Buletin FKA

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Exploring the Versatility of PLS-SEM Analysis in Research: From Social Sciences to Engineering Applications

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Introduction

Partial Least Squares Structural Equation Modeling (PLS-SEM) has emerged as a powerful statistical analysis tool, especially within the realms of social sciences and business research. Unlike traditional statistical methods, PLS-SEM focuses on maximizing the explained variance of the dependent latent constructs, making it particularly useful for complex models and when dealing with real-world data that may not meet strict assumptions of normality. Its application through software like SmartPLS has simplified the process, making advanced statistical analysis accessible to researchers and practitioners alike.

History

The roots of PLS-SEM trace back to the 1960s, with the foundational work by Herman Wold, who aimed to create a statistical modeling approach that could handle complex predictive models and formative constructs efficiently. Over the decades, PLS-SEM gained traction, evolving through technological advancements and methodological refinements. The introduction of user-friendly software like SmartPLS in the early 21st century marked a significant milestone, democratizing access to PLS-SEM for a broader audience. This period also saw a surge in scholarly work, further establishing PLS-SEM's credibility and applicability across various disciplines.

Advantages

PLS-SEM offers several advantages that make it a preferred choice among researchers and practitioners:

- *Flexibility with Data:* PLS-SEM can handle data that are not normally distributed, making it suitable for real-world data which often deviates from ideal statistical assumptions.

- *Complex Model Estimation:* It allows for the estimation of complex models with multiple dependent and independent constructs, facilitating the examination of intricate theoretical frameworks.

- *Formative and Reflective Constructs:* PLS-SEM accommodates both formative and reflective constructs, providing flexibility in model specification and measurement.

- *Predictive Accuracy:* The method focuses on maximizing the explained variance of the dependent variables, enhancing the predictive accuracy of the model.

- *Ease of Use:* Tools like SmartPLS have made PLS-SEM more accessible to non-statisticians, with intuitive interfaces and visual model representations.

Scope of Analysis

PLS-SEM is widely applicable across various research fields and questions, including:

- *Marketing:* Consumer behavior models, brand loyalty, and service quality assessment.

- *Management:* Organizational behavior, human resources practices, and strategic management.

- *Information Systems:* Adoption of technology, user satisfaction, and system usability studies.

- *Health Sciences:* Patient satisfaction, healthcare management, and public health interventions.

- *Environmental Studies:* Environmental behavior, policy impact analysis, and sustainability research.

- *Product Design and Development*: Engineers use PLS-SEM to model the relationships between design attributes, user satisfaction, and functional performance. This approach helps in understanding how different aspects of product design impact user experience and acceptance.

- *Manufacturing and Process Engineering*: In manufacturing, PLS-SEM can be employed to analyze the impact of process changes on product quality and operational efficiency. It allows for the exploration of complex causal relationships between variables such as machine parameters, material properties, and the final product characteristics.

- *Construction Engineering and Management*: PLS-SEM is utilized to study factors affecting project success, including project management practices, stakeholder engagement, and risk management. By modeling these relationships, researchers can identify key drivers of project performance and areas for improvement.

- *Environmental Engineering:* This involves using PLS-SEM to assess the impact of engineering projects on the environment, or conversely, how environmental factors affect infrastructure and design. Studies might explore the relationships between construction materials, techniques, and environmental sustainability metrics.

- *Systems Engineering*: PLS-SEM supports the analysis of complex systems, facilitating the understanding of how components interact within larger systems. This is crucial in optimizing system performance, reliability, and user satisfaction.

This wide applicability is due to PLS-SEM's ability to model complex relationships between latent constructs, making it a valuable tool for exploratory and confirmatory studies alike.

Sample of Figure

A typical output from SmartPLS might include a path model diagram displaying latent variables (rectangles), observed indicators (ovals), and the relationships between them (arrows). For example, a figure could illustrate a model where customer satisfaction (latent variable) is influenced by service quality and price fairness (latent variables), each measured by multiple indicators (e.g., survey questions). The path coefficients (arrows) between latent variables indicate the strength and direction of the relationships, while R^2 values for endogenous constructs reflect the model's explanatory power.

Analysis Procedure

The procedure for conducting a PLS-SEM analysis using SmartPLS involves several key steps:

1. *Model Specification*: Define the theoretical model, identifying latent variables and their indicators, and specifying relationships (paths) between them.

2. *Data Collection and Preparation*: Gather and prepare the dataset, ensuring it meets the requirements for analysis (e.g., measurement scales, sample size).

3. *Model Estimation*: Input the model into SmartPLS and run the analysis. The software estimates path coefficients, latent variable scores, and reliability and validity metrics.

4. *Assessment of Results*: Evaluate the model's reliability and validity (e.g., Cronbach's alpha, Composite Reliability, AVE) and the significance of path coefficients (using bootstrapping).

5. *Interpretation and Reporting:* Interpret the findings in the context of the research questions. Report the results, including path coefficients, R^2 values, effect sizes, and significance levels.

This methodology underscores the importance of a rigorous approach to model specification, data quality, and result interpretation within the PLS-SEM framework.

Future Use in Research

The future of PLS-SEM in research looks promising, with ongoing developments in software capabilities, statistical techniques, and methodological guidelines enhancing its utility and accuracy. Emerging trends include the integration of machine learning algorithms for predictive modeling, the application in interdisciplinary research, and the increasing focus on model validation and robustness checks. As the complexity of data and models in social sciences and business research continues to grow, PLS-SEM's flexibility, efficiency, and accessibility suggest it will remain a valuable tool for empirical investigation.

References

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