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Discriminant validity assessment in PLS-SEM: A comprehensive composite-based approach

S. Mostafa Rasoolimanesh
Taylor's University, Malaysia

Abstract

This paper aims to discuss modern approaches to assess discriminant validity in the context of structural equation modeling via partial least squares (PLS-SEM). It illustrates the application of these approaches using the WarpPLS 7.0 software. The Fornell-Larcker criterion, cross-loadings method, heterotrait-monotrait (HTMT) ratio, and full collinearity test have been discussed in this paper. A step-by-step guide is provided to assess discriminant validity using these four tests in WarpPLS 7.0. The first three criteria are applicable for reflective constructs, while the full collinearity test can be applied for both reflective and formative constructs. In different social science disciplines, a combination of reflective and formative constructs is a common practice, therefore reporting the full collinearity test for the assessment of discriminant validity can be an advantage.

Keywords: Discriminant Validity; Fornell-Larcker Criterion; Cross-Loading Method; Heterotrait-Monotrait (HTMT) Ratio, Full Collinearity Test; Reflective; Formative; WarpPLS.

Introduction

Partial least squares – structural equation modeling (PLS-SEM) enables composite-based SEM. It has witnessed growing attention by researchers in recent years and follows a two-step process including assessment of the measurement model and structural model (Ali et al., 2018; Kock, 2014).

Assessment of the measurement model entails the evaluation of validity and reliability of involved constructs in the model (Kock, 2014). This refers to evaluating of relationships between construct and the associated items; whereas the assessment of structural model focuses on the causal relationships between constructs (Ali et al., 2018; Amora, 2021; Kock, 2014).

To assess the measurement model, various criteria should be applied based on the nature of constructs. There are two types of measurement model known as reflective and formative, which formative can be causal and composite. For the reflective and formative measurement models, reliability and validity (i.e., convergent and discriminant validity) should be assessed.

However, the suggested criteria for assessment of reliability and validity of reflective and formative constructs are totally different. Reliability and convergent validity refer to the assessment of strong correlation of indicators to their corresponding construct and are deemed

acceptable when indicators load strongly on their associated constructs (Amora, 2021). Discriminant validity refers to the distinction between constructs in the model.

Discriminant validity is established when the constructs are distinct from each other. In this short paper, different criteria to establish discriminant validity have been discussed using WarpPLS 7.0 software (Kock, 2020a). This software incorporates a number of advance features in addition to those discussed in this article (Amora, 2021; Hubona & Belkhamza, 2021; Moqbel et al., 2020; Kock, 2020b; 2020c; 2020d; 2021a; 2021b; Morrow & Conger, 2021).

Discriminant Validity

In order to establish discriminant validity, researchers are required to verify all the constructs in a model are distinct from each other (Kock, 2014; 2015; 2020b; Kock & Lynn, 2012). Lack of discriminant validity in a model leads to questionable conclusions, disputing whether results can truely be supported by the data or they are obtained because of using a construct twice in the model.

Previous studies suggested a few approaches to assess discriminant validity using PLS-SEM including the Fornell-Larcker criterion, cross-loadings, heterotrait-monotrait (HTMT) ratio, and full collinearity assessment (Fornell & Larcker, 1981; Henseler et al., 2015; Kock & Lynn, 2012; Rasoolimanesh et al., 2017). The three first approches can only be applied to the reflective constructs, not the models involving formative constructs, but the last approch (i.e., full collinearity) can be applied for both reflective and formative constructs (Rasoolimanesh et al., 2017).

To establish discriminant validity using Fornell-Larcker criterion the square root of AVE of each construct should be greaer than the correlation with any other construct in the framework (Fornell & Larcker, 1981), whereas to establish discriminant validity using cross-loadings method, the outer loading of each item on its associated construct should be greater than the loading of item on other constructs (Chin, 1998). There are two methods to assess discriminant validity using HTMT; comparing with threshold of either 0.85 or 0.9 (Henseler et al., 2015), and using inference statistic to test the hypothesis that HTMT=1 (Franke & Sarstedt, 2019). Using suggested thresholds, the value of HTMT should be lower than 0.85 or 0.9, whereas to apply inference statistic the hypothesis HTMT=1 should be rejected.

Fornell-Larcker criterion, cross-loading method, and the HTMT can only be applied to reflective constructs to establish discriminant validity. The full collinearity test to assess discriminant validity was suggested by Rasoolimanesh et al. (2017), which can be applied to both reflective and formative constructs.

The literature has proposed calculation of variance inflation factors (VIFs) as measures of collinearity for each construct and then compare these VIFs with a threshold of 10, 5, or the more conservative threshold of 3.3 (Kock, 2020; Kock & Lynn, 2012).

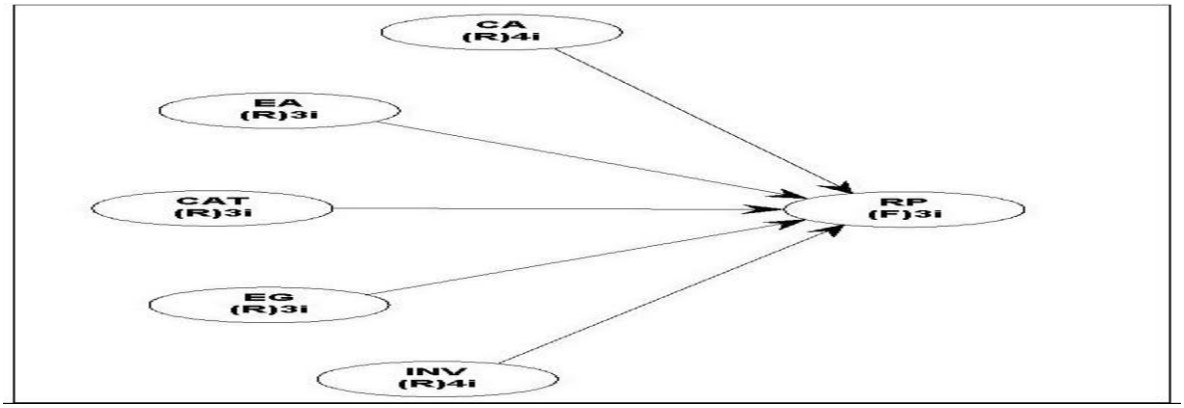
Empirical illustration

To illustrate different types of discriminant validity, this study has used the model and data from Rasoolimanesh et al. (2019). Figure 1 shows the model from Rasoolimanesh et al. (2019).

As discussed earlier, to establish discriminant validity, the literature recommended four criteria. WarpPLS 7.0 provides all four criteria for assessment of discriminant validity. After

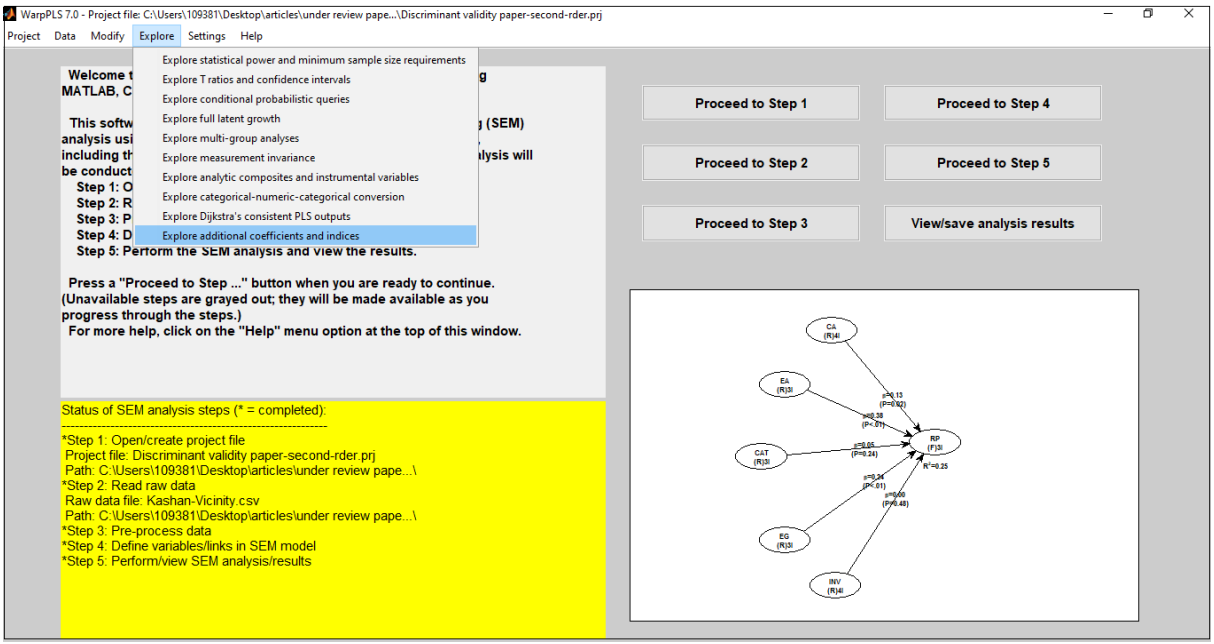
creating model and performing SEM analysis in Step 5, we need to go to "Explore" option and select "Explore additional coefficients and indices" (See Figure 2).

Figure 1. Conceptual framework



Notes: CA=Community Attachment; EA=Environments Attitude; CAT=Cultural Attitude; EG=Economic Gain; INV=Involvement; RP=Residents' Perceptions.

Figure 2. Explore additional coefficients and indices



In "Explore additional coefficients and indices", we need to select "Discriminant validity coefficients (extended set)" (See Figure 3), and then we can get the results for assessment of discriminant validity using four criteria. WarpPLS 7.0 provides the results for Fornell- Larcker criterion, cross-loadings, heterotrait-monotrait (HTMT) ratio, and the full collinearity test.

Figure 3. Discriminant validity coefficients (extended set)

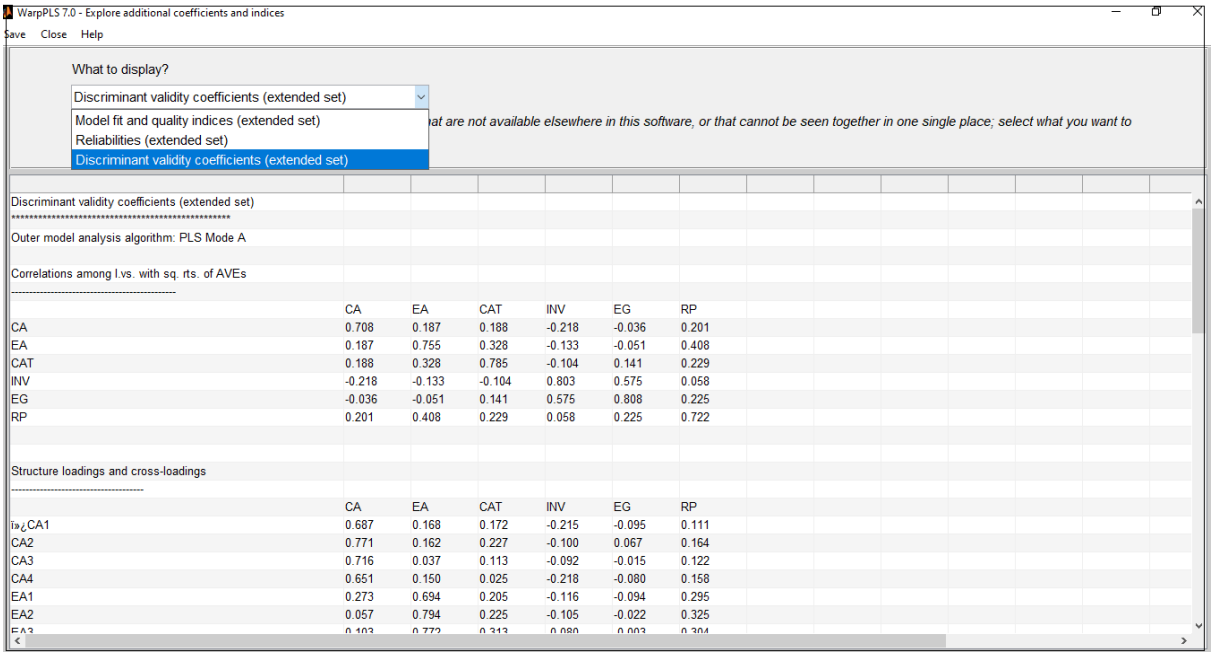


Figure 4 shows the square root of AVE of all constructs greater than the correlation with other constructs, indicating the establishment of discriminant validity for this study.

Figure 4. Results of discriminant validity assessment using Fornell-Larcker criterion

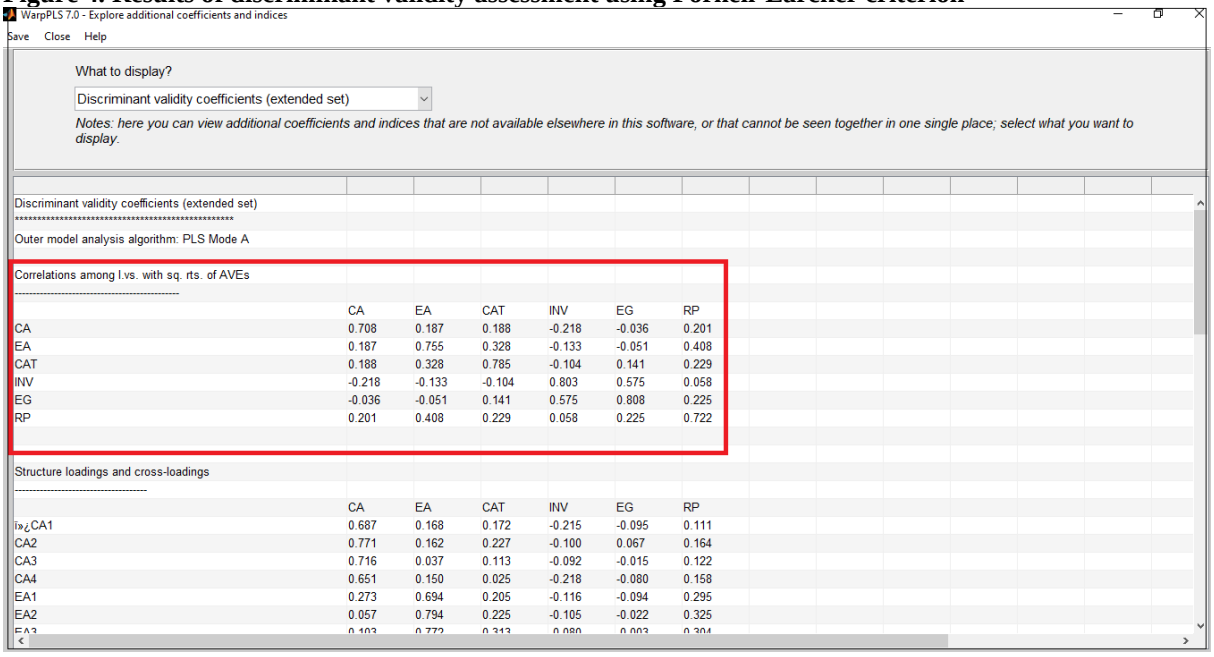
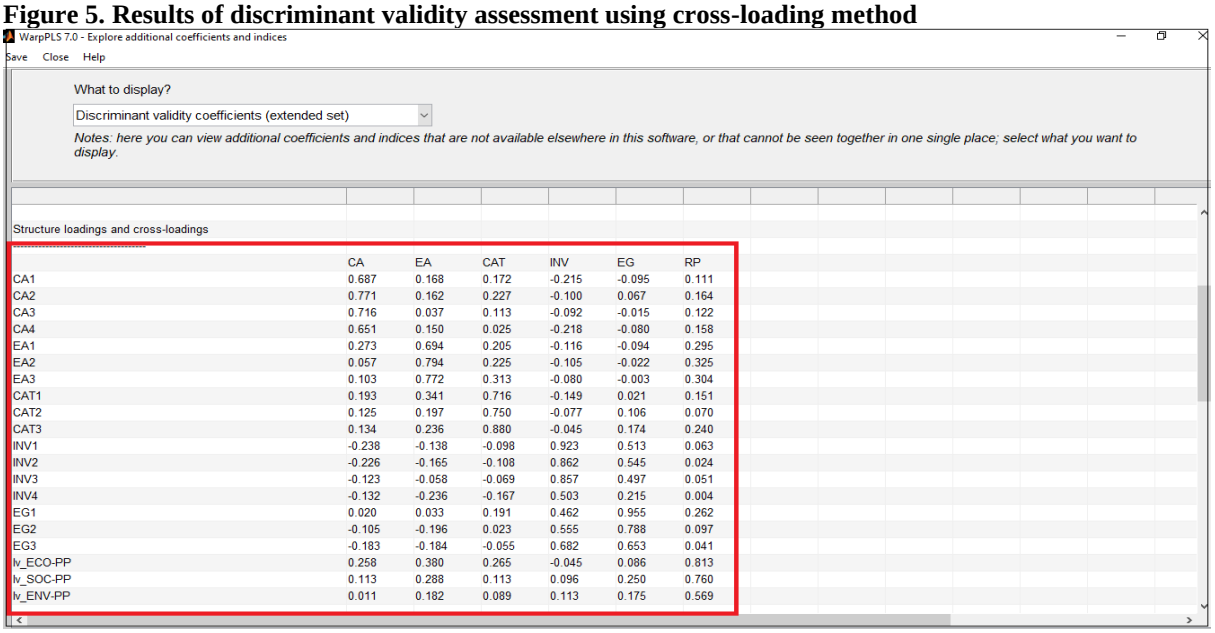


Figure 5 shows the results of discriminant validity assessment using cross-loading, while Figure 6 shows the results using HTMT, and the value of HTMT ratio for all constructs are lower than 0.85. In addition, WarpPLS 7.0 provides the inferece statistic to test HTMT=1 hypothesis

using p value, which should be lower than 0.05, and confidence interval (CI), which 1 should not fall within lower and upper levels of CI. Figure 7 shows the results using inference statistic for HTMT, indicating the establishment of discriminant validity for the model.

Figure 5. Results of discriminant validity assessment using cross-loading method



WarpPLS 7.0 - Explore additional coefficients and indices

Save Close Help

What to display?

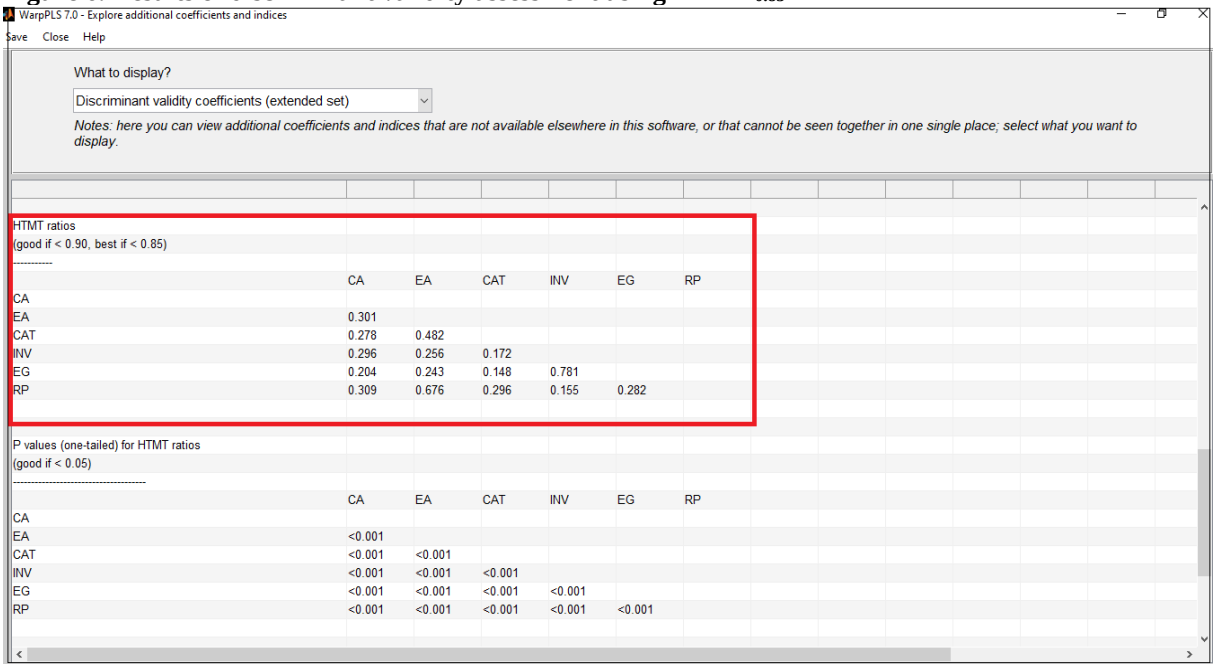
Discriminant validity coefficients (extended set)

Notes: here you can view additional coefficients and indices that are not available elsewhere in this software, or that cannot be seen together in one single place; select what you want to display.

Structure loadings and cross-loadings

	CA	EA	CAT	INV	EG	RP
CA1	0.687	0.168	0.172	-0.215	-0.095	0.111
CA2	0.771	0.162	0.227	-0.100	0.067	0.164
CA3	0.716	0.037	0.113	-0.092	-0.015	0.122
CA4	0.651	0.150	0.025	-0.218	-0.080	0.158
EA1	0.273	0.694	0.205	-0.116	-0.094	0.295
EA2	0.057	0.794	0.225	-0.105	-0.022	0.325
EA3	0.103	0.772	0.313	-0.080	-0.003	0.304
CAT1	0.193	0.341	0.716	-0.149	0.021	0.151
CAT2	0.125	0.197	0.750	-0.077	0.106	0.070
CAT3	0.134	0.236	0.880	-0.045	0.174	0.240
INV1	-0.238	-0.138	-0.098	0.923	0.513	0.063
INV2	-0.226	-0.165	-0.108	0.862	0.545	0.024
INV3	-0.123	-0.058	-0.069	0.857	0.497	0.051
INV4	-0.132	-0.236	-0.167	0.503	0.215	0.004
EG1	0.020	0.033	0.191	0.462	0.955	0.262
EG2	-0.105	-0.196	0.023	0.555	0.788	0.097
EG3	-0.183	-0.184	-0.055	0.682	0.653	0.041
lv_ECO-PP	0.258	0.380	0.265	-0.045	0.086	0.813
lv_SOC-PP	0.113	0.288	0.113	0.096	0.250	0.760
lv_ENV-PP	0.011	0.182	0.089	0.113	0.175	0.569

Figure 6. Results of discriminant validity assessment using HTMT$_{0.85}$



WarpPLS 7.0 - Explore additional coefficients and indices

Save Close Help

What to display?

Discriminant validity coefficients (extended set)

Notes: here you can view additional coefficients and indices that are not available elsewhere in this software, or that cannot be seen together in one single place; select what you want to display.

HTMT ratios

(good if < 0.90, best if < 0.85)

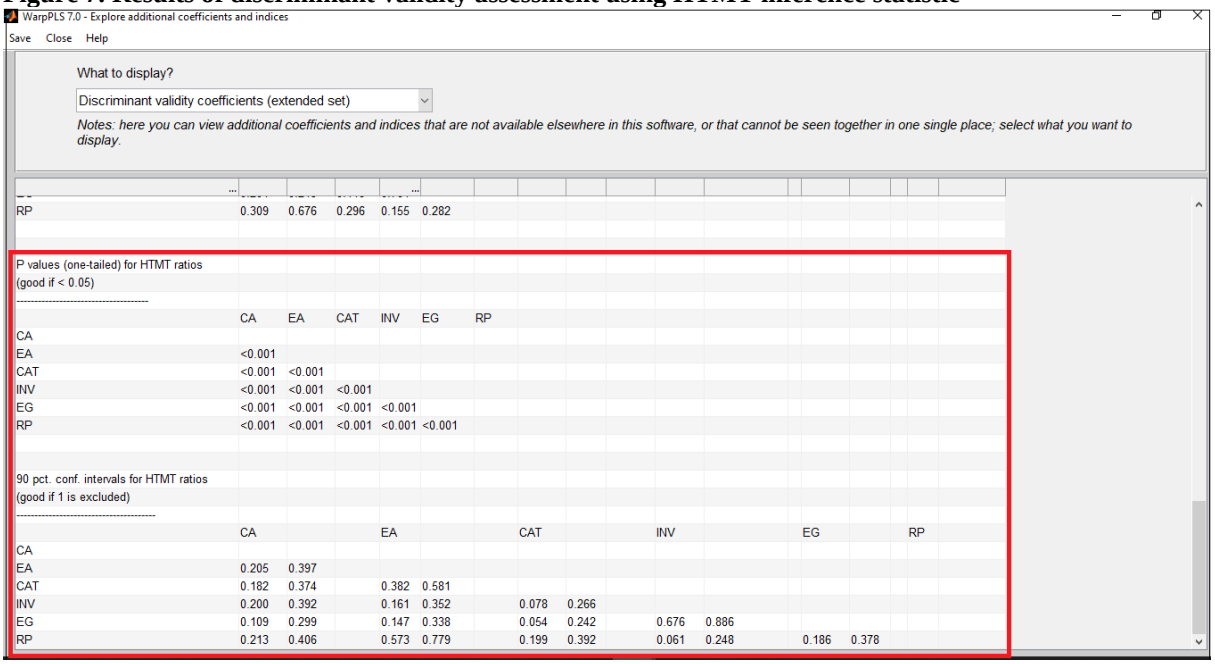
	CA	EA	CAT	INV	EG	RP
CA						
EA	0.301					
CAT	0.278	0.482				
INV	0.296	0.256	0.172			
EG	0.204	0.243	0.148	0.781		
RP	0.309	0.676	0.296	0.155	0.282	

P values (one-tailed) for HTMT ratios

(good if < 0.05)

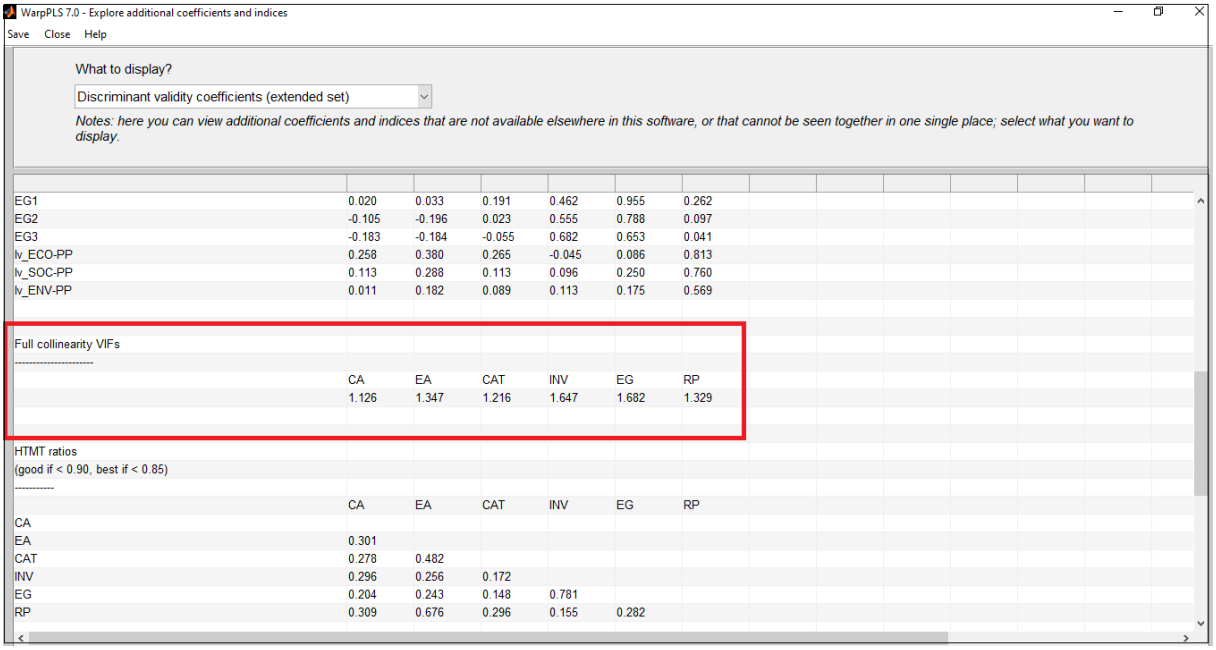
	CA	EA	CAT	INV	EG	RP
CA						
EA	<0.001					
CAT	<0.001	<0.001				
INV	<0.001	<0.001	<0.001			
EG	<0.001	<0.001	<0.001	<0.001		
RP	<0.001	<0.001	<0.001	<0.001	<0.001	

Figure 7. Results of discriminant validity assessment using HTMT inference statistic



Finally, Figure 8 shows the results of discriminant validity assessment using the full collinearity test, which is the prefered approch for the current study, due to the formative nature of the residents' perceptions. The full collinearity VIFs for all constructs are lower than 3.3.

Figure 8. Results of discriminant validity assessment using the full collinearity test



Conclusion

The current study briefly discusses four criteria, namely the: Fornell-Larcker criterion, cross-loadings, heterotrait-monotrait (HTMT) ratio, and full collinearity assessment of discriminant validity in the PLS-SEM context, and application of these methods using WarpPLS 7.0.

The first three criteria are applicable for reflective constructs, while the full collinearity test can be applied for both reflective and formative constructs. In different social science disciplines, a combination of reflective and formative constructs is a common practice, therefore reporting the full collinearity test for the assessment of discriminant validity can be an advantage.

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