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Value-based performance and risk management in supply chains: A robust optimization approach

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ABSTRACT

Integrated performance and risk management is the key lever to increase shareholder value holistically. In this paper, we develop a corresponding framework for value-based performance and risk optimization in supply chains. Economic Value Added (EVA) as a prevalent metric of value-based performance is applied to mid-term sales and operations planning (S&OP). Robust optimization methods are utilized to deal with operational risks in physical and financial supply chain management due to the uncertainty of future events. Multiple aspects of robustness and general implications of the framework are highlighted using a case-oriented numerical analysis.

1. Introduction

Creating shareholder value is commonly considered the paramount business goal (Young and O'Byrne, 2001) and requires an integrated approach to performance and risk management (cf. Ritchie and Brindley, 2007; Oehmen et al., 2009). Value-based management (VBM) provides a corresponding framework utilizing value driver trees and risk-adjusted performance metrics as major concepts for performance and risk management (Kaplan and Atkinson, 1998). Value driver trees drill down a top-level performance metric into operational levers for performance management (Rappaport, 1998). Risk implications are considered within the performance metrics via risk-adjusted cost of capital (Young and O'Byrne, 2001). From an operations research perspective, there are two major drawbacks of this common VBM approach. First, value driver trees are only explanatory frameworks and do not provide decision support. Second, risk implications are only covered indirectly omitting scenario-based information to derive robust plans.

Conceptual frameworks for value-based performance (cf. Walters, 1999; Lambert and Pohlen, 2001) and risk management (cf. Cavinato, 2004; Oehmen et al., 2009) are widely discussed in the supply chain context. Lainez et al. (2009) and Hahn and Kuhn (2011) provide decision models for value-based performance optimization at the long-term and mid-term level of supply chain management. However, the authors cover risk implications only indirectly via risk-adjusted cost of capital and the management of supplier–customer relationships. Therefore, the aim of this paper is to develop a framework for integrated value-based performance and risk optimization with a primary focus on the mid-term level. Robust optimization methods are applied to account for the risk-averse attitude of corporate decision-makers and to immunize financial performance against the impact of imperfect information (cf. Mulvey et al., 1995; Bai et al., 1997).

The remainder of this paper is structured as follows: Section 2 provides a literature review on decision-oriented approaches to financial performance and risk management in supply chains as well as robust optimization methods. The conceptual framework for value-based performance and risk optimization is derived in Section 3. In Section 4, a corresponding decision model for the supply chain context is presented. Multiple aspects of robustness and general implications of the framework are highlighted in Section 5 using a case-oriented example. Section 6 concludes the paper with a summary of the findings and an outlook for further research.

2. Literature review

Recent papers show increasing interest in decision-oriented approaches to financial performance and risk management. Guillen et al. (2007) optimize change in equity as a financial performance metric in their approach for integrated supply chain planning and scheduling in the chemical industry. Comelli et al. (2008) combine supply chain master planning with activity-based costing for aggregated supply chain processes. Bertel et al. (2008) maximize average cash position in their decision model for operational supply chain planning based on a flow shop scheduling

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formulation. Hahn and Kuhn (2011) develop a deterministic decision framework to optimize Economic Value Added (EVA) as a value-based performance metric at the mid-term level of sales and operations planning (S&OP). As opposed to the three aforementioned papers, the authors consider risk implications at least indirectly via risk-adjusted cost of capital in the calculation of EVA.

OR-based approaches to risk management mainly focus on the physical domain of supply chain management and omit financial implications (cf. Tang, 2006). Pongsakdi et al. (2006) and You et al. (2009) provide two-stage stochastic programming approaches to risk management in chemical supply chains. Pongsakdi et al. (2006) investigate a case study in refinery operations planning and utilize risk curves as well as the sample average approximation method to reduce risk impact. You et al. (2009) evaluate different risk metrics and their implications for global supply chain planning. Multi-stage frameworks for risk management are provided in Goh et al. (2007) and Sodhi and Tang (2009). However, only Sodhi and Tang (2009) consider material and financial flows simultaneously in their approach to supply chain risk management motivated by asset–liability management.

Mulvey et al. (1995) introduce robust optimization as a generalization of stochastic programming focusing on optimality and feasibility of the solution. An alternative approach to robust optimization is provided in Kouvelis et al. (1992) mainly focusing on the worst-case scenario. As a consequence, their approach omits scenario probabilities and does not utilize scenario-specific control variables in the decision model (Scholl, 2001). Properties of risk-averse utility functions in robust optimization are examined in Bai et al. (1997). Scholl (2001) develops a generalized framework for robust planning and optimization. Bayraksan and Morton (2006), Kaut and Wallace (2007), and Zenios (2007) investigate the impact of scenario generation methods on the robustness of results. Whilst Zenios (2007) focuses on statistical quality criteria to evaluate the generated scenario set, Bayraksan and Morton (2006) and Kaut and Wallace (2007) consider decision quality to decide whether the approach leads to superior decisions or not.

A large body of literature deals with stochastic production and supply chain planning to cover different sources of risk (cf. Wang and Liang, 2005; Mula et al., 2006). Robust optimization methods according to the aforementioned concepts are applied to problems in supply chain master planning at the mid-term level in Yu and Li (2000) and Leung et al. (2007). Eppen et al. (1989), Bok et al. (1998), and Aghezzaf (2005) investigate robust approaches to capacity expansion and facility location planning at the long-term level.

In summary, stochastic programming and robust optimization methods are prevalent in physical supply chain planning as well as financial performance and risk management. However, current decision frameworks only consider selected aspects and do not provide a comprehensive robust approach to value-based performance and risk optimization. Therefore, we extend the value-based optimization approach of Hahn and Kuhn (2011) towards a robust framework for integrated performance and risk management. Implications for scenario generation are considered to account for robustness from both the data and the decision model perspective.

3. Conceptual approach

3.1. Value-based performance and risk management

Business creates shareholder value if earnings exceed total costs of invested capital (Rappaport, 1998). We utilize the EVA concept as a prevalent metric of value-based performance at the mid-term level (cf. Young and O'Byrne, 2001). In (1), *EVA* in period *t* is calculated from net operating profit after tax *NOPAT* in period *t* minus total costs of invested capital in net operating assets *NOA* at the end of the previous period $t-1$ considering weighted average cost of capital i^{wacc} (Kaplan and Atkinson, 1998).

$$EVA_t = NOPAT_t - NOA_{t-1} \cdot i^{wacc} \tag{1}$$

Since shareholder value creation is a composite function of multiple interdependent factors, value driver trees are common frameworks to illustrate causal relationships between operational levers and a value-based performance indicator such as EVA (Rappaport, 1998). Walters (1999) identifies three relevant operational value drivers from a mid-term planning perspective. Customer retention and sales growth as well as synergies from the integration with supply chain partners increase *operating profit margin*. Improved capacity management drives cost efficiency in operations and enhances *asset utilization*. Working capital management shortens the cash conversion cycle and increases *operational cash flow*.

Although an integrated approach to performance and risk management is required to increase financial performance holistically (cf. Stulz, 1996), the aforementioned frameworks for value-based performance management consider risk impact indirectly via risk-adjusted cost of capital. However, a direct approach to risk management is recommended to consider comprehensive scenario-based information instead of the expected value of the distribution.

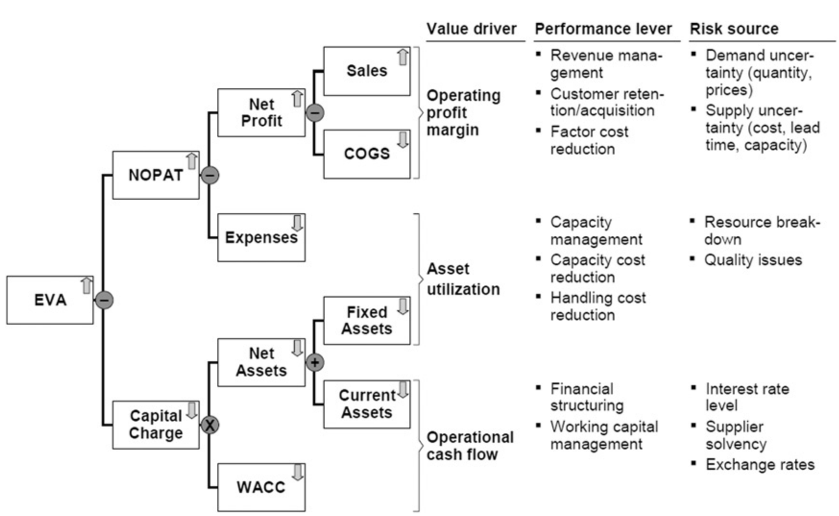

Fig. 1. Value-based performance and risk drivers.