT model is robust across different conditions. However, when applying the UTAUT model to different conditions and groups, possible differences due to measurement non-invariance should be taken into account, especially in cases of transnational or cross-technology comparison. The paper discusses implications of the study results and makes recommendations for future research.

Keywords: UTAUT, technology adoption, invariance analysis, measurement models

Introduction

One main reason for building theoretical models is to compare certain phenomena across various conditions – different technologies, user groups, and occasions. In order to be able to compare a model precisely across different conditions, the measures of the model must be invariant across those conditions (Deng et al. 2008; Steinmetz et al. 2009). Otherwise, it is difficult to determine whether the differences, if there are any, exist because of the conditions being compared or because of differences in the measurements (Lai and Li 2005). Invariance analysis is a statistical method to test reliability and validity of measurement instruments across individuals, groups, and contexts using multi-group confirmatory factor analysis (Billiet 2002; Doll et al. 1998; Jöreskog and Söbom 1993; Klenke 1992).

Adoption of technology has been one of the most important topics in the Information Systems field. The technology acceptance model (TAM), TAM2, theory of reasoned action (TRA), theory of planned behavior (TPB), and other theories have been used to explain users' behavior with regard to technology adoption. Recently, a unified model of technology adoption was proposed by Venkatesh et al. (Venkatesh et al. 2003). The model, "Unified Theory on Acceptance and Use of Technology (UTAUT)," integrates eight theories on technology adoption and provides a comprehensive view of the factors related to users' adoption behavior. The original UTAUT model consists of four main constructs – performance expectancy, effort expectancy, social influence, and facilitating conditions – and four moderating variables – gender, age, experience, and voluntariness of use. Since UTAUT is the most comprehensive model in the area of technology adoption, it was selected as the model whose invariances are tested in this study.

In spite of the importance, the invariance of models for technology adoption has not been tested to the extent to which it should be. Invariance of TAM measurements has been tested in a few past studies (Lai and Li 2005), while invariance of the UTAUT model, to the best of our knowledge, has not been rigorously tested yet. Only a few studies have tested the validity of the measurement instruments of the UTAUT across countries (Oshlyansky et al. 2007), but a full-range invariance analysis has still not been performed.

Invariance analysis of a model is important because it tests if the measures of the model are invariant across conditions and ensures that the model can be applied under different conditions without concerns about the reliability and validity of its measures. In this study, invariance of the measures of the UTAUT model is tested in three different dimensions – countries, technologies, and gender. The analysis contributes to the field of technology acceptance by ensuring the reliability of the measures of the model. The main goals of this study are to:

1. Test the reliability and validity of the measurement instruments of the UTAUT model;
2. Assess the measurement equivalence of UTAUT instruments across countries, technologies, and gender; and
3. Identify sources of non-invariance or difference, if any.

The UTAUT Model

The main constructs of the UTAUT model are performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), behavioral intention (BI), and use behavior (UB). The relationships of these constructs and their measurement instruments are shown in Figure 1 and Table 1. Since its advent, the UTAUT model has been applied to various technologies such as tablet PCs (Anderson et al. 2006), instant messenger (Lin and Anol 2008), and information kiosks (Wang 2009). Other studies compared the UTAUT model across countries (Al-Gahtani et al. 2007; Bandyopadhyay and Fraccastoro 2007).

Although invariance analysis can be conducted on any constructs of the UTAUT model, the main focus of this study lies on the four independent constructs – PE, EE, SI, and FC, because the two dependent constructs, BI and UB, have been repeatedly tested in previous TAM studies and the moderating variables are not of main interest in most studies on technology adoption.

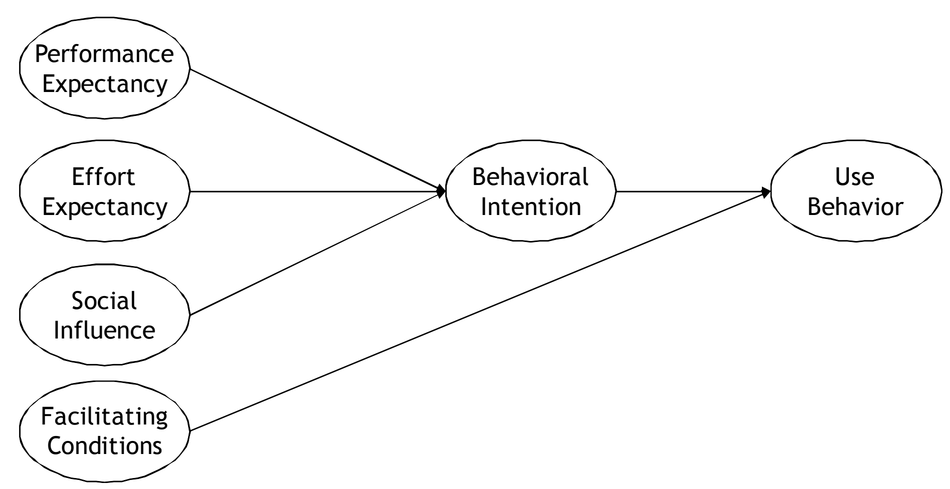

Figure 1. The UTAUT Model

Table 1. Constructs and Measurements of the UTAUT

Constructs	Measurements
Performance Expectancy (PE)	pe1: I would find the system useful in my job. pe2: Using the system enables me to accomplish tasks more quickly. pe3: Using the system increases my productivity. pe4: If I use the system, I will increase my chances of getting a raise.
Effort Expectancy (EE)	ee1: My interaction with the system would be clear and understandable. ee2: It would be easy for me to become skillful at using the system. ee3: I would find the system easy to use. ee4: Learning to operate the system is easy for me.
Social Influence (SI)	si1: People who influence my behavior think that I should use the system. si2: People who are important to me think that I should use the system. si3: The senior management of this business has been helpful in the use of the system. si4: In general, the organization has supported the use of the system.
Facilitating Condition (FC)	fc1: I have the resources necessary to use the system. fc2: I have the knowledge necessary to use the system. fc3: The system is not compatible with other systems I use. fc4: A specific person (or group) is available for assistance with system difficulties.

Previous studies that adopted the UTAUT model used the original instruments or slightly modified ones. Although most studies conducted reliability and validity tests using confirmatory factor analysis (CFA), average variance extracted (AVE), and other reliability statistics such as Cronbach's alpha, only few studies carried out invariance analysis. Past studies using the UTAUT model are summarized in Table 2.

Li and Kishore (Li and Kishore 2006) conducted an invariance analysis on the UTAUT model across gender, Weblog experience, and Weblog use frequency. Their results showed that several constructs were not invariant – PE and SI across gender; FC across Weblog experience; and SI and FC across Weblog frequency. Their analyses have limitations because only two types of invariance analyses – *tau* values (configural invariance and factorial loadings invariance) and full model – were conducted and only Chi-square difference statistics were presented. More detailed discussions on invariance analysis methods are discussed in the 'Invariance analysis' section below.

Table 2. UTAUT Studies

Study	Context	Data Source	Constructs	Measures	Analysis Types
(Anderson et al. 2006)	Tablet PC	U. S.	PE, EE, SI, FC	Venkatesh et al. (2003)	Composite Reliability AVE
(Bandyopadhyay and Fraccastoro 2007)	Prepayment Metering Systems	India	PE, EE, SI	Chau and Hu (2001) Davis (1989) Venkatesh et al. (2003)	Reliability Factor Loadings Construct Reliability AVE
(Garfield 2005)	Tablet PC		PE, EE, SI, FC		N/A (Conceptual)
(Li and Kishore 2006)	Online Community Weblog systems	U. S.	PE, EE, SI, FC	Venkatesh et al. (2003)	Chi-Square Difference
(Lin and Anol 2008)	Instant Messaging	Taiwan	EE, SI, FC	EE : Davis (1989) SI : Taylor and Todd (1995) FC : Thompson et al. (1991)	CFA
(Marchewka et al. 2007)	Course Management Software	U. S.	PE, EE, SI, FC	Venkatesh et al. (2003)	Reliability
(Robinson 2006)		U. S.	PE, EE, SI	Venkatesh et al. (2003) Minor adaptations	Reliability
(Wang 2009)	information kiosks	Taiwan	PE, EE, SI, FC	Venkatesh et al. (2003). Moon and Kim (2001)	Reliability AVE CFA

Invariance Analysis

There are several conceptual definitions of and methods for invariance analysis. In many studies invariance analysis is also referred to as measurement invariance analysis (Deng et al. 2008; Lai and Li 2005; Steinmetz et al. 2009). Measurement invariance analysis refers to testing if the same measurement can be used across different groups, which includes invariance of measurement parameters such as factor loadings and measurement errors, response biases, and the relationship between observed mean and latent mean (Deng et al. 2008; Lai and Li 2005; Steinmetz et al. 2009).

Among the studies about invariance analysis Steinmetz et al. (Steinmetz et al. 2009) is most comprehensive. Other studies employ simpler approaches that test only a few sources depending on their main focus. The most comprehensive seven-step approach covers the seven dimensions of invariance:

1. Invariance of configural loadings (Configural invariance)
2. Invariance of factorial loadings (Metric invariance)
3. Invariance of variance of latent variables (Factor variance invariance)
4. Invariance of covariance of latent variables (Factor covariance invariance)

5. Invariance of item intercepts (Scalar invariance)
6. Invariance of latent mean of latent variables (Factor mean invariance)
7. Invariance of random measurement errors (Error variance invariance)

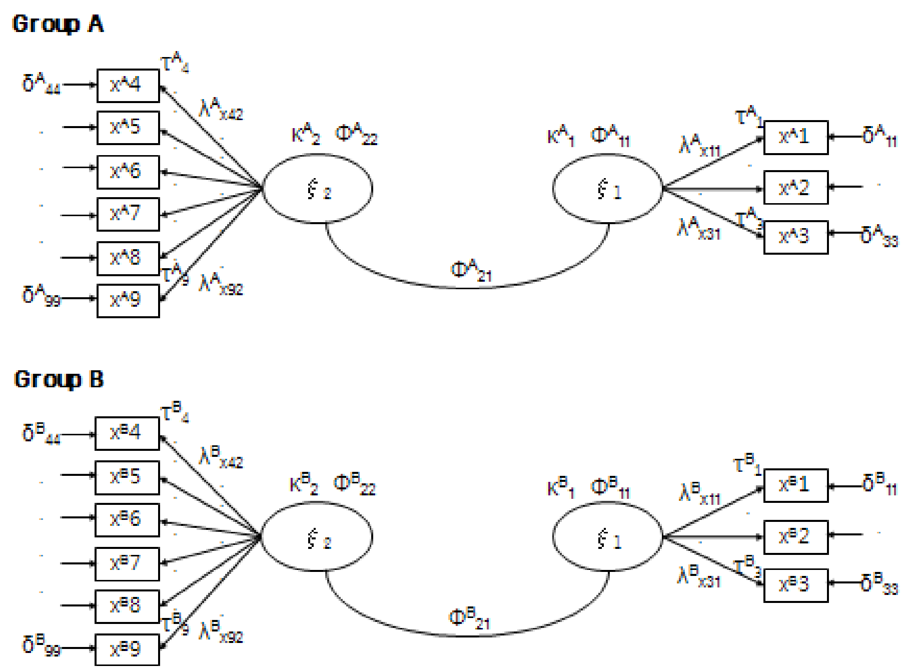

Figure 2. Types of Invariance Tests

Types of Test	Constraints
Invariance of configural loadings (*Configural invariance*)	no constraints
Invariance of factorial loadings *(Metric invariance)*	λA = λB
Invariance of variance of latent variables (*Factor variance invariance*)	φjjA= φjjB
Invariance of covariance of latent variables (*Factor covariance invariance*)	φjkA = φjkB
Invariance of item intercepts *(Scalar invariance)*	τA = τB
Invariance of latent mean of latent variables (*Factor mean invariance*)	κA = κB
Invariance of random measurement errors (*Error variance invariance*)	ΘA= ΘB

Configural invariance analysis assesses whether same pattern of factor loadings exists across different groups (Murray et al. 2007). It implies the equal number of factors in each group and the equal pattern of fixed and free parameters (Steinmetz et al. 2009). Configural invariance is a fundamental condition to be met for a model to be invariant across groups.

Metric invariance analysis assesses whether the factor loadings are identical for each scale item across groups. It implies equal factor loadings across groups (Murray et al. 2007). Since equal factor loadings means similar measure calibration across groups, the equal factor loadings across groups indicates the same meanings of the values on the observed scale across groups (Vandenberg and Lance 2000).

Configural invariance and metric invariance concern about construct compatibility across groups. Some studies consider configural invariance as sufficient for construct compatibility test (Steenkamp and Baumgartner 1998), while other studies argue that both configural and metric invariance must be satisfied (Vandenberg and Lance 2000).

Factor variance invariance analysis examines whether the variances of factor loadings are identical for each scale item across groups (Murray et al. 2007). Factor variance invariance is present when groups have the same variances in their respective latent variables (Steinmetz et al. 2009).

Factor covariance invariance analysis assesses whether the relationships among factors are equal across groups (Murray et al. 2007). This analysis tests possible differences in homogeneity of the latent variables across the groups (Steenkamp and Baumgartner 1998). Invariance of factor covariance represents equality of the associations among the latent variables (Steinmetz et al. 2009). Therefore, if the covariance of factors differs across groups, it indicates that the meanings or conceptualizations of latent variables are not equal across groups.

Scalar invariance analysis examines whether there is consistency between groups in latent versus observed means by imposing equal intercept constraints (Murray et al. 2007; Steenkamp and Baumgartner 1998). Item intercept can be interpreted as systematic biases of a group in the responses to an item (Hayduk 1989). A group may have a higher or lower tendency in responding to an item than the other groups. Therefore, if there is a significant difference in the item intercepts across groups, scalar invariance is present.

Table 3. Invariance Analyses in IS and Marketing

	Configural invariance	Metric invariance	Factor variance invariance	Factor covariance invariance	Scalar invariance	Factor mean invariance	Error variance invariance
(Doll et al. 1998)	O	O					O
(Deng et al. 2008)	O	O					
(Delgado-Ballester 2004)	O	O					O
(Doll et al. 2004)	O	O					O
(Wu and Wang 2005)	O	O			O		
(Deng et al. 2005)	O	O	O	O			
(Teo et al. 2009)	O	O			O		
(Li and Kishore 2006)	O	O					O
(Stein et al. 2006)	O	O	O			O	O
(Lai and Li 2005)	O	O	O	O		O	O
(Steenkamp and Baumgartner 1998)	O	O	O	O	O		O
(Murray et al. 2007)	O	O	O	O	O		O
(Steinmetz et al. 2009)	O	O	O	O	O	O	O

Factor mean invariance analysis checks if the means of factors (latent variables) are compatible across groups (Steinmetz et al. 2009). Focusing on covariance of factors, most structural equation model analyses assume the zero intercept and the zero means. However, researchers in some studies are interested in comparing means of latent variables across groups (Bollen 1989; Hayduk 1989). In those cases, the equality of means of latent variables (factor mean invariance) needs to be tested.

Error variance invariance analysis examines whether the variances of errors are identical for each scale item across groups (Murray et al. 2007). If configural invariance and metric invariance are present, error variance invariance can be interpreted as the validity of the measurements (Steinmetz et al. 2009).

Different types of invariance tests discussed above are graphically summarized in Figure 2. Among these, the most basic and common things tested in the majority of invariance analysis studies are configural invariance and metric invariance. In this study, the seven-step approach is employed since it is the most comprehensive invariance analysis method. In the figure, 'constraints' indicates the constraints imposed when analyzing the corresponding invariance. When 'metric invariance' is being tested, for example, $\lambda A = \lambda B$ is imposed as the constraints. If the statistics with and without the constraints are not significant, it is concluded that the corresponding invariance exists.

Authors have done an extensive search in IS and marketing fields and found many studies that employed invariance analysis as a research methodology, which are categorized based on the types of invariance analysis conducted (Table3). The results show that the majority of studies carried out only three or four types of invariance analyses and only few studies have conducted a comprehensive invariance analysis including six or seven types of invariance analyses.

Hypothesis Development

There can be various conditions under which the UTAUT model is tested. In this study, three conditions that are thought to be compared frequently are considered – culture (country), technology, and gender. Data from two countries (the U.S. and Korea) on two different technologies (MP3 players and Internet banking) were collected and invariance analyses on the three dimensions were conducted. The hypotheses for the invariance test were developed as follows:

H1 – Invariance across countries

H1-1: The Performance Expectancy instrument is invariant across U.S. and Korean samples.

H1-2: The Effort Expectancy instrument is invariant across U.S. and Korean samples.

H1-3: The Social Influence instrument is invariant across U.S. and Korean samples.

H1-4: The Facilitating Conditions instrument is invariant across U.S. and Korean samples.

H2 – Invariance across technologies

H2-1: The Performance Expectancy instrument is invariant across both technologies (Internet banking and MP3 players).

H2-2: The Effort Expectancy instrument is invariant across both technologies (Internet banking and MP3 players).

H2-3: The Social Influence instrument is invariant across both technologies (Internet banking and MP3 players).

H2-4: The Facilitating Conditions instrument is invariant across both technologies (Internet banking and MP3 players).

H3 – Invariance across gender

H3-1: The Performance Expectancy instrument is invariant across genders.

H3-2: The Effort Expectancy instrument is invariant across genders.

H3-3: The Social Influence instrument is invariant across genders.

H3-4: The Facilitating Conditions instrument is invariant across genders.

Empirical Test

The invariance of the UTAUT model was tested using the data collected from two countries (Korea and the U.S.) about two technologies (Internet banking and MP3 players). The two technologies were chosen because they represent different types of technologies – an 'online service' and a 'physical good'. UTAUT and other models about technology adoption typically are applied to innovative technologies. Internet banking and MP3 players are quite common ones in these days, but the data were collected in 2004 when these two technologies were still perceived as "innovative" technologies.

The initial questionnaire was developed based on the original UTAUT model (Venkatesh et al. 2003). The questionnaire was refined through two rounds of pilots. The first pilot was to validate the questionnaire items. The questionnaire was reviewed by two experts to check the content validity. In the second round, the questionnaire was administered to participants in order to analyze the statistical reliability and validity.

The questionnaire was initially developed in English, then translated into Korean after the pilots. The first translated questionnaire was re-translated into English by a separate translator to ensure the equivalence of measurement. The two different versions (original questionnaire and the re-translated questionnaire) were reviewed by a third party and any incongruence was corrected.

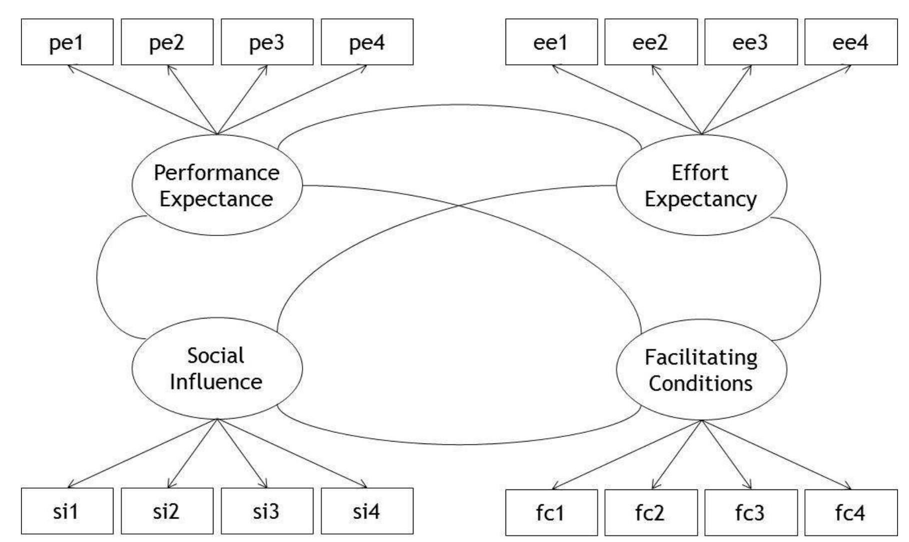

Figure 3. Confirmatory Factor Analysis (CFA) Model

The respondents to the main survey were undergraduate students and part-time MBA students in a university on the East coast in the U.S. and undergraduate students and office workers in Korea. Since most part-time MBA students are working full-time, the two samples from the U.S. and Korea are compatible in terms of background and job experience.

Respondents were asked to answer a survey that was designed to measure UTAUT model and other constructs. A brief description about the technology was provided and respondents' experiences with the technology were measured. Then, respondents were asked to answer questions about the UTAUT.

Among the 660 distributed questionnaires, a total of 550 responses were collected. A total of 501 responses were used for the final analysis after invalid responses were removed. Among the 501 respondents, 363 were from Korea and 138 were from the U.S., and 250 were on Internet banking, while 251 were on MP3 players. Female (253) and male (248) respondents were almost the same in number. One concern is the small size (138) sample from the U.S. Since the recommended minimum sample size for confirmatory analysis is 100 (Harris and Schaubroeck 1990) and in some previous studies, smaller samples had been used (for example, (Lai and Li 2005) and (Deng et al. 2008), 138 can be considered acceptable.

Before the main invariance testes, general validity of the model was tested. The method commonly used in previous studies (Lai and Li 2005) is employed. A confirmatory factor analysis (CFA) was conducted as shown in Figure 3, and the results are summarized in Table 4.

All constructs have Cronbach's alpha greater than 0.7 except for 'facilitating conditions (FC)'. In the main invariance analysis, thus, an item from FC (fc3) was deleted according to this reliability test result.

Table 4. Confirmatory Factor Analysis and Reliability Test Results

Constructs	Confirmatory Factor Analysis				Reliability Test			
	Measurement Items	Factor Loading	Standardized Factor Loading	C. R.	α if item deleted	Cronbach's α		
						Korea	U.S.	Entire Sample
Performance Expectancy (PE)	pe1	1.000*	0.833	N/A	0.880	0.875	0.855	0.863
	pe2	1.016	0.847	22.5	0.806			
	pe3	1.086	0.905	24.2	0.777			
	pe4	0.656	0.547	12.7	0.896			
Effort Expectancy (EE)	ee1	1.000*	0.842	N/A	0.929	0.931	0.906	0.938
	ee2	1.034	0.871	25.2	0.920			
	ee3	1.111	0.935	28.7	0.907			
	ee4	1.076	0.906	27.1	0.919			
Social Influence (SI)	si1	1.000*	0.882	N/A	0.761	0.824	0.842	0.824
	si2	1.050	0.926	24.4	0.742			
	si3	0.674	0.594	14.4	0.778			
	si4	0.547	0.482	11.2	0.828			
Facilitating Conditions (FC)	fc1	1.000*	0.810	N/A	0.488	0.659	0.519	0.657
	fc2	1.182	0.958	22.3	0.455			
	fc3	0.134	0.109	2.4	0.746			
	fc4	0.488	0.395	8.9	0.594			

* : Indicates a parameter fixed at 1.0 in the original solution

Configural invariance

Table 5. Configural Invariance

Dimensions	Subgroups	χ^2	df	P	RMR	TLI	CFI	RMSEA
Entire Sample		505.15	84	0.000	0.08	0.90	0.92	0.10
Nationality	Korea (n=363)	431.33	84	0.000	0.08	0.88	0.91	0.11
	U.S. (n=138)	158.56	84	0.000	0.08	0.92	0.93	0.08
	Stacked Model	589.88	168	0.000	0.08	0.89	0.91	0.07
Type of Technology	Internet Banking (n=250)	304.01	84	0.000	0.08	0.89	0.91	0.10
	MP3 Players (n=251)	310.01	84	0.000	0.09	0.89	0.92	0.10
	Stacked Model	614.02	168	0.000	0.08	0.89	0.91	0.07
Gender	Female (n=253)	323.13	84	0.000	0.09	0.88	0.90	0.11
	Male (n=248)	297.08	84	0.000	0.09	0.90	0.92	0.10
	Stacked Model	620.21	168	0.000	0.09	0.89	0.91	0.07

The first step of invariance analysis is running the model to sub-groups and check configural invariance. The analysis results are summarized in Table 5. The statistics for the entire sample were acceptable ($\chi2$ = 505.150, GFI = 0.876, RMR = 0.085, CFI = 0.919, RMSEA = 0.100). Although the GFI is below 0.9 and RMSEA is over the generally accepted threshold (0.5), it is acceptable considering the complexity (references).

Table 5 also shows that the indices of model fit across groups (country, technology, and gender) are similar. This implies that the configurations of the model (number of factors and their structures) across groups are compatible, which indicates that configural invariance exists. Configural invariance is the pre-requisite of other types of invariance analyses.

Metric invariance

The next step is to test metric invariance (invariance of factor loadings). As Table 6 shows, the factor loadings across nationality and gender are invariant, while those for technology type are not (p = 0.000). In the table, the rows labeled as "2" show the results of the invariance analysis on entire constructs, and the rows labeled as "2.1", "2.2" and so on show the results of invariance analysis on individual constructs. The table shows that the sources of differences across technologies were PE (p = 0.001) and SI (p = 0.001).

Factor variance-covariance invariance

The invariance of variance-covariance of factors (latent variables) was tested as summarized in Table 7. The results show that there is invariance of the variance and covariance of latent variables across technology type and gender. However, there are differences across countries. Unequal covariances imply inequality of construct meanings (Steinmetz et al. 2009). The analysis of individual constructs shows that the sources of difference across countries were EE and FC.

Scalar invariance and factor mean invariance

In the invariance tests discussed above, model 2 (factor loadings constrained) was used as a reference model. Model 2, however, cannot be compared with model 6 in Table 8 because they are not nested models. Therefore, AIC is tested instead of RMSEA. As discussed above, most applications of structural equation modeling assume zero indicator intercepts and zero latent means. Therefore, scalar invariance and invariance of latent means are tested only when the researcher is interested in comparing means and intercepts across groups (Steinmetz et al. 2009). That is why invariance of intercepts and mean of latent variables is thought to be relatively less important than other types of invariance.

Error variance invariance

In order to test invariance of random measurement errors, model 2 (factor loadings constrained) and model 3 (model 2 + error variances constrained) were compared. The test results in Table 9 show that there is non-invariance (difference) across all sub-groups. Examination of individual constructs shows that the sources of difference were EE and FC for nationality, PE and FC for technology type, and EE, SI, and FC for gender.

Table 6. Metric Invariance

Groups	Models	χ^2	df	$\Delta\chi^2$	Δdf	P	RMR	TLI	CFI	RMSEA
Nationality	Default Model	589.88	168				0.08	0.89	0.91	0.07
	2 (all factor loadings constrained)	599.59	179	9.71	11	0.556	0.08	0.90	0.91	0.07
	2.1 (only PE is constrained)	593.42	171	3.54	3	0.316	0.08	0.89	0.91	0.07
	2.2 (only EE is constrained)	590.17	171	0.29	3	0.962	0.08	0.89	0.91	0.07
	2.3 (only SI is constrained)	593.85	171	3.97	3	0.265	0.08	0.89	0.91	0.07
	2.4 (only FC is constrained)	591.80	170	1.93	2	0.382	0.08	0.89	0.91	0.07
Type of Technology	Default Model	614.02	168				0.08	0.89	0.91	0.07
	2 (all factor loadings constrained)	655.72	179	41.69	11	0.000	0.10	0.89	0.91	0.07
	2.1 (only PE is constrained)	629.74	171	15.72	3	0.001	0.09	0.89	0.91	0.07
	2.2 (only EE is constrained)	617.86	171	3.84	3	0.279	0.09	0.89	0.91	0.07
	2.3 (only SI is constrained)	630.84	171	16.81	3	0.001	0.09	0.89	0.91	0.07
	2.4 (only FC is constrained)	619.14	170	5.11	2	0.077	0.09	0.89	0.91	0.07
Gender	Default Model	620.21	168				0.09	0.89	0.91	0.07
	2 (all factor loadings constrained)	628.76	179	8.55	11	0.865	0.09	0.90	0.91	0.07
	2.1 (only PE is constrained)	623.52	171	3.31	3	0.769	0.09	0.89	0.91	0.07
	2.2 (only EE is constrained)	621.38	171	1.18	3	0.416	0.09	0.89	0.91	0.07
	2.3 (only SI is constrained)	623.70	171	3.49	3	0.743	0.09	0.89	0.91	0.07
	2.4 (only FC is constrained)	620.75	170	0.54	2	0.973	0.09	0.89	0.91	0.07

Table 7. Factor Variance-Covariance Invariances

Groups	Models	χ^2	df	$\Delta\chi^2$	Δdf	P	RMR	TLI	CFI	RMSEA
Nationality	2 (all factor loadings constrained)	599.59	179				0.08	0.90	0.91	0.07
	4 (variance is constrained)	622.42	183	22.83	4	0.000	0.11	0.90	0.91	0.07
	4.1 (only PE is constrained)	599.70	180	0.11	1	0.745	0.08	0.90	0.91	0.07
	4.2 (only EE is constrained)	611.35	180	11.76	1	0.001	0.10	0.90	0.91	0.07
	4.3 (only SI is constrained)	601.69	180	2.10	1	0.148	0.08	0.90	0.91	0.07
	4.4 (only FC is constrained)	614.21	180	14.62	1	0.000	0.09	0.90	0.91	0.07
	5 (covariance is constrained)	637.32	185	37.73	6	0.000	0.15	0.89	0.91	0.07
Type of Technology	2 (all factor loadings constrained)	655.72	179				0.10	0.89	0.91	0.07
	4 (variance is constrained)	657.54	183	1.83	4	0.767	0.10	0.90	0.91	0.07
	4.1 (only PE is constrained)	655.75	180	0.03	1	0.863	0.10	0.89	0.91	0.07
	4.2 (only EE is constrained)	657.28	180	1.57	1	0.211	0.10	0.89	0.91	0.07
	4.3 (only SI is constrained)	655.88	180	0.16	1	0.688	0.10	0.89	0.91	0.07
	4.4 (only FC is constrained)	655.93	180	0.22	1	0.641	0.10	0.89	0.91	0.07
	5 (covariance is constrained)	663.33	185	7.62	6	0.267	0.10	0.90	0.91	0.07
Gender	2 (all factor loadings constrained)	628.76	179				0.09	0.90	0.91	0.07
	4 (variance is constrained)	631.30	183	2.54	4	0.638	0.09	0.90	0.91	0.07
	4.1 (only PE is constrained)	628.86	180	0.10	1	0.756	0.09	0.90	0.91	0.07
	4.2 (only EE is constrained)	631.03	180	2.27	1	0.132	0.09	0.90	0.91	0.07
	4.3 (only SI is constrained)	628.78	180	0.01	1	0.909	0.09	0.90	0.91	0.07
	4.4 (only FC is constrained)	629.17	180	0.40	1	0.526	0.09	0.90	0.91	0.07
	5 (covariance is constrained)	655.73	185	26.96	6	0.000	0.11	0.90	0.91	0.07

Table 8. Scalar Invariance and Factor Mean Invariance

Groups	Models	χ²	Df	Δχ²	Δdf	P	TLI	CFI	AIC
Nationality	6 (intercept is constrained)	746.13	190				0.88	0.90	955.94
	6.1 (only PE is constrained)	756.22	191	10.09	1	0.001	0.87	0.90	1005.56
	6.2 (only EE is constrained)	849.17	191	103.05	1	0.000	0.85	0.88	957.03
	6.3 (only SI is constrained)	751.15	191	5.02	1	0.025	0.88	0.90	972.53
	6.4 (only FC is constrained)	910.46	191	164.33	1	0.000	0.84	0.87	956.79
	7 (intercept and mean are constrained)	924.46	194	178.33	4	0.000	0.84	0.87	1003.92
	2 (all factor loadings constrained)	599.59	179				0.90	0.93	837.72
	7 (intercept and mean are constrained)	924.46	194	324.87	15	0.000	0.84	0.87	1003.92
Type of Technology	6 (intercept is constrained)	795.94	190				0.86	0.89	955.94
	6.1 (only PE is constrained)	847.56	191	51.62	1	0.000	0.85	0.88	1005.56
	6.2 (only EE is constrained)	799.03	191	3.09	1	0.079	0.86	0.89	957.03
	6.3 (only SI is constrained)	814.53	191	18.59	1	0.000	0.86	0.89	972.53
	6.4 (only FC is constrained)	798.79	191	2.85	1	0.091	0.86	0.89	956.79
	7 (intercept and mean are constrained)	851.92	194	55.99	4	0.000	0.85	0.88	1003.92
	2 (all factor loadings constrained)	655.72	179				0.88	0.91	837.72
	7 (intercept and mean are constrained)	851.92	194	196.21	15	0.000	0.85	0.88	1003.92
Gender	6 (intercept is constrained)	649.11	190				0.89	0.92	809.11
	6.1 (only PE is constrained)	662.43	191	13.33	1	0.000	0.89	0.91	820.43
	6.2 (only EE is constrained)	671.14	191	22.04	1	0.000	0.89	0.91	829.14
	6.3 (only SI is constrained)	653.25	191	4.14	1	0.042	0.89	0.91	811.25
	6.4 (only FC is constrained)	700.62	191	51.52	1	0.000	0.88	0.91	858.62
	7 (intercept and mean are constrained)	703.06	194	53.95	4	0.000	0.88	0.91	855.06
	2 (all factor loadings constrained)	628.76	179				0.89	0.92	810.76
	7 (intercept and mean are constrained)	703.06	194	74.30	15	0.000	0.88	0.91	855.06

Table 9. Error Variance Invariance

Groups	Models	χ²	df	Δχ²	Δdf	P	RMR	TLI	CFI	RMSEA
Nationality	2 (all factor loadings constrained)	599.59	179				0.08	0.90	0.91	0.07
	3 (factor loadings and error variances constrained)	648.36	194	48.77	15	0.000	0.08	0.90	0.91	0.07
	3.1 (only PE is constrained)	606.26	183	6.67	4	0.154	0.08	0.90	0.91	0.07
	3.2 (only EE is constrained)	625.66	183	26.07	4	0.000	0.08	0.90	0.91	0.07
	3.3 (only SI is constrained)	601.69	183	2.10	4	0.717	0.08	0.90	0.91	0.07
	3.4 (only FC is constrained)	613.44	182	13.85	3	0.003	0.08	0.90	0.91	0.07
Type of Technology	2 (all factor loadings constrained)	655.72	179				0.10	0.89	0.91	0.07
	3 (factor loadings and error variances constrained)	706.31	194	50.60	15	0.000	0.10	0.89	0.90	0.07
	3.1 (only PE is constrained)	684.10	183	28.38	4	0.000	0.10	0.89	0.90	0.07
	3.2 (only EE is constrained)	656.41	183	0.69	4	0.952	0.10	0.90	0.91	0.07
	3.3 (only SI is constrained)	659.29	183	3.57	4	0.467	0.10	0.90	0.91	0.07
	3.4 (only FC is constrained)	673.71	182	17.99	3	0.000	0.10	0.89	0.91	0.07
Gender	2 (all factor loadings constrained)	628.76	179				0.09	0.90	0.91	0.07
	3 (factor loadings and error variances constrained)	702.37	194	73.61	15	0.000	0.09	0.89	0.90	0.07
	3.1 (only PE is constrained)	630.96	183	2.20	4	0.700	0.09	0.90	0.91	0.07
	3.2 (only EE is constrained)	671.81	183	43.05	4	0.000	0.09	0.89	0.91	0.07
	3.3 (only SI is constrained)	640.61	183	11.85	4	0.019	0.09	0.90	0.91	0.07
	3.4 (only FC is constrained)	645.37	182	16.61	3	0.001	0.09	0.90	0.91	0.07

Summary and Discussion

The results of the invariance tests are summarized in Table 10 and 11. Overall, the UTAUT model is invariant across countries, technologies, and gender in most dimensions of invariance. The most important ones, configural invariance and metric invariance, were proved to exist except for technology type in the category of metric invariance. Some differences exist in other dimensions of invariance. Most notable is the non-invariance across countries. It probably is because cultural differences are having profound impacts on the responses. The sources of these non-invariances need to be investigated further. Another noteworthy result is that the degree of invariance varies across conditions. For example, metric invariance is not present for different technologies while factor variance invariance is not present for different countries. It is important to examine these differences and find out why these differences exist. The bottom line is that the degree of invariance may vary across conditions. Therefore, researchers need to take this into considerations when they conduct research with a model such as UTAUT.

Table 10. Summary of Invariance Analysis Results

Tests	Nationality	Type of Technology	Gender
1. Configural invariance	Invariant	Invariant	Invariant
2. Metric invariance	Invariant	Non-invariant (PE, SI)	Invariant
3. Factor variance invariance	Non-invariant (EE, FC)	Invariant	Invariant
4. Factor covariance invariance	Non-invariant	Invariant	Non-invariant
5. Scalar invariance	Non-invariant	Non-invariant (PE, SI)	Non-invariant
6. Factor mean invariance	Non-invariant	Non-invariant	Non-invariant
7. Error variance invariance	Non-invariant (EE, FC)	Non-invariant (PE, FC)	Non-invariant (EE, SI, FC)

These results raise both theoretical and practical questions for IS researchers. The non-invariances of a given model probably originate in the different ways different subgroups perceive and respond to survey questions. The way women read a particular question, for example, may differ from the way men do. This is a well-known limitation of the survey method in the social sciences. Given that non-invariances cannot be eliminated completely, the extent to which we should tolerate them becomes a fundamental question. When are configural and metric invariances sufficient? When are other invariances called for, and which ones, and why? These questions can only be addressed by the IS research community as a whole, whose ultimate goal should be to agree upon appropriate levels and types of invariance for different research circumstances.

Second, more practically, what should researchers do about invariance when they conduct research with a theoretical model? Ideally, researchers would test the model for invariance before making use of it. In many cases, however, this is not possible, due to restrictions on time and resources. We suggest that researchers comb the literature for extant studies of the invariances of the model they are employing. If the model is shown to be invariant across the conditions they are investigating, they can use the same instruments. If there are not enough studies to ensure the invariance of the model, however, they would be well advised to test the invariances of the model (and instruments) in pilot studies. As the present study shows, even if a model and its measurements are known to be invariant for a given condition (e.g. country), the model and measurements will not necessarily be invariant for other conditions. If investigators cannot test invariance in a pilot study, they will need to test it in their main study, if they are to ensure that their results are not skewed by non-invariances in the measures.

Conclusions and Implications

This paper tests invariance of the UTAUT model across two countries, two technologies, and gender. Invariance of a model is critical when the model is to be applied to different conditions and groups. This study showed that the UTAUT model is robust across different conditions overall. However, some dimensions of the model differ across sub-groups. In order to apply the UTAUT model to different conditions and groups, especially when cross-country or cross-technology comparisons are conducted, the possible differences due to measurement non-invariance should be taken into account.

This study provides several implications for both theoretical research and practices. The theoretical implications are discussed first and the practical implications are discussed.

There are three major theoretical implications of this study. First, this study illustrates a comprehensive invariance analysis method. For an established theoretical model such as UTAUT, it is very important to investigate if the model is invariant across conditions. In testing invariance of a model it is desirable to conduct a thorough analysis. This study introduces a comprehensive seven-step invariance analysis and illustrates how the analysis should be carried out. Second, this study shows that the degree of invariance varies depending on the conditions. Therefore, researchers should be careful when comparing a model across different conditions which have not been tested for the invariance. Third, the results of this study imply that other theoretical models in the IS field such as Media Richness Theory will have to be tested their invariance across different conditions for more precise and rigorous comparisons across those conditions.

The most significant practical implication is that there exist significant variances in various aspects of the UTAUT model (e.g. factor loading and factor variance, etc.). This implies that consumers in different countries may respond to same technologies differently. Even consumers in a same country may respond to different technologies differently. Therefore, technology developers and marketers should not assume that the strategy worked for a technology would also work for other technologies. Second, despite some non-invariance just mentioned, the UTAUT model is robust (invariant) for the most important dimensions of invariance. Therefore, practitioners can use UTAUT for different markets and conditions and still expect substantially robust results.

Limitations and Future Research

This study has limitations due to the nature of the data and research methods, and future extensions are recommended. First, although the data sample is fairly large, further study is desirable with a larger dataset. Second, this study only tested the existence of invariance and did not investigate the causes of differences. Further study on the causes of the differences would provide valuable information about applying the UTAUT model. Third, some statistics (i.e. Cronbach's alpha for FC) are marginally accepted. It is probably because of the sampling of this study. Subjects with different occupations (student vs. workers) would have different support for their use of IT. This is a limitation of this study.

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