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A CLASSIFICATION FRAMEWORK FOR SUPPLY CHAIN FORECASTING LITERATURE

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Abstract: *Forecasting in Supply Chain Management (SCM) is an important yet underestimated research topic. Over the past years numerous methods and concepts have been developed, tested and deployed. In this paper we present a classification framework for the SC Forecasting literature using eight criteria, namely focus, approach, method triangulation, data generation, range, timeline, theoretical background, and target group. Additionally, we present examples for the respective criteria and summarize the major findings. This state-of-the-art review paper is targeted toward both researchers and industry experts who want to get an overview of the goals of contemporary SC Forecasting research.*
Keywords: *Forecasting, Forecasting Models, Supply Chain Forecasting, Supply Chain Management*

INTRODUCTION

Forecasting is an important and well-established research topic in economics as well as in business. Not only exists a plethora of literature which deals with various aspects of forecasting and prediction, but even highly specialized journals (e.g. Long Range Planning, Journal of Forecasting, Journal of Business Forecasting, International Journal of Forecasting, Foresight: The International Journal of Applied Forecasting) and conferences (e.g. Supply Chain Forecasting and Planning Conference, Sales & Operations Planning (S&OP) Conference, Workshop on Industry & Practices for Forecasting) exclusively focus on that area. Notwithstanding the long tradition of this research stream, Datta et al. [1] state that "Forecasting is an underestimated field of research in Supply Chain Management" (SCM) (p.187). At first sight, this seems surprising, given the high importance of forecasting for an effective and efficient supply chain. For instance, one of the most important phenomena in business, the so-called Bullwhip (Forrester) effect, was discovered more than 50 years ago [2]. Today scholarly papers still deal with this highly complex subject [3] [4]. We found four major reasons for the enduring importance of SC Forecasting on which we will elaborate in the following subsections.

Increasing Market Volatility

The financial crisis of 2007/08, which was followed by a global recession that affected the entire world economy, has caused many companies to rethink their overall business strategies. Following the economic downturn, a general awareness now exists that increasingly complex international business networks lead to dependencies on business partners and a greater-than-ever vulnerability to market fluctuations triggered by political crises, natural disasters and economic cycles [5]. Current research and political indicators point towards an ongoing market volatility in the future [6], which tend to make corporate forecasting and planning crucial yet increasingly difficult.

Methodological Developments

New and innovative methods take time to diffuse from formal to applied science and finally to the industry. Frequently, established methods are modified in order to fit a prevalent problem. Datta et al. [7], for example, illustrate how to adapt an advanced forecasting technique, GARCH (i.e. Generalized Autoregressive Conditional Heteroskedasticity) with the goal of improving it into a flexible decision support tool. Those models are based on ARCH models, which were originally developed by Nobel prize laureate Robert Engle [8] decades ago. Datta et al. [7] further refine them by adding vector auto regression (VAR) methodology and model volatility for a vector rather than a single series. They suggest to call the proposed model VAR-MGARCH and conclude that "in one isolated experiment [...] the model provided a forecast that was appreciably closer to the observed or realized value" (p. 1469). However, they also stress the need for further methodological refinement: "This observation is immature. [...] Several more experiments with rigorous controls must be performed before this result may be even considered to offer 'preliminary' evidence that the GARCH type model proposed in this paper may represent an advanced tool" (p. 1469). This is but one of many examples in which existing methods are altered in order to fit the demand of modern SCM.

Big Data

In a current issue of the Journal of Business Logistics (JBL), Waller and Fawcett [9] describe data science, predictive analysis and big data as "a revolution that will transform supply chain design and management" (p. 77). They show that, in spite of being often named a buzzword, big data holds a lot of potential for those companies which understand how to capitalize on it. The opportunities for organizations to gain valuable information from big datasets are simply too attractive to ignore them. Furthermore, as is the case with most hypes, numerous companies are afraid of losing market share to competitors who capitalize on the "first mover advantage". Modern

technology has made it possible to easily gather data in hitherto unimaginable quantities. Quite naturally, in many cases these data contain valuable information which can be used for extracting meaningful forecasting information that helps to generate agile supply chains [10].

Supply Chain Focus

Although a significant amount of papers exists which exclusively deals with forecasting in the supply chain, the majority of published research either focuses on methodological issues or has a different kind of operational focus. Hence, a huge untapped potential of forecasting knowledge exists, which allows SC researchers to simply transfer existing know-how in order to tackle problems specifically pertaining to supply chains. This is of crucial importance, since the overall importance of SC Forecasting is constantly growing [11]. The remainder of this paper is organized as follows: In section 2 we will briefly elaborate on the methodology we used for this research, followed by the presentation and discussion of our classification framework in section 3. Finally, we summarize our findings, highlight implications and options for further research and also mention several limitations.

METHODOLOGY

In this conceptual research-in-progress paper we followed the procedure suggested by Tranfield et al. [12] for conducting a systematic literature review. We first identified relevant keywords related to SC Forecasting and used the scholarly databases "ProQuest" and "EBSCO" as a starting point. The literature review was carried out from September 2013 until March 2014 and was constantly refined by including articles being cited in the analyzed papers or which we found via Internet search (e.g. by using Google Scholar). We finally ended up with a total of 92 papers which had both a focus on supply chains as well as forecasting and which we deemed relevant for the study at hand. In the first phase we classified each paper according to its main research goal. Next, we created various categories suitable to further categorize the papers. If a paper did not fit into one of our categories, we revised and extended our framework. In line with the qualitative and explorative nature of this research, we did not strive to categorize all papers exhaustively and did not provide any descriptive data pertaining to the absolute number of papers within a specific category, but rather used the publications in order to create a sufficient number of categories in our framework. In the following section we will not only introduce the framework itself, but also briefly discuss various examples of papers in order to illustrate the meaning of the respective categories.

SCM FORECASTING IN THE LITERATURE: A CLASSIFICATION FRAMEWORK

During the classification process a total of 8 different categories emerged. It has to be noticed that this framework is neither fully exhaustive nor mutually exclusive, but its main purpose is rather to highlight the various existing goals of contemporary SC Forecasting research. We will provide one or more examples in each category for illustration purposes.

Focus

A lot of published research in academic literature focuses on developing and refining methods. Apart from the previously mentioned paper from Datta et al. [7], another example stems from Ferbar et al. [13], who utilize the theory of wavelets in order to create a wavelet denoising model which they find to be superior to the commonly used exponential smoothing method. A second stream of research focuses on the classification of existing methods. Armstrong [14], for example, presents a selection tree for various forecasting methods, whose choice depends on criteria such as available data, expected changes, available expertise, similar cases and domain knowledge. This tree may be used to select the best suited method for a given problem with various characteristics. Finally, scholarly papers exist which compare methods and give recommendations on how to choose the most appropriate one. Acar and Gardner [15], for example, select the most appropriate method based on operational performance in a real supply chain. They compare various exponential smoothing methods and base their final choice on tradeoff curves between total costs and customer service.

Approach

In academic literature, quantitative approaches are prevalent, as is shown by the meta-study from Fildes et al. [16] who analyzed a total of 558 publications in forecasting research. 27.2% of the papers used univariate methods, 21.5% causal and multivariate methods and 13.4% computer-intensive methods such as non-linear statistical methods and neural nets. Only in 8.2% of the cases judgment, i.e. a qualitative approach, was used. The authors also categorized 879 articles from operational research journals and found a similar dominance of quantitative methods with only 8.5% of the papers under investigation using judgment. This coincides with our findings that the vast majority of the scholarly papers relies on quantitative data. However, we also found examples for papers which combine qualitative and quantitative approaches [17] [18], or which solely rely on a qualitative approach. An example of the latter category comes from McCarty and Golicic [19], who use depth interviews with executives in three firms in order to come up with seven guidelines for implementing interfirm collaborative forecasting. As far as quantitative research is concerned, the majority of publications deals with the development, testing and refinement of forecasting techniques. However, we also found evidence for survey-based research. Nakano [20], for example, administered a survey among 65 Japanese manufacturers and used confirmatory factor analysis in order to examine the perceived impact of internal and external collaborative forecasting and planning on logistics and production performance.

Method Triangulation

The aforementioned study from Fildes et al. [16] also lists the usage of method triangulation, i.e. the combination of various methods in

order to study a situation or phenomenon. 3.8% of the forecasting and 6.1% of the operational research publications actually applied method triangulation, indicating that the vast majority of publications relies on using a single method only. Notable exemptions include Caniato et al. [17] who integrate quantitative and qualitative approaches to improve demand forecasting in the cement industry and who report improved forecasting accuracy as well as increased knowledge within the organization. The second example stems from Forge [18], who uses a qualitative forecast derived from a scenario for a quantitative projection. Although not exclusively focused on SCM, his approach may be used for all studies which need to simultaneously take into account socio-economic, technological and market developments. Third, Goodwin and Fildes [21] report that in the industry statistical forecasts are frequently adjusted using management judgment. They differentiate between large adjustments, which tend to improve accuracy, and small ones, which often turned out to be a waste of time.

Data Generation

Another distinctive feature which we observed in the literature is the type of data generation. Researchers have a choice between collecting real world data from companies [22] and using some kind of Monte Carlo experiment in order to obtain the required distribution of an unknown probabilistic entity [23]. We observed the latter procedure mainly in the context of testing new methods. In some cases the authors split an existing real world data set in order to create a model and use the remaining data for testing purposes [24].

Range

Collaborative planning, forecasting and replenishment (CPFR), i.e. the joint planning of key supply chain activities, has gained significant attention in recent years. Previous research has shown that CPFR yields numerous positive results, such as the need to innovate and strong relationships between business partners [25]. Several authors therefore consider the potential impact of decisions that go beyond company boundaries. Aviv [26], for example, presents a time-series framework for supply chain inventory management which takes into account the benefits of various types of information-sharing agreements between supply chain members. He presents a methodology which allows for the investigation of the benefits of various types of information-sharing options, such as sharing subsets of demand-related information or sharing information in one direction of the channel. Acar and Gardner [15] discuss the case of a global manufacturer which owns plants in America, Europe and Asia. Their paper is about forecasting method selection in a real supply chain and they conclude that "forecasting must be evaluated at the aggregate level […] for the entire supply chain" (p. 847).

Timeline

We found a large number of publications investigating changes over time, which is common in forecasting research. Although it is possible that these papers are purely conceptual and do not use data, as is the case with Giloni et al. [27] who investigate the problem of demand propagation in multi-stage supply chain and demonstrate the benefits of information sharing, many of the papers we found rely on actual time series data [30].

Theoretical Background

The importance of theory varies between scholarly disciplines, as does its purpose and usage [28]. We found that most research on SC Forecasting focuses on solving specific operational problems and does not refer to a specific underlying theoretical background. Notable exceptions include Stapleton et al. [29] who discuss in their conceptual paper the applicability of chaos theory principles to selected supply chain functions and who conclude that chaos theory bears some potential to help explain unpredictability within nonlinear systems. Ferbar et al. [13] use a mathematical approach when they apply the theory of wavelets in order to denoise signals.

Target Group

We found that the publication outlet mainly determines the respective target group (researchers vs. practitioners), which is usually the case in all kinds of academic and non-academic communities. We were therefore especially interested in publications which might serve as a bridge between these groups, i.e. which might be well-suited to transfer cutting-edge knowledge into the industry. We found several examples, e.g. in the Journal of Business Forecasting Methods & Systems, such as the papers from Peterson [31], who reports on the supply chain integration efforts of the Bayer HealthCare Division and how they improved forecasting by reducing bias, and Picksley and Brentnall [32] who describe how Bayesian modeling might help to enhance supply chain forecasting and planning. A similar outlet is the Journal of Business Forecasting, in which Khadar [33], for example, describes how a vendor inventory management program helped to create visibility in the supply chain and let to improved forecasting. Occasionally, relevant papers were published in high-impact journals such as Harvard Business Review (HBR), as is evidenced by the publication from Fisher et al. [34] who illustrate how companies manage to cope with uncertain demand.

***Table 1** – SCM Forecasting Literature Framework Category*

Focus	Methodology	vs.	Application
Approach	Quantitative	vs.	Qualitative
Method Triangulation	Yes	vs.	No
Data Generation	Real World Data	vs.	Simulation
Range	Single Location	vs.	Chain
Timeline	Cross Sectional	vs.	Time Series
Theoretical Background	Yes	vs.	No
Target Group	Researchers	vs.	Industry

Table 1 summarizes the eight major categories of our framework. Most papers can be classified according to all of the criteria, some of which overlap.

CONCLUSIONS AND LIMITATIONS

Supply Chain Forecasting is a topic which is of utmost importance to both practitioners and academics. Numerous papers in this area have been published over the past decades, and new methods and concepts are constantly being developed, tested and refined. In this review paper we present a framework which may be used for

classifying existing research according to its main goal. We differentiate between eight categories (focus, approach, method triangulation, data generation, range, timeline, theoretical background, target group) and provide several examples in order to illustrate the respective categories. We show that numerous papers exist which shed light on the intricate subject of SC Forecasting from different angles. Authors use a wide variety of methodological approaches, data generation methods and research designs in order to make useful contributions for their respective target groups.

This paper is research in progress and part of an extensive SC Forecasting project. Therefore, several limitations exist. First, our framework needs to be refined with further categories and a more detailed distinction between them. Rather than having only two options in each category, more choices might be appropriate. Second, we suggest to find categories which are mutually exclusive and collectively exhaustive, and, third, a comprehensive quantitative study is needed which shows the distribution of papers in each category.

Finally, we also want to highlight opportunities for further research. Our preliminary results already suggest potential research gaps, such as the significant time lag of knowledge diffusion into the industry. We found a huge number of cutting-edge research papers, but there is strong indication that the actual application of novel research findings in the industry frequently has a significant delay. Future studies might enhance our framework and use the results in order to systematically identify research gaps in the area of SC Forecasting.

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