

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*

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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.

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