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Customer satisfaction: a mathematical framework for its analysis and its measurement

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Abstract The customer satisfaction, an important concept in the field of general marketing and in the management of firms, is the measure of the degree of customer satisfaction. More precisely, the customer satisfaction provides an assessment of the discrepancy between the perceived performance by the customer (i.e. all the sensations and impressions after use of a product or the fruition of a service) and the expectations (expectations and desires) of the same customer but also represents the company's ability to anticipate and to manage the expectations of the customer, to satisfy its needs with competence and responsibility. The company resources, in fact, must be organized taking account of the demands of customers who represent a precious commodity for the company, even if their value does not appear in the financial statements, the fulcrum around which revolves the whole system business. To have satisfied customers is, therefore, fundamental for a company and, therefore, the customer satisfaction can be defined as a touchstone for the management of customer relationships, as a key to create the competitive advantage as of a company. In this article, the authors present some of the main processes and detection systems required for a scrupulous and reliable process of measuring of the customer satisfaction or better they present a mathematical framework to determine and to improve the customer satisfaction and to demonstrate how it has a great impact on corporate performance. In particular, the authors propose a model of structural equations with latent variables which is the most rigorous methodology currently available for the evaluations of the customer satisfaction and they hope that the paper, which at first sight has little in common with

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mathematics, is a very useful for stimulating research at the interface of mathematics and marketing and that it builds a link that can become beneficial for both disciplines involved.

Keywords Structural equations models · Customer satisfaction · Interpretation models · Path diagram · Partial least squares

1 Introduction

In the current competitive environment, no company can hope to survive without placing utmost importance on customer satisfaction; the companies, in fact, increasingly derive revenue from the creation and from sustenance of long-term relationships with their customers which represent the fulcrum around which revolves the whole system business or better a resource from which no organization can disregard without the risk to compromise the its own existence.

According to some researchers (Gruca and Rego 2005; Payne and Frow 2006), the companies, the firms that are able to get the greatest annual increases in the value of their shares, are those who make investments to increase the level of satisfaction of their customers. The satisfied customers allow, in fact, to the companies to achieve an increase and a stabilization of the net cash flows and even the rise and consolidation of revenues (Fornell et al. 2006; Lambin 2008). In other words, the satisfied customers have a positive effect on cash flow because they decrease its variability since they tend to be loyal in time, to bring down the costs of companies, to generate continuous cash flows, to buy always by the same person and they are indifferent to the competitive offers and promotions.

For (Oliver 1999) the customer satisfaction represents a determinant moment in the process of building of customer loyalty. In fact, if the level of the customer satisfaction is high, its loyalty tends to increase and to become the main driver of financial performance in the long term. Therefore, the customer satisfaction and, consequently, the customer loyalty are important for the increase in profitability, or rather both tend to become a prerequisite for survival of the firm. The customer satisfaction, namely, feeds, powers the company's value, which in turn increases the satisfaction of the lenders that can invest in human resources, in know-how, in manufacturing processes and in products (Busacca and Bertoli 2009; Valdani and Busacca 1999). The customer satisfaction can be, then, defined as a "modus operandi" of the entrepreneur; is not, namely, simply a technique but a company's management philosophy and has become one of the most important issues on the agenda of management problems of enterprises (Busacca and Bertoli 2009; Valdani and Ancarani 2009). As a result of this approach, in recent years, the marketing activities and the performance evaluations are increasingly organized around relationships with customers rather than around products. In other words, the focus of firms has shifted from treating customer as an simple entity, involved in the business process, to treating it as a crucial component of their success. The customer is considered, namely, in terms of ongoing relationships rather than in terms of transactions. Consequently, the customer life cycle has taken a central role in marketing strategy compared to product life cycle considered in the past (Ferrentino et al. 2016). From a firm's perspective, the customer life cycle can be best understood as a series of transactions between the firm and its customer over the entire time period during which the customer remains in business with the firm. Furthermore, the customer life cycle varies from business to business and from customer to customer and could be short or long depending on the nature of business of the firm, on the profile of its customers and on the interaction between the firm and its customers. As an example, older customers with a long history of transactions with a bank have most probability to be retained and, hence, have a longer life cycle as compared to younger customers newly acquired (Ferrentino et al. 2016; Wheaton 2000).

From the above, emerges the need, for businesses, oriented to the customer satisfaction, to develop capacity of interaction and co-production direct, to understand in depth the cognitive system of customers and, at the same time, the need to acquire analytical systems to verify systematically the alignment between the their cognitive system and that of the customers. In conclusion, in the marketing strategies, the relationships management with their customers becomes a key factor in any business and, consequently, the satisfaction of the customer becomes decisive for the enterprise. The analysis and the management of the customer satisfaction represent, namely, the conditions necessary to ensure to the company a future as a protagonist in the current political scenery (Ferrentino et al. 2016; Valdani and Ancarani 2009).

2 Research aims

The customer satisfaction is one of the themes to which the researches present in the literature have placed more attention and the growing interest towards this topic has contributed, over the past decades, to the development of several statistical methods for its the measurement.

The objective of this paper is to analyze, in depth, the concept of customer satisfaction and to present some methods for its measurement and for its detection: among these, in particular, the model of structural equations with latent variables, the most rigorous methodology currently available. More precisely, the aim of this paper is to review various research articles that have appeared in the marketing literature and dealing the customer satisfaction, to summarize their findings, to take stock of the advances and to identify the areas for possible extensions and for future research. In this paper the authors, first, present a conceptual framework that allows a marketing manager to determine which elements of customer satisfaction have a greatest impact on corporate performance and how much money should be spent to improve particular elements of customer satisfaction, a framework that shows how the customer satisfaction fits in the value chain and what are its key drivers. Next, the authors present some general mathematical models for the determination of the customer satisfaction, or better, they offer a systematic general approach to its computation.

Though not exhaustive, the major contribution of this paper is that it provides a general mathematical framework for assessing the value of the customer satisfaction and that it has a context less specific compared to discussion, on the customer satisfaction, of papers present in literature.

The paper is organized as follows. In Sect. 2, after the introduction, the authors present the aim of the paper while in Sect. 3 they search to define the customer satisfaction and to describe briefly both the reasons for which it is important its measurement that the current research focus on the customer satisfaction. In Sects. 4 and 5, instead, is formally introduced the substantial part, the plan of this paper; are, namely, provided some important modelling approaches present in literature and adopted to calculate and estimate the customer satisfaction. In particular, in Sect. 4, is proposed an overview of the most used methods and are explained what benefits can be drawn from the measurement of customer satisfaction while Sect. 5 is entirely dedicated to the process of measuring of the customer satisfaction and are outlined some methods used to measure it. In particular, is proposed the model of structural equations with latent variables which is the most rigorous methodology currently available for the evaluations of the customer satisfaction and are presented the different phases of the process. Section 6, finally, provides a conclusion and contains a general discussion on directions for future research. In fact, given the relevance of this topic and the increasing focus of researchers on it, the authors hope in the growth of marketing research in this area. In others words, the article ends with some concluding remarks while the last part of this article represents the reviewed references.

3 The customer satisfaction

The customer satisfaction is a theme old but modern at the same time: it is a measure of the degree of customer satisfaction, namely the overall evaluation that the customer gives to its experience starting from purchase decision up to the results arising from the use of the related good or the service purchased. More precisely, the customer satisfaction provides an assessment of the discrepancy between the perceived performance by the customer (i.e. all the sensations and impressions after use of a product or the fruition of a service) and the expectations (expectations and desires) of the same customer.

Specifically, if the expectations of the customer exceed the perceived performance, the customer remains dissatisfied; if the perceived performance coincides with the expectations of the customer, the customer is satisfied while if the perceived performance exceeds the expectations, then the customer is enthusiast. In the last case, the sense of fulfillment would go beyond the satisfaction and could become customer delight. The customer delight is originated, therefore, by the fact of having obtained, surprisingly, a value that is even went beyond the desired value (Guido et al. 2010). In reality, the concept of customer satisfaction has a very wide scope and covers both the internal satisfaction (of the employees) that the satisfaction external (of the clients) (Gruca and Rego 2005; Payne and Frow 2006). The internal satisfaction is the fundamental starting point for the satisfaction of the external customers. The employees involvement becomes, namely, crucial for the implementation of a management renewal policy that has as its ultimate destination the achievement of higher levels of the customer satisfaction.

From the above, it follows that the customer satisfaction also expresses the company's ability to know in depth the customers and to anticipate and to manage their expectations, to satisfy their needs with competence and responsibility. Therefore, the management of the relationships with its customers becomes a strategic factor for any company, a key factor in any business since the relationships increase the level of satisfaction of the customers and, consequently, the value of the company. According Myers et al. (1999), the customer must be the focal point in the planning of the company activities and the resources must be organized keeping in mind the needs and the demands of customers; the company, namely, must be able to put at the center of its choices the customer whose satisfaction determines the breadth of relations with the company and, consequently, its performance (Valdani and Busacca 1999). The customer is, namely, the fulcrum around which revolves the entire enterprise system in search of its maximum satisfaction; it is, that is, a precious asset for the company, even if its value does not appear in the financial statements. It follows that to have satisfied customers is fundamental for an enterprise; the customer satisfied, in fact, is the premise to have a loyal customer that represents an important resource because, as claimed by Myers et al. (1999), acquiring new customers costs five times more than maintaining existing ones. Instead, an enterprise, that does not satisfy its customers, risks to have as consequences the collapse in revenues, the decline in profits and even a possible withdrawal of capital from investors (Fornell 2008). A customer not satisfied by the use of a product or by the image that a particular mark gives, hardly decides to repurchase the same product or to continue to be customers of the same brand while the profits of a company depend mostly by continuous flows of revenue resulting from repeated purchases (Fornell et al. 1994; Heskett et al. 1990, 1994). For Valdani (1995), the customer satisfaction is a management discipline and a style of behavior that characterizes the company. In conclusion, the customer satisfaction is considered a touchstone for the management of customer relationships, a key to create the competitive advantage of a company; it represents, namely, the objective of all companies who wish to sell their products or services.

In the next paragraphs the authors will analyze the interpretative models of customer satisfaction most widespread, or best-known, in the literature.

4 Measurement of customer satisfaction: a simple approach

In recent decades, the Customer satisfaction has become one of the most important issues in the agenda of the management issues of the companies or, more precisely, the main criterion of evaluation used to assess the quality of a company. The strategy of a company cannot prescind, in fact, by the customers satisfaction and by their personal needs; hence the need for the businesses to monitor constantly the level of customers satisfaction, to achieve systematic measurements of the customer satisfaction. In other words, the value of customer satisfaction is an important construct in designing and in budget of a number of marketing decisions, such as the customer acquisition programs (Ferrentino et al. 2016).

In literature, the measurement of the customer satisfaction is often made by taking into account some indicators such as the number of complaints or the customer retention rate. All exposed indicators can be useful, but they are so only to give to the phenomenon of the satisfaction a very rough measure, given the limitations that each of them presents. The measurement of the customer satisfaction, instead, must be done in a rigorous way to ensure the validity of the results. In this context has become increasingly prevalent the set of procedures suitable to the detection of the customer satisfaction. Have been proposed many models dealing the customer satisfaction; many researchers, namely, have studied the customer satisfaction because, often, it is used as a basic for making strategic or tactical decisions.

The conceptual models for the evaluation of the Customer Satisfaction are different. In the sequel, a brief description of the main models proposed by literature on the topic and, in particular, a brief description of the *Servqual model*, of the *Servperf model*, of *Normed Quality Model*, of the *Two Way Model*, of the *Qualitometro* model and of the *Kano model*.

• The *Servqual model* (*Service Quality*), proposed by Parasuraman et al. (1985) in 1988, assesses the gap between the customers expectations and their perceptions about the performance received. In essence, the quality of the service can be defined as the degree of discrepancy (*gap*) between the customers expectations and their perceptions. To evaluate the quality of a service are identified five dimensions: *tangible aspects* (understood as aspects of installations, of equipments, of communication tools), *reliability* (understood as the ability to realize the service diligently and accurately), *ability to respond* (understood as will to help the customers and to provide the service with readiness), *reassurance skills* (understood as competence and courtesy of employees and their ability to inspire confidence and security) and *empathy* (understood as attention particular to the needs of customers). To each of the five dimensions are associated some manifest variables or some indicators to define a measurement model and, furthermore, a percentage weight that expresses its importance. Consequently, the satisfaction measurement is obtained by evaluating, by means of a synthetic indicator of quality, the discrepancy between the expectations of the customers individuals and their perception of the real *performance* of the good/service, weighed with the importance assigned from the customers to the performance considered. In other words, the customer satisfaction is determined through the comparison of their perceptions p and of their expectations a.

Indicated with p_{jih} and a_{jih}, respectively, the scores of quality perceived and expected and with w_{jh} the weight (importance) assigned by the h-th customer ($h = 1, 2, \ldots, N$) for the i-th manifest variable $\left(i = 1, 2, \ldots, q_j\right)$ of the j-th dimension ($j = 1, 2, \ldots, 5$), the overall indicator for the evaluation of the Customer Satisfaction, namely the *global customer satisfaction index* (CSI), is:

$$CSI = \frac{1}{N} \sum_{h=1}^{N} \left[\sum_{j=1}^{5} w_{jh} \left(\sum_{i=1}^{qj} \frac{p_{jih} - a_{jih}}{q_j} \right) \right]$$

In fact, the *gap* between perceptions and expectations for each of the indicators detected is:

$$\left(p_{jih} - a_{jih}\right)$$

while

$$\sum_{i=1}^{q_j} \frac{p_{j\,i\,h} - a_{j\,i\,h}}{q_j}$$

is the simple arithmetic mean of the gaps in relation to the indicators of each single customer.

Consequently, the individual satisfaction index will be:

$$\sum_{j=1}^{5} w_{jh} \left(\sum_{i=1}^{qj} \frac{p_{j\,i\,h} - a_{j\,i\,h}}{q_j} \right)$$

namely, the arithmetic mean of the values obtained, weighted with the weights $w_{j\,h}$ assigned to each dimension.

The overall indicator, namely *the customer satisfaction index* (CSI), is, instead, obtained as the arithmetic mean of the scores of global satisfaction of all customers; is found again, that is, the previous formula:

$$CSI = \frac{1}{N} \sum_{h=1}^{N} \left[\sum_{j=1}^{5} w_{jh} \left(\sum_{i=1}^{qj} \frac{p_{j\,i\,h} - a_{j\,i\,h}}{q_j} \right) \right]$$

where

$$\sum_{j=1}^{5} w_{j\,h} = 1$$

In order to be able to calculate the averages, it is necessary that the scores are expressed on metric scale: the scoring scale must, then, be transformed through a suitable *metric scaling*. Alternatively, the averages can be conveniently replaced by the medians, interpreting the scores as ranks in a sorting.

• The *Servperf* model (*Service Performance*), proposed by Cronin and Taylor (1994), is a simplified version of the Servqual model in which is required, to who is interviewed, to express a judgment only on the perceptions.

In Servperf the attention is focused, therefore, on the evaluation of the perceptions p rather than on the *gaps* between perceptions and expectations $p - a$: it is believed, in fact, that perceptions measurement incorporate also the comparison with the expectations. In other words, the theoretical foundation of this model is the consideration of only "perceptions" without the component of "expectations".

This model reduces considerably the number of questions needed to measure the *customer satisfaction* and it provides better results because solves some problems observed in the Servqual's application, namely the size instability, the ambiguity of interpreting expectations and unreliability of the differential score.

The *global satisfaction index* (CSI), for the Servperf model, is:

$$CSI = \frac{1}{N}\sum_{h=1}^{N}\left[\sum_{j=1}^{5} w_{jh}\left(\sum_{i=1}^{qj}\frac{p_{jih}}{q_j}\right)\right]$$

• The *Normed Quality Model* (proposed by Teas 1993) is based on the meaning of the expectations which can be interpreted by the customer in two ways: compared to an ideal level, expecting for each attribute the absolute maximum level, or compared to an achievable ideal, taking into account the actual conditions of the delivery of service. In other words, the theoretical foundation of this model presupposes that is made distinction between the ideal expectation and the achievable expectation.

The global satisfaction index (CSI), for the Normed Quality Model, is given by:

$$CSI = \frac{1}{N}\sum_{h=1}^{N}\left[\sum_{j=1}^{5} w_{jh}\left(\sum_{i=1}^{qj}\frac{\left(p_{jih} - AE_{jih}\right) - \left(AE_{jih} - AI_{jih}\right)}{q_j}\right)\right]$$

where *AI* is the ideal expectation while *AE* is the achievable expectation.

• In the *Two Way Model* (proposed by Schvaneveldt et al. 1991), who is interviewed must to evaluate numerous features of a service under two aspects: one *objective* aspect, with reference to some attributes of quality, and one aspect *subjective*, with reference to degree of satisfaction or of dissatisfaction for the received service.

Is used a questionnaire with pairs of questions related to the two aspects that allows to classify responses given by customers and to evaluate the service offered.

• Finally, the *Qualitometro* model, proposed by Rossetto and Franceschini (1998), is born with the aim of making some evaluations "in line" of the quality of a service, in the sense of a monitoring over time of the differential δQ between expected quality Q_a and perceived quality Q_p. In this approach, the two qualities are detected separately: the expected quality is detected ex-ante the fruition of the service, the perceived quality is detected ex-post. In other words, the theoretical foundation of this model predicts that expectations and perceptions are measured in separate moments. The dimensions of the quality of the service, used in the Qualitometro, are the same as that of the Servqual. The monitoring in line is developed through a card for attributes that allows to check if the *gap* exceeds a certain limit.

• Another methodology which allows to detect the customer satisfaction is the *model of Kano*, proposed by Prof. Noriaki Kano. This model is the first to hypothesize that attributes contribute differently to creating satisfaction and it focuses on the different requirements that must characterize the product/service to create satisfaction. The classification of requirements allows to better understand the features that influence more the customer satisfaction, helps to prioritize of intervention on the requirements that increase the degree of satisfaction, and, furthermore, allows to quickly select the requirement on which to take action to make happier the consumers. Depending on the expectations of each customer segment, the requirements vary, and for this reason it is possible to develop an intervention plan by selecting all the requirements necessary to satisfaction. According to Kano, the identification of requirements can be obtained with interviews through a focus group. The criticisms directed at the detection method of the customer satisfaction of Kano focus mostly on the need to have a numerous staff for the administer of the questionnaire that is very complex and not manageable by the customers.

5 Evaluation and interpretation models: the structural equations models

In the preceding paragraphs were underlined the importance of customer satisfaction and its high potential within the company, both from a point of view of selling and of marketing and both from a point of view of the strategic-decision and it has been specified that the fundamental objective of a company is to determine the levers on which to act to improve the overall satisfaction of its customers (by removing, consequently, the cause of dissatisfaction). To achieve this, it is need a good measure model of customer satisfaction, a precise method able to give indications not only on the levels of satisfaction in general, but also on what specific actions would be taken to improve its business and what might be the consequences of the choices from a financial viewpoint. The scope and the methodologies of analysis on which to focus must be drastically circumscribed fixing the attention on causal models econometric—statistical which investigate the relationships between more variables, some of which have the role of cause, the other the role of effect. These relationships, formalized in opportune equations, ensure that such models, once resolved, allow to the company not only to identify the specific causes of dissatisfaction of its clients but also to order them by importance; they represent, namely, a very precious indication.

5.1 Structural equations model or structural equations modeling (SEM)

This section, in particular, gives an overview of the models specifically formulated to estimate the customer satisfaction or better provides a synthesis of some key models and extends this calculation to obtain optimal methods of resource allocation to optimize the customer satisfaction.

Among the various causal models that can be used, what the authors will deal or will consider is *the model of structural equations* with latent variables which is the most rigorous methodology currently available for the evaluations of the customer satisfaction. The acronym recurrent in the literature to denote the model of structural equations with latent variables is *SEM* (*Structural Equations Model* or, sometimes, *Structural Equations Modeling*). The structural equations model with latent variables appears, in this context, more appropriate because it can also treat phenomena that, for their abstractness and for their many facets and nuances, cannot be measured directly, such as, for example, the customer satisfaction, given the psychological component. In other words, this model puts in relation the latent level of the customer satisfaction of those who use a product or service with the level of other latent variables such as the customer expectations, the perceived quality, or the perceived value.

The structural equations models, developed in the early 70s, take the form of systems of algebraic equations, each of which represents a causal relationship, and, then, these models are nothing more than a set of causal relationships between variables formalized, as a whole, by means of a system of algebraic equations where each dependent variable is expressed as a function of the independent variables which act on it.

Such models are used as both sophisticated measuring instruments to generate some stairs and some indices of which, then, evaluate the reliability, as both procedures to evaluate the various forms of validity of the measures and as both methodologies to perform hypothesis testing, to predict the trend of variables or to support inferences about causes and effects. More precisely, the structural equations models include a set of methodologies statistics that allow to estimate the causal relationships between two or more latent concepts, which, because of their nature, are not directly measurable. Can be considered latent concepts, for example, the satisfaction, the verbal skills, the trust or the intelligence, namely theoretical concepts for which there are not measuring instruments. The idea that underlies the structural equations models is to define existing causal connections between a set of latent concepts, defined, in particular, as "latent variables", starting from the recognition of some variables directly observable, usually defined as a "manifest variables" or "Indicators". In fact, a fundamental point of structural equation models with latent variables is the distinction between latent variables and manifest variables. The latent variables are designed to analytically represent "something that really exists", but of which is difficult, if not impossible, to have a direct quantitative observation. In other words, the latent variables are simply variables not directly observable and measurable because they concern abstract concepts that are at the basis of decisions taken from customers: loyalty, perceived quality, expectations, generosity, resourcefulness, indifference etc.; they represent, namely, all those phenomena that evidently escape at a direct quantification. The manifest variables or indicators are, instead, of the variables directly observable and measurable, which are connected to the latent variables before mentioned. To treat these variables in an econometric model—statistical, which obviously must be fed with quantitative data, at each latent variable are associated two or more manifest variables, which act as indirect measurers. More precisely, the bonds that exist between manifest variables and latent variables can be formalized through a precise explicative model of the relationships of dependency or of relationships of causality between variables. This model is the structural equations model that allows to process simultaneously multiple relations between independent and dependent variables not observed (Straub et al. 2000) and is especially appropriate for analyzing data in the field of social research and of marketing.

The problematic aspect is, however, the use of latent variables that are not directly observable; to obtain, in fact, the values of these variables will be made some estimates starting from the corresponding manifest variables, estimates which are obtained by different techniques. These techniques are grouped into two different approaches:

- *Covariance structure analysis* The approach to structural equations models, based on the covariance.
- *Component-based methods* The approach to structural equations models, based on the component.

In other words, the point where the academics divide in the application of models to structural equations refers mainly the parameter estimation methods, which can be summarized (using the english terms most commonly used in literature) in *Covariance-based methods* and in *Component-based methods*.

The distinction between the two approaches is linked to the different pursued objective. In particular, in covariance-based methods, the model parameters are identified in order to obtain a reconstruction of the variance–covariance matrix between the manifest variables as close as possible to the observed one. The methods so-called component-based, on the other hand, have as their objective to estimate latent variables so that they are as representative as possible of their block of manifest variables, and that, at the same time, are able to explain, as much as possible, the relationships found in the structural model.

In approaches based on covariance (*Covariance-based methods*), the best known method of estimation is, without any doubt, one proposed by Jöreskog (1970) in 1970 and based on method of Maximum Likelihood: the SEM-ML (where ML stands for Maximum Likelihood) or the FASEM method. This method, also known as LISREL (Linear Structural Relationship) was for several years the only method of estimation for structural equation models and was renamed by Bentler (1986) with the term FASEM (Factor Analysis Simultaneous Equation Model). In addition to the approach of maximum likelihood, other estimation techniques may be used to estimate the structural equation models, like the method of Least Squares Generalized (GLS) or the method of Asymptotically Distribution Free (ADF). All these methods are based on covariance (*Covariance-based methods*) because they reproduce the covariance matrix of the manifest variables, matrix that is obtained by sample data.

In approaches based on components (*Component-based methods*), instead, the estimation techniques provide an estimate of the latent variables so that they are the most related between them and the most representative of each corresponding manifest variables block. In approaches based on component, the best known method of estimation is the Partial Least Squares Path Model (whose acronym is PLS-PM); it is a technique more flexible than the SEM-ML method.

In conclusion, until today, the methods established in the literature for the resolution of the SEM are, in chronological order: the method known by the acronym LISREL and the one known by the acronym PLS-PM (Partial Least Squares-Path Modeling); they are statistical methods used as tools for forecasting of the needs and of the expectations of customers and therefore statistical methods for analysis of the customer satisfaction.

The structural models are, in particular, used for the definition of *some national indices*. There are, in fact, some traditional indices of measurement known as national indices, such as: SCSB (*Swedish Customer Satisfaction Barometer*), ACSI (*American Customer Satisfaction Index*), ECSI (*European Customer Satisfaction Index*).

The Swedish index, introduced in 1989, was the first true national model for measuring the customer satisfaction. The Sweden, namely, was the first country to have developed a national economic indicator of customer satisfaction; it is a composite weighted index that allows to estimate also the customer loyalty, since not all the faithful customers are satisfied and happy customers tend to be loyal.

The ACSI index is an extension of the swedish index SCSB and has been used for the first time in 1994 while the European index of customer satisfaction (ECSI), born in 2000, is, instead one of the most recent and is an extended version of ACSI index which differs from it by mode of measurement of fidelity.

The ACSI index is the most widespread and the most taken into consideration, because the others not are that an adaptation or a maximum processing. So to speak the ACSI index is the reference taken from one of the leaders among the institutions specialized marketing research in Customer Asset Management.

These indexes of the customer satisfaction are built with structural equations modeling (SEM), because it is a model that, tendentially, can be applied to any company; the resulting advantage is to make perfectly comparable, between one company and another, the satisfaction index obtained from the model. All these indices are estimated by the statistical method PLS (Partial Least Squares) which provides an estimation procedure iterative integrating the analysis of principal components with multiple regression (Johnson and Joannopoulos 2001).

In this section, the authors expose and confront, in extreme synthesis, two different methodological settings to treat models of structural equations models. Exist, in fact, two approaches to estimating the parameters, which, being developed separately, have an algebraic notations lightly different: *the LISREL approach* and t*he Partial Least Squares approach.* In the paper, the authors present every approach with its notation to keep it as uniform as possible to literature.

5.2 Resolution of a SEM according to the LISREL approach

The possibility to express, in mathematical form, a model which allows to measure the customer satisfaction is the determinant element to can apply to the same model the conceptual and operational tools developed by mathematics and by statistic. As already mentioned, are used the structural equations models.

The constituent unit of the structural equations model is the structural equation, namely a regression equation that expresses the causal relationship existing between a dependent variable and several independent variables. The causal relationships between the variables are, in fact, formalized, as a whole, through a system of equations. There is an equation for each dependent variable: the dependent variable is reported in the first member of the equation, while in the second member of the equation appear the independent variables whose coefficients (called structural parameters or path coefficients) suggest, then, how much the dependent variable depends on each of these variables. The approach at multiple equations is the only really appropriate to provide a representation of real processes. It takes into account not only of the multiplicity of causes that act on a dependent variable but also of existing connections between the different causes.

In a structural equation model, the variables can be, simultaneously, dependent in an equation and independent in another and this fact (namely, that the variables can be, in the same structural equation model, simultaneously dependent and independent), requires a modification of the terminology used till now, in order to not create confusion. To this end, all the variables that intervene in the structural model always and only as independent variables and which are "external" to the structural model, will be called *exogenous variables* while will be defined *endogenous variables* all the "internal" variables to the model which, alternately, may assume in the various equations the role both of dependent variable both of independent variable. The endogenous variables are stochastic variables, because they contain the margin of uncertainty caused by the stochastic error while the exogenous variables are not necessarily of this type and can be both probabilistic both deterministic. In any case, their value is determined outside of the model and does not depend on any internal variable. To build a structural equation model not is sufficient to define only the relations between the endogenous variables (among them) and between the endogenous and exogenous variables but it is also necessary to clarify the relations between the exogenous independent variables (among them) and between the errors of each structural equation or better are needed the variances and the covariances of the exogenous variables and the variances and the covariances of the errors. Therefore, is need to add at the structural coefficients the variances of the independent variables, with their covariances, and the variances of the errors, with their covariances. All of these elements allow to represent, algebraically and as a whole, a structural equations model.

As already mentioned, *the LISREL approach,* for the structural equations model, represents one of the more common techniques because it allows to evaluate the relationships between latent variables measured by variables observed to them tied because differ by them only for random errors or for systematic errors and is constituted by two sets of linear equations or better by two submodels.

The first submodel, which describes the causal relations between the latent variables (not observable), is said *structural model*; it, assuming the more general case in which the endogenous variables are m and those exogenous n, is formalized in:

$$\eta = B\eta + \Gamma\xi + \zeta$$

where η is the vector $(m \times 1)$ of the endogenous latent variables of the model, ξ is the vector $(n \times 1)$ of the exogenous latent variables and ζ is the vector $(m \times 1)$ of the errors of the variables η in the model. The matrix $B\,(m \times m)$ is the matrix of structural coefficients of endogenous variables and, therefore, is a matrix square of dimensions equal to the number of endogenous variables and has some zeros on the main diagonal while the matrix $\Gamma\ (m \times m)$ is the matrix of the structural coefficients, of the regression coefficients that express the bonds between the endogenous variables and the exogenous variables.

The second submodel (said *measurement model*) defines the relations, always linear, between the latent variables and the corresponding variables observables or manifest (namely, specifies how the latent variables are measured through the observed variables) and can be so formalized:

$$y = \Lambda_y\eta + \varepsilon$$
$$x = \Lambda_x\xi + \delta$$

where, as already mentioned, η is the vector of the endogenous latent variables of the model, ξ is the vector of exogenous latent variables, y is the vector of corresponding endogenous observed variables and x is the vector of corresponding exogenous observed variables. The vectors y and x have respectively dimensions $(p \times 1)$ e $(q \times 1)$ with $p \geq m$ e $q \geq n$.

The matrices Λ_y and Λ_x are the matrices of factorial weights and contain the coefficients expressing the linear link between the observable variables and the latent variables while the vectors ε e δ, of the dimension $(p \times 1)$ and $(q \times 1)$, represent, respectively, the vectors of the errors of measurement of the variables y and x.

Because the model is complete, must be considered also the matrices that represent the links between variables not explicitly included in the causal model, namely the matrices of covariance Φ, Ψ, Θ_ε, Θ_δ, where Φ the variance/covariance matrix of the exogenous latent variables ξ. Ψ the matrix of variance/covariance of errors ζ of the of the endogenous latent variables η. Θ_δ the matrix of variance/covariance of errors δ of the manifest variables x. Θ_ε the matrix of variance/covariance of errors ε of the manifest variables y.

From what has been said, it is deduced that, for a complete specification of the model, it is necessary to estimate the four matrices of variance/covariance mentioned above and the matrices of the coefficients: B, Γ, Λ_x, Λ_y. The first 4 matrices are always square and symmetrical while the other 4 are rectangular.

None of the structural equations must be redundant and, then, the equations of the model that express the various η must be independent between them; this means no endogenous variable η can be a linear combination of other endogenous variables. In matrix terms, the matrix B is no singular, that is, exists B^{-1}.

The linear model of structural equations, according to the Lisrel method, can have an alternative formulation. In fact, starting from the following definitions:

$$n^* = \begin{pmatrix} \eta \\ \xi \end{pmatrix} \quad y^* = \begin{pmatrix} y \\ x \end{pmatrix} \quad \Lambda^* = \begin{bmatrix} \Lambda_y & 0 \\ 0 & \Lambda_x \end{bmatrix}$$
$$\xi^* = \begin{pmatrix} \zeta \\ \xi \end{pmatrix} \quad \varepsilon^* = \begin{pmatrix} \varepsilon \\ \delta \end{pmatrix} \quad B^* = \begin{bmatrix} I - B & -\Gamma \\ 0 & I \end{bmatrix}$$

the previous equations can be written in the form most compact:

$$B^* \eta^* = \zeta^*$$
$$y^* = \Lambda^* \eta^* + \varepsilon^*$$

or, in an equivalent way, in the reduced form:

$$\eta = (I - B)^{-1} \Gamma\xi + (I - B)^{-1} \zeta$$
$$y^* = L\xi^* + \varepsilon^*$$

where

$$L = \begin{bmatrix} \Lambda_y (I - B)^{-1} & \Lambda_y (I - B)^{-1} \Gamma \\ 0 & \Lambda_x \end{bmatrix}$$

5.3 Resolution of a SEM according to the PLS-PM approach

The approach *Partial Least Squares* (PLS) to structural equations models, also known as PLS-PM approach (Partial Least Squares Path Modeling), was proposed by H. Wold in the 1973 to estimate, in the socio-economic context, models with non-observable variables and it stands as an estimation procedure of the models of structural equations, alternative to LISREL approach.

This approach, therefore, is a prediction technique that allows to estimate both the causal relationships between two or more latent or unobservable variables, both but also the relationships between these dependent variables and their indicators (or independent variables) in order to predict the behavior of the variable dependent by the obtained values of the explanatory variables.

In other words, the PLS-PM approach appears as a less restrictive estimation technique than the classic estimation methods of the parameters because it allows, preliminarily, to:

- to make few assumptions
- to work on a reduced sample of data
- to avoid any hypothesis about population distribution
- do not be bound to specific measurement scales.

As consequence of these characteristics, is not posed the problem of non-convergence and of indeterminacy of scores, dictated by simple sampling errors or by an excessive number of parameters to be estimated and for this greater flexibility than SEM-ML, the PLS-PM approach can to be used as an exploratory medium of analysis to study the relationships between the indicators and the latent variables, even when there are few observations, and to identify timely indicators less suitable indicators among the estimates of scores of the latent variables. All these reasons make the PLS-PM method particularly suitable for solving *data analysis problems*, with the intention of describing the observed data and of making reasonable predictions for the new observations, and for to support the *business decision-making* in the field of marketing and of the strategies for the study of consumer-behaviour, of the customer satisfaction, of those analyzes, namely, that are rich in constructs but also difficult to translate quantitatively.

In essence, the PLS-PM method estimates, first of all, the relationships that link each manifest variable with the corresponding latent variable; later, it puts in relation some endogenous latent variables with the other latent variables, considering the values of latent variables as linear combinations of their manifest variables.

In formal terms the PLS-PM approach is described by two models: the *measurement model* (also called the external model) and the *structural model* (or internal model).

The *measurement model* analyzes the external relations between the latent variables and their indicators, that is, the corresponding variables observed.

A latent variable ξ is, as already mentioned, an unobservable variable, indirectly described by a block of observed variables x, defined manifest variables or indicators. Consequently, the manifest variables can be related to their respective latent variables in different ways; there are, namely, different methods of formulating the sub-model of measurement. In particular, are available three different methods of formulating the measurement sub-model: the reflective scheme, the formative scheme, and MIMIC (acronym of english terms: Multiple Indicators Multiple Causes).

– In the reflective scheme, each manifest variable reflects the corresponding latent variable below; in other words, the manifest variable is connected to its corresponding latent variable through a simple linear regression:

$$x_h = \pi_{h0} + \pi_h \xi + \varepsilon_h$$

and analogously

$$y_j = \pi_{j0} + \pi_j \eta + \varepsilon_j$$

where ξ is the latent variable (with mean zero and standard deviation 1) while the π are the so-called "weights" that measure the contribution that each single indicator provides separately to the relevance of the construct to which it is associated. In particular, π_{h0} is defined "external" weight while π_h "factorial" weight or loading. The term ε represents the error of deviation, the imprecision in the process of measurement. The only hypothesis is that the residue ε has as average 0 and is uncorrelated to the latent variable ξ.

– In the formative scheme, the manifest variables determine and explain the latent variables so that these last are estimated as a linear combination of their manifest variables

$$\xi = \sum h \; \omega_h x_h + \delta$$

and analogously

$$\eta = \sum h \; \omega_h y_h + \varepsilon$$

Thus, the latent variable ξ is a linear function of its block of manifest variables x plus a residual term, the error δ, that represents the part of the corresponding latent variable not explained by the manifest variables. The block of manifest variables can be multidimensional and the assumption at the base of the model is that the error vector δ has an average of 0 and is uncorrelated with the manifest variables x_h.

– The MIMIC method allows to have, in the same block, ties of formative type and ties of reflective type. In other words, the MIMIC scheme allows to estimate the measurement model but also poses serious theoretical problems since it needs separate treatment for the different indicators and this suggests the possible presence of errors in the choice of the indicators. Regardless of the type of indicators present, the objective of the sub-model of measurement is to minimize the residue errors in order to make the values of the theoretical model as close as possible to those observed; the only difference is the type of regression used: simple if the method is reflective, multiple if the method is formative. Opposed to the sub-model of measurement, the competence of the structural sub-model is to define the network of causal relationships existing between latent variables.

The structural model specifies the relationships between latent variables (also called *internal relations* or *inner relations*) according to a system of structural linear equations of the type:

$$\xi_j = \beta_{j0} + \sum \beta_{j\,i}\, \xi_i + v_j$$

In the internal model, the parameters to be estimated are the path coefficients $\beta_{j\,i}$, namely the regression coefficients connecting the latent variables between them (represent the relationships between endogenous latent variables and between exogenous and endogenous latent variables). If a latent variable ξ never appears as a dependent variable it is called exogenous variable, otherwise it is called endogenous variable.

In estimation techniques based on PLS-PM, all latent variables are indicated in the same way, whether they are endogenous or exogenous (in estimation methods FASEM, this variables are differentiate, as already seen). Are applied the usual assumptions on residues.

To check the internal consistency of a block of manifest variables in reference to the respective latent construct to which it is associated (the unidimensionality of the block) there are available three tools:

• *The analysis of the main components of a block* The analysis of the main components is a statistical tool that allows to establish whether it is possible reduce the dimensionality of available data without an excessive loss of informations. In order to use the reflective scheme, the block of indicators must be one-dimensional, since the observable variables derive from a single latent variable. If the analysis of the main components detects the presence of only significant eigenvalue (greater than 1) then there are clues of unidimensionality, otherwise there is the suspect that the same block measures different abstract concepts.

A block is considered one-dimensional if the first eigenvalue of the correlation matrix of the block of manifest variables is greater than 1 and the second is less than 1 or at least very far from the first.

• *The Cronbach's alpha coefficient* The index α of *Cronbach* is constructed as a ratio between the sum of variances of the manifest variables and the variance of the sum of the same and varies between 0 (lack of reliability) and 1 (maximum reliability) and is used to measure the one-dimensionality of a block of p variables xh where p is the number of manifest variables when they are all positively correlated:

$$\alpha = \frac{\sum_{h \neq h'} cor\,(x_h, x_{h'})}{p + \sum_{h \neq h'} cor\,(x_h, x_{h'})} \times \frac{p}{p-1}$$

where $cor(\ ,\ )$ indicates the linear correlation coefficient.
• *The Dillon–Goldstein'index*: the sign of the correlation between each manifest variable xh and its latent variable ξ is known from building of the item and is supposed to be positive. This hypothesis implies that all the πh factor weights are positive. *The index of Dillon–Goldstein* is considered a measure of the a one-dimensionality of a block better than the alpha coefficient of Cronbach (Chin 1998)

$$\rho = \frac{\left(\sum_{h=1}^{P} \pi_h\right)^2}{\left(\sum_{h=1}^{P} \pi_h\right)^2 + \sum_{h=1}^{P}\left(1 - \pi_h^2\right)}$$

Both indexes, α of *Cronbach* and ρ *of Dillon–Goldstein,* provide a measure (between 0 and 1) of what that in the literature is called *homogeneity of a block* of manifest variables linked to a latent variable according to the reflective scheme. If the indicators of a latent variable are homogeneous, it is possible say that latent variable is *one-dimensional*; homogeneity of the indicators and unidimensionality of a construct are two faces of the same medal.

Within the literature on structural equation models there is no an agreement on the symbols to use to define latent variables and all other parameters of the models. Generally, in all covariance-based estimation techniques, the endogenous and exogenous latent variables and their manifest variables and the parameters are indicated differently, while in the component-based estimation techniques, especially in PLS-PM, all latent variables are indicated in the same way, whether if they are endogenous or if they are exogenous.

With reference to the estimation method named PLS (Partial Least Squares) for the analysis of customer satisfaction, the authors consider models in which are described the links of "reflective" type between p latent variables Y_j with $j = 1, \ldots, p$ (not directly measurable) and the links between each latent variable and the corresponding p_j $(j = 1, \ldots p)$ manifest indicators X_{jh} $\left(h = 1, \ldots p_j\right)$,

In particular, the authors consider a causal model of "recursive" type, namely a model of the type:

$$Y_j = \sum_{k=1}^{j-1} \beta_{jk} Y_k + \zeta_j$$

where the Y_j are the generic endogenous variables, the Y_k are the variables, endogenous and exogenous, from which Y_j can only depend while ζ_j are the errors of the equations.

The exogenous latent variables (which do not depend on any other variable) are $q < p$ $(q \geq 1)$ while the endogenous latent variables (which depend on one or more variables) are $(p - q)$.

Furthermore, the authors hypothesize that the manifest variables X_{jh} $\left(h = 1, \ldots p_j\right)$ are functions of latent variables (and not vice versa), that is

$$\left(X_{jh} - \bar{x}_{jh}\right) = \lambda_{jh} Y_j + \varepsilon_{jh} \quad j = 1, \ldots, p, \quad h = 1 \ldots p_j$$

where $\bar{x}_{jh}$ represents the arithmetic mean.

Very important is the study of the reliability of the measure scales, namely the control of the correct specification of the sub-models of measurement, which is executed through the index α of Cronbach.

In particular, fixed

$$T_j = \sum_{h=1}^{p_j} X_{j\,h} \text{ with values } t_{i\,j} = \sum_{h=1}^{p_j} x_{i\,j\,h}$$

and indicated with

$$s^2_{j\,h} = s^2\left(X_{j\,h}\right) = \frac{1}{n-1}\left(\sum_{i=1}^{n} x^2_{i\,j\,h} - \frac{1}{n}\left(\sum_{i=1}^{n} x_{i\,j\,h}\right)^2\right)$$

$$s^2_j = s^2\left(T_j\right) = \frac{1}{n-1}\left(\sum_{i=1}^{n} t^2_{i\,j} - \frac{1}{n}\left(\sum_{i=1}^{n} t_{i\,j}\right)^2\right)$$

the variances of manifest variables $X_{j\,h}$ and of totals of group T_j, the index α of Cronbach becomes:

$$\alpha_j = \frac{p_i}{p_j - 1}\left(1 - \frac{\sum_{h=1}^{p_j} s^2_{jh}}{s^2_j}\right) \quad j = 1, \ldots, p,$$

or better

$$\alpha_{j(h)} = \frac{p_j - 1}{p_j - 2}\left(1 - \frac{\sum_{k \neq h} s^2_k}{s^2_{j(h)}}\right) \quad j = 1, \ldots, p,\ h = 1, \ldots, p,$$

where

$$s^2_{j(h)} = s^2_j + s^2_{jh} - 2\frac{1}{n-1}\left(\sum_{i=1}^{n} t_{i\,j} x_{i\,j\,h} - \frac{1}{n}\left(\sum_{i=1}^{n} t_{i\,j}\right)\left(\sum_{i=1}^{n} x_{i\,j\,h}\right)\right)$$

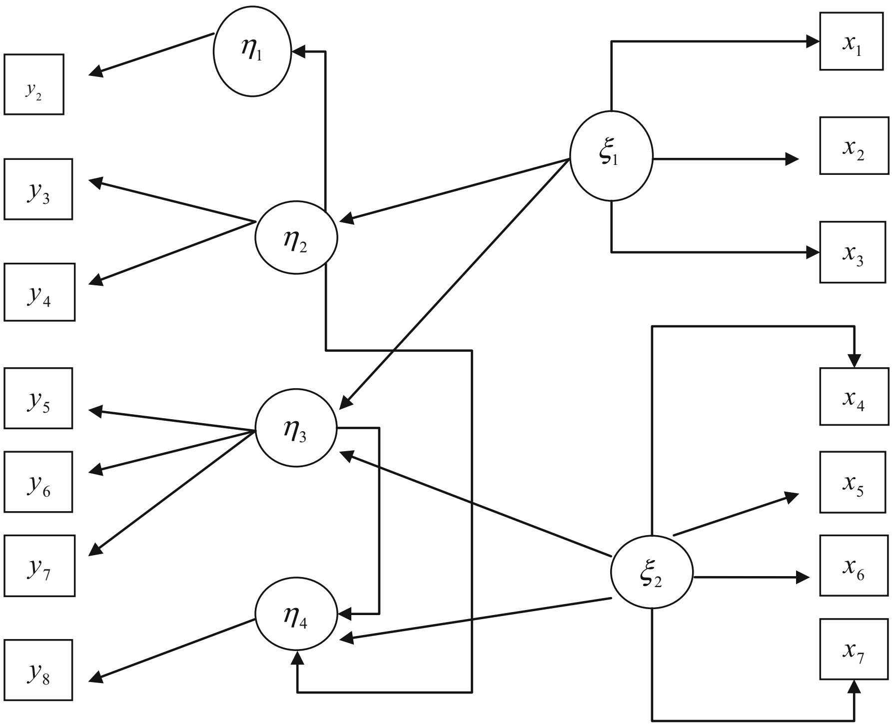
5.4 Path diagram

The graphic representation of structural equations models uses the symbolism introduced by path analysis and takes the name of *path diagram*. In this representation, some of the elements of the structural equations model are reported: the variables, their errors and the existing links between the variables (in the graphical form by the arrows and in the numerical form by the regression or correlation coefficient or by the covariance). The other parameters of the model, namely the covariances of the exogenous variables and of the errors, are not always reported graphically.

All endogenous and exogenous latent variables are usually represented by a circle or even by an ellipse, while all the manifest variables, indicated by the letters of the latin alphabet x and y and generally detected by a questionnaire, are represented by a rectangle. The letters of the greek alphabet are usually used to indicate the latent variables, while the letters of the latin alphabet are used usually for the manifest variables. All manifest variables are located at the right and left edges of the path diagram.

In particular, the endogenous latent variables, indicated by the greek letter η, are positioned to the left and linked to the manifest variables y, while all the exogenous latent variables, indicated by the greek letter ξ, are positioned to the right and are linked to the manifest variables x. Finally, the exogenous latent variables ξ are linked to endogenous latent variables η.

In the following, the authors propose the path diagram for a SEM of 4 equations, how many are, namely, the endogenous variables η (η_1, η_2, η_3, η_4).



Being a purely technical topic, the authors are limited in this paper to the essential traits exposed in discursive terms.

Even the terms that indicate errors should be included in the path diagram, but the authors preferred to omit them so as not to render too heavy the representation.

To each latent variable are associated two or more manifest variables, which act as indirect measuring instruments: the alternative term, indicators, is so very eloquent. The relationships between the latent variables constitute the *structural model*; it is also called *inner model*. The manifest variables, linked to each of the latent variables, constitute the *model of measurement*, which is also called *outer model*. It is possible note that here all manifest variables are positioned at the right and left edges of the path diagram.

The causal direct link between two variables is indicated with an oriented arrow (at one direction) that moves (in straight line) from the variable cause (independent) to the variable effect (dependent). In other words, the direction of the arrows goes from the variable considered cause to the variable considered the effect. This is true, certainly, within the structural model while the notion of causality, within the measurement model, presents most complex aspects and sometimes controversial aspects on which authors do not stop.

In the graphical representation of the model, namely in the represented *path diagram*, is used the convention to put in the column all endogenous latent variables to the left and all the exogenous latent variables to the right. In the literature there are, however, representations that do not follow this scheme, and in this case, the role of endogenous or exogenous variables is deducible only by the presence of the arrows and by their direction; so, the convention adopted here facilitates the reading of the path diagram.

It must also be said that the use of these greek letters and of associated latin letters (namely, x associated with ξ and y associated with η) is the one recurring in the LISREL approach, which is the solution method of SEM proposed first, while in PLS-PM approach the notation to be preferred may be different.

6 Concluding remarks and future perspectives for research

In this paper, have been discussed some of the main processes and detection systems that are necessary for a scrupulous and reliable measurement process of customer satisfaction, were examined several studies dealing with the customer satisfaction; more precisely, were presented many models to calculate the customer satisfaction that is has become an increasingly important concept in both academia and in both practice.

The authors hope to have provided, through this paper, a small step in research on the customer satisfaction and also useful and interesting research directions; they believe, however, that is still needed a significant research, given the relevance of this topic and the increasing focus of researchers on it. In other words, the authors hope that this paper will stimulate extensions and practical applications which quantify and objectify the value of customer satisfaction and that the huge potential of the customer satisfaction will be exploited in years to come; more precisely, they hope that the paper, which at first sight has little in common with mathematics, is a very useful for stimulating research at the interface of mathematics and marketing and that it builds a link that can become beneficial for both disciplines involved.

It will be interesting to see how future research will take care of customer satisfaction, how, namely, the study of customer satisfaction will offer, in the future, some valid ideas from which the companies, with greater foresight and resourcefulness, will find useful informations and they will be able to gain competitive advantage. In conclusion, the development of mathematical models to measure the customer satisfaction (models that take into consideration factors underlying behaviour of the repeated purchase) remains, without a doubt, a challenge for future researchers.

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