Push vs. Pull: How to Best Allocate Supply Risk in Random Yield Supply Chains

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Introduction. Supply risk is prevailing in today's uncertain global economy. As reported by McKinsey Global Survey 2006, nearly two thirds of the surveyed executives saw the risks of their supply chain been elevated over the past five years, and supply uncertainty was listed as the third most significant such risk. One major supply risk is production yield risk, which can be frequently observed in many industries, such as agriculture business, semi-conductor manufacturing, etc.

A firm controlling its own production and selling directly to the market, when facing production yield uncertainty, will inflate the started production quantity to account for yield risks. However, within a supply chain setting with a buyer (retailer) controlling the order and a producer (supplier) controlling the production quantity, there are risks of under-ordering and/or overproduction due to misaligned incentives in the presence of yield uncertainty. The contract under which the supply chain operates (e.g., wholesale price contract) allocates supply risk between the channel firms and affects the efficiency of the chain. We are interested in understanding how a "push" vs. "pull" implementation of a wholesale price contract for a random yield supply chain through different supply risk allocation between retailer and supplier (see Cachon, 2004, for use of the terms "push" and "pull" for wholesale price contracts). Under a push [pull] contract, the downstream [upstream] firm controls the production decision and bears all the supply risk. Another variant of a wholesale price contract is the "push-pull" one with the retailer ordering and the supplier deciding on the started production quantity. In this case, both supply chain parties share the supply risks by inflating their order/production quantities. Our research focuses on understanding how the supply risk allocation among supply chain parties under different contracts affects their individual and channel performance. Furthermore, we try to understand what might be the resulting wholesale prices in a rational negotiation process between retailer and supplier in a random yield supply chain under different wholesale price contract implementations.

Literature Review. First of all, this paper is related to the supply chain contract literature. Cachon (2004) completely characterizes the joint Pareto set among push and pull contracts for demand uncertainty chains, and shows that the supply chain can maintain high efficiency under such contracts. Dong and Zhu (2007) extend the previous work by fully characterizing the Pareto set of advanced-purchase discount contracts. As mentioned, these papers analyze supply chains with demand uncertainty, while our study focuses on contract analysis for random yield settings.

Secondly, this paper is relevant to the supply uncertainty literature. Chick et al. (2008) and Tang and Kouvelis (2014) are among the first to study channel coordination issues under yield uncertainty. Our work is different from this research stream, as we explicitly focus on the analysis and implementations of wholesale price contracts, with an emphasis on how those contracts better share the risk and improve the channel efficiency.

Model. We study a supply chain consisting of a retailer (he) and a supplier (she). The demand is deterministic and the supply suffers from proportional random yield, which is modeled as a continuous random variable with positive support on interval $(0, 1)$. Ordering is via a wholesale price contract and the retailer pays for the delivered quantity. We study three implementations of this contract that induce different risk allocations: (1) *push contract*, in which the retailer controls the production quantity and bears the supply risk; (2) *pull contract*, in which the supplier decides the production quantity and delivers the minimal of the realized output and the demand to the retailer and, thus, bears the supply risk; and (3) *push-pull contract*, in which the retailer decides order quantity and the supplier decides production quantity. The delivered quantity is the minimum between the order and the realized output and, thus, the supply risk is shared between the two firms. We compare these contracts under both *exogenous* and *endogenous* wholesale price scenarios.

Summary of Results. Our analysis shows that for an exogenous wholesale price identical across different contract types, the push-pull contract leads to the highest production quantity among the three contract types and induces the highest channel profit. However, the channel's preference may not necessarily coincide with the individual firm's choice. The supplier prefers to delegate the production decision to the retailer to completely protect itself from potential supply risk, when the predetermined wholesale price is low. Otherwise, she prefers to completely control the supply risk. In contrast, the retailer prefers the supplier to control and bear at least part of the supply risk, which leads to a higher delivered quantity. The exogenously preset wholesale price analysis exposes inherent channel conflicts and resulting inefficiencies.

It is paramount to understand how to effectively set wholesale prices under various contract types to better align interests in supply chains, share risk, and improve overall channel efficiency. The primary focus of our paper is to study how does the wholesale price affect the allocation of the supply risk and, thus, the channel performance under the various push/pull contract types. To tackle this issue, we adopt the concept of Pareto set from Cachon (2004) and Dong and Zhu (2007). By eliminating potential inferior contracts, the Pareto set provides reasonable predictions of contract negotiation outcomes. Such outcomes will lead to a higher channel efficiency.

When the firms restrict their negotiation within a single type contract, we find that the minimal

channel efficiency of the push-pull Pareto set is significantly larger than those of the other two types. Moreover, every push-pull contract is Pareto efficient within its own type. However, the results are different when firms are willing to consider more than one contract type. We can show that the minimal channel efficiency of the joint Pareto set of push and pull contracts coincides with that of the push-pull Pareto set, and the set of Pareto efficient push-pull contracts indeed consists of the union of Pareto efficient push and pull contracts within their joint Pareto set. Those findings imply that supply chain party negotiations on wholesale price when considering both push and pull contracts will achieve the same minimal channel efficiency of the push-pull Pareto set, which is high according to our analytical and numerical studies, i.e., over 91% under Uniform yield distribution. Moreover, we can further show that the minimal channel efficiency of the Pareto set consisting of at least two contract types always equals to that of the push-pull Pareto set. The practical implication is that the wholesale price negotiation process among supply chain parties does not need the complexity of working with two or more distinct contract types, but can converge faster and with the same efficiency by restricting considerations to only push-pull contract type.

To conclude, our paper contributes in two ways: (1) we study the impact of push and pull implementations of single wholesale price contracts on the supply risk allocation in a supply chain with random yield, and completely characterize the Pareto set for any contract types combination; and (2) we propose the use of push-pull contracts as ones to be used during wholesale price contract negotiation, and show that their use guarantees the best minimal channel efficiency among all contracts. Among our side results in the paper, there is a technical contribution of providing a general condition on the yield distribution to ensure the unimodality of the Stackelberg leader's profit function, which differs from the IGFR property used in the stochastic demand literature. Our condition will play useful role in future random yield research. Finally, as a managerial insight aside, we offer support for the "pay-by-delivery" rather than the "pay-by-order" payment scheme, when considering random yield setting under push and push-pull contracts.

References

Cachon, G. P. 2004. The allocation of inventory risk in a supply chain: push, pull, and advanced purchase discount contracts. *Management Science* **50**(2) 222–238.

Chick, E., H. Mamani, D. Simich-Levi. 2008. Supply chain coordination and influenza vaccination. *Operations Research* **6**(56) 1493–1506.

Dong, L., K. Zhu. 2007. Two-wholesale-price contracts: push, pull, and advanced-purchase discount contracts. *Manufacturing and Service Operations Management* **9**(3) 291–311.

Tang, Y., P. Kouvelis. 2014. Pay-back-revenue-sharing contract in coordinating supply chains with random yield. *Production and Operations Management* **12**(23) 1059–1478.