European Journal of Operational Research 000 (2015) 1–13

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Decision Support

# Dual sourcing under disruption risk and cost improvement through learning

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ARTICLE INFO

*Article history:*
Received 3 June 2014
Accepted 8 September 2015
Available online xxx

*Keywords:*
Dual sourcing
Learning effects
Disruption risk

ABSTRACT

As suppliers are crucial for successful supply chain management, buying companies have to deal with the risks of supply disruptions due to e.g. labor strikes, natural disasters, supplier bankruptcy, and business failures. Dual sourcing is one potential countermeasure, however, when applying it one loses the full potential of economies of scale. To provide decision support, we analyze the trade-off between risk reduction via dual sourcing under disruption risk and learning benefits on sourcing costs induced by long-term relationships with a single supplier from a buyer's perspective. The buyer's optimal volume allocation strategy over a finite dynamic planning horizon is identified and we find that a symmetric demand allocation is not optimal, even if suppliers are symmetric. We obtain insights on how reliability, cost and learning ability of potential suppliers impact the buyer's sourcing decision and find that the allocation balance increases with learning rate and decreases with reliability and demand level. Further, we quantify the benefit of dual sourcing compared to single sourcing, which increases with learning rate and decreases with reliability. When comparing the optimal policy to heuristic dual sourcing policies, a simple 75:25 allocation rule turns out to be a very robust policy. Finally, we perform sensitivity analysis and find that increasing certainty about supplier reliability and increasing risk aversion of a buyer yield more balanced supply volume allocations among the available suppliers and that the advantage of dual sourcing decreases with uncertainty about supplier reliability. Further, we discuss the impact of demand uncertainty.



## 1. Introduction

When analyzing an optimal sourcing strategy, a buyer has to consider ineffectiveness of the supply chain resulting from supply disruptions. Disruptions may be caused by different forces from inside and outside the organization and can have a strong impact on the supply performance and, in particular, increase sourcing costs considerably. In 1997, for example, a fire at the Aisin Seiki Co. disrupted Toyota's supply chain. Aisin was the sole source for low-cost P-valves, which were crucial for all Toyota vehicles. Due to the fire, Toyota lost about 160 billion yen in revenues (Nishiguchi & Beautdet, 1997). In 2000, a fire shut down a plant in New Mexico, that supplied the two competing firms Nokia and Ericsson. Ericsson did not manage to source from alternative suppliers directly after the fire. The result was a $400 million loss (Latour, 2001). After the 9/11 terrorist attack, the U.S. border and air traffic were closed, causing high losses for many supply lines (Sheffi & Rice, 2005). Natural disasters, such as hurricane Katrina devastating New Orleans in 2005 or the earthquake in Japan in 2011, forced many companies to cope with supply disruptions. Financial instability of suppliers and the consequences of supplier default, insolvency, or bankruptcy can also cause supply disruptions and result in the temporary or permanent perturbation or termination of buyer–supplier relationships (Wagner & Bode, 2006). A well-known example is the automotive parts manufacturer Delphi Corporation, who filed for Chapter 11 bankruptcy protection in 2005. The OEM (Original Equipment Manufacturer) experienced substantial problems when dealing with the loss of Delphi's production.

These cases show that relying on a single supplier can have strong impacts in case of a supplier disruption as such events can cause extreme supply chain problems up to and including a permanent disruption of a supply chain partner. In a survey 519 respondents from 71 countries across 15 industry sectors were taken into account; 75 percent of the respondents experienced at least one supply chain disruption in the last year. A wide range of disruption sources over the past 12 months was identified, with major differences in main causes of disruption across industry and region. It turned out that insolvency is one of the top reasons for disruption. 38 percent of the respondents experienced at least one insolvency in their

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http://dx.doi.org/10.1016/j.ejor.2015.09.017

supply chain during the year (Business Continuity Institute, 2013). The probability of disruptions increases due to more and more globalized operations and the growing interconnectivity of supply networks. As a consequence of the financial crisis, the annual filings for supplier bankruptcy within the automotive sector roughly doubled from 2007 to 2008 (World Economic Forum, 2012).

To operate efficiently despite potential disruptions, dual sourcing is a prevailing strategy for mitigating supply risk. However, dual sourcing forfeits some potential economies of scale associated with single sourcing. Empirical studies in several industries verified that unit costs decline as organizations gain experience or knowledge in production (Li & Rajagopalan, 1998). Depending on the industry, the cost decline per doubling cumulative output typically ranges between 10 percent and 30 percent in most industrial situations (see e.g. Jaber, 2005; Yelle, 1979). Irwin and Klenow (1994) provide empirical evidence on learning, for example, within the semiconductor industry, finding an average of 20 percent cost decrease. The challenge for the buying firm is to deal with supply disruptions and integrate long-term learning effects of the suppliers based on production experience into the optimal sourcing decision. Most of the existing literature focuses on the ways to manage supply disruptions, assuming constant costs for the suppliers over the entire planning horizon. In long-term planning, however, the phenomenon that suppliers learn how to reduce cost over time through production has to be included into the buyer's procurement decision.

Paying attention to both managing supply disruptions and quantifying supplier relationships when supply cost follows a learning curve requires a general supply cost function, where costs decrease with cumulative production. Whenever we only take into account supplier cost improvements through learning, we find that the buyer will clearly favor a single sourcing strategy in order to benefit most from future cost reductions. However, the negative consequences of a disruption are generally higher when ordering from a single supplier than when ordering from two suppliers. Under dual sourcing, the other supplier potentially survives and accumulates experience that decreases future supply cost in case of a disruption. Therefore, a diversification between two suppliers to reduce the risk of higher future purchasing cost can result in an overall lower total cost for the buyer. The question of how to properly allocate the demand to the two suppliers plays a key role for success. In practice, however, it is common to use simpler policies by assigning static faction of demand to the suppliers. Dual sourcing is either implemented in a balanced allocation when the cost disparity of the suppliers is small, or in a more unbalanced allocation, for example, a 75:25 allocation rule (Klosterhalfen, Minner, & Willems, 2014).

The objective of this paper is to provide managerial insights into how a buyer should optimally allocate demand volume between two suppliers under given supplier reliability, procurement cost and cost improvement potentials through learning and the savings potential over single sourcing. We develop a discrete-time stochastic dynamic program with a single buyer purchasing from two potential suppliers who are exposed to the risk of supply disruptions by studying the feature of permanent supply disruption, e.g. supplier failure due to financial distress. The suppliers may differ in their reliability, learning ability, or cost structure (e.g. the supply base may consist of one unreliable but low cost supplier and one reliable but high cost supplier). The research questions are: What is the impact of supplier characteristics, reliability, cost and learning ability on the optimal policy and on the optimal volume allocation between the suppliers? What is the benefit of dual sourcing compared to single sourcing and simple rules such as 50:50 or 75:25 dual sourcing options?

The remainder of this paper is organized as follows. In Section 2, we discuss related literature. In Section 3, we present the base model with known disruption probabilities and a constant deterministic demand and derive structural properties of the buyer's optimal policy analytically and through numerical examples. A sensitivity analysis of the limiting model assumptions of known parameters and a risk-neutral decision maker is provided in Section 4. In Section 5, we give concluding remarks.

## 2. Literature review

### 2.1. Supply disruption risk and sourcing strategies

Comprehensive literature reviews on sourcing strategies and the optimal number of suppliers are provided by Elmaghraby (2000) and Minner (2003). Reviews covering supply risk management strategies and supply disruption in detail are found in Tang (2006) and Snyder et al. (2012). A review of the random yield literature is given in Yano and Lee (1995) and Grosfeld-Nir and Gerchak (2004).

Several single-period decision models compare single and multiple sourcing under supply failure risk using a decision tree approach. Berger, Gerstenfeld, and Zeng (2004) find the optimal number of suppliers who are subject to failure; they include super-events that affect all suppliers. The assumption of identical supply failure probabilities and linear costs is relaxed by Berger and Zeng (2005). Ruiz-Torres and Mahmoodi (2007) extend this model by introducing supplier-specific failure probabilities. They show that additional outsourcing may be required as the suppliers become less reliable.

In the literature on managing supply disruption risk with multiple suppliers, different reasons for supply uncertainty have been discussed. One stream of literature focuses on supply disruption models where suppliers fail with random duration when supply is completely unavailable, see: Parlar and Perry (1996) and Gürler and Parlar (1997). Single- and multi-period models on the optimal order quantity in the presence of two uncertain suppliers are examined in Anupindi and Akella (1993). They show that the optimal policy depends on the current inventory, i.e. order from both suppliers when inventory is low. Tomlin (2006) discusses supply disruption management strategies for an infinite-horizon model and shows that the optimal strategy depends on the percentage uptime and disruption length. Dada, Petruzzi, and Schwarz (2007) consider a newsvendor served by multiple suppliers differing in cost and reliability. They show that the optimal order quantity under uncertain supply and demand is higher than in the standard newsvendor setting and that the size allocated to a supplier depends on his reliability. Federgruen and Yang (2008) investigate a newsvendor framework procuring from multiple suppliers with yield uncertainty, supplier dependent fixed cost and a service level constraint. As the order allocation among suppliers based on the shortfall probability is difficult to analyze, they propose two approximations for the shortfall probability. Federgruen and Yang (2009) also consider multiple unreliable suppliers, analyzing two planning models: a service constraint model and a total cost model. Wang, Gilland, and Tomlin (2010) propose a model where process improvement efforts increase supplier reliability. They show that, for random capacity, improvement is preferred over dual sourcing when the cost difference between the suppliers increases. Schmitt and Tomlin (2012) study infinite horizon models, focusing on sourcing strategies (diversification and backup strategies) to manage disruption risk. They conclude that the average disruption length and the frequency of disruptions have a major impact on the preferred strategy. The impact of supplier reliability forecasting using Bayesian updating and the decision whether to use dual sourcing or single sourcing where supplier learning (updating) is only present for one of the two sources is discussed in Tomlin (2009).

Our work differs from Tomlin (2009) as follows: Tomlin (2009) assumes that supply costs do not change over time, whereas we assume that costs decline with experience. Further, Tomlin (2009) focuses on supply disruption where an order placed with a supplier might either succeed or fail. Our work assumes that a supplier might survive and gain experience, which reduces future supply cost. Alternatively, the supplier fails and gets permanently disrupted and needs