Guest editorial

New developments in partial least squares (PLS) path modeling

PLS path modeling is a multivariate statistical technique that is frequently used in various disciplines of business research, such as information systems (Hair *et al.*, 2017; Ringle *et al.*, 2012), international business (Richter *et al.*, 2016), marketing (Hair *et al.*, 2012b; Henseler *et al.*, 2009; Reinartz *et al.*, 2009), operations management (Peng and Lai, 2012), organizational behavior (Sosik *et al.*, 2009), or strategic management (Hair *et al.*, 2012a; Hulland, 1999).

After lively discussions about whether and, if so, how PLS needs to emancipate from covariance-based SEM and to progress (Rigdon, 2012, 2014; Sarstedt *et al.*, 2014), several substantial changes in the understanding of PLS took place over the last two years, accompanied by new developments:

- Whereas PLS traditionally has been understood to estimate formative and reflective measurement models, Henseler *et al.* (2014) pointed out that PLS actually estimates a composite measurement model. Composite measurement can be understood as a prescription for dimension reduction (Dijkstra and Henseler, 2011) and is a measurement model in its own right.
- Whereas PLS has been understood to not face identification issues, this is not the case. Every construct measured by more than one indicator needs a non-zero relation with at least one other construct in the model (Henseler *et al.*, 2016).
- Researchers have for many years bemoaned the lack of adequate measures to assess the global goodness of model fit (Henseler and Sarstedt, 2013). According to Dijkstra and Henseler (2015a), the overall model fit of PLS path models can and should be tested by means of bootstrap-based tests of goodness-of-fit.
- If a PLS path model contains reflective measurement models, they should be estimated using consistent PLS (PLSc, Dijkstra and Henseler, 2015b).
- To assess discriminant validity, researchers should analyze the heterotrait-monotrait ratio of correlations (Henseler *et al.*, 2015a; Voorhees *et al.*, 2016).

As a result of these changes, PLS path modeling has grown into a full-blown structural equation modeling technique that aims to estimate and test structural equation models containing one or more composites, with new guidelines for its use (Henseler *et al.*, 2016).

In the light of the changes, the 2nd International Symposium on Partial Least Squares Path Modeling – The Conference for PLS Users took place in June 2015 in Seville, Spain (for the proceedings, see Henseler *et al.*, 2015b). More than 100 participants exchanged ideas about the new developments around PLS path modeling. The authors of the best conference papers were invited to submit their papers to one of three special issues: The first one aims at prediction-oriented modeling in business research by means of PLS path modeling and is published in the *Journal of Business*

Industrial Management & Data Systems
Vol. 116 No. 9, 2016
pp. 1842-1848

0263-5577
DOI 10.1108/IMDS-09-2016-0366

The author acknowledges a financial interest in ADANCO and its distributor, Composite Modeling.

Research (Cepeda Carrión *et al.*, forthcoming). The second one focuses on European management research using PLS structural equation modeling (PLS-SEM) and is published in the *European Management Journal* (Richter *et al.*, forthcoming). I had the pleasure to serve as guest editor of the third special issue (the present one), which is published in *Industrial Management and Data Systems* and combines tutorials about specific extensions of PLS with scientific applications.

This special issue has two parts. The first part focuses on guidelines and tutorials on PLS path modeling and contains five papers. The second part contains applications of PLS path modeling which illustrate how PLS path modeling can help generate new insights in industrial management, information systems, and technology management.

PLS path models frequently include constructs which do not affect others directly, but only indirectly via a mediating construct. This is the domain of mediation analysis (Helm *et al.*, 2010). In their paper "Mediation analysis in partial least squares path modeling: Helping researchers discuss more sophisticated models," Nitzl *et al.* (2016) find that PLS-based mediation analyses often rely on outdated guidelines. This is important, because mediation analysis using variance-based SEM techniques requires particular attention. For instance, if the mediator variable is imperfectly measured, Type-I and Type-II errors can be more likely than anticipated (Henseler, 2012). Nitzl *et al.* (2016) depart from the classic view on mediation analysis Baron and Kenny (1986) presented, discuss its shortcomings when blindly transferred to PLS path modeling, and present new guidelines based on the framework Zhao *et al.* (2010) proposed. The contribution of Nitzl *et al.* (2016) has the potential to become the authoritative paper for mediation analysis using PLS path modeling.

PLS path modeling has been identified as a popular tool for research on business success factors (Albers, 2010). Importance-performance map analysis (IPMA) is an extension of PLS path modeling that aims to present in an easily understandable and convincing manner the results of success factor research. It contrasts the average level of the success factors with their effects on one or more performance variables. IPMA is a PLS application par excellence, because it relies on the scores of the composite measurement models. It is one of the few situations in which PLS is conducted with unstandardized variables, which requires particular attention. Christian M. Ringle and Marko Sarstedt's contribution "Gain more insight from your PLS-SEM results: The importance-performance map analysis" (Ringle and Sarstedt, 2016) provides a thorough and easy-to-follow tutorial on how to conduct IPMA using extant PLS software.

In business research, it is often the case that the strength of a relationship between constructs is not always the same, but depends on contingencies (see e.g. Hofer, 1975). Such contingencies can be modeled elegantly by means of moderating effects. In the paper "Testing moderating effects in PLS path models with composite variables," Fassott *et al.* (2016) demonstrate how using PLS path modeling. This paper is an easy-to-follow tutorial and can be viewed as an update on Henseler and Fassott (2010), which is one of the most often cited contributions of the *Handbook of Partial Least Squares* (Esposito *et al.*, 2010). It incorporates recent developments, such as the orthogonalizing approach (Henseler and Chin, 2010; Little *et al.*, 2006) and spotlight analysis (Spiller *et al.*, 2013).

Researchers sometimes apply PLS path modeling to analyze data stemming from longitudinal studies. Analyses of this nature can be found in for instance information systems (see e.g. Braojos-Gomez *et al.*, 2015), management (see e.g. Shea and Howell, 2000),

or marketing (see e.g. Johnson *et al.*, 2006). In absolute numbers, the use of PLS path modeling for this type of data remains scarce. A possible reason could be the lack of clear guidelines on how to conduct this type of analysis. Ellen Roemer's paper "A tutorial on the use of PLS path modeling in longitudinal studies" resolves this. It identifies three PLS path model types depending on the purpose of the study and the longitudinal data basis at hand, it provides a decision tree for model specification and an appropriate sequence of complementary analyses, and it suggests the use of multigroup analyses to test the difference between the path coefficients of constructs at different points. As an empirical example, Roemer (2016) analyzes the adoption of battery-electric vehicles.

While analysis of variance (ANOVA) is the dominant family of techniques for analyzing the outcomes of experiments, there is much to gain by using SEM. In contrast to ANOVA and its extensions, SEM can examine the indirect effects of experimental factors and test entire theories. Already 25 years ago, Bagozzi *et al.* (1991) suggested using PLS path modeling in experimental designs. However, researchers were left without good guidance on how to concretely use PLS path modeling to analyze factorial data stemming from experiments. In the paper "PLS FAC-SEM: an illustrated step-by-step guideline to obtain a unique insight in factorial data," Streukens and Leroi-Werelds (2016) fill this gap and provide a comprehensive tutorial for this situation. The authors also dive into details and explain for instance how to apply multigroup analysis if there are more than two factor levels.

The first application of PLS path modeling in this special issue elucidates the concept of electronic service quality. In the paper "Measuring quality perception in electronic commerce: A possible segmentation in the Hungarian market," Kemény *et al.* (2016) conceptualize electronic service quality, determine its dimensions, and assess its validity. They employ PLS path modeling to analyze the data stemming from an empirical study in a Hungarian retail market and find evidence for the construct's criterion validity. The authors also use PLS as an auxiliary technique to create construct scores, which serve as the basis for a segmentation.

In the article "Does size matter? An investigation into the role of virtual team size in IT service provisioning," Watanuki and Moraes (2016) examine the direct and indirect consequences of the size of virtual teams. To do this, they employ the PLS-based approach for mediation analysis, as Nitzl *et al.* (2016) proposed. Interestingly, the size of virtual teams appears not to have any effect.

In the paper "Intensifying online loyalty! The power of website quality and perceived value of the consumer/seller relationship," Hsieh *et al.* (2016) investigate to what extent system quality, information quality, and e-service quality help create customer-perceived value and ultimately online loyalty. The authors also employ PLS-based multigroup analysis (see Sarstedt *et al.*, 2011) to test for a moderating effect of online shopping experience.

Finally, in the paper "On the drivers and performance outcomes of green practices adoption: An empirical study in China," Yang and Zhang (2016) examine the antecedents and consequences of green practices in the context of the Chinese manufacturing industry. The authors build a conceptual model in which the pressure internal and external stakeholders exert is hypothesized to facilitate green practices. These practices are hypothesized to affect environmental, operational, and financial performance. An empirical study among 124 Chinese firms suggests that customers have the strongest influence on green practices, followed by the internal

stakeholders. Whereas green performance influences environmental and operational performance, no impact on financial performance is observed.

I would like to thank the Editor-in-Chief, Alain Chong, for providing the opportunity of this special issue, for the support during the process, and for serving as Editor of a paper I co-wrote. This special issue would not have been possible without the help of the reviewers: Murad Ali, Andreea Apetrei, Arviansyah, Sangeeta Bharadwaj, Antonio Blanco-Oliver, Arturo Calvo de Mora Schmidt, Gabriel Cepeda, Bjorn de Koeijer, Nidal Dwaikat, Ina Garnefeld, Pablo Gonzalo Lazaro, Siggi Gudergan, Andres Guiral, Joe Hair, Dhouha Jaziri Bouagina, Ildikó Kemény, Caroline Lancelot Miltgen, Francisco José Liébana-Cabanillas, Chen-Yu Lin, Omer Malik, Miia Martinsuo, Mara Mataveli, Tobias Müller, Christian Nitzl, Araceli Picón, Lacramioara Radomir, Aparna Raman, Ellen Roemer, Tobias Scholz, Florian Schuberth, José Ramón Segarra-Moliner, Azadeh Shafaei, Wen-Lung Shiau, Pedro Soto-Acosta, Sandra Streukens, Krisztián Szűcs, John Tripp, Eveline van Zeeland-van der Holst, Frederik Vos, Li Da Xu, and Gerrit Willem Ziggers. Thank you very much! Thank you also to the authors who submitted their best research for this special issue. I am confident that the published papers will make a valuable contribution to scientists and practitioners, and wish they will all be read widely.

Jörg Henseler

Department of Design, University of Twente, Enschede, The Netherlands and NOVA Information Management School, Universidade Nova de Lisboa, Lisbon, Portugal

References

Albers, S. (2010), "PLS and success factor studies in marketing", in Esposito Vinzi, V., Chin, W.W., Henseler, J. and Wang, H. (Eds), *Handbook of Partial Least Squares*, Springer, Berlin and Heidelberg, pp. 409-425.

Bagozzi, R.P., Yi, Y. and Singh, S. (1991), "On the use of structural equation models in experimental designs: two extensions", *International Journal of Research in Marketing*, Vol. 8 No. 2, pp. 125-140.

Baron, R.M. and Kenny, D.A. (1986), "The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations", *Journal of Personality and Social Psychology*, Vol. 51 No. 6, pp. 1173-1182.

Braojos-Gomez, J., Benitez-Amado, J. and Llorens-Montes, F.J. (2015), "How do small firms learn to develop a social media competence?", *International Journal of Information Management*, Vol. 35 No. 4, pp. 443-458.

Cepeda Carrión, G., Henseler, J., Ringle, C.M. and Roldán, J.L. (forthcoming), "Prediction-oriented modeling in business research by means of PLS path modeling", *Journal of Business Research*.

Dijkstra, T.K. and Henseler, J. (2011), "Linear indices in nonlinear structural equation models: best fitting proper indices and other composites", *Quality & Quantity*, Vol. 45 No. 6, pp. 1505-1518.

Dijkstra, T.K. and Henseler, J. (2015a), "Consistent and asymptotically normal PLS estimators for linear structural equations", *Computational Statistics & Data Analysis*, Vol. 81 No. 1, pp. 10-23.

Dijkstra, T.K. and Henseler, J. (2015b), "Consistent partial least squares path modeling", *MIS Quarterly*, Vol. 39 No. 2, pp. 297-316.

Esposito Vinzi, V., Chin, W.W., Henseler, J. and Wang, H. (2010), "Handbook of partial least squares: concepts, methods and applications", in Gentle, J.E., Härdle, W.K. and Mori, Y. (Eds), *Springer Handbooks of Computational Statistics Series*, Springer, Berlin and Heidelberg.

Fassott, G., Henseler, J. and Coelho, P.S. (2016), "Testing moderating effects in PLS path models with composite variables", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 1887-1900.

Hair, J.F., Hollingsworth, C.L., Randolph, A.B. and Chong, A.Y.L. (2017), "An updated and expanded assessment of PLS-SEM in information systems research", *Industrial Management & Data Systems*, Vol. 117 No. 1 (in print).

Hair, J.F., Sarstedt, M., Pieper, T.M. and Ringle, C.M. (2012a), "The use of partial least squares structural equation modeling in strategic management research: a review of past practices and recommendations for future applications", *Long Range Planning*, Vol. 45 Nos 5-6, pp. 320-340.

Hair, J.F., Sarstedt, M., Ringle, C.M. and Mena, J.A. (2012b), "An assessment of the use of partial least squares structural equation modeling in marketing research", *Journal of the Academy of Marketing Science*, Vol. 40 No. 3, pp. 414-433.

Helm, S., Eggert, A. and Garnefeld, I. (2010), "Modeling the impact of corporate reputation on customer satisfaction and loyalty using partial least squares", in Esposito Vinzi, V., Chin, W.W., Henseler, J. and Wang, H. (Eds), *Handbook of Partial Least Squares*, Springer, Berlin and Heidelberg, pp. 515-534.

Henseler, J. (2012), "Why generalized structured component analysis is not universally preferable to structural equation modeling", *Journal of the Academy of Marketing Science*, Vol. 40 No. 3, pp. 402-413.

Henseler, J. and Chin, W.W. (2010), "A comparison of approaches for the analysis of interaction effects between latent variables using partial least squares path modeling", *Structural Equation Modeling*, Vol. 17 No. 1, pp. 82-109.

Henseler, J. and Fassott, G. (2010), "Testing moderating effects in PLS path models: an illustration of available procedures", in Esposito Vinzi, V., Chin, W.W., Henseler, J. and Wang, H. (Eds), *Handbook of Partial Least Squares: Concepts, Methods and Applications*, Springer, Berlin and Heidelberg, pp. 713-735.

Henseler, J. and Sarstedt, M. (2013), "Goodness-of-fit indices for partial least squares path modeling", *Computational Statistics*, Vol. 28 No. 2, pp. 565-580.

Henseler, J., Hubona, G. and Ray, P.A. (2016), "Using PLS path modeling in new technology research: updated guidelines", *Industrial Management & Data Systems*, Vol. 116 No. 1, pp. 2-20.

Henseler, J., Ringle, C.M. and Sarstedt, M. (2015a), "A new criterion for assessing discriminant validity in variance-based structural equation modeling", *Journal of the Academy of Marketing Science*, Vol. 43 No. 1, pp. 115-135.

Henseler, J., Ringle, C.M. and Sinkovics, R.R. (2009), "The use of partial least squares path modeling in international marketing", in Sinkovics, R.R. and Ghauri, P.N. (Eds), *Advances in International Marketing*, Emerald, Bingley, pp. 277-320.

Henseler, J., Ringle, C.M., Roldán, J.L. and Cepeda Carrión, G. (2015b), *Proceedings of the 2nd International Symposium on Partial Least Squares Path Modeling (Seville, Spain, June 16-19)*, University of Twente, Enschede.

Henseler, J., Dijkstra, T.K., Sarstedt, M., Ringle, C.M., Diamantopoulos, A., Straub, D.W., Ketchen, D.J. Jr, Hair, J.F., Hult, G.T.M. and Calantone, R.J. (2014), "Common beliefs and reality about PLS: comments on Rönkkö & Evermann (2013)", *Organizational Research Methods*, Vol. 17 No. 2, pp. 182-209.

Hofer, C.W. (1975), "Toward a contingency theory of business strategy", *Academy of Management Journal*, Vol. 18 No. 4, pp. 784-810.

Hsieh, M.-T., Tsao, W.-C. and Lin, T.M.Y. (2016), "Intensifying online loyalty! The power of website quality and perceived value of the consumer/seller relationship", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 1987-2010.

Hulland, J. (1999), "Use of partial least squares (PLS) in strategic management research: a review of four recent studies", *Strategic Management Journal*, Vol. 20 No. 2, pp. 195-204.

Johnson, M.D., Herrmann, A. and Huber, F. (2006), "The evolution of loyalty intentions", *Journal of Marketing*, Vol. 70 No. 2, pp. 122-132.

Kemény, I., Simon, J., Nagy, Á. and Szűcs, K. (2016), "Measuring quality perception in electronic commerce: a possible segmentation in the Hungarian market", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 1946-1966.

Little, T.D., Bovaird, J.A. and Widaman, K.F. (2006), "On the merits of orthogonalizing powered and product terms: implications for modeling interactions among latent variables", *Structural Equation Modeling*, Vol. 13 No. 4, pp. 497-519.

Nitzl, C., Roldán, J.L. and Cepeda, G. (2016), "Mediation analyses in partial least squares structural equation modeling: helping researchers discuss more sophisticated models", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 1849-1864.

Peng, D.X. and Lai, F. (2012), "Using partial least squares in operations management research: a practical guideline and summary of past research", *Journal of Operations Management*, Vol. 30 No. 6, pp. 467-480.

Reinartz, W.J., Haenlein, M. and Henseler, J. (2009), "An empirical comparison of the efficacy of covariance-based and variance-based SEM", *International Journal of Research in Marketing*, Vol. 26 No. 4, pp. 332-344.

Richter, N.F., Cepeda, G., Roldán, J.L. and Ringle, C.M. (forthcoming), "European management research using partial least squares structural equation modeling (PLS-SEM)", *European Management Journal* (in print).

Richter, N.F., Sinkovics, R.R., Ringle, C.M. and Schlägel, C. (2016), "A critical look at the use of SEM in international business research", *International Marketing Review*, Vol. 33 No. 3, pp. 376-404.

Rigdon, E.E. (2012), "Rethinking partial least squares path modeling: in praise of simple methods", *Long Range Planning*, Vol. 45 Nos 5-6, pp. 341-358.

Rigdon, E.E. (2014), "Rethinking partial least squares path modeling: breaking chains and forging ahead", *Long Range Planning*, Vol. 47 No. 3, pp. 161-167.

Ringle, C.M. and Sarstedt, M. (2016), "Gain more insight from your PLS-SEM results: the importance-performance map analysis", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 1865-1886.

Ringle, C.M., Sarstedt, M. and Straub, D.W. (2012), "Editor's comments: a critical look at the use of PLS-SEM in MIS quarterly", *MIS Quarterly*, Vol. 36 No. 1, pp. iii-xiv.

Roemer, E. (2016), "A tutorial on the use of PLS path modeling in longitudinal studies", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 1901-1921.

Sarstedt, M., Henseler, J. and Ringle, C. (2011), "Multi-group analysis in partial least squares (PLS) path modeling: alternative methods and empirical results", *Advances in International Marketing*, Vol. 22 No. 1, pp. 195-218.

Sarstedt, M., Ringle, C.M., Henseler, J. and Hair, J.F. (2014), "On the emancipation of PLS-SEM: a commentary on Rigdon (2012)", *Long Range Planning*, Vol. 47 No. 3, pp. 154-160.

Shea, C.M. and Howell, J.M. (2000), "Efficacy-performance spirals: an empirical test", *Journal of Management*, Vol. 26 No. 4, pp. 791-812.

Sosik, J.J., Kahai, S.S. and Piovoso, M.J. (2009), "Silver bullet or voodoo statistics?", *Group & Organization Management*, Vol. 34 No. 1, pp. 5-36.

Spiller, S.A., Fitzsimons, G.J., Lynch, J.G. Jr and McClelland, G.H. (2013), "Spotlights, floodlights, and the magic number zero: simple effects tests in moderated regression", *Journal of Marketing Research*, Vol. 50 No. 2, pp. 277-288.

Streukens, S. and Leroi-Werelds, S. (2016), "PLS FAC-SEM: an illustrated step-by-step guideline to obtain a unique insight in factorial data", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 1922-1945.

Voorhees, C.M., Brady, M.K., Calantone, R. and Ramirez, E. (2016), "Discriminant validity testing in marketing: an analysis, causes for concern, and proposed remedies", *Journal of the Academy of Marketing Science*, Vol. 44 No. 1, pp. 119-134.

Watanuki, H. and Moraes, R. (2016), "Does size matter? An investigation into the role of virtual team size in IT service provisioning", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 1967-1986.

Yang, F. and Zhang, H. (2016), "On the drivers and performance outcomes of green practices adoption: an empirical study in China", *Industrial Management & Data Systems*, Vol. 116 No. 9, pp. 2011-2034.

Zhao, X., Lynch, J.G. and Chen, Q. (2010), "Reconsidering Baron and Kenny: myths and truths about mediation analysis", *Journal of Consumer Research*, Vol. 37 No. 2, pp. 197-206.