Policy Paper

Volume Allocation for DMPA Procurement
A Study of Competition and Risk

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# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents</td>
<td>iii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>v</td>
</tr>
<tr>
<td>List of Tables</td>
<td>vii</td>
</tr>
<tr>
<td>1 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2 LITERATURE REVIEW</td>
<td>3</td>
</tr>
<tr>
<td>3 PROBLEM DESCRIPTION</td>
<td>7</td>
</tr>
<tr>
<td>3.1 COMPETITION</td>
<td>7</td>
</tr>
<tr>
<td>3.2 LEAD TIMES</td>
<td>8</td>
</tr>
<tr>
<td>3.3 DEFAULTS</td>
<td>9</td>
</tr>
<tr>
<td>4 THEORETICAL MODEL</td>
<td>9</td>
</tr>
<tr>
<td>5 THE SIMULATION MODEL – MODELLING CHOICES AND IMPLEMENTATION</td>
<td>11</td>
</tr>
<tr>
<td>5.1 OVERVIEW</td>
<td>11</td>
</tr>
<tr>
<td>5.2 COMPETITION MODULE</td>
<td>11</td>
</tr>
<tr>
<td>5.3 LEAD TIME MODULE</td>
<td>13</td>
</tr>
<tr>
<td>5.4 DEFAULT MODULE</td>
<td>14</td>
</tr>
<tr>
<td>5.5 SIMULATION IMPLEMENTATION</td>
<td>15</td>
</tr>
<tr>
<td>5.6 INPUT AND DATA SOURCES</td>
<td>16</td>
</tr>
<tr>
<td>6 RESULTS</td>
<td>19</td>
</tr>
<tr>
<td>6.1 REFERENCE CASE</td>
<td>19</td>
</tr>
<tr>
<td>6.2 SENSITIVITY ANALYSES: COMPETITION</td>
<td>22</td>
</tr>
<tr>
<td>6.2.1 Suppliers’ Cost</td>
<td>22</td>
</tr>
<tr>
<td>6.2.2 Suppliers’ Capacities</td>
<td>25</td>
</tr>
<tr>
<td>6.2.3 Entrant Discount and Incumbent Premium</td>
<td>26</td>
</tr>
<tr>
<td>6.3 SENSITIVITY ANALYSES: LEAD TIMES</td>
<td>27</td>
</tr>
<tr>
<td>6.3.1 Mean Lead Time</td>
<td>28</td>
</tr>
<tr>
<td>6.3.2 Variability of Lead Time</td>
<td>28</td>
</tr>
<tr>
<td>6.3.3 Product Registration</td>
<td>29</td>
</tr>
<tr>
<td>6.4 SENSITIVITY ANALYSES: DEFAULTS</td>
<td>30</td>
</tr>
<tr>
<td>6.4.1 Default Probability</td>
<td>31</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1: Negotiation Process ................................................................. 12
Figure 2: Re-Routing Example (blue arrows indicate re-routing activities to cover for late (red) order) ........................................................................................................ 14
Figure 3 – Lead Time Histogram and Density Function - USAID ............. 16
Figure 4 – Examples of Cost Functions ..................................................... 19
Figure 5 – Risk-induced Shortages in the Reference Case ................. 20
Figure 6 – Price-induced Shortage in the Reference Case ................. 21
Figure 7 – Weighted Average Unit Price for Varying Differences in Variable Cost $\Delta s$ 23
Figure 8 – Weighted Average Unit Price for Varying Differences in Fixed Cost $\Delta f$ ...... 24
Figure 9 – Weighted Average Unit Price for Different Economies of Scale ($\nu$) and Different Entrant Capacities ........................................................................................................ 25
Figure 10 – Weighted Average Unit Price for Different Entrant’s Maximum Capacity 26
Figure 11 – Weighted Average Unit Price for Different Incumbent Premium and Entrant Discount ........................................................................................................ 27
Figure 12 – Risk-induced Shortages for Varying Mean Lead Time Difference $\Delta \mu$ ...... 28
Figure 13 – Risk-induced Shortage for Varying Entrant Lead Time Variability ........ 29
Figure 14 – Risk-induced Shortage for Varying Entrant Registration Scenarios ........ 30
Figure 15 – Risk-induced Shortage for Varying Entrant Default Probabilities ........ 31
Figure 16 – Risk-induced Shortage for Varying Compensation Capacity of the Incumbent ........................................................................................................ 32
Figure 17 – Risk-induced Shortage for Varying Compensation Capacity of the Incumbent and Higher Default Risk ................................................................. 32
Figure 18 – Procurement Gap, Price and Risk-induced Shortage in a High Risk Scenario ........................................................................................................ 36
Figure 19 – Procurement Gap, Price and Risk-induced Shortage in a High Risk Scenario with Increased Entrant Capacity ................................................................. 36
Figure 20 – Change of Procurement Gap ........................................................................................................ 36
Figure 21 – Effects of TPV Increase ........................................................................................................ 38
Figure 22 – Coordinated Decision ........................................................................................................ 40
Figure 24 – Coordinated Decision with Reduced Budget .................................................. 42
Figure 25 – Risk-induced Shortage for a Buffer Inventory................................................ 43
Figure 26 – Coordinated Decision with Quality Testing Cost of $.05/unit for USAID .. 45
List of Tables

Table 1 – Overview Input Parameters ................................................................. 17
Table 2 – Cost Function Parameter Values ....................................................... 18
Table 3 – Registration Scenarios – List of Countries ....................................... 49
1 Introduction

Multiple sourcing is typically used in both the private and the public sector to reduce the adverse consequences from potential supplier defaults or volatile lead times. The benefits of multiple sourcing result from a diversification effect: if two suppliers are contracted and two orders are placed to two different suppliers, the risk of both orders arriving late or both suppliers defaulting decreases compared to the single sourcing case, assuming that the events are not perfectly correlated. However, potential supply risks are not the only reason to split procurement volumes. Buyers also split volumes between multiple suppliers to introduce competition and to ensure a healthy market development. While single-sourcing may induce strong competition in the short run, in markets with only a few buyers, non-contracted suppliers may withdraw from the market, which can lead to a monopolistic supply situation with high prices in the long run. In the short run multiple sourcing may be necessary if capacity of one supplier is not sufficient to meet the entire demand. However, there are also additional reasons why single sourcing may be more beneficial: suppliers may offer substantial volume discounts for large volumes to improve their position in the market, and these volume discounts could also be amplified through the presence of economies of scale.

These two effects – risk and competition – yield a complex decision problem for a buyer: choosing the right volume split among the suppliers to 1) benefit from competition, and 2) minimize the exposure to supply risks is difficult, as both effects are typically interrelated and oftentimes work in opposite directions. For buyers in the donor-funded procurement of essential medicines for low and low-medium income countries, solving this complex decision problem is even more difficult: a non-for profit buyer does not aim to make a profit nor does she generally want to minimize cost. Instead, she is interested in contributing to a global welfare objective. Translating competition, purchasing costs and supply risks into a coherent measure of welfare is obviously a challenging task. Furthermore, the decisions of multiple non-for profit buyers could affect each other and, thus, make the decision even more complicated (especially from a global welfare perspective). In the last couple of years, buyers made great advances in balancing these multiple objectives of risk, competition and
“market shaping”, however it is still not known how these actions take effect and how coordination among stakeholders should take place effectively\(^1\).

This report presents findings from a research project evaluating risk and competition effects in the donor funded procurement of *Depot medroxyprogesterone acetate* (DMPA); a long-term injectable contraceptive used in low and low-medium income countries to provide women with family planning options. The procurement for the donor-funded DMPA demand is split between United States Agency for International Development (USAID), an U.S. Government agency, and United Nations Population Fund (UNFPA), an United Nations agency. Over the last years both organizations could only procure from a single supplier because this was the only one pre-qualified by the World Health Organization (WHO).

Recently, generic suppliers (already producing DMPA for other markets) have started the WHO-prequalification process and are to join the pool of eligible suppliers in the next years. If the first additional supplier becomes WHO-prequalified USAID and UNFPA will have to decide how to split their respective procurement volumes between the entrant and the incumbent – considering competition and risk effects.

In this report we present the results of a simulation study that was designed to provide directional insight into the optimal splitting decision in the DMPA market. The tool consists of three modules representing the major drivers, namely a competition module, evaluating how prices develop under competitive pressure, a lead time risk module, evaluating how order splitting influences expected shortages from late deliveries, and a default risk module, evaluating how default risks and compensation capacities influence expected shortages from supplier defaults. The tool was first used to carry out various sensitivity analyses to validate the outcomes of the simulation and to understand the main drivers of the competition and risk effects. Thereafter, multiple future scenarios were developed and analyzed to provide further insights.

The simulation tool was set-up to be very flexible in order to support stakeholders from different organizations in their decision making process. However, we focus on answering the following five questions:

1) What is the optimal volume split?

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\(^1\) The Reproductive Health Supplies Coalition 2014
2) What is the downside of procuring from the entrant?
3) How does in-country registration impact the volume split?
4) What is the value of coordination between USAID and UNFPA?
5) How do procurement budgets impact the optimal split?

We use the results to provide answers to these questions and create insights into how the trade-offs in these decisions develop under varying conditions. We highlight the insights and managerial implications delineated from our work regarding these questions in Chapter 8.

The remainder of this document is structured as follows. Chapter 2 provides an overview of related literature. In Chapter 3 we describe the practical settings of the three modules and how their realization is motivated. Chapter 4 frames the decision process of the buying organizations and presents a stylized theoretical model of the decision problem; Chapter 5 presents the implementation and functionality of the three modules. In Chapter 6 a reference case is developed and analyzed, followed by a sensitivity. Chapter 7 presents analyses of different scenarios based on the most important developments that stakeholders expected to see in the future. Chapter 8 contains the managerial implications to the main questions and Chapter 9 summarizes this work.

2 Literature Review

Literature relevant to this work comes from research on market competition and research addressing operational drivers of risk, such as lead time uncertainty or potential supplier defaults.

Regarding competition, it is especially relevant for our study to consider how suppliers bid in a competitive environment. To this end we review the literature on auction in two supplier settings. Anton, Yao (1989) examine a split-award auction with two suppliers and an endogenous split. They find that this setting features strong collusive behavior of the bidding suppliers and in such a setting “there is no split-award equilibrium in which the buyer pays less than in a winner-take-all […] auction” (Anton, Yao (1989, p. 548)). However if the buyer has future benefits of split-award outcomes, these “future benefits translate directly into a preference for dual-source production” (Anton, Yao (1989, p. 550)). In Anton, Yao (1992) they present similar results but show that in a private information setting it is
much more difficult for the suppliers to coordinate, which takes out part of the collusive properties of the auction. In addition Anton et al. (2010) include uncertain scale economies into their model and derive that if a split-award outcome is the equilibrium, it is always the efficient outcome. However, they argue that if the buyer has a preference for splitting, “buyer preference provides the bidders with an opportunity to leverage their bids upwards” (Anton et al. (2010, p. 37)).

Gong et al. (2012) analyze a split-award auction where suppliers can invest prior to the auction into cost-reducing efforts. They show that a split-award auction can dominate a winner-take-all auction because it “improves the suppliers’ investment incentives, intensifies competition at the bidding stage, and minimizes the buyer’s procurement costs” (Gong et al. 2012, p. 188). Splitting procurement volumes is also beneficial for the buyer if market entry (for suppliers) is costly. In their research, Perry, Sákovics (2003) study a buyer that performs a sequential auction for a large and a small contract and show that if the number of bidders is fixed, this split-award auction always increases the buyer’s costs in comparison to a winner-take-all auction. However, if suppliers face entry costs, the buyer can set the split to increase the number of participating suppliers, which intensifies competition and lowers procurement costs. Klotz, Chatterjee (1995) look at a similar, but multi period, setting in which suppliers face entry costs and in addition production learning effects. In their model they learn that splitting the procurement volume helps control “the rate at which suppliers move down their learning curves” (Klotz, Chatterjee 1995, p. 1325) and increases competition in future periods with less cost asymmetries. Also, similar to what Perry, Sákovics (2003) found, suppliers’ incentives to join the competition are enhanced by splitting the procurement volume.

Our setting is different to the previously described papers as it is characterized by limited supplier capacity, i.e. one supplier is generally not able to satisfy the buyers’ demand. Ausubel (2004) shows that in such a setting both suppliers have a minimum volume that they can sell for sure. In Ausubel’s stylized analysis, these units are clinched and exempt from competition because suppliers know that they can sell them for the buyer’s reservation price. This implies that the capacity available in the market is a major driver of competition. Chaturvedi et al. (2014) investigate a multi period problem in which a buyer faces costly qualification of suppliers to join the supply base. The buyer is confronted with the trade-off between awarding the contract to few or only a single supplier to increase competition and
lower costs in the short term and the risk of alienating losing suppliers, which may in turn
decrease competition and increases costs in the long run. They identify drivers that
influence the optimal size of the supply base and the extent of multiple sourcing.
Next to these results from research on auction theory we also consider the theoretical work
that addresses bargaining and negotiations, as the problem we study in this document can
also be characterized as a negotiation between a buyer and one or two suppliers. In their
early work, Fudenberg, Tirole (1983) consider a sequential bargaining game between a
seller and a buyer that have incomplete information about each other. The model consists
of two periods, in which the seller can make offers and the buyers can accept or decline
these offers. If both offers are declined, no trade occurs. They find, for example, “that the
buyer may do better if he is more impatient” (Fudenberg, Tirole 1983, p. 221) and that a
seller that is more eager to sell “may increase the possibility of disagreement” (Fudenberg,
Tirole 1983, p. 239). Binmore et al. (1986) study a two person bargaining game in which the
players can make alternating offers until they reach an agreement. They propose models
that incorporates either the impatience of the bargainers or the fear of not coming to an
agreement and find that the impatience or fear of a bargainer weakens his bargaining
position.
An extensive body of literature on risks and volume splitting has emerged, especially
during the last decade. To cover the main aspects we distinguish two major streams: a lot
of research has been done on supplier defaults and diversification. Yu et al. (2009), for
example, analyze a two stage supply chain where a buyer faces price sensitive demand and
can procure goods from two possible suppliers (global and domestic) with different prices
and disruption risks. They find that “either single or dual sourcing can be effective
depending on the magnitude of the disruption probability” (Yu et al. (2009, p. 798)). Sting,
Huchzermeier (2012) explore the dual vs. single sourcing of a manufacturer that faces
correlated supply and demand uncertainty. The two sourcing options are an unreliable
offshore supplier and a reliable local supplier. They find that “adding offshore supply to
the sourcing portfolio becomes more favorable under positive correlation” (Sting,
Huchzermeier (2012, p. 69)) and that the decision for responsive supply is not as
straightforward and depends on the relationship between the correlation of supply and
demand, supply lag and costs.
Another research stream considers the benefits of dual sourcing under stochastic lead. A contribution by Kouvelis, Li (2008) explicitly considers the effect of lead time uncertainty on volume splitting among two suppliers. They study a replenishment decision under constant demand where the buyer has the option, after ordering from a supplier with stochastic demand, to additionally use a flexible back-up supplier if orders may arrive late. They find that benefits of dual sourcing are enhanced when lead time uncertainty is high.

In another paper, Ramasesh et al. (1991), conduct a total expected cost analysis on a stochastic lead-time (s,Q) inventory model with the option of dual sourcing. They conclude that when uncertainty is high and ordering costs are low, dual sourcing can be the cost optimal option. Chiang, Benton (1994) look at how dual-sourcing influences the performance of inventory models and find that “except for cases where the ordering cost is high, the lead-time variability is low, or the customer service level is low, dual sourcing performs better than sole-sourcing” (Chiang, Benton (1994, p. 609)). Kelle, Silver (1990) analyze how splitting replenishment orders among vendors influences the expected shortage. They suggest that with this policy the service level can be improved or the safety stock can be reduced for a given service level. In their paper from 2001, Kelle, Miller find that order splitting can reduce the stockout risk, even if one supplier is much worse in terms of reliability.

Finally, some researchers have started to merge the economic perspective of competition and operational risks to analyze the potential trade-offs: Yang et al. (2012), for example, analyze a setting in which a buyer can choose to single or to dual source from two default-prone suppliers. The buyer has incomplete information regarding the suppliers’ reliability. Competition is captured by having two suppliers available but choose only one of the suppliers continuous upon suppliers’ reliability to maximize expected profits. A winner-take-all auction results in single sourcing with high competition benefits “as the buyer enjoys the selection and rent reduction benefits of competition” (Yang et al. (2012, p. 215)). The buyer can also choose to dual source and reduce the risk exposure through diversification. The authors highlight that because a buyer loses competition benefits through dual sourcing, a decision maker may be inclined to diversify less. Moreover, they show that even if supplier reliability decreases, the buyer may be inclined to diversify less because of the decrease in competition. They argue that this is mainly driven by asymmetric information about risk.
Another study by Babich et al. (2007) also investigates competition and diversification benefits of a buyer. Two suppliers set prices as leaders in a Stackelberg game and the buyer chooses order volumes by weighing the benefits of competition against diversification effects. The major driver of the decision is correlated defaults of the suppliers. When offering prices, suppliers consider default correlation (in this paper referred to as codependence). The results show that higher (that is positive) codependence induces higher competition (lower prices) and that these benefits can outweigh the risk-related cost of high codependence, i.e. little diversification effects.

The research results in this chapter were used mainly for two things. First, they helped for a better understanding of how competition effects and risk effects evolve in different contexts, and therefore, helped us in designing the simulation in an appropriate manner. Second, the results found in these various papers served as guidance for the results we obtained from the simulation, as we tried to compare our findings to what the theoretical literature proposes as results.

3 Problem Description

This chapter describes the major aspects of DMPA procurement. To keep the terminology consistent, we will refer to the buyers (or buying organizations) as female and the suppliers as male.

3.1 Competition

Currently, both buyers (USAID and UNFPA) can only procure injectable DMPA from a single supplier at a price of approximately $0.80 per unit. Stakeholders expect that competition will increase and prices will decrease if a new generics supplier, with lower production costs, enters the market. However, splitting the volume among two suppliers will reduce the volume of the incumbent and increase his production costs due to lower scale economies. Hence, it is not clear if the weighted average price actually declines when volumes are split among the two suppliers.

As pointed out in our literature review, competition is driven by total available production capacity. If neither one of the suppliers can fulfill the entire demand of a single buying organization, they know that they will sell at least a minimum share of their capacity.
Therefore, lower supplier capacity reduces competition. As stakeholders expect the new entrant to only cover a small portion of the total demand with his capacity, competition-induced price declines may be low.

In addition, the buyers are willing to accept different prices from an established incumbent supplier and an entrant supplier. They may, for example, be willing to pay a higher price (for the same volume) from a pharmaceutical manufacturer who performs in-house R&D while expecting generics suppliers to set-up an efficient manufacturing process that results in lower costs and lower prices.

In the past, both buyers negotiated (separately) with the incumbent supplier. If a new entrant joins we assume they continue conducting a multi-round negotiation format which basically entails consecutive bilateral negotiations between one buyer and each of the suppliers.\(^2\)

### 3.2 Lead Times

Buyers negotiate on lead times with the suppliers, however, this negotiated lead times are only expectations and the actual lead times are variable and uncertain, and suppliers may differ in their average lead time as well as their lead time variability. Reasons for differing lead times are batch-production, variability in quality and fluctuation of raw material supply, to name a few. Consequently, lead times of orders can exceed the lead time that each buyer has negotiated with a supplier.

This risk of uncertain lead times is carried by the buyer and in case a supplier exceeds the negotiated lead time a buyer will try to re-route other orders that arrived early to avoid shortages. A buyer may re-route either products from the same supplier that were dispatched early to other countries or re-route order volumes from a different supplier (see Figure 2). Since a supplier has to register his product in each country separately, however, the option to re-route volumes from a different supplier is only available if this supplier has also registered his product in the country with a potential shortage.

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\(^2\) Such Negotiations are an often applied method if only two suppliers are available. For example, Management Sciences for Health (2012), an advisory organization from Cambridge that is part of the global health workforce alliance\(^3\) of the WHO, suggests in its third edition of *MDS-3: Managing Access to Medicines and Health Technologies* that the condition of only few suppliers favors “Competitive negotiation” (Management Sciences for Health 2012, §§ 21.3).
3.3 Defaults

Stakeholders shared their concern that a supplier may become unavailable at any time during a procurement cycle. In the past there have been instances of the incumbent supplier not being able to deliver over a long period of time. Such a longer term supplier default may occur for various reasons: for example, a supplier may have to stop production because he encounters technical problems or quality issues. Such a production halt may also be initiated by a regulating authority, such as the World Health Organization (WHO). A supplier may also run into financial problems that can result in permanent production outages. Most stakeholders are especially concerned that generics supplier from an emerging country that just recently received WHO prequalification may be more prone to a default compared to an incumbent supplier with a long and positive track record. In case of a default of one supplier, buyers expect to be able to (at least to some extent) place emergency orders at the surviving supplier to avoid shortages.

4 Theoretical Model

Not-for-profit organizations such as USAID and UNFPA aim to increase welfare in low and low-medium income countries, by supplying women with reproductive health commodities such as DMPA. As these buying organizations are donor-funded, they aim to maximize the number of women supplied with DMPA with a given budget and given demand. To the latter we will refer to as the “Target Program Volume” (TPV) of the buyers. The TPV does not have to coincide with the actual demand for DMPA, because TPV is the volume that buyers plan to satisfy. Maximizing the supply of DMPA can also be expressed as minimizing the procurement gap, which is equal to the gap between the target program volume and the procured volume plus units that are lost due to risk effects such as lead times and defaults of the suppliers.

We use “procurement gap” as a proxy for this welfare objective of the buying organizations (see equation (1)). We refer to the difference between TPV and the actual procured volume, as the price-induced shortage. It reflects the (expected) amount of units that can be bought depending on the given budget and (expected) prices. The risk-induced shortage is the (expected) amount of units lost due to lead time uncertainty and supplier defaults. The procurement gap is then the sum of these two values.
The problem can be written as

\[
\min_{\alpha_{ij}, \alpha_E} \mathbb{E}[\text{Procurement gap}] := \sum_j \left( TPV_j - \mathbb{E}[p_j(\alpha_{ij}, \alpha_E)] \right) + \mathbb{E}[\text{Shortages}(\alpha_{ij}; \alpha_E)] \\
\text{subject to} \quad \sum_j \alpha_{ij} \cdot TPV_j \leq \text{cap}_i
\]

(1)

Subject to \quad \sum_j \alpha_{ij} \cdot TPV \leq \text{cap}_i \quad \text{(Capacity Constraint)}

Notation:
- \mathbb{E} - Expectation operator
- \( j \) - Buyer \( j \)
- \( I \) - Incumbent
- \( E \) - Entrant
- \( \alpha_{ij} \) - Allocated share of the TPV from buyer \( j \) to supplier \( i \)
- \( TPV_j \) - Target program volume of buyer \( j \)
- \( b_j \) - Procurement budget of buyer \( j \)
- \( p_j(S_{ij}; S_{Ej}) \) - Weighted average price for buyer \( j \) at chosen volume allocation
- \( \text{cap}_i \) - Production capacity of supplier \( i \)

Although this optimization problem looks rather simple at a first glance, it is difficult to solve for multiple reasons: 1) it involves balancing risk and competition effects which are uncertain and interdependent; 2) it has to account for the interdependencies between the decisions of the two buyers; 3) multiple decisions at multiple points in time have to be considered in order to account for lead time shortages (supplier defaults and counter measures (i.e. re-routing). From a mathematical point of view, we are trying to solve a stochastic, non-linear, dynamic multi-period optimization problem. To identify good feasible solutions, to derive structural insights and to provide guidance for decision makers we employ a simulation model that captures most of the relevant features of the real life problem. The next chapter presents the overall structure of the simulation model, the three core modules competition, lead time risk and default risk, and how they were implemented.
5 The Simulation Model – Modelling Choices and Implementation

5.1 Overview

The simulation we built is based on the theoretical model and “procurement gap” represents our objective, which is calculated by (1), and that we aim to minimize. This objective is the sum of the two major effects we described in the previous chapter: 1) the difference between TPV and the procured volume which depends on the expected prices, the TPV and budget of each buyer as input and results in the price-induced shortage as output; 2) risk-induced effects which depend on the lead time uncertainties and default probabilities of the suppliers as input and results in risk-induced shortage as output. The simulation is basically composed of three modules representing the two effects: in the competition module we model how prices evolve under different supplier characteristics and the output is a volume dependent price function that is used, in combination with budget and TPV, to calculate the price-induced shortage; in the lead time and the default module we simulate the lead times and defaults of the suppliers and how splitting volumes between the two suppliers affects these risks under different supplier characteristics, and the output is the risk-induced shortage dependent on the volume split between incumbent and entrant. In the following we describe how we modelled the three modules, which are based on the practical settings described in Chapter 3.

5.2 Competition Module

In the market for DMPA there is an incumbent manufacturer with sufficient capacity to satisfy demand in the past. A new generics supplier that is expected to have lower production costs will join the market with only a fraction of the incumbent’s capacity.

As discussed in Chapter 3 the mechanism of choice in this scenario is a multi-round negotiation between each buying organization and the two suppliers. We model the negotiation as follows: suppliers are offered a large share (of the TPV) \( \alpha_i, i \in \{Incumbent, Entrant\} \) and a small share \( 1 - \alpha_i \) and compete against each other based on unit prices for the respective shares. In each round suppliers have to lower both bids, \( b_i(\alpha_i) \)
and $b_i(1 - a_i)$, to win the large share. Alternatively, a supplier can quit the negotiation and receive only the small share at the last offered bid $b_i(1 - a_i)$.

Each supplier benefits from economies of scale, i.e. he has volume dependent unit costs $c_i(a_i)$. As the model explicitly considers economies of scale it is reasonable to assume that prices of the suppliers decrease monotonically in the volume $a_i$, allowing to interpolate the prices for shares between the larger and the smaller share. Therefore, after the negotiation ends, the buyer obtains a volume depended price function. For reasons mentioned previously, a buyer will expect a lower price from the entrant. This is reflected by a minimum entrant discount $\delta$ the entrant must provide to win the larger share. Simply speaking, this discount can be interpreted as the minimum price reduction at which the buyers start to consider it worthwhile to engage with a second supplier. Also, the buyers are willing to pay the incumbent a surcharge to acknowledge his efforts in R&D and to provide incentives for future innovations. This surcharge is reflected by the maximum incumbent premium $\pi$. When the negotiation starts the bids are equal to the price the incumbent offered in the last procurement period. The negotiation starts with the entrant. Figure 1 provides an overview of the negotiation logic and process.

![Figure 1: Negotiation Process](image)

The negotiation in our approach evolves as follows: In each round suppliers consecutively evaluate if it is still profitable to lower their bid in order to win the large share, or if it is better to terminate the negotiation and to receive only the small share. If it is profitable, a
supplier will adjust his bid for the small share by the factor \( \delta \) or \( \pi \) compared to the lowest bid of the competitor (because it is necessary to stay in the competition for the large share).

For the smaller share, supplier \( i \) then adjusts his bid to \( b_E(1 - a_E) = (1 - \delta) \cdot b_E(a_E) \), or \( b_I(1 - a_I) = (1 + \pi) \cdot b_E(a_E) \). For the larger share, supplier \( i \) can only offer a lower bid if his new lowered bid yields higher profit than that for the small share\(^3\). Therefore, the offered bids always satisfy \( a_I \cdot (b_I(a_I) - c_i(a_I)) \geq (1 - a_I) \cdot (b_I(1 - a_I) - c_i(1 - a_I)) \) (2). We define \( b_{I,\text{min}}(a_i) \) as the price that makes (2) an equation. Therefore, supplier \( i \) will only offer a bid \( b_I(a_i) \) that satisfies the inequality \( b_{I,\text{min}}(a_i) \leq b_I(a_i) \leq b_I(1 - a_i) \). As we model a negotiation between the buyer and the suppliers, we assume that the bid \( b_I(a_i) \) is a random outcome of the event of negotiating, and that it is randomly drawn from a distribution with support on \([b_{I,\text{min}}(a_i); b_I(1 - a_i)]\). To keep it simple we assume it to be uniformly distributed. When the negotiation terminates, we take the two bids for minimum and maximum share of each supplier and interpolate a straight line between the two, which gives us, for each supplier, a bid function dependent on volume. This lets us calculate a weighted price function that depends on the volume split between the two suppliers.

We assume here that suppliers provide bids in a myopic bidding strategy, i.e. we explicitly exclude strategic behavior that may arise in a sequential mechanism. Furthermore, we assume that both suppliers will not terminate the negotiation process in the first round (unless they incur a negative profit). We provided a pseudocode representation of the negotiation algorithm in the Appendix.

5.3 Lead Time Module

We model uncertain lead times of both suppliers as the average lead time \( \mu_L \), the variability of lead times \( \sigma_L \), \( i \in \{\text{Incumbent}, \text{Entrant}\} \), and the days \( t_s \) until a late order induces an actual shortage and the demand for this order (i.e. the need) is lost. To model uncertainty we assume the lead times to follow a probability distribution \( F_i(x) \) with mean \( \mu_i \) and standard deviation \( \sigma_i \), which we derive from historical order data (see Chapter 6.1).

We assume that the buyers and the suppliers negotiated a certain lead time, which we refer to as “contracted lead time” \( t_c \). If orders exceed this contracted lead time a buyer will try to re-route volumes that are dispatched to other countries before the contracted lead time (see

\(^3\) Otherwise the supplier would be better of winning the small share.
Figure 2 for a simple example with two countries and one supplier). If there is insufficient volume available to re-route an order is considered to become short from time $t_s > t_c$ on. However, as described in Chapter 3.2, orders from another supplier can only be re-routed to countries in which the supplier is registered. Supplier $i$’s product is registered in country $l$, $l \in \{\text{Countries}\}$, if $r_{i,l} = 1$, otherwise $r_{i,l} = 0$. Furthermore, we assume that the incumbent is registered in all countries, i.e. $r_{\text{incumbent},l} \equiv 1$, $\forall l \in \{\text{Countries}\}$.

In the example displayed in Figure 2 two orders are placed at different points in time. The first is two units from Afghanistan, the second is four units from Nigeria. The contracted order lead time $t_c$ depicts the point in time when the order is due. As the order for Nigeria arrives before the due date (arrival before $t_c$) and the order from Afghanistan arrives late (arrival after $t_s$), two units originally dedicated to Nigeria are shipped to Afghanistan to fulfill its demand. As the order from Afghanistan arrives before the Nigerian demand is due, the two units can be shipped to Nigeria and no shortage occurs.

5.4 Default Module

In the event of a supplier default, this supplier is from the day of default on unable to provide any additional order. Hence, the default module has a direct influence on the lead
time module, as orders of a defaulted supplier will be cancelled and will become shortage if not compensated by the other supplier. We model the event of a supplier default with a default probability \( p_i \), \( i \in \{ \text{Incumbent, Entrant} \} \), representing the probability of supplier \( i \) to default within a procurement cycle (e.g. one year). We consider the default of a supplier to be equally likely at any point in time and draw the day of default of one supplier from a discrete uniform distribution with minimum 1 (default on the first day of the year) and maximum 365 (default on the last day). From the day of default on, all orders of the defaulted supplier will be lost and become short if the other supplier can not compensate some of the lost orders. Defaults of both suppliers are assumed to be independent, i.e. they are modelled as independent probability distributions.

To account for the fact that a supplier can compensate for the default of another supplier, we model a compensation capacity \( cc_i \). If supplier \( j \) defaults at time \( t \), supplier \( i \) can fulfill the lost orders \( o_{t,j} \) until his compensation capacity is exhausted at time \( t + k \), i.e. \( \sum_{n=t}^{t+k} o_{n,j} \leq cc_i \). Compensation is again constrained by product registration since compensation capacity can only be used for a defaulting supplier’s orders if the compensating supplier’s product is registered in the country. Orders that can not be compensated result in shortage. Also, compensated orders underlie the same principle as all other orders and can also lead to shortage due to long lead time.

5.5 Simulation Implementation

To implement the model we use Microsoft Excel and the add-in @Risk (Palisade). The competition module and the lead time and default modules are implemented separately, because the first one is responsible for unit prices, and therefore the price-induced shortages, while the last two are responsible for units lost due to lead time shortages or defaults, and therefore the risk-induced shortages. From the competition module we obtain a price function dependent on the split between incumbent and entrant and with this we can calculate, combined with the budget and TPV of each buyer, the price-induced shortages. From the lead time and default modules we directly obtain the risk-induced shortages dependent on the split. The results of these separate implementations were then re-united (summed up like in (1)) into the final target value, procurement gap.
5.6 Input and Data Sources

The input data for our simulation is based on available data and assessments from industry and Global Health experts. We use this data to build a reference case that basically reflects the 2013 procurement situation (in terms of lead times, order sizes, order patterns, countries etc.) but with increased target program volume equally distributed over all countries. We assume buyers have a new entrant supplier available. The time horizon of the simulation is equal to one year, but can also be interpreted as one procurement cycle.

We utilize the publicly available order data from the RHInterchange\(^4\) (RHI) database. This database contains the injectable DMPA order volumes and order placement and delivery dates from countries who received DMPA through USAID and UNFPA. Using distribution fitting\(^5\) for the lead times we derive type and parameter of the lead time distributions. Figure 3 depicts the density function and the underlying lead time data from RHI database for USAID.

![Lead Time Histogram and Density Function - USAID](image)

For the reference case we assume that the incumbent’s lead times remain the same as given in the RHI database. We also assume that the entrant has the same lead times as the incumbent. Accordingly, we chose the same distribution and the same parameters for both suppliers (see Table 1) and set the contracted lead time equal to the mean of the lead time

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\(^4\) [http://www.myaccessrh.org/rhi-home](http://www.myaccessrh.org/rhi-home)

\(^5\) We fitted the data with the Microsoft Excel add-in @Risk (Palisade), based on the Akaike information criterion (AIC) introduced by Akaike (1973) which has since then been a tremendous success in statistical modelling.
distribution and the late threshold equal to the standard deviation. We use the order patterns and volumes for all recipient countries of both buying organizations as direct input for the simulation. Based on the total order quantities of the years 2012 and 2013 from the RHI database (approx. 33 mil. units USAID and 30 mil. units UNFPA) we assume a significant demand increase resulting in a target program volume for the reference case of 58 mil. units for USAID and 48 mil. units for UNFPA. We estimate the capacity of the incumbent and the entrant based on industry experts interviews. This results in an incumbent capacity that was sufficient to satisfy past demand, i.e. 95 Mil. units/year and an entrant capacity of 15 Mil. units/year. We estimate each buyer’s current procurement budget as sufficient to procure the target program volume in 2013. Consequently, USAID’s budget amounts to $0.8 times their TPV of 2013 and UNFPA’s budget equals $0.8 times their TPV of 2013. From expert interviews we obtained estimators for the default probability of incumbent and entrant. We assume for the reference case that the entrant is registered in all countries and that both suppliers are identical in terms of lead times uncertainty and default probability. Table 1 gives a brief overview over the input parameters.

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>USAID</th>
<th>UNFPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Time Distribution</td>
<td>Gamma(2.009; 24.712)</td>
<td>Gamma(2.4175;28.728)</td>
</tr>
<tr>
<td>Procurement Volume per year</td>
<td>58,000,000</td>
<td>48,000,000</td>
</tr>
<tr>
<td>Procurement Budget per year</td>
<td>38,400,000 $</td>
<td>32,000,000 $</td>
</tr>
<tr>
<td>Order book 2012/2013</td>
<td>RHI database</td>
<td>RHI database</td>
</tr>
<tr>
<td>Common</td>
<td>USAID &amp; UNFPA</td>
<td></td>
</tr>
<tr>
<td>Incumbent Capacity</td>
<td>95,000,000 Units</td>
<td></td>
</tr>
<tr>
<td>Inc. Compensation Capacity</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Entrant Capacity</td>
<td>15,000,000 Units</td>
<td></td>
</tr>
</tbody>
</table>

6 http://www.myaccessrh.org/rhi-home
Ent. Compensation Capacity

Current Unit Price for DMPA

Default Probability Incumbent 3% per year

Default Probability Entrant 3% per year

Incumbent Premium $\pi$

Entrant Discount $\delta$

Contracted Lead Time $\mu$

Shortage Threshold $\sigma$

For the cost functions of the suppliers we draw on Schotanus et al. (2009) to describe how suppliers’ experience economies of scale. A supplier’s unit cost function is given by

$$c_i(\alpha_i \cdot TPV) = s_i + \frac{f_i}{(\alpha_i \cdot TPV)^{\nu_i}}; \alpha_i \cdot TPV \geq 1, \alpha_i \cdot TPV \leq cap_i.$$ (2)

Where $s_i$ denotes the variable unit production costs per unit, $f_i$ denotes the fixed costs that all units have to carry, and $\nu_i$ reflects magnitude of economies of scale. Larger values of $\nu_i$ indicate better ability to exploit economies of scale, i.e. increases the steepness of the unit cost function. Unit costs depend on the produced volume $\alpha_i \cdot TPV$, where $\alpha_i$ is supplier $i$’s share of the $TPV$ (Target Program Volume, in million units).

We conducted industry expert interviews to derive some estimates for the cost functions, however these are only rough estimates. We assume that both suppliers use basically the same production technology, hence the shape parameter $\nu_i$ of their cost functions is equal. Their cost functions differ in that the entrant has some cost advantage over the incumbent which is represented by the differences in $s_i$ and $f_i$. Table 2 presents the values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Incumbent</th>
<th>Entrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_i$</td>
<td>0.657</td>
<td>0.592</td>
</tr>
<tr>
<td>$f_i$</td>
<td>1.191</td>
<td>0.953</td>
</tr>
<tr>
<td>$\nu_i$</td>
<td>3.618</td>
<td>3.618</td>
</tr>
</tbody>
</table>
Figure 4 gives examples of the cost functions for different parameter values. One can see that $v$ drives elasticity of the scale economies while $s$ influences the absolute level of costs and $f$ the difference between maximum and minimum costs per unit.

6 Results

6.1 Reference Case

We begin the analysis of the reference case by presenting separately the risk-induced shortage, i.e. the impact of lead time uncertainty and potential supplier defaults, and the price-induced shortage, i.e. the impact of competition among the suppliers. We assume that both buyers can negotiate for the same proportional share of production capacity of the suppliers. This means that both can source up to 15% of TPV from the entrant, while they have to source at least 5% of TPV from the entrant because the incumbent can not satisfy the whole TPV.
Figure 5 – Risk-induced Shortages in the Reference Case

Figure 5 presents the risk-induced shortage of both buyers depending on the volume allocation to the entrant (in percent of each buyer’s target program volume). Starting with single sourcing from the incumbent on the far left of the curve, an increase of the entrant’s share first lowers the shortage. This decrease is caused by a diversification effect: by splitting the volume among entrant and incumbent the risk-induced shortage declines because the probability that both suppliers experience a default or exceed the lead time is lower. In the reference case this diversification effect would be highest if the buyer would split the volume equally among the suppliers because both suppliers have the same lead time uncertainty.

Note that the difference in the risk-induced shortage between USAID and UNFPA is based on the fact that USAID procures a higher target program volume. However there is some difference in the curves between USAID and UNFPA, as USAID’s curve is steeper for very low and very high shares of the TPV, which indicates a slightly higher benefit of risk pooling than at UNFPA. Part of this difference is caused by the differences in order books and lead times between both buyers, part of it is due to the differences in Target Program Volumes. USAID procures 58 million units while UNFPA procures 48 million units; hence the volume is larger and, because of this, USAID has a higher absolute potential for a reduction of risk-induced shortages. Both buyers experience the maximum reduction of approximately -20% with an entrant share of 50%.
The results displayed in Figure 5 assume sufficient capacity of both suppliers to supply the target program volume. However, as already mentioned in the reference case, capacity of the entrant is scarce, therefore the vertical dashed lines indicate the limits for the buyers’ allocation decisions due to constrained capacities.

Figure 6 illustrates how the price-induced shortage evolves in the reference case depending on the entrant share. Again, as capacity is scarce, the dashed lines are the allocation decision limits due to capacity constraints. Figure 6 clearly shows that in the reference case an increase of the entrant’s share reduces the gap between TPV and procurement volume. This result is driven by the fact that the entrant has lower costs than the incumbent, which are decreasing due to economies of scale. The lower costs result in lower bids, which increase competition and result in lower overall procurement prices for each buyer. With a given budget, each buyer can therefore procure larger volumes; as a consequence, the price-induced shortage declines. Also note that the rate at which shortage is reduced increases in the entrant share. The curve for USAID is steeper than that for UNFPA; this is due to the difference in budgets of both buyers\(^7\).

![Price-Induced Shortage Reference Case](image)

*Figure 6 – Price-induced Shortage in the Reference Case*

We observe that in the reference case the buyer can benefit from a diversification effect and a competition effect; both effects lower shortages in the entrant share. Therefore, it is

\(^7\) We provide detailed explanations for this effect in Chapter 7.5.
optimal for both buyers to award as much volume as possible to the entrant in order to reduce the procurement gap in the reference case with maximum entrant capacity of 15%. Understanding the results and dynamics of the reference case is an important first step. First of all, the reference case allows us to validate our simulation tool based on realistic data that reflects the recent past. Second, these results help us understand the underlying dynamics in terms of competition and risk effects and their interaction. Our analysis, however, is targeted at medium and long term decision support for the future DMPA market. In what follows we first perform sensitivity analyses to better understand what the main drivers of are. In these analyses we focus on the parameters for which we only have low confidence estimators and keep the reference case a starting point for our analyses. In Chapter 7 we will then derive and analyze various scenarios reflecting potential future changes to the DMPA market to derive robust recommendations for the decision makers.

6.2 Sensitivity Analyses: Competition

Price-induced shortages are driven by the weighted average unit price buyers’ can negotiate with their suppliers. The lower the average unit price, the more doses of DMPA can be obtained with a given budget. Therefore, we will present the effect of relevant parameters (i.e. suppliers’ costs and capacities, incumbent premium, entrant discount) on the weighted average unit price. The weighted average unit price results from the two price functions that we extract from the competition module.

6.2.1 Suppliers’ Cost

To evaluate the impact of the parameters we vary the difference in variable cost between incumbent and entrant, i.e. \( \Delta s = s_{\text{Incumbent}} - s_{\text{Entrant}} \), the magnitude of scale economies \( \nu_i \) and the difference of fixed cost \( \Delta f = f_{\text{Incumbent}} - f_{\text{Entrant}} \). In the following analysis we set the entrant’s capacity to 50% because it provides better visibility into effects. However, the following results also hold for our reference case of 15% entrant capacity and other potential entrant capacity scenarios.

Figure 7 presents, on the left hand side, the effect of the variable cost difference \( \Delta s \). Starting from a significant cost disadvantage of the incumbent, i.e. \( \Delta s = 0.232 \), we lower the incumbent’s cost until incumbent and entrant have the same unit cost, i.e. \( \Delta s = 0 \). On the right hand side of Figure 7 we illustrate how changes of the variable costs of the entrant...
affect the price while keeping the incumbents cost fixed. We calculate the outcomes for a maximum entrant capacity of 50%.

Figure 7 – Weighted Average Unit Price for Varying Differences in Variable Cost $\Delta s$

Figure 7 depicts the resulting weighted average unit prices depending on the entrant share for varying incumbent cost (left) and varying entrant cost (right). The prices typically decrease in the entrant share (left graph; black, blue, & red line). Also smaller cost differences lower the unit price; this is based on the fact that the incumbent becomes more competitive and exerts more pressure to reduce prices. Note, that the shape of the price curve also changes from strictly decreasing (black) to increasing and only for larger entrant shares decreasing (yellow). This change in shape indicates that with a high cost incumbent the marginal competition benefit of one unit allocated to the entrant is always positive, i.e. price reducing. Once the incumbent’s cost are close to the entrant this marginal benefit kicks only in for high allocations to the entrant. However, the curve is always slightly lower for higher entrant shares because the buyer still requires an entrant discount and allows for an incumbent premium.

Whereas, if the entrant’s variable costs exceed those of the incumbent, the marginal benefit of higher allocations to the entrant is negative, i.e. prices increase in the entrant share (right graph, blue and black line).
In Figure 8 we illustrate the effect of a change in the difference of fixed cost $\Delta f$ of both suppliers. As before we assume an entrant capacity of 50% of TPV. We draw two conclusions from this analysis. First, the influence of fixed costs on prices is very small compared to that of variable costs; this is reasonable, because fixed costs are carried by all units. Second, in this analysis with 50% entrant capacity, the impact of the entrant’s fixed costs is stronger than the incumbent’s. This is because fixed costs have more effect on small volumes and the entrant’s minimum share is 5% of TPV while the incumbent’s is 50%. The impact of fixed costs is stronger on the 5% share, i.e. changing the entrant’s fixed cost has more impact on prices.

In Figure 9 we vary the magnitude of scale economies $\nu_i$ of both suppliers, on the left hand side for an entrant capacity of 95% of the TPV (same as the incumbent) and on the right hand side for an entrant capacity of 50% of the TPV. Figure 9 confirms that higher economies of scale result in lower average prices. This is intuitive as higher economies of scale result in lower cost for a given production volume. Interestingly, the magnitude of the influence changes for different entrant capacities. This is because the outcome of the negotiation is driven by the cost of the high cost supplier, in our case the incumbent. In the right hand graph (with a maximum entrant share of 50%) the magnitude of scale economies has little impact on prices, because the incumbent is assured a minimum share of 50% and economies of scale strongly influence the cost for lower production volumes. In the left hand graph the incumbent only has a minimum share of 5%, for which the production costs are more sensitive to the economies of scale. Therefore stronger economies of scale (production costs decrease much faster) lead to lower prices; in this case, the economies of
scale of the incumbent have a stronger impact on prices. These findings are in line with results from auction theory: in competitive situations like those given by a reverse auction with two suppliers, the outcome is usually the cost of the supplier with higher costs (see for example Gong et al. (2012)), as the low cost supplier has no reason to bid less than the lowest bid of the high cost supplier.

![Figure 9 – Weighted Average Unit Price for Different Economies of Scale ($\nu_i$) and Different Entrant Capacities](image)

6.2.2 Suppliers’ Capacities

We now move to the suppliers’ capacities and how they influence competition (and weighted average unit price). In Chapter 5.2 we defined the negotiation process with maximum and minimum shares for incumbent and entrant. If one of the suppliers has insufficient capacity to supply total demand, its maximum share will be limited, leading to an increased minimum share of the other supplier. This is reasonable because competition will only arise for volumes that can be awarded to both suppliers. For example, if demand is equal to 10 units of the product and each supplier can supply a maximum of 5 units, the maximum share of each supplier will be equal to 5; hence, the minimum share of the respective “other supplier” will also be 5 units. This leads to a situation without competitive pressure, because both suppliers are needed and have no incentive to “bid” for the large share. In our model this would result in both suppliers terminating the negotiation, as they cannot improve their position by winning the large share. If now, for example, the capacity of both suppliers’ increases to 6 units, the maximum share of each supplier is 6, and the minimum shares equal to 4, leaving a difference of 2 units for each supplier between maximum and minimum share. These 2 units are subject to competition, as total market
capacity exceeds total demand by 2 units. This capacity effect on competition is very similar to what Ausubel (2004) describes in his paper as “clinching”: Bidders clinch units whenever they are indispensable for the market to clear and hence competition arises only for units that can be provided by both suppliers. In our model the suppliers now have an incentive to compete for the large share, as it can improve their position, i.e., their profit. Following this logic, we expect total costs to decrease for increasing capacities, with a minimum if both suppliers can supply the whole demand.

Figure 10 shows the effect of increasing the capacity of the entrant from 20% to 80% of the TPV. On the one hand, this is due to more intense competition and lower bids of both suppliers, because more volume is at stake. On the other hand, the whole price function shifts downward, because the entrant lowers his bids. This is due to the fact that the unit costs of the entrant decrease (economies of scale) as his volume increases. These results are in line with what Chaturvedi (2015) found in his analyses of procurement auctions with capacitated suppliers: “a supplier decreases its bid as the capacity of the opponent supplier increases and it typically decreases its bid as its own capacity increases” (Chaturvedi 2015, p. 4).

6.2.3 Entrant Discount and Incumbent Premium

Entrant discount and incumbent premium mimic the pressure a buyer exerts on the suppliers. We vary separately both parameters to see their effects on weighted average prices. Figure 11 presents the corresponding results
The results in the left hand graph are rather straightforward: a higher incumbent premium allows the incumbent to bid a higher price, resulting also in a higher weighted average price. Hence, giving the incumbent additional leeway and being willing to accept a higher bid from the incumbent reduces the price pressure. Increasing the entrant discount has the opposite effect, as can be verified in the right hand graph. The marginal effect of the entrant discount declines because the entrant is bounded by production costs, and will never bid below.

6.3 Sensitivity Analyses: Lead Times

Next we consider lead times fluctuations and their influence on the risk-induced shortages. Note that in the following presentation we do not consider capacity constraints, i.e. we assume that both suppliers have unlimited capacity. This greatly simplifies exposition and has no impact on the directional results because capacity only restricts the valid solution space of the optimization problem of the buyers. As defined in Chapter 5.3 the parameters that might influence the risk-induced shortage are the mean $\mu_l$ and standard deviation $\sigma_l$ of the lead times distributions. We investigate how the differences in the mean lead time, $\Delta\mu = \mu_{Entrant} - \mu_{Incumbent}$, and in the standard deviation, $\Delta\sigma = \sigma_{Entrant} - \sigma_{Incumbent}$, impact the results. Additionally, we will present how registration scenarios affect shortage. As a reference we use the values that we obtained for our reference case (see Table 1) and we will present the risk-induced shortage of each buying organization, USAID and UNFPA, separately.
6.3.1 Mean Lead Time

Figure 12 presents the risk-induced shortage for increasing entrant shares of TPV at different values of $\Delta \mu$. We vary the entrant’s mean lead time, while the incumbent’s lead time is fixed. The results show that shortage increases with higher entrant lead time. However, even with higher lead times, there is still a benefit in awarding the entrant some share of the TPV due to a diversification effect. This is interesting as it implies that even if one supplier performs worse in terms of mean lead time, he should still receive a share if the buyer wants to reduce the risk-induced shortage. Figure 12 illustrates that the optimal, i.e. shortage minimizing entrant share, shifts towards 0% entrant share for higher entrant mean lead time and towards 100% entrant share for lower entrant mean lead time. We also note that from a certain mean lead time threshold of the entrant on, the risk diversification effect is not existent anymore and it is optimal (in terms of risk) to award the entire quantity to the incumbent. Using data of the reference case for USAID this is already the case for $\Delta \mu \approx 10$, i.e. if the entrant’s average lead time is 10 days longer than the lead time of the incumbent.

![Figure 12 – Risk-induced Shortages for Varying Mean Lead Time Difference $\Delta \mu$](image)

6.3.2 Variability of Lead Time

Figure 13 provides the risk-induced shortages for differences of the standard deviation $\Delta \sigma$. A higher $\Delta \sigma$ implies that the entrant’s lead time has a higher variability compared to the variability of the incumbent, which leads to a higher uncertainty and more lost units due to shortages. Simply speaking, the higher $\Delta \sigma$ the less reliable the entrant’s lead time compared to the incumbent. Figure 13 displays that risk-induced shortage increases if the entrant is
less reliable. However, similar to the prior analysis on mean lead times, there is still a benefit of awarding volume to the entrant warranted by the diversification effect.

The results for differences in both lead time mean and variability are straightforward in a directional sense: If a supplier has higher lead times and/or higher uncertainty in terms of lead time variability, one would assume that this makes the supplier less attractive compared to the other, more reliable supplier. One may conclude that in terms of risk it would then be better to award no volume to this supplier. The simulation results show, however, that even if one supplier performs worse, it can still be attractive for the buyer to award some volume to this supplier to benefit from diversification effects (at least up to a certain threshold level of higher mean lead time or variability, after which the risk-induced shortage curve becomes monotonically increasing in entrant share). These findings are consistent with the results of theoretical analyses mentioned in the literature review; Kelle, Miller (2001), for example, find that “dual sourcing frequently provides a lower stockout risk” and “this property holds even for a second supplier with much worse delivery characteristics” (Kelle, Miller (2001, p. 407)).

6.3.3 Product Registration

Country registrations $r_{Entrant,l}$ of the entrant can restrict the diversification potential and therefore the positive effect of splitting the TPV between incumbent and entrant. For the reference case we assumed that the entrant’s product is registered in all countries and, therefore, no restrictions were imposed on order re-routing. Obviously, this changes if some countries cannot be supplied by the entrant. Hence, the risk-induced shortage will be higher than in the reference case. However, we still expect benefits in awarding the entrant
volume, because the diversification effect will remain and can still be used to pool risk for the buyers. It is therefore interesting to see how the benefits of dual sourcing change if country registrations of the entrant are considered. From expert interviews we obtained two possible scenarios for the entrant’s product registrations (see appendix for a list of the respective countries). The first scenario is the current status of the entrant and is called “Current Countries Registered”. In this scenario the entrant can fulfill orders from countries that make up approximately 45% of both buyers’ TPV. The second scenario is called “Additional Countries Registered”, it reflects a potential future setting in which the entrant has registered its product in additional countries. In this case country demands account for approximately 95% (USAID) and 75% (UNFPA) of TPV. Figure 14 provides the risk-induced shortage curves obtained from the simulation for these two scenarios and additionally compares them to the “All Countries Registered” scenario from the reference case.

The graphs illustrate that diversification benefits increase with the number of countries the entrant is registered in, and that it is always beneficial to the split the volume among entrant and incumbent,. With more countries registered the risk-induced shortages converge to the “All Countries Registered” scenario.

6.4 Sensitivity Analyses: Defaults

Defaults of suppliers also impact the risk-induced shortage. As described in Chapter 4.3, two parameters are the main drivers of shortages in the default module. The first is the difference between default probabilities of both suppliers, $\Delta d := d_{\text{Incumbent}} - d_{\text{Entrant}}$, with $d_i$ being the respective default probability of supplier $i$ in one year. If $\Delta d > 0$, the
incumbent’s default probability is higher than the entrant’s, and vice versa. The second
driver is the compensation capacity $c_{c_i}$ of each supplier that captures the amount of orders
that an active supplier can compensate if the other supplier defaults. As in Chapter 6.3 we
will present the shortage of USAID and UNFPA separately.

6.4.1 Default Probability

We first analyze the impact of changes to the entrant’s default probability while keeping
the incumbent’s default probability fixed. Figure 15 shows the risk-induced shortages
depending on entrant shares for different values of $\Delta d$. Clearly, the buyers participate again
in a diversification effect and the largest benefits are achieved by splitting the volume
equally among suppliers in case both suppliers present the same probability to default
($\Delta d = 0$). If the entrant is more prone to default, i.e. $\Delta d$ increases, risk-induced shortages
increase. However, the buyer still benefits from diversification; but the optimal share of the
riskier entrant decreases. Vice versa, if the entrant has a lower default probability, the
minimum shifts to the right, favoring a higher entrant share (not shown in Figure 15).

![Figure 15 – Risk-induced Shortage for Varying Entrant Default Probabilities](image)

6.4.2 Compensation Capacity

If one supplier defaults, the other supplier may provide the buyers with some dedicated
compensation capacity to (partially) fulfill the otherwise lost orders of the supplier that
defaulted. The size of this compensation capacity $cc_i$ of supplier $i$ determines how much
this supplier can compensate for until the compensation capacity is exhausted. Let us
assume that the incumbent supplier provides a large compensation capacity. It will then
probably be more attractive for the buyer to award more volume to the entrant, even if the
entrant has a higher default risk.
Figure 16 illustrates the effect of different compensation capacities if the incumbent provides different amounts of compensation capacity while the entrant cannot compensate. The graphs indicate that shortages decrease with increasing incumbent’s compensation capacity and the optimal split shifts towards higher entrant shares, i.e. the supplier with less compensation capacity. This is intuitive because (i) available compensation capacity reduced the negative consequences of a default and (ii) available compensation acts as an insurance and therefore lets a buyer procure more volume from the other supplier. The effects are amplified by higher default probabilities. For example, if the default probabilities (for both suppliers) increase (see Figure 17 with default risks of both suppliers at 25%), benefits associated with compensation capacity increase.
6.5 Summary

The sensitivity analyses of the competition module show that the module appropriately reflects competitive dynamics; the model results are supported by findings from theoretical literature. Lower unit costs of suppliers’ yield lower prices and large cost differences of suppliers reduce competitive pressure and result in higher prices (see Chapter 6.2.1). Economies of scale impact competition as larger volumes become less expensive to produce and thereby let suppliers submit lower prices for large volumes (see Chapter 6.2.1). Vice versa, the threat of only receiving a small share put a lot of competitive pressure on the larger allocations and in consequence drive down prices (see Figure 9). Capacity impacts the benefits of competition because suppliers only compete for volumes if there is a chance of losing this volume to a competitor (see Chapter 6.2.2). Our simulation results suggest that stronger competition evolves if there is more un-clinched, i.e. not sold for sure, production capacity in the market. Finally, the buyer’s willingness to accept higher prices from the incumbent (incumbent premium) and the buyer’s pressure on the entrant to provide lower prices (entrant discount) moderate the competitive pressure: accepting higher premiums or smaller discounts results in higher prices (see Chapter 6.2.3).

Regarding the lead times module, the results highlight that a buyer can benefit from the entrant by exploiting a diversification effect. Disregarding any capacity constraints, a buyer should split volumes equally (50/50) as long as the suppliers’ lead time characteristics, i.e. mean lead time (see Chapter 6.3.1) and lead time variability (see Chapter 6.3.2), are the same. But even if the entrant’s characteristics are unfavorable (compared to the incumbent) a buyer can typically benefit from diversification. Risk-induced shortages, however, increase and the volume split that minimizes risk-induced shortages moves to lower entrant shares. Decision makers must be aware of this diversification, as choosing a random split may let them be more exposed to risk than necessary. The simulation provides a rigorous approach to identify where diversification benefits are highest – and also allow to pinpoint under which conditions a very risky entrant lets risk-induced shortage unilaterally increase in the entrant’s share. The simulation, therefore, enables decision makers to analyze the magnitude and directionality of changes to lead time parameters on to risk-induced shortages. Moreover, it can be used to characterize strategic choices – either for the buyer themselves or for suppliers. For example, the simulation allows to characterize the impact
of different product registration scenarios (see Chapter 6.3.3). Buyers can better understand the consequences of registration and choose which country registration should be supported. Also, suppliers can utilize the information to decide which countries to register their product in to provide highest value to their customers.

The sensitivity analysis of the default module highlights the presence of a diversification effect that creates benefits from splitting volume among the two suppliers, even if one of the suppliers is more prone to default (see Chapter 6.4.1). Potential emergency compensation of a supplier in case the other supplier defaults reduces risk-induced shortages and provides insurance (see Chapter 6.4.2). This suggests that a buyer should award more volume to the other, riskier supplier.

7 Scenario Analyses

The simulation model aims to highlight the major effects and provide guidance for stakeholders in the decision to split procurement volumes among the incumbent and a generics entrant. The analyses in Chapter 6 equipped us with a better understanding of the directional effects. We have shown that the outcomes of the model follow an economic logic and can be well interpreted and understood. With the help of this model it is easier to understand directional influences of different parameters and the effects of certain assumptions. In order to develop strategies for different future scenarios and to show how strategies change under different circumstances we develop various examples for scenarios that could arise in the future market of DMPA. For this purpose we combine the, until now separated, two decision values price-induced shortage and risk-induced shortage into the procurement gap (see Chapter 4). The scenarios were built upon various assumptions of stakeholders, and also on market trend prognoses made by industry experts. Note that the following analyses should not be understood as final and exhaustive, but more as examples as to how the simulation model could support the decision making process and how evaluations could be performed.

7.1 Risk

Interviews with industry experts and anecdotal evidence suggest that a generics supplier may be more risky. Consequently this supplier may offer longer lead times, higher lead
time variability and higher default probability compared to the incumbent. By means of an example we show analyses to be conducted with our simulation tool that presents the impact of a very risky entrant and showcases potential analysis around such a setting.

We have shown in Chapter 6.3 that an entrant with longer lead time, higher lead time variability or higher default probability does not always lead to higher risk-induced shortages for every volume that is allocated to the entrant. More specifically, we highlighted that buyers can participate in a diversification effect suggesting to split volume among incumbent and entrant. Depending on how much more (combined) risk the buyers are exposed to by contracting the entrant, the optimal split with respect to risk-induced shortages moves to smaller shares for the entrant (see Figure 12, Figure 13, and Figure 15). Figure 18 presents the risk-induced shortages, price-induced shortages and the procurement gap as a function of the entrant shares for a high risk scenario, which is characterized by a higher entrant lead time $\Delta \mu = 10$, a higher entrant default probability $\Delta d = 6\%$ and a higher entrant lead time variability $\Delta \sigma = 2$. All other parameter are equal to the reference case. First, note that the sum of different risks evaluated here does not directionally change the impact on the risk-induced shortages as presented in Chapter 6. The more share the entrant receives the higher are the risk-induced shortages. This is driven by the fact that from a certain level of risk on a buyer can not benefit from diversification anymore. Second, recall that we know from the reference case the entrant introducing competition resulting in a decrease of the price-induced shortages for higher entrant shares. Combining both effects to the measure procurement gap shows that USAID is nearly indifferent between dual-sourcing or only buying from the incumbent, while for UNFPA there is still some benefit in splitting volumes, despite the risky entrant. We conclude that the two effects, risk and competition, work in opposite directions.

The simulation allows decision makers to develop and test strategies to effectively deal with a given scenario. For example, a way to manage this situation could be to incentivize the entrant to increase his capacity. Figure 19 presents the changes if the entrant would double his capacity: as more volume is open for competition, prices of both suppliers decline (price-induced shortages shift downwards) and as the entrant experiences economies of scale for larger volumes, he offers lower prices (price-induced shortages fall at a higher rate). In this scenario, both buyers should dual-source, as the procurement gap declines with higher
entrant shares despite buying from a risky entrant by motivating this entrant to build capacity.

Figure 18 – Procurement Gap, Price and Risk-induced Shortage in a High Risk Scenario

Figure 19 – Procurement Gap, Price and Risk-induced Shortage in a High Risk Scenario with Increased Entrant Capacity

Figure 20 – Change of Procurement Gap
Figure 20 summarizes the results if a buyer chooses the optimal split and the entrant increases capacity: For USAID (left hand side) the procurement gap decreases when moving from the “High Risk Case” to the “High Risk Case with Increased Entrant Capacity”, because the positive effect from competition decreases the price-induced shortage by 1,754,418 units while risk-induced shortages increase by only 589,647 units. The analysis for UNFPA yields a similar result. This analysis highlights some interesting managerial insights: the strictly increasing risk effect caused by a very risky entrant can still be outweighed by the positive influence the entrant has on competition, making a new supplier attractive for the buyers even if it causes additional risk exposure.

7.2 TPV

Stakeholders also suggested changes to Target Program Volumes. This may, for example, occur because of a shift in contraceptive methods, from short to longer acting methods like injectables. However a decrease is also conceivable if other contraceptive methods become more attractive (such as contraceptive implants) or, for example, due to empirical evidence suggesting higher HIV infection rates when using DMPA. Another reason may be the introduction of Sayana® Press which may lead to a lower demand for conventional DMPA. If, in the future, some countries decide to procure on their own, their demand will also drop out of the institutional TPV of USAID and UNFPA. The TPVs have an influence on the relative market power of the suppliers, because as TPV changes so does their relative market capacity. We now study how changes in TPV affect competition and price-induced shortages.

Changes in TPV mainly influence the outcomes of the competition module and we will therefore restrict this scenario analysis to the effects on competition and prices. In Figure 21 two effects of an increased TPV are shown (middle bar): The first effect is due to budget

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8 Ralph et al. 2015
9 Katie Thomas 11/13/2014
10 Polis et al. 2014
11 In the sensitivity analysis we have shown that changes in capacity influence competition. As capacity is relative to TPV, it is straightforward that changes in TPV also influence competition.
12 There is, of course, an impact on risk-induced shortages, if less or more units are bought. However, as directional effects do not change in absolute volume, we only focus on the effects on competition.
limitations. For fixed budgets as TPV increases, price-induced shortage increases equally, because the additional units cannot be bought and become price-induced shortage. The second effect is due to higher prices and based on changes in competition. We have shown in Chapter 6.2.2 that competition is driven by capacities of both suppliers, and these capacities are relative to TPV. If TPV increases, excess capacity (compared to TPV) declines, and the competitive pressure on both suppliers decreases. As a consequence, prices increase and, with this, the procurement gap. As a managerial consequence it should be understood that if TPV is increased, it could happen that budgets have to be adjusted not only to the increased TPV but also to higher prices. Of course capacities of the suppliers will limit this scenario and some price-induced shortage may arise because it simply cannot be fulfilled due to constrained capacities. A factor that could work against the loss in competitive pressure is scale economies, because, if present, they lead to lower production costs for larger volumes and hence lower prices. Figure 21 presents two possible ways to reduce price-induced shortage after TPV increased. First, the buyers could increase budgets, which lets them procure more units and, hence, lowers the gap between the procured volume and the TPV (left column). Second, if for example the entrant would increase his capacity, competition again increases and prices decline, hence, price-induced shortage decreases (right column).

Figure 21 – Effects of TPV Increase
A same holds for a reduction of TPV. With less demand, suppliers are facing the situation that they might get awarded less volume, which in turn leads them to act more aggressive in price competition and offer lower prices. However, this may be limited if strong economies of scale are present; then the reduced TPV will lead to lower volumes and higher production costs for the suppliers.

One reason for declining TPV of injectable DMPA may be found in uptake of Sayana® Press. As stakeholder interviews suggest that Sayana® Press will be produced on a new production line resulting in free production capacity at the incumbent and competitive pressure will increase as suggested above (not considering that the incumbent may react be divesting part of its injectable DMPA production capacity).

7.3 Buyer Coordination

In this scenario we explore the benefits of coordinated decision making between buying organizations. USAID and UNFPA already coordinate their activities to some extent, e.g. through the Coordinated Supply Planning (CSP) group\(^\text{13}\), which was founded in 2012. As the aim of our simulation model is to minimize the procurement gap for the whole system, one should consider the benefits of a coordinated decision, i.e. the difference between the outcomes if buyers decide individually and if they consider a coordinated volume split. For example, average prices could be lower if one buyer procures only from the incumbent and the other one only from the entrant. In Chapter 5 we showed that one buyer has higher benefits of diversification than the other, which might also be a reason to coordinate. The previous scenarios also highlighted that TPV and budgets influence the results, and as these two vary among the two buying organizations, this might also influence the outcome of a coordinated decision.

Previously we assumed that both buyers engage in negotiations with the suppliers for half of the suppliers’ available production capacities. We now relax this assumption and consider different scenarios how buyers may split up production capacities among each other. This may be, for example, due to an understanding of both buyers, that one buyer foregoes to negotiate some of the capacity of the suppliers, while the other buyer is then able to negotiate on the remaining (larger) capacity. This shift of available capacities will

\(\text{UNFPA 12/18/2014}\)
change to possible allocations of volumes, and therefore has impact on competition and risks. It is not straightforward how this possibility of coordination changes the optimal solution if the buyers try to minimize their aggregate procurement gap, rather than individually minimizing the procurement gap.

As already presented in the reference case (see Chapter 6.1) both buyers always benefit from the entrant and should buy as much as possible from him. Therefore the question arises, if one buyer benefits more than the other from buying from the entrant. In this case the negotiation basis changes, as one buyer negotiates over more capacity while the other negotiates over less, resulting in changes in competition in the respective negotiations. Figure 23 depicts this decision of USAID and UNFPA. Mapped on the x-axis is the coordinated allocation of entrant share between the buyers in the form 

\[
\frac{\text{USAID Entrant Share}}{\text{UNFPA Entant Share}}.
\]

The graph represents the aggregate procurement gap (red curve) and the aggregate changes of price-induced shortage (dotted curve) and risk-induced shortage (dashed curve) compared to the uncoordinated optimal decision ((15%)/(15%)).

Figure 23 suggests that the aggregate procurement gap (red line) is minimized if only USAID procures from the entrant (30%/0%) because in comparison to the reference case (15%/15%) the price-induced (dotted) as well as the risk-induced (dashed) shortages decrease. In this case only USAID would dual source while UNFPA solely sources from the
incumbent. The overall benefit from this type of coordination is the difference of the aggregate procurement gap of the individual decision and the coordinated decision; it amounts to approximately 1,000,000 units less in procurement gap.

7.4 Budget

In general, one expects procurement budgets to increase if TPV increases (and vice versa). However, donors of one (or both) buying organizations may lower funding for procurement of DMPA and/or buyers may re-allocate funding to other contraceptive health commodities. In this chapter we highlight with our simulation model the impacts of decreasing budgets.

Clearly, the available budget has a direct effect on price-induced shortages because fewer units can be purchased\textsuperscript{14}; hence, changes to budgets influence the procurement decision of each buying organization individually and, also, impact the coordinated decision discussed in the previous chapter. To illustrate this, we reduce the budget of one buying organization, say UNFPA, by 20\% and examine how the coordinated decision changes (see Figure 24) with all other parameters remaining the same as in the reference case. First, we see that the aggregated procurement gap is higher overall, because with a lower budget, fewer units can be purchased. Second, the procurement gap curve is favoring USAID buying more from the entrant compared to the reference case (difference between reference case and optimal decision in Figure 23 is .65 mil units whereas in Figure 24 difference is .95 mil. units), indicating that it becomes even more desirable for USAID to source the entire volume from the entrant. A reason for this is the difference in budgets between the two buying organizations, which causes the buyer with the higher budget better utilizing the lower price offered by the entrant.

\textsuperscript{14} Recall that $\{\text{Price induced shortage} = TPV - \frac{\text{Budget}}{\text{Unit Price}}\}$. 

41
We characterize this effect with a simple example: Consider two buyers A and B. Each buyer wants to maximize the number of units to procure with a given budget of $10. They can buy the goods from either a costly manufacturer, a cheap manufacturer, or both (because the manufacturers are capacitated). To maximize the aggregate number of units they have 3 options: (i) both buyers dual source at a weighted price of $1/unit, (ii) A buys from the cheap supplier at $.5/unit and B from the costly supplier at $2/unit, (iii) or vice versa.

In the case of equal budgets of $10, there is no difference between option (ii) and (iii), in both cases the aggregate units bought are equal to 25, while option (i) is inferior, with only 20 units possible. Now consider the options with buyer B’s budget reduced to $5. The outcomes of the options are: (i) 15 units, (ii) 22.5 units and (iii) 15 units. Clearly A should buy from the cheap supplier, and this is because A can better utilize the lower price with her larger budget.

This budget effect is the reason why a financially stronger buyer should enjoy the lower prices of an entrant due to the better utilization of prices. And even if this may be counterintuitive at first, it maximizes the total bought units in the system.

7.5 Buffer Stock

Risk-induced shortages occur due to unforeseeable variations in suppliers’ lead times. One way to prevent or mitigate these shortages is to hold inventory and decouple country orders.
from the manufacturers’ production schedule. The benefits of such a buffer stock must outweigh the additional costs for holding the inventory which we assume must be paid out of the procurement budget.

To evaluate the implications of a buffer stock, we provide a sample calculation for one buyer (USAID). In this analysis we highlight how our simulation tool enables us to analyze the trade-off among benefits and cost of operating a buffer stock. We assume that 80% of the orders are satisfied from the buffer stock which lowers mean lead time to 10 days (for order processing, picking, and sending it to the port of origin) with a standard deviation of 15 days. In Figure 25 the risk-induced shortages in the reference case is compared to the risk-induced shortages with a buffer stock satisfying our assumptions.

Assuming an entrant share of 20% of the TPV (i.e. a 20%/80% split), the buffer stock lowers risk-induced shortage by approximately 4.7 mil units. At the weighted average price of $0.727 per unit this shortage reduction has a monetary equivalent of $3,416,900. Therefore, if USAID can operate the buffer stock at a cost of $3,416,900 per year, USAID would be indifferent between installing this buffer stock or not. This back-of-the-envelope calculation presents an estimate for a cost and benefit analysis of a buffer stock.

There is evidence that, at least in some countries and to some degree, buffer stocks are already in place (see USAID 2009).
A more precise calculation must consider the negative effects from reducing the procurement budget. As discussed in Chapter 7.4 this increases price-induced shortages and may reduce the benefits of buffer stock. Buying less volume also lowers shortage\(^{16}\). In order to obtain a more detailed picture the simulation would iteratively solve for reduced budgets and procurement volume. One such iteration shows that the benefit of the buffer stock increases to approximately 5,000,000 units and therefore USAID would be indifferent at operating cost of approximately $3,635,000 per year. We conclude that if cost for such a buffer stock would be significantly below this value, the buffer stock can lower the procurement gap. Additionally, if the buffer stock could lower the lead times for all orders (we assumed in our example 80\%) its benefit would increase even more.

7.6 Quality Testing

To assure a certain quality standard, buyers have to implement quality monitoring\(^{17}\), which will cause additional costs. USAID states in its guidelines: “Any pharmaceuticals purchased with USAID/OFDA funds are safe, effective, and provided by duly certified vendors who adhere to internationally accepted standards”\(^{18}\). However, if a generics supplier becomes WHO prequalified it will still take time until he also receives FDA/SRA approval\(^{19}\). Since USAID can only procure from a non FDA approved supplier with extensive quality testing we explore under which condition USAID should still procure from the non FDA approved supplier? As the entrant will be in a qualification process, quality monitoring operations will probably be intensified and as we can hardly make an assumption about the scale of additional costs for quality testing, we will analyze up to which amount of additional unit cost the necessary quality testing has an influence on the outcome of the coordinated decision introduced in Chapter 7.4.

We find that the tipping point for the coordinated decision is reached at quality testing costs of $.05 per unit. Figure 26 depicts the coordinated decision for this value and one can see that because of the increased unit cost for USAID, the optimal decision is indifferent between USAID sourcing all capacity from the entrant or UNFPA, while an even split of

\(^{16}\) If fewer units are bought, fewer units will become short.
\(^{17}\) UNFPA 2014
\(^{18}\) USAID 2012a
\(^{19}\) USAID 2012b
entrant capacity among the two buyers is only slightly worse in terms of the procurement gap.

The result of this analysis is that if the quality testing cost for USAID is below $.05/unit the coordinated decision is not affected and USAID should still procure the whole entrant capacity. However, if the unit quality testing cost is above this threshold, the price for USAID to source from the entrant becomes too high and it will be better to let UNFPA buy from the entrant.

![Figure 25 - Coordinated Decision with Quality Testing Cost of $.05/unit for USAID](image)

8 Managerial Implications

Our simulation tool supports decision makers to better understand the different drivers of competition and risk from lead times and defaults and their interactions, which are otherwise very difficult to comprehend. For example, the competition module enables managers to experiment with different supplier settings to better understand the dynamics and the impact on the health outcome. In view of incomplete information about suppliers’ cost and economies of scale, a broader investigation of different settings will help to prepare negotiations. While we can not predict the exact price that results from competition, the simulation equips decision makers with an understanding of the parameter interactions and directional insight into potential outcomes.
To this end, we highlighted analyses around different scenarios in Chapter 7 that – based on our discussions with stakeholders – appear to be of particular interest. We now summarize the managerial insights along the five important questions we stated in the beginning (see Chapter 1):

**What is the optimal volume split?**

Our simulation enables decision makers to characterize the optimal volume split USAID and UNFPA should choose once a new entrant becomes available and how it is depending on suppliers’ characteristics. The results indicate that balancing the competition-induced benefits with risk-induced drawbacks is a very complex task as many parameters influence the outcome. In many cases the decision, however, boils down to a unilateral preference to procure from the entrant as he introduces competition, which lowers prices and decreases price-induced shortages as well as decreases risk-induced shortages through a diversification effect. Benefits from the entrant, however, should not be taken for granted: First of all, carefully considering the characteristics of suppliers is necessary because strong differences in cost or risk characteristics between the two suppliers can significantly change the results as, for example, shown in the high risk case of Chapter 7.1. In this high risk case, buyers do not participate in diversification benefits and increase their risk exposure when procuring from the entrant; only if competition results in significant benefits a buyer should award volume to the entrant. Similarly, if marginal cost differences are not sufficient to let prices decline (see Chapter 6.2.1), the buyer must ensure to choose the right split to benefit sufficiently from diversification. The simulation tool aids decision makers in exploring the trade-off between competition and risk carefully and helps to understand which split is optimal and how suppliers’ characteristics influence the optimal split.

**What is the downside of procuring from the entrant?**

Our analysis emphasizes the common intuition that a buyer can lower his risk exposure from having two suppliers. The results show that even if an entrant performs worse in terms of average lead time or lead time fluctuations, or is more prone to default, the buyer can participate in this diversification effect. To optimally exploit diversification, however, buyers need access to rigorous quantifications to pinpoint the optimal split among entrant and incumbent depending on the parameters. Our simulation tool also provides a way to quantify the buyers’ benefits if an entrant is expected to be of lower risk – for example, if he can deliver with lower lead times variability (see for example Chapter 6.3.1). Also, we
indicated that diversification is not always available. Once the difference in risk characteristic among two suppliers is too large, the more risky supplier can unilaterally increase a buyer’s risk exposure. The simulation allows decision maker to pinpoint the threshold parameters from which risks increase.

**How does in-country registration impact the optimal split?**

In-country registration is an important factor in the splitting decision. Our analyses of different cases of entrant registration show that it substantially impacts the risk-induced shortages and can severely limit the benefits of diversification (see Chapter 6.3.3). Choosing the right split to minimize risk exposure must be based on an in-depth analysis of the impact that registration has. Our simulation can guide decision makers to quantify the benefits of each additional country in which the entrant registers the product. The results can, for example, support buyers in developing a target country list for new registrations and support an entrant supplier in optimally allocating their registration efforts.

**What is the value of coordination between USAID and UNFPA?**

Prior to engaging with the suppliers USAID and UNFPA may agree on how much each organization shall procure from the (capacitated) entrant. This coordination may happen due to legal restrictions (supplier not SRA approved), severe budget constraints, or efficiency arguments. Our analysis exposes that such coordination may benefit the overall health outcome as it can spur more competition, thereby lowering both the price-induced shortage and the risk-induced shortages (see Chapter 7.3). Vice versa, the results also highlight that letting only one buyer procure from the entrant can significantly reduce the health outcome if no rigorous analysis of the consequences is performed. The simulation tool provides decision makers with a way to quantify the value of coordination.

**How do procurement budgets impact the optimal split?**

Intuitively, one would allow the supplier with the smaller (or with a decreasing) budget to buy from the entrant – the rationale being that he can than procure more units with his smaller budget. However, if both organizations follow a global welfare objective and want to maximize overall supply of DMPA to women, the results of our simulation support the notion that the buyer with more funds should procure from the less expensive supplier (see Chapter 7.4). The reasoning is that the buyer with a higher budget can buy more of the less expensive units reducing the price-induced shortage more than the other buyer can.
9 Conclusion

In this work we studied the procurement problem that two donor funded procurement organizations face in the market for *Depot-medroxyprogesterone acetate* (DMPA), an injectable contraceptive, when a new generics supplier enters the market. We developed and implemented a very powerful and flexible simulation tool in order to create insights into how competition and risk effects influence the procurement decision of the buying organizations.

Our results show that a new entrant supplier introduces competition among suppliers which may result in lower prices. The benefits of competition, however, strongly depend on the capacity and the cost of the entrant relative to the incumbent. We also highlights that risks from late deliveries or potential defaults of suppliers have a significant impact on the buyers’ decision. We found that splitting volume between two suppliers can improve the buyer’s position if both suppliers have equal risk characteristics. However, even if the entrant is riskier there can be benefits of splitting the volume between the two suppliers. Additionally we found that as the buyers differ in various dimensions (demand, customers, and budget) there should also be interest in coordinating the procurement decision between the two organizations, which we found can yield additional benefits for the overall health outcome.
10 Appendix

Pseudocode of the Competition Module

**Negotiation**

WHILE no supplier quits the negotiation

IF entrant can make more profit with large share THEN

entrant accepts lowered price for small share (discount)

entrant offers a lower price for large share

ELSE entrant quits

IF incumbent can make more profit with large share THEN

incumbent accepts lowered price for small share (premium)

incumbent offers a lower price for large share

ELSE incumbent quits

ENDWHILE

interpolate price functions for both suppliers between their minimum and maximum share prices

Registration Scenarios

Table 3 shows all countries incorporated in the simulation. All countries are in the reference case “All Countries Registered” scenario, the countries with dashed underlines are in the “Current Countries Registered” scenario, and the countries with dashed and drawn through underlines are in the “Additional Countries Registered” scenario.

*Table 3 – Registration Scenarios – List of Countries*

<table>
<thead>
<tr>
<th>Afghanistan</th>
<th>Albania</th>
<th>Angola</th>
<th>Bahamas</th>
<th>Bangladesh</th>
<th>Benin</th>
<th>Bhutan</th>
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<td>Djibouti</td>
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11 Bibliography


